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WAR DEPARTMENT TECHNICAL MANUAL

ELECTRICAL COMMUNICATION SYSTEMS ENGINEERING

WAR DEPARTMENT 25 APRIL 1945

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TM 11-486

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(For explanation of symbols, see FM 21–6.)

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CHAPTER 1

GENERAL

Section I. PURPOSE AND SCOPE

101. PURPOSE.

This manual deals with electrical communications from the systems engineering standpoint. It is a general reference manual primarily intended for use by staff signal officers engaged in planning the electrical communication systems,—telephone, manual telegraph, teletypewriter, and facsimile; wire and radio, —required for theater of operations.

102. SCOPE.

a. The manual is divided into chapters as follows:

1. General
2. Telephone systems
3. Telegraph systems
4. Facsimile systems
5. Voice-frequency and carrier telephony over wires
6. Radio systems
7. Power
8. Foreign civil central offices
9. Outside plant
10. Electrical protection
11. Technical administration
12. Transmission yardsticks

Chapters 1 to 11 deal with engineering considerations and include sufficient detail for general engineering. Chapter 12 has been included to insure thorough understanding of the transmission yardsticks which are essential in transmission engineering, both for telephony and telegraphy.

b. Detailed information concerning electrical communication equipment together with comparisons of systems, and problems which illustrate methods for determining the equipment required for complete systems, are given in TM 11-487, Electrical Communication Systems Equipment.

c. It is recognized that communication requirements near the front differ from those in rear areas. Near the front, speed of installation is essential and to meet this, service requirements sometimes have to be relaxed. Experience has shown, however, that good workmanship is feasible, even near the front lines, and results in superior performance of communication systems. In rear areas, it is necessary to approach service standards comparable to those of commercial telephone and telegraph systems. This manual deals with both front and rear area communications.

d. Tactical communication equipment is designed for maximum ruggedness, ease of transportation, speed of installation, and good performance; hence, these equipments are used extensively in forward and rear areas. As the volume of traffic and the number and length of circuits required in the Communications Zone increase, it is necessary to augment the initial network with types of equipment having greater capabilities. For this purpose, a line of packaged equipment has been developed for fixed plant use; features to greatly facilitate its installation are included, and in other respects it equals or approaches standard commercial systems in its capability and performance. For fixed plant requirements which cannot be met by available equipment, Army Communications Service of the Office of the Chief Signal Officer should be consulted.

e. It is assumed that plans will be made to utilize to the utmost any foreign civil communication equipment and wire that are found intact or that can be rehabilitated with reasonable effort. Chapters 5, 8, and 9 discuss some general aspects of this problem. It is important that all available detailed information on the systems employed in the area under consideration be obtained by the planner as early as possible.

f. In operating an extensive communications network it is vital to have responsibilities defined. It is also important for efficient operation with minimum personnel and material to have definitely prescribed administrative routines, switchboard operating practices, and plant maintenance methods. Some general guides on this subject of technical administration are given in chapter 11.

g. Reference is made in this manual to certain British military systems and equipment which may be used in conjunction with United States military systems and equipment.

h. This manual does not discuss signal intelligence, radar, or the important problem of planning for messenger service. Aircraft radio and ground radio equipment for communicating with aircraft are discussed to the extent that they are useful in ground communication systems.

i. Throughout this manual references are made to technical manuals which give detailed information on specific systems or equipments. In addition to these references the following manuals are of value in systems engineering.

FM 11–5, Mission, Functions, and Signal Communication in General
FM 11–21, Signal Operations in the Theater of Operations (when published)
FM 11–22, Signal Operations in the Corps and Army
FM 24–5, Signal Communication
FM 24–18, Radio Communication
FM 24–20, Field Wire Systems
TM 11–455, Radio Fundamentals
TM 11–456, Wire Telegraphy
TM 11–462, Signal Corps Reference Data
TM 11–475, Principles of Long Distance Telephone and Telegraph Transmission
TM 11–487, Electrical Communication Systems Equipment
TM 11–498, Fundamentals of Telephony and Manual Telegraphy
TM 11–499, Radio Propagation Handbook
TM 11–2001, Complete 100-Mile Spiral-Four Carrier System
TM 11–2022, Application of Packaged Equipment to Open Wire Lines
TM 11–2037, Installation, Operation, and Maintenance of Open Wire Offices, Packaged Equipment

j. Technical manuals and other War Department publications may be requisitioned from the various headquarters which are listed as distributing agencies. This information is covered in FM 21–6, List of Publications for Training. References herein followed by the words *when published,* indicate manuals in preparation which should not be requisitioned until listed in FM 21–6.

Section II. WIRE VERSUS RADIO

103. MAIN FIELDS OF USE.

a. Radio communication facilities are, in general, better adapted to rapid installation than are corresponding wire facilities; therefore radio is extensively used as a primary means of communication during initial combat operations. Reliable radio communication is essential to tactical control of highly mobile elements such as aircraft, armored units, and amphibious vehicles, particularly during fast moving situations. It is also essential for communication over large bodies of water, over territory controlled by hostile forces, and over terrain where the construction of wire lines is impractical. Radio is extensively used for overseas communication to all parts of the world for handling telephone, telegraph, teletypewriter, and facsimile message traffic between the United States and Military and Naval forces in the various Theaters of Operation. In some situations it may be used as a means for broadcasting urgent information to friendly or hostile forces, and as an emergency facility or standby circuit to supplement wire communication circuits.

b. Wire facilities are more suitable for handling the bulk of ground communication, particularly between permanent, semipermanent, or temporarily-established points in a theater or combat zone. They are also extensively used by forward observers and in fire control networks, especially where security is important.

104. MAIN CHARACTERISTICS.

a. In general, radio facilities are smaller and lighter than corresponding wire facilities and consequently require less shipping space and transportation facilities. Radio sets, however, usually require more electrical power than corresponding wire facilities.

b. The total number of radio communication channels which can be utilized is generally limited by frequency assignment and interference considerations. On the other hand the total number of wire circuits which can be utilized is generally limited only by the amount of material and personnel available for installation and maintenance of the lines.

c. Radio communication ranges are less predictable than communication ranges of wire lines. At medium and high frequencies radio transmission is subject to variations due to changes in sky (ionosphere) conditions. Very-high-frequency (v-h-f) radio transmission is relatively free of these variations; however, hills or other obstructions to line-of-sight transmission will considerably affect the communication range. The communication range of some types of wire lines is adversely affected by changing weather conditions, and depends to some extent upon the amount of maintenance and supervision exercised over the lines.

d. Radio communications can be readily intercepted or interfered with (jammed) by hostile stations. This disadvantage can be minimized by exercising strict discipline in handling traffic and by employing radio countermeasures. Wire communication is subject to interruption (and interception to a small degree) at any point along the wire route because of physical damage from bombing, shell fire, sabotage, etc., whereas in radio only the antennas and terminal equipment are vulnerable. The vulnerability of wire circuits to such damage can be minimized by installing additional lines over alternate routes.

e. In general, radio stations are subject to position-finding by hostile forces, with the result that the enemy may be able to obtain valuable information. This disadvantage can be minimized by exercising strict discipline and by using radio countermeasures.

f. Radio gives the enemy a greater opportunity to observe the volume and geographical distribution of our message traffic.

g. Since most tactical radio sets are operated on a push-to-talk basis they are not well adapted for interconnection with standard wire communication circuits, particularly with circuits terminated in telephone switchboards. Some of the newer types of radio equipment, however, notably Radio Sets AN/TRC–1, AN/TRC–3, and AN/TRC–4, having the carrier on continuously, are suitable for such interconnection and, from a switching standpoint, may be handled in the same manner as wire circuits. Personnel using such integrated facilities, however, are required to observe security rules applicable to radio transmission.

Section III. TELEPHONY VERSUS TELEGRAPHY

105. GENERAL.

a. The greatest advantage of the telephone is that it affords immediate personal contact between individuals. It is superior when ideas must be developed or special circumstances explained speedily. The main disadvantages of telephony are lack of a record of the conversation (unless a voice recorder is used), the tendency to consume too much time in talk, and the possibility of noncompliance with security regulations. Telegraphy is basically best suited to one-way messages or orders which require little explanation. Handling most of the normal business by telegraph leaves the telephone circuits free for their principal purpose, which is the exchange and explanation of ideas. One-half to two-thirds of the circuits, in the theater of operations are telegraph.

b. Telegraph circuits are, in many cases, superimposed on telephone circuits; this is particularly true of d-c telegraph. When telegraph circuits are obtained in this way, additional terminal equipment is required but there is no increase in the amount of outside plant.

106. TRAFFIC CAPACITY.

a. A telephone channel can transmit information in the clear faster than a single telegraph channel of the usual type. A fast talker without much training can read 150 to 250 words per minute of ordinary material so that it can be understood over a good telephone circuit. Most military telegraph operators can not consistently handle more than 15 words per minute, although highly-skilled manual telegraph[1] operators will reach about 40 words per minute for short periods. Operators working direct-keyboard teletypewriters usually send at a nominal speed of about 25 to 30 words per minute, but with sending from previously prepared tape the nominal speed is about 60 words per minute. As pointed out in chapters 3 and 11, the net speeds, including time for typing headings and acknowledgments, are somewhat less than these operating speeds. On specially arranged telegraph channels, employing wide frequency bands, speeds up to about 400 words per minute may be obtained by transmitting International Morse code with automatic senders and recording devices (for example Boehme equipment).

b. The traffic capacity of a facility suitable for one reasonably high grade telephone channel can be increased by equipping it with a suitable multichannel voice-frequency carrier telegraph system. By applying six channels of carrier telegraph to a 2-wire telephone channel and using teletypewriters with previously prepared tapes, a total of about 360 words per minute can be transmitted in each direction. Twelve channels of carrier telegraph may be applied to a 4-wire telephone channel, in which case a total of about 720 words per minute can be transmitted in each direction.

c. When messages are enciphered, there is little or no decrease in telegraph transmission speed; this disregards any time required for enciphering and deciphering. Over a telephone circuit, an enciphered message can be read by using the Army phonetic alphabet; the speed is 15 to 20 words per minute, which about equals manual telegraph speed.

107. TRAINING REQUIRED.

Very little training is required to use a telephone circuit but considerable training is required to operate a manual telegraph circuit satisfactorily. Anyone can send messages slowly by teletypewriter, and an operator, after a short training period, should be able to send from 15 to 30 words per minute. Considerable training is required, however, to maintain teletypewriters satisfactorily.

[1] Manual telegraphy as used here means sending International Morse code by means of a key.

108. APPARATUS.

In size and weight of equipment, field telephones and manual telegraph sets are similar. Teletypewriter equipment is bulky and heavy and requires power for small motors.

109. EFFECT OF IMPERFECTIONS IN TRANSMISSION MEDIUM.

a. It is easier to transmit manual telegraph signals than speech, over either wire or radio. This is because of the simpler nature of the signals, the narrower frequency band width required, and the more effective use of transmitter power.

b. On wet field wire (Wire W–110–B) in good repair, the talking range, without amplifiers, is about 11 miles, whereas the range for d-c telegraphy is greater by several fold.

c. Under noisy radio conditions, about 25 times as much power is required to transmit speech as would be required for transmitting slow-speed manual telegraph signals by the c-w method. This assumes that the radio transmitter is fully modulated by speech, which under practical conditions often is not true; hence, even more carrier power is required with speech, the amount of increase depending on the particular conditions. With single-channel, ground-wave radio transmission, the required power for teletypewriter is ordinarily roughly the same as for fully-modulated speech operation.

d. Because of limitations inherent in machine operation, such factors as rapid variations in loss and rapidly-changing noise (for example, static) affect the intelligibility of speech less than that of ordinary teletypewriter signals. However, by using the improved transmitting and receiving arrangements for long-haul radio circuits, described in chapter 3, satisfactory teletypewriter operation may be obtained where speech would be impossible.

e. Poor transmission gives more trouble with teletypewriter than with manual telegraph, because the teletypewriter, unlike a listener, does not exercise judgment in interpreting signals.

CHAPTER 2

TELEPHONE SYSTEMS

Section I. SCOPE

201. INTRODUCTION.

a. This chapter contains information relative to the initial steps in the engineering of telephone communication systems. The planning of the telephone system and the grade of transmission which should be the objective in order to obtain satisfactory telephone service are discussed in section II. In establishing a telephone system, telephone station equipment, telephone centrals, voice-frequency and carrier-frequency telephone transmission equipment, outside plant, and radio are utilized. Sections III and IV of this chapter describe the types of telephone station equipments and telephone central equipments which are available, and the manner in which these equipments fit into the telephone system. The related subjects of information centers for aircraft warning systems and the railway train dispatching system are covered in sections V and VI respectively.

b. The engineering of wire telephone lines, except where distances are short, is a broad subject. It involves the selection and integration of types of wire facilities, repeaters, and terminal equipments for both voice-frequency and carrier circuits. It also embraces considerations of noise and crosstalk in equipment and on wire lines. There are differences in the engineering factors as between tactical plant and fixed plant. Long distance wire telephone engineering is therefore treated separately in chapter 5. Wire line construction is covered in chapter 9 and radio in chapter 6. Additional information concerning engineering, installation, operation, and maintenance of telephone systems is given in chapter 11.

Section II. LAYOUT

202. GENERAL.

a. A complete telephone system includes speech transmission channels, telephones, switching, and signaling. Throughout this manual the term *telephone transmission channel* is used to denote the path which carries a single conversation between two telephones. For satisfactory transmission, the received speech must be loud enough, and in addition, certain unwanted effects including noise, crosstalk, and the tendency of repeaters to sing must be controlled. These effects are the basis of many of the limitations stated in chapters 5 and 6.

b. Experience has shown that about 30-db circuit loss between the usual local battery telephones is the maximum that permits satisfactory conversation for most people listening in reasonably noisy locations, and with normal line noise. With very low room and line noise, or when each talker speaks loudly and is willing to repeat parts not at first understood, greater losses up to perhaps 50 db might be tolerated. However, these greater losses should not be used as the basis for engineering layouts, since it is practically impossible to be assured that talking and listening can be confined to quict locations, and since under trouble conditions the line loss and the line noise may increase considerably beyond the normal.

c. Telephones are of two types: *battery-vowered* and *sound-powered.* The latter are operated by the voice without any battery supply. Sound-powered telephones have much lower transmitting efficieny and can therefore be used only when the transmission loss between the telephones is small. Battery-powered telephones may use batteries located at the telephone (local battery), or may obtain battery supply over the loop from a telephone central (common battery). Where a telephone is used for a large part of the time it is desirable to use battery supplied from a telephone central, on account of the short life of dry batteries. This may result in shortening allowable loop lengths (par. 208).

d. Signaling on wire circuits is by means of direct current, 20-cycle ac, or voice frequency. Direct current is used for signaling on loops from telephones to common battery switchboards and on automatic signaling trunks. Twenty-cycle ac is used to ring bells at telephones and to signal operators over magneto loops and ringdown trunks. Carrier telephone channels and certain repeaters will not transmit 20-cycle signaling; on these, voice-frequency signaling must be used. A voice-frequency ringer converts the 20-cycle signal received locally to a frequency (1,000 or sometimes 500 cycles) which will pass freely over the telephone channel. This frequency is ordinarily interrupted at about 20 cycles, to provide a signal which can be distinguished from voice currents in the distant receiving equipment. Interrupted 500 cycles is used when tying in with British equipment. At the other end of the circuit, the voice-frequency ringer reconverts the received signal to 20-cycle ringing. The voice-frequency ringing range is 30 db. In general, any Army signaling means will function satisfactorily over the ranges which give satisfactory speech transmission. Specific range data for switchboards are given in TM 11–487.

e. The 1,000- or 500-cycle signaling means which are suitable for use on long distance wire lines can also be used when multichannel radio relay systems are employed. With *push-to-talk* radio circuits these signaling means are not used, and communication is established either on a time-schedule basis or by monitoring continuously at the receiver so that attention is obtained by calling on the circuit.

203. TELEPHONE SWITCHING PLAN.

In order to be able to extend a connection promptly from any telephone to any other telephone in a system, there must be a switching plan. In the simplest system, all telephones can be interconnected through one switchboard or central. In the more complex systems, telephones served by different centrals are interconnected over intervening trunks. A connection may be over a direct trunk from the originating to the terminating central or it may be built up by switching together trunks at one or more intermediate centrals. For every central it should be determined how connections to other centrals in the system will be established including alternate routes, where possible, for use when service over the regular routes is interrupted. The determination of both regular and alternate routes is closely interrelated with the telephone transmission plan discussed in paragraph 204. The factors involved in the selection and engineering of trunking arrangements, including alternate routing, are discussed in section IV of this chapter and in chapter 11; further data are in TM 11–487.

204. TELEPHONE TRANSMISSION PLAN.

a. In laying out the telephone transmission plan for an area, two kinds of circuits must be considered: *point-to-point* circuits (fig. 2-1-A), which are permanently connected to individual telephones at each end; and *switched* circuits (fig. 2-1-B), which terminate at one or both ends in a switchboard, so that connections may be established to various telephones.

b. In order to obtain satisfactory telephone communication on all connections which may be set up on switched circuits, it is necessary to form a general transmission plan which is adhered to in laying out individual parts of the plant. If this were not done, many connections might be unsatisfactory. For example, a connection from A to B may be good and a connection from B to C may be good, but a connection from A via B to C may be entirely unusable.

c. Switched circuits are divided into *loops* and *trunks*. A loop terminates in a telephone at one end and a switchboard at the other.[1] A trunk terminates in a switchboard at both ends. From a transmission standpoint there are two kinds of trunks, *terminal* and *via*. Terminal trunks are suitable only for connection to loops. Via trunks are suitable for connection to loops or to other via trunks. A via

[1] The term *local circuit* or *local* is used in other literature to denote both a circuit between a telephone and a switchboard and a circuit between two telephones. Loops are also known as *lines, station lines*, or *subscriber lines*.

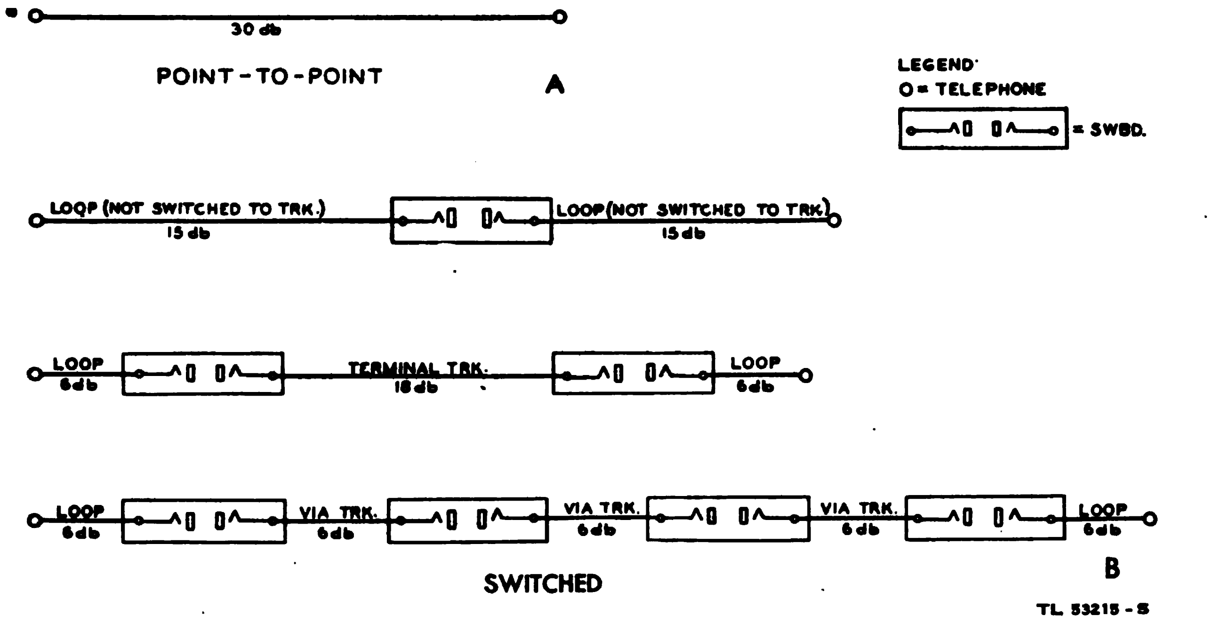

Figure 2-1. Point-to-point and switched circuits, schematic.

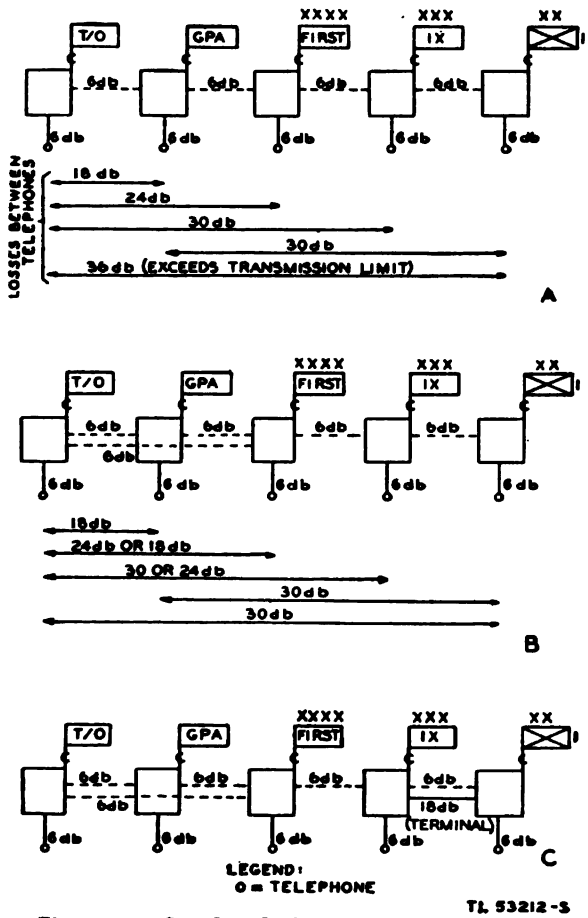

Figure 2-2. Simple telephone transmission plans.

trunk is sometimes called a *link*. Figure 2–1–B illustrates these kinds of circuits.

d. The trunk plant comprises *all* switched circuits except loops, including the trunks from long distance centrals to local centrals (par. 214).

e. Adequate provision of trunks of via grade is essential to insure satisfactory transmission on switched connections. Such trunks, when used on terminal business, will have better transmission than needed. While the details of actual plans are complex, the principle is simple. *The sum of the losses of two loops alone, or two loops plus the maximum trunk losses, should not exceed about 30 db.* In laying out trunk losses it is generally wise to allow 6 db for the loss of each loop, though in particular cases the loop loss may be less. This leaves 18 db for the sum of the trunk losses. This 18 db would be used up by three 6 db via trunks in tandem.

f. Figure 2-2 shows a few simple applications. In figure 2-2-A, the 30-db requirement is met for all connections shown except the one from theater headquarters to division headquarters. When there is sufficient traffic over such a channel, an improved circuit should be provided, for example, as shown in figure 2-2-B, where one or more via trunks are provided directly between theater and Army headquarters. It may be possible to provide the improved circuit by adding repeaters.

g. The number and type of trunks provided depends, among other things, on traffic requirements. For example, in addition to the via trunks, one or more terminal trunks might be provided between division and corps, as indicated in figure 2-2-C.

h. Variations of the plans illustrated above can be used, if they comply with the general principle. For example, in a situation where not over two via trunks must be connected in tandem, the permissible loss of each via trunk is 9 db. Likewise, loops which are never switched to trunks may have a loss of 15 db.

i. Figure 2-3 gives illustrative values of the maximum length of various types of wire and radio circuits which should provide satisfactory voice transmission for various kinds of switched circuits and point-to-point circuits. Chapters 5 and 6 give additional information.

j. The grade of transmission which it is practicable to provide will be greatly affected by the tactical situation. Near an active front, speed of installation is essential, and circuits are more liable to damage; hence transmis-

SWITCHED CIRCUIT

Type of Circuit	*Transmission loss (db)*	*Type of wire*		*Approximate maximum length (miles)*
Loops[a]	6	W-130-A (assault wire)		1
		W-110-B (field wire)		2
		W-143 (long range tactical wire)		5
Terminal trunks[b]	18	W-110-B		6
		W-143 nonloaded		15
		CC-358-( ) (spiral-four cable) voice frequency		24
		W-143 loaded		56
		Open wire	080 C-S (40%)	72
			104 C-S (40%)	100
		Lead-covered cable, repeatered		Greater distance
Via trunks	6	W-143 nonloaded		5[b]
		W-143 loaded		19[b]
		CC-358-( ) with CF-1 carrier		150
		Open wire carrier		Greater distance
		Lead-covered cable, repeatered		Greater distance
Radio	6	Radio Sets AN/TRC-3 and AN/TRC-4 or AN/TRC-11 and AN/TRC-12 with 4-channel carrier		100[c]

[a] Maximum loop lengths are for local battery telephones. With usual common battery telephones, distance for Wire W-130-A or Wire W-110-B would be less. Sound-powered instruments not suitable except in special situations.

[b] These lengths can be increased by using telephone repeaters on cable or open wire or by loading on cables where not already applied (ch. 5).

[c] Can be increased by discarding the top one of the four channels. Distance is nominal and depends on terrain, repeater spacing, and other factors.

Figure 2-3. Maximum lengths of various types of circuit.
(continued on opposite page)

POINT-TO-POINT WIRE CIRCUIT

Type of wire[b]		Approximate maximum length, miles)[a]	
		Local battery telephones[b]	Sound-powered telephones
W-130-A		5	3
W-110-B		11	5
W-143		25	12
Open wire:	080 C-S (40%)	120	60
	104 C-S (40%)	165	85

POINT-TO-POINT RADIO CIRCUIT

Transmission frequency	Approximate maximum lengths
25-250 megacycles, nonrepeatered	1 to 50 miles multichannel and 1 to 100 miles single channel, depending on type of sets and terrain.
25-250 megacycles, repeatered	Up to fairly long distances depending on type of sets and terrain.
2-25 megacycles	1 mile to very long distances depending on type of sets, terrain, and ionospheric conditions.

[a] These lengths can be increased by using telephone repeaters on cable or open wire or by loading on cables where not already applied (ch. 5).

[b] Allowable transmission loss of wire is 30 db with local battery telephones; 15 db with sound-powered telephones.

Figure 2-3. Maximum lengths of various types of circuit (continued).

sion may have to suffer. On this account it is all the more important to provide good transmission on trunks farther to the rear, so that the transmission loss between telephones on built-up connections will be reasonably satisfactory. On long circuits well to the rear, where opportunity permits, the grade of construction and transmission approaches or equals that of good commercial telephone practice.

Section III. TELEPHONE STATION EQUIPMENT

205. GENERAL.

a. A telephone system consists of a network of interconnecting wires, wire transmission equipment, and radio equipment which provide means for the transmission of electrical energy between any two terminals of the system. In order to use this network for speech communication a telephone handset, head and chest set, or some other arrangement of microphone and telephone receiver must be connected to each of its terminals. The characteristics of microphones and telephone receivers must conform to the communication system with which they are used. For example, the transmitting efficiency of sound-powered telephones makes them unsuitable for use in extensive switched telephone systems (par. 209); also only certain types of microphones are suitable for use where ambient (acoustic) noise is high (par. 212b). As another example, a telephone receiver may have a *peaked* response-frequency characteristic which makes it ideal for the reception of Morse telegraph yet inferior for use in a speech communication system. The principal features of the telephones most commonly used in communication systems are discussed in paragraphs 206 to 210, inclusive, and the characteristics of microphones and telephone receivers are discussed in paragraph 212.

b. Telephones and head and chest sets include a microphone (telephone transmitter) which converts sound waves to electrical waves and a telephone receiver which converts electrical waves to sound waves. The effectiveness of microphones and receivers as converters of energy greatly affects the performance of a telephone system. Other factors which affect transmission of speech and are of particular importance in the design of microphones, telephone receivers, and telephones include:

(*1*) High ambient noise (engine, gunfire, etc.) at the talker or listener stations.

(*2*) Operation at extreme temperatures and humidities.

(*3*) Operation with oxygen masks or gas masks.

(*4*) Operation at high altitudes.

c. A telephone usually includes signaling apparatus consisting of a switchhook or hand generator to signal the telephone central or other telephones; also a bell or buzzer and, in some cases, a lamp, by which the operator may be signaled. Some telephones are also equipped with a push-to-talk switch whereby the microphone is connected to the circuit only when this switch is closed.

d. A battery-powered telephone has a carbon microphone which requires an external source of d-c power for converting sound waves into electrical waves. It acts not only as a converter of energy but also as an amplifier. An antisidetone type of coil is utilized through which the microphone and receiver are connected to the line. This type of coil is used to reduce masking of received speech by noise picked up by the microphone, thereby improving transmission. It also reduces the volume of the user's own voice in his receiver thereby tending to cause him to talk louder, thus further improving transmission.

e. The sound-powered microphone is similar in construction to the telephone receiver, and since no amplification is provided, such as that inherent in the carbon microphone, its efficiency is comparatively low. The carbon microphone, such as that used in Handset TS–9, is about 25 db more sensitive than the most efficient sound-powered type, such as that used in Handset TS–10. Because of this low efficiency an antisidetone coil normally is not used in sound-powered telephones. Specific information regarding microphones, telephone receivers, telephones, head sets, chest sets, and head and chest sets may be obtained from TM 11–487.

206. LOCAL BATTERY TELEPHONES.

a. Local battery antisidetone telephones such as the EE–8–( ) are used on point-to-point circuits and on loops to magneto switchboards. They are also used on long loops to common battery switchboards where, because of the high resistance of the line, an adequate amount of direct current does not reach the microphone. They also may be used on short loops to common battery switchboards if common battery telephones are not available.

b. With good batteries, the direct current through the microphone in Telephone EE–8–( ) will be from 0.06 to 0.07 ampere.

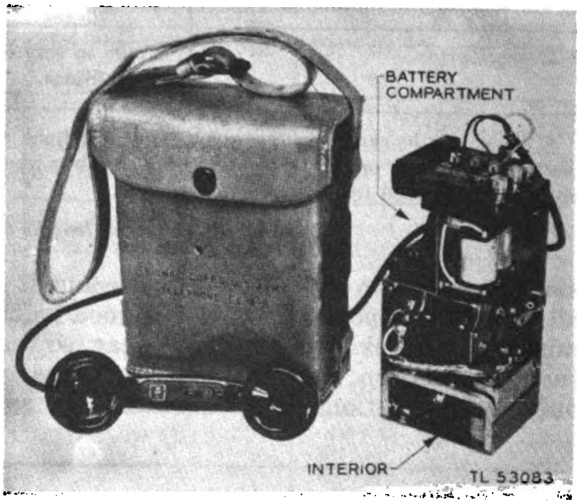

Figure 2-4. Telephone EE–8–B.

A satisfactory grade of transmission will be obtained between two such telephones connected by lines having transmission losses up to 30 db. Average talking into a local battery telephone will deliver to the loop a volume in the neighborhood of —5 vu, and for the loud talkers the output from the telephone may be +3 vu (ch. 12).

c. Handset TS–9–( ) which is furnished as part of Telephone EE–8–( ) contains a compensated magnetic-type receiver in which the diaphragm is damped and free to move at the edge. This type of receiver reproduces about equally well all the frequencies in the speech transmission band which are important from the standpoint of intelligibility (200 to 3,000 cycles).

d. The speech transmission loss caused by bridging a Telephone EE–8–( ) across a 600-ohm line is about 3 db. However, because of resonance between the capacitance and inductance elements in the telephone, the impedance of Telephone EE–8–( ) is very low *at 500 cycles* and the bridging loss at this frequency may under some conditions be as much as 15 db. It is therefore important to avoid bridging of Telephones EE–8–( ) on circuits using 500-cycle ringing.

e. Figure 2-4 is a photograph of a typical Telephone EE–8–( ) and figures 2-15 and 2-20 show the response-frequency characteristics of the microphone and receiver of Handset TS–9–( ).

207. TELEPHONE TP–9.

a. This telephone combines the functions of Telephone EE–8–( ) and transmitting and receiving amplifiers located at the same point. It is equipped with a transmitting amplifier which gives a fixed gain of 17 db compared to Telephone EE–8–( ) and is capable of providing a maximum power output of 15 db above one milliwatt. Because of this limitation on power output, the maximum gain of 17 db will be available only with talkers whose speech volume is not above average. The receiving amplifier provides a variable gain up to a maximum of about 55 db. The direction of transmission is controlled by the push-to-talk switch in the handset handle. During talking the receiver circuit is open and the talker neither hears sidetone nor can he hear the distant party if he attempts to interrupt. This telephone cannot be used on common battery loops since no coil is provided to complete the d-c signaling path.

b. This telephone is intended for use where line losses are so great that transmission with Telephone EE–8–( ) is unsatisfactory. Since it has a power output which is approximately 15 db greater than that of the EE–8–( ), the probability of introducing crosstalk into other telephone circuits and overloading telephone repeaters is materially increased.

c. The large gains in receiving efficiency which are available will be effective in improving transmission on loops which have high attenuation losses and are not subject to interference from power circuits or other extraneous sources, and in locations where ambient (acoustic) noise is high.

d. The high receiving gain of this telephone points to the possibility of using it for listening in on enemy circuits either through a direct high impedance bridge or through crosstalk into a coupled path.

e. Figure 2-5 is a photograph of a typical Telephone TP–9. Additional information is given in TM 11–2059.

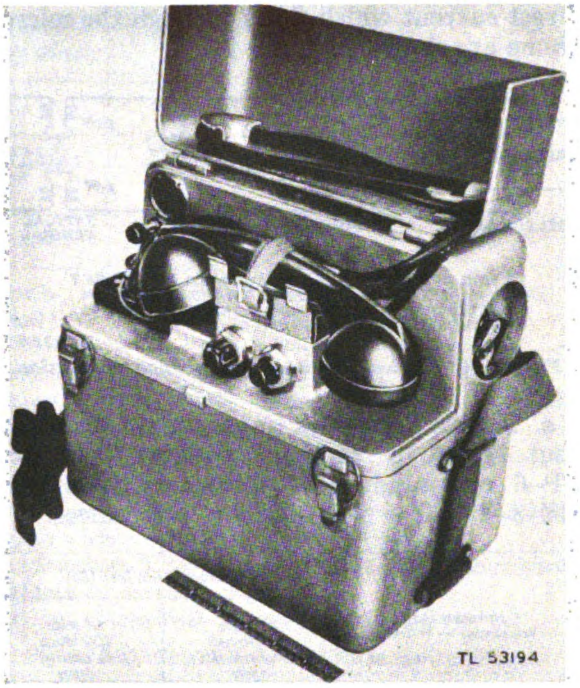

Figure 2-5. Telephone TP–9 (model).

208. COMMON BATTERY TELEPHONES.

a. Common battery antisidetone telephones such as Telephone TP–6 are used on loops to common battery switchboards, and the direct current for the microphone is obtained over the loop. The transmitting efficiency of these telephones is therefore poorer when connected to a long loop than when connected to a short loop. On very short loops the transmitting efficiency is about the same as that of a local battery telephone.

b. The microphone and receiver used in the handset which is a part of the TP–6 are similar in their performance to the microphone and receiver in Handset TS–9–( ).

c. The transmitting loss of the common battery antisidetone telephone for different loops, compared to that of the local battery telephone, is given by the empirical formula, $L = \frac{R}{4E} - 4$ db, where L is the amount, in db, by which the transmitting loss of the common battery set exceeds the transmitting loss of the local battery set, R is the total circuit resistance, and E is the voltage of the common battery supply.

d. The various elements of a typical loop circuit which contribute to the total circuit resistance and consequently to the amount of direct current which flows through the microphone are shown in figure 2-6.

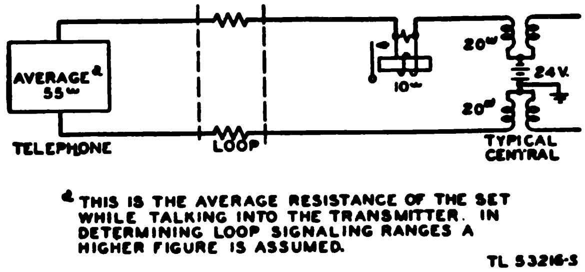

Figure 2-6. Typical common battery loop connection.

e. Figure 2-7 shows approximate transmitting losses of common battery Telephone TP-6 compared to local battery Telephone EE-8-( ) for different loop resistances.

Conductor loop resistance — (ohms)	Transmission loss (db)	
	24 volts 50 ohms in central office	48 volts 400 ohms in central office
0- 200	[a]	[a]
200- 400	0	0
400- 600	2	1
600- 800	4	2
800-1,000	7	3

[a] For these short loops the common battery telephone is slightly better than the local battery telephone.

Figure 2-7. Approximate transmitting losses of common battery Telephone TP-6 compared to local battery Telephone EE-8-( ).

f. The receiving efficiencies of antisidetone telephones such as common battery Telephone TP-6 and local battery Telephone EE-8-( ) are about the same.

g. Figure 2-8 is a photograph of a typical Telephone TP-6.

Figure 2-8. Telephone TP-6.

209. SOUND-POWERED TELEPHONES.

a. Sound-powered telephones are used for point-to-point connections where the line loss is relatively low. They can also be used on switchboard connections where the performance of dry batteries in local battery telephones is unsatisfactory. However, substandard transmission will be obtained on switchboard connections unless the loop and trunk losses are very low (subpar. d below).

b. Compared to the local battery Telephone EE-8-( ), the sound-powered Telephone TP-3 which employs Handset TS-10, is about 25 db poorer in transmitting efficiency.

c. Handset TS-10 contains a resonant magnetic receiver in which the diaphragm is undamped and clamped at the edge and the armature drives the diaphragm through a mechanical coupling. In this type of receiver greater efficiency is obtained over the conventional type of magnetic receiver, where there is no mechanical coupling between the diaphragm and the pole pieces, without introducing an excessive amount of frequency distortion. The receiving efficiency of Telephone TP-3 is about 10 db better than that of Telephone EE-8-( ). This 10-db improvement in receiving efficiency is ineffective where the line noise is high. The response-frequency characteristics of the microphone and the receiver of Handset TS-10 are shown in figures 2-15 and 2-20.

d. The sound-powered telephone is suitable for use on point-to-point lines which have a maximum loss of about 15 db. If the line noise is excessive, this limit may drop to 5 db. If it is used in the transmission plan referred to in paragraph 204, transmission will be below standard, even where the loops are very short, since the trunks alone may exceed 15 db.

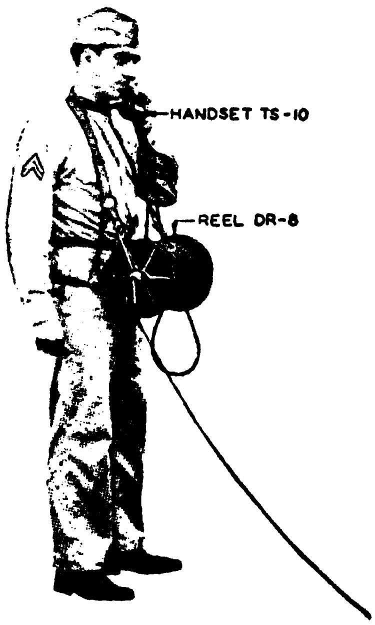

Figure 2-9. Reel Equipment CE-11.

e. Because of the relatively high impedance of the sound-powered handset, the maximum efficiency is obtained when no induction coil is employed and it is connected directly to the telephone line. On some short point-to-point circuits where signaling is not required the sound-powered Handset TS–10 may be used without other parts of the telephone. Such an arrangement is provided in Reel Equipment CE–11 (TM 11–2250), as shown in figure 2-9.

210. SUMMARY OF TELEPHONE STATION FEATURES.

The essential features of the above telephones are summarized in figure 2-10.

211. STATION WIRING PLANS.

a. A station wiring plan consists of one or more telephone stations with associated keys to permit switching to different loops without the assistance of a switchboard operator. Wiring plans may also include arrangements for intercommunication between nearby telephones without going through the switchboard. Buzzers, controlled from push buttons, are sometimes provided for signaling in connection with wiring plans.

Item	*EE-8-( )*	*TP-9*	*TP-6-( )*	*TP-3*
Type of case	Leather or canvas	Metal	None (desk set)	Leather or canvas
Type [a]	LB	LB	CB	SP
Battery supply	Dry batteries	Dry batteries	CB	None
Ringer	Yes	Yes	Yes	Yes
Generator	Yes	Yes	No	Yes
Push-to-talk switch	Yes	Yes	No	No
Dial	No	No	Optional	No
Induction coil	AST	[c]	AST	None
Handset	TS-9-( )	TS-9-( )	[d]	TS-10-( )
Switchboard [a]	Mag or CB [b]	Mag	CB	Mag
Technical Manual	TM 11-457 TM 11-333	TM 11-2059	TM 11-458	TM 11-2043

[a] LB = local battery; CB = common battery; SP = sound-powered; AST = antisidetone; Mag = magneto.
[b] Telephone EE-8-( ) uses dry batteries for transmitter supply when connected to CB switchboard.
[c] Telephone TP-9-( ) includes amplifiers in microphone and receiver circuits.
[d] Part of telephone, no separate nomenclature.

Figure 2-10. Summary of telephone station features.

b. The simplest wiring plan is a 2-position key such as Switchbox BE–54-A which enables a telephone to be connected to either one of two loops. A group of six mechanically interlocked push buttons such as the Western Electric Company key No. 6021K can be provided to pick up any one of six loops. A key can be provided at one telephone to cut off another telephone from a loop. Arrangements for holding supervision on loops are sometimes provided so that a call on a loop can be held while the telephone is connected to another loop or local intercommunicating line. Various wiring plans are described further in TM 11–474.

212. MICROPHONES AND TELEPHONE RECEIVERS.

a. **General.** In addition to the microphones and receivers used in telephones, a variety of

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other microphones and receivers are available for use in head and chest sets, chest sets, headsets, and hand-held microphones. The physical and electrical characteristics of these instruments and photographs of many of them are given in TM 11–487. They are used in the operation of a telephone system for telephone switchboards, AWS operations centers (sec. V), radio sets, and other services where continuous operation or other special features require their use. The characteristics of these telephone instruments are such that maximum intelligibility of speech will be obtained when they are used as a part of the particular system for which they were designed.

b. Microphones.

(*1*) The hand-held microphone such as Microphone T–17–( ) (fig. 2-11) is suitable for use in high ambient noise fields without acoustic shielding. It is designed to discriminate against ambient noise which is predominantly high or low in frequency. It does not discriminate against ambient noise which is of the same frequency as the more important speech sounds.

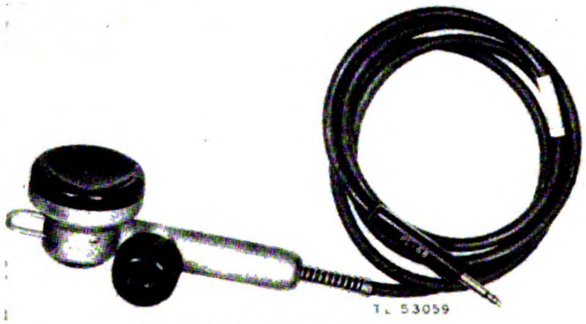


Figure 2-11. Mircrophone T–17.

(*2*) Microphones such as Microphone T–45–( ) are of the differential type, having both sides of the diaphragm open to the sound field. This type is worn suspended over the lip and when used in an ambient sound field originating from a source at some distance, the ambient noise is partially cancelled out, thereby giving an improvement in speech-signal to ambient noise ratio over that obtained with the conventional type of microphone. For intense ambient noise this improvement in signal-to-noise ratio is about 15 db. The satisfactory performance of this transmitter in high ambient noise fields is therefore dependent on wearing it in the proper position. Figure 2-12 is a photograph of Microphone T–45 in use.

Figure 2-12. Microphone T–45.

(*3*) The amphibious forces require microphones and telephone receivers which must be capable of withstanding submersion in water. Headset Assembly CW–49507A (Navy nomenclature) which is suitable for this purpose consists of lip Microphone M–6( )/UR and two very thin watch case type receivers CW–49505 (Navy nomenclature). A photograph of Headset Assembly CW–49507A is shown in figure 2-13.

Figure 2-13. Headset Assembly CW–49507A (Navy nomenclature).

(*4*) Microphone T–30–( ), which is worn at the throat, is also used where ambient noise is extremely high. The intelligibility of speech transmitted by this microphone is appreciably poorer than speech transmitted by Microphones T–17–( ) or T–45–( ), because it picks up only the low-frequency throat sounds and does not pick up the higher frequencies developed in the head cavities, which are necessary for good intelligibility.

(*5*) Microphones of the ANB–M–C1 and T–44–( ) types (fig. 2-14) which are for use in oxygen masks are designed for greater efficiency at high than at low voice frequencies. This complements the response of the enclosure, wherein the low frequencies of speech are reinforced, so that the response characteristic of such a mask-microphone combination is essentially flat.

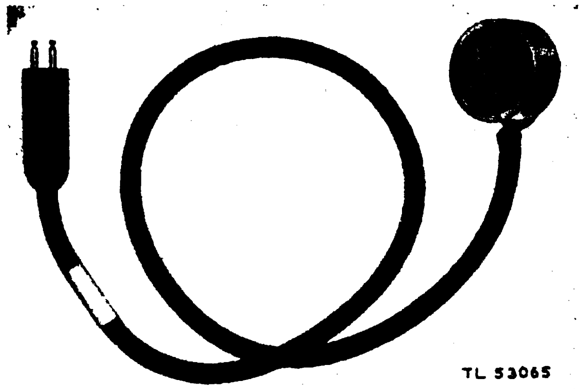


Figure 2-14. Microphone ANB–M–C1 (Cover M–369 removed).

(*6*) Figure 2-15 shows the response-frequency characteristics of representative microphones. They indicate the relative efficiencies of these microphones at different frequencies in the speech transmission band. These efficiencies are shown in db relative to a reference condition, which is arbitrarily located in the general neighborhood of the curve for the microphone in Telephone EE–8–( ).

c. Telephone Receivers.

(*1*) Compensated magnetic receivers such as those used in Head and Chest Sets HS–17–( ) and HS–19–( ) and in Headset HS–30–( ) (TM 11–487) are suitable for the reception of speech as they reproduce about equally well all the more important frequencies in the speech transmission band. They are about equal in performance to the receiver in Handset TS–9–( ). The performance of the compensated

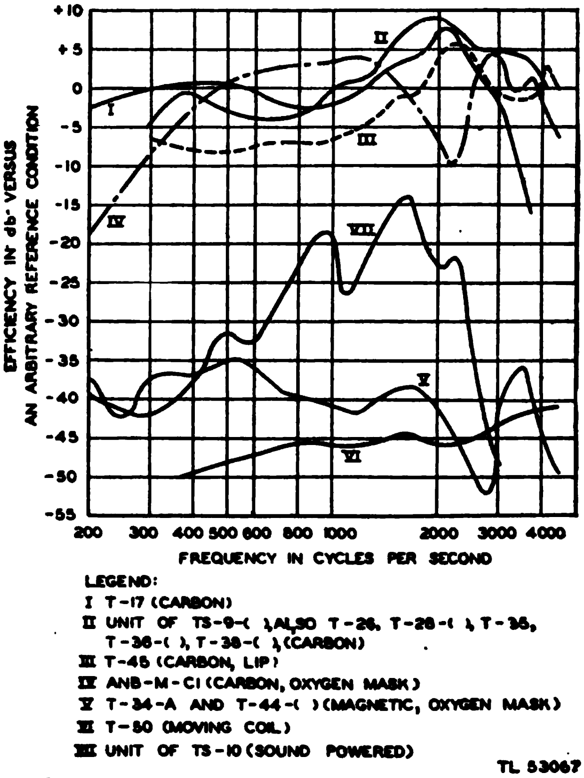


Figure 2-15. Response-frequency characteristics of microphones.

magnetic watch-case type receiver under conditions of high ambient noise has been improved with the development of new types of ear cushions. The large volume of enclosed air in *over-the-ear* Cushion MC–114 used with Headset HS–17–( ) results in an appreciable loss in receiving efficiency. In the development of the ANB–H type receiver the use of a smaller Cushion MC–162–( ) (Headset HS–33–( )) gives a better seal against interfering noise and a wider response-frequency range is also obtained. This type of

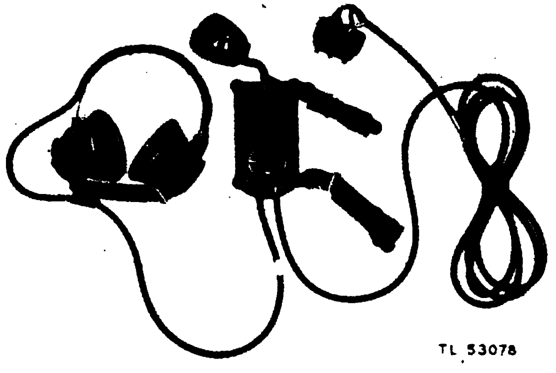


Figure 2-16. Head and Chest Set HS-17.

Figure 2-17. Headset HS-33.

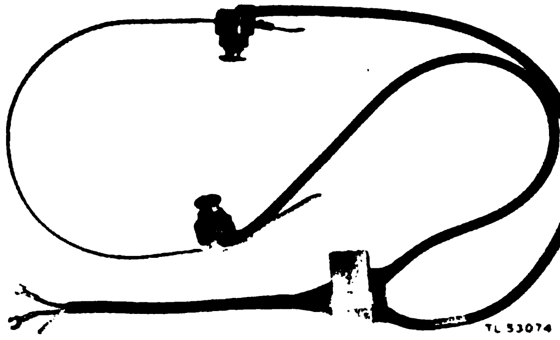


Figure 2-18. Headset HS-30.

receiver is particularly effective when listening to a microphone such as the T-17-( ) which discriminates against low-frequency ambient noses. Headset HS-30-( ) uses hearing-aid type receivers with Inserts M-300, which provide a good seal against interfering noise. It can be worn under the battle helmet. This headset replaces the headset used in the above head and chest sets and in many other headsets. Photographs of typical Head and Chest Sets HS-17-( ), Headset HS-33-( ), and Headset HS-30-( ) are shown in figures 2-16, 2-17, and 2-18, respectively and cording ar-

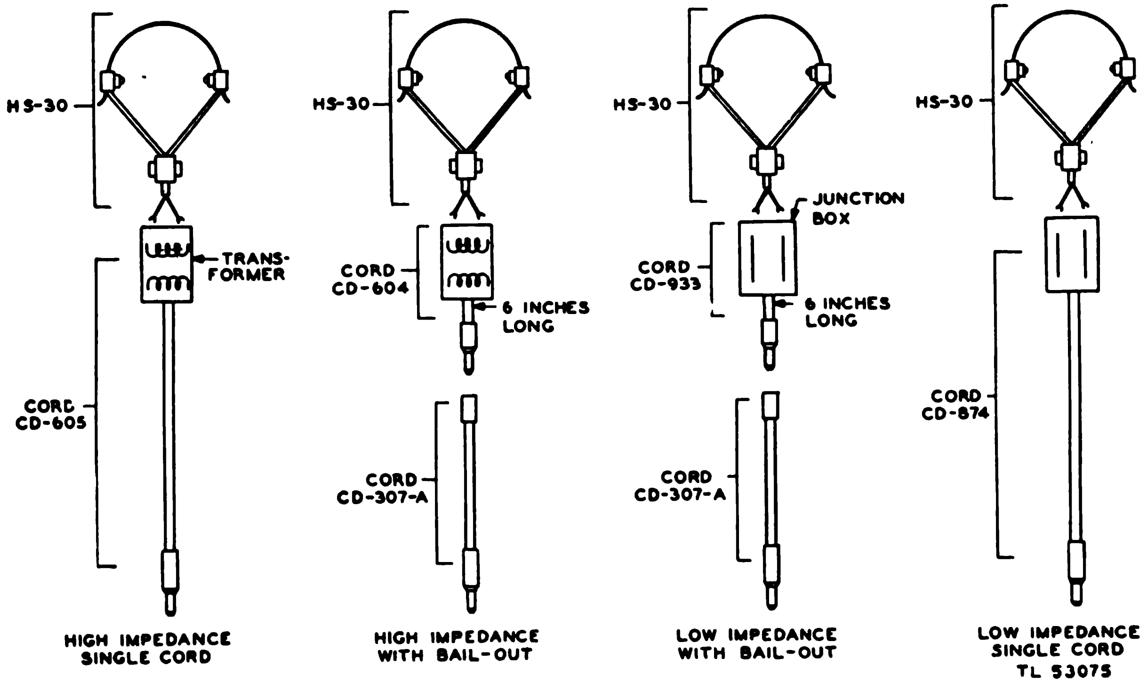
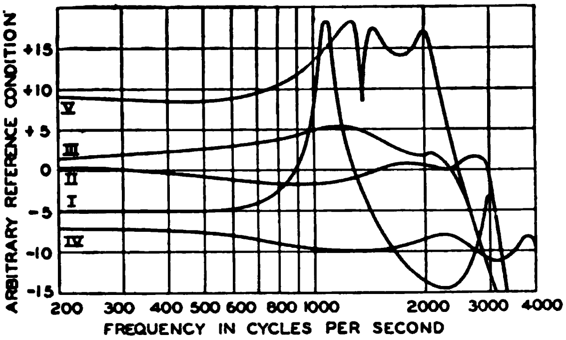


Figure 2-19. Headset HS-30-( ), cording arrangements.

rangements which are available for use with Headset HS–30–( ) are shown in figure 2-19.

(*2*) The resonant magnetic receiver such as that used in Headset P–16 is most suitable for the reception of tone signals if the resonant peak of the receiver matches the frequency of the tone. Its use should be confined to the reception of tone telegraph signals.

(*3*) Figure 2-20 shows response-frequency characteristics of representative telephone receivers. They indicate for the different receivers the sound power output with frequency. The efficiencies are shown in db relative to a reference condition which is arbitrarily located in the general neighborhood of the curve for the receiver in Handset TS–9–( ).



LEGEND:
I R-13, ALSO R-2, R-2-A, R-3, R-14, AND R-15 (RESONANT MAGNETIC)
II UNIT OF TS-9, ALSO R-21, AND R-22 (COMPENSATED MAGNETIC)
III R-30-( )(COMPENSATED MAGNETIC)
IV ANB-H-1 (COMPENSATED MAGNETIC)
V UNIT OF TS-10 (SOUND POWERED)

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Figure 2-20. Response-frequency characteristics of telephone receivers.

Section IV. TELEPHONE CENTRALS

213. INTRODUCTION.

The principal equipment in a telephone central is a switchboard for interconnecting loops and trunks. The central may include power equipment, distributing frames, and protectors; testing, monitoring, observing, and recording equipments; repeaters, carrier equipment, telegraph equipment, and various accessories. This section describes the principal features of switchboards and closely associated equipments. Telegraph equipments are described in chapter 3, repeaters and carrier equipments in chapter 5, power equipment in chapter 7, and protectors in chapter 10. Data and brief descriptions covering these equipments are contained in TM 11–487.

214. TYPICAL CENTRALS.

a. General. A telephone central is generally located near the center of the area which it serves and is connected by loops to the telephones in the area, and by trunks to centrals in other areas. The size of the area served by a switchboard is determined by a combination of many factors including the number of telephones in the area, the distribution of traffic between the telephones, the availability of certain types of wires and switchboards, the permissible transmission losses, and the signaling ranges. The objective in planning the size of an area is to keep at a minimum the quantity of materials for loops, trunks, and switchboards and to produce maximum efficiency in the operation and maintenance of the communication system. In general, one large central is preferable to several smaller centrals in the same area because the larger central will provide the better telephone service as a result of fewer trunked calls and a larger and more efficient team of maintenance and operating personnel; this is discussed further in chapter 11.

b. Typical Centrals for Small and Large Areas. Typical centrals for small and large areas are illustrated in figure 2-21. In a small area, such as Area A in this figure, only a single central may be provided, while in a larger area, such as Area B, several centrals may be provided. A central which serves loops and has all of its trunks terminated in the same area is called a local central. One which handles only long distance traffic is called a long distance (LD) central. Army centrals commonly handle both local and long distance traffic and such a central is called a combined local and long distance central.

c. Switchboards for Telephone Centrals. The switchboards used in Army centrals are of various types and these are broadly classified as tactical switchboards which are designed for use principally in forward areas, and fixed plant switchboards which are like those designed for civil telephone central offices. The

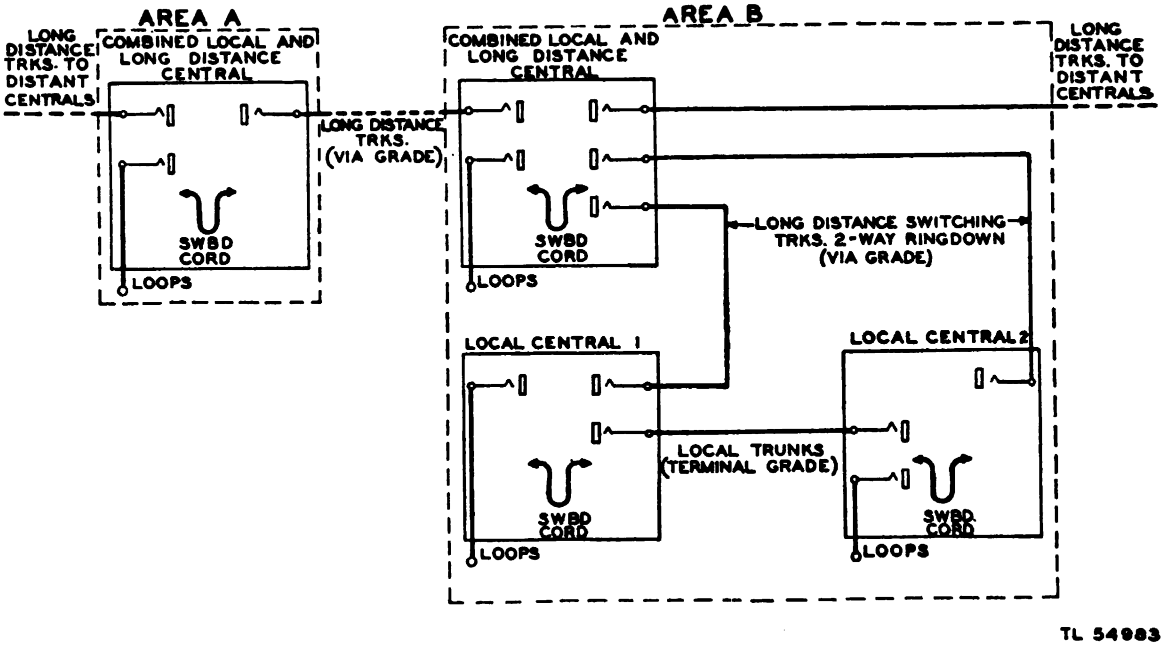


Figure 2-21. Typical centrals for small and large areas.

principal features of the switchboards which can be regularly procured for Army centrals are described in the following paragraphs of this section. Foreign civil central office switchboards which can be interconnected with these Army switchboards are described in chapter 8.

d. Typical Trunks. The trunks between centrals in different areas are called long distance trunks. Trunks between centrals in the same area are called local trunks if they are not used on connections to long distance trunks. If they are used for long distance calls, they are called long distance switching trunks. Trunks of this type are provided between a local central and a combined local and long distance central or a local central and a separate long distance central. However, a separate group of local trunks may be provided between local centrals and combined local and long distance centrals if the traffic is heavy. A via grade of transmission is generally provided on long distance trunks while the terminal grade of transmission is provided on local trunks (par. 204). The trunks between telephone centrals are classified as ringdown or automatic, according to the type of signaling. Trunks which use ac for signaling are known as *ringdown* trunks, and those which use dc for signaling are known as *automatic* trunks. Two-way ringdown trunks are commonly used between Army switchboards. These are also used between these switchboards and civil magneto central offices. Trunks which are automatic in one direction and ringdown in the other direction (called common battery trunks) are generally provided between Army switchboards and civil common battery central offices.

e. Typical Loops. The loops which connect telephones to centrals are classified as *magneto* or *common battery* according to the types of telephones and signaling. The telephones on magneto loops are equipped with hand generators (sometimes called magnetos) for signaling, and the microphones are energized by local dry batteries. Telephones EE-8-( ) are commonly used on magneto loops. The telephones on common battery loops are equipped with switchhooks for signaling and the microphones are generally energized by currents which flow over the loops from a common battery in the central. Telephones TP-6 are generally used on common battery loops. A local battery Telephone EE-8-( ) can be used on a common battery loop when the screw switch in the telephone is in the position for common battery signaling with the switchhook; in this case however, microphone current is obtained from the batteries in the telephone. The telephones on both types of loops are equipped with bells which ring

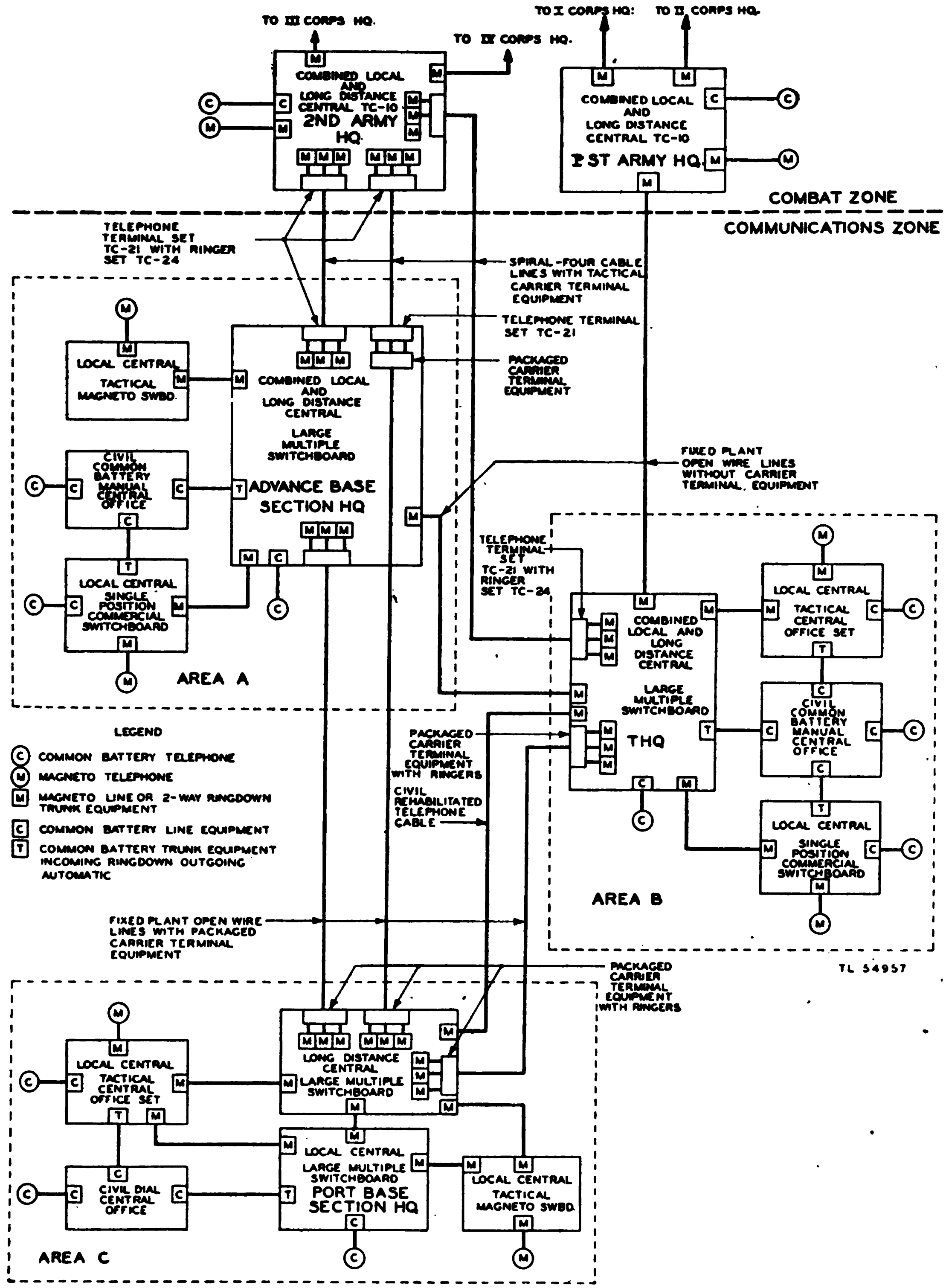


Figure 2-22. Typical applications of telephone centrals in a communications zone illustrating types of switchboards, trunks, and loops.

when 20-cycle ringing voltage is applied to the loops at the switchboards. All common battery switchboards can be connected to at least a few magneto loops in addition to the common battery loops. Magneto switchboards have no provision for common battery loops.

f. Typical Centrals for a Communications Zone. Figure 2-22 illustrates the types of switchboards which may be used in centrals which make up a communications zone. In this illustration the communications zone is divided into three areas, each large enough for several local centrals. The First and Second Army Headquarters in the combat zone each have only a single central. In the areas, trunks are provided to the switchboards of civil telephone systems over fixed plant equipment. Connections to the combat zones are established over tactical equipment through switchboards such as those of the First and Second Army Headquarters. Connections from combat zone switchboards to the areas further to the rear may be established over direct trunks or over trunks connected in tandem through intermediate switchboards. The trunks between areas are terminated on long distance or on combined local and long distance switchboards.

g. Mobile Centrals. Mobile centrals can be assembled by mounting tactical switchboards and associated equipment such as carrier terminals in mobile shelters or semitrailers. Arrangements for such centrals are described in chapter 11.

215. TACTICAL SWITCHBOARDS.

a. Tactical switchboards are ruggedly constructed to withstand frequent moving and are designed for quick installing and dismantling, as may be required in forward areas. These switchboards are available in various sizes from one position with a capacity of six loops up to six positions with a capacity of 540 loops. Each of the switchboards having a capacity of 40 loops or less is an individual position containing all of the equipment required for operation, including protectors and binding posts for the line wires. The larger tactical switchboards are components of telephone central office sets. These have separate components for the power equipment, test equipment, and distributing frames with protectors. Cabling arrangements include rubber-covered cables which are attached to binding posts or screw terminals without soldering.

b. The small tactical switchboards which have capacities of 12 loops or less are of the magneto monocord type such as the Switchboard BD–72 (par. 219). The functions of a small tactical magneto switchboard can also be performed by Emergency Switchboard SB–18/GT or by a group of Adapter Plugs U–4/GT (par. 218) with Telephone EE–8–( ). The next larger tactical switchboard is the magneto cordless Switchboard BD–95 (par. 220) which has a capacity of 20 loops or trunks. The larger tactical switchboards are of the manual cord type (par. 221) and may be either magneto or common battery. The largest tactical switchboards are of the multiple common battery type (par. 223) with universal cord circuits (par. 231) which can be connected to magneto and common battery loops.

216. FIXED PLANT SWITCHBOARDS.

a. Switchboards of the fixed plant type are less rugged than the tactical switchboards and are practically the same as those used in commercial telephone systems. They are more suitable than tactical switchboards for stable situations particularly for very large installations, and over a long period of time they will have less maintenance and will give better service than tactical switchboards. Most of the cables to these switchboards are textile insulated and the wires are soldered to terminals. They require various amounts of auxiliary equipment depending on their size and application, including distributing frames, protectors, power plants, test equipment, and relay racks; and they should generally be engineered and installed by experienced men. These switchboards are furnished through the Army Communications Service on specific order.

b. The sizes of these switchboards are from one position with 12 loops up to about 60 positions with about 3,000 loops. The smallest of these is the common battery cordless switchboard described in paragraph 220. The next larger switchboards are of the single position nonmultiple cord type (par. 222), with capacities from 60 to 100 loops per position. The largest switchboards are of the multiple common battery type described in paragraph 223.

217. DIAL SWITCHBOARDS.

a. Step-by-step and all-relay types of dial switchboards are available for certain fixed plant conditions. The capacity of the step-by-step switchboards in Signal Corps stock is 2,000 loops; however, larger switchboards have been supplied to the theaters. The capacity of each all-relay switchboard in stock is 600 loops. Connections originated at telephones connected to loops from these switchboards are automatically established by switches or relays which are controlled from the dials at the telephones. However, a manual switchboard is provided with each dial switchboard so that operators can complete incoming and outgoing calls over trunks to manual centrals and render assistance to dial telephone users, principally on long distance calls.

b. The number of operators required in connection with a dial switchboard is less than that for a manual switchboard serving the same number of loops. The speed of establishing connections through a dial switchboard is generally a little faster than that through a manual switchboard. However, over-all advantages from a dial switchboard cannot be realized unless the conditions where it is installed are stable and the telephone directory information is kept up to date. Without reliable directory information, a large proportion of the telephone traffic would probably require assistance from the operators, and this would tend to nullify the advantages of dial service.

c. Greater skill is required to maintain dial equipment than to maintain manual equipment. The floor space and power requirements for a dial switchboard are greater than those for a manual switchboard of equivalent size. The use of dial switchboards by the Signal Corps has been extensive in the zone of the interior, and considerable use has been made of these switchboards in the theaters of operation However, further discussion of these switchboards is not included in this chapter.

218. ADAPTER PLUGS FOR INTERCONNECTING MAGNETO LOOPS AND TRUNKS.

The simplest equipment for interconnecting a few loops and trunks consists of a group of 2-pronged Adapter Plugs U–4/GT and a Telephone EE–8–( ). These plugs can be connected to magneto loops and 2-way ring-down trunks and serve as a lightweight substitute for a small magneto switchboard. Emergency Switchboard SB–18/GT (fig. 2-23) consists of seven Adapter Plugs U–4/GT, one Plug Holder MT–313/GT, and one Case CY–229/GT. Each plug weighs only about 1.5 ounces. It consists of a neon glow lamp, two binding posts, two pins, and two sockets, all molded together in translucent plastic. The pins serve as the thumbscrews of binding posts to which wires are connected. They are

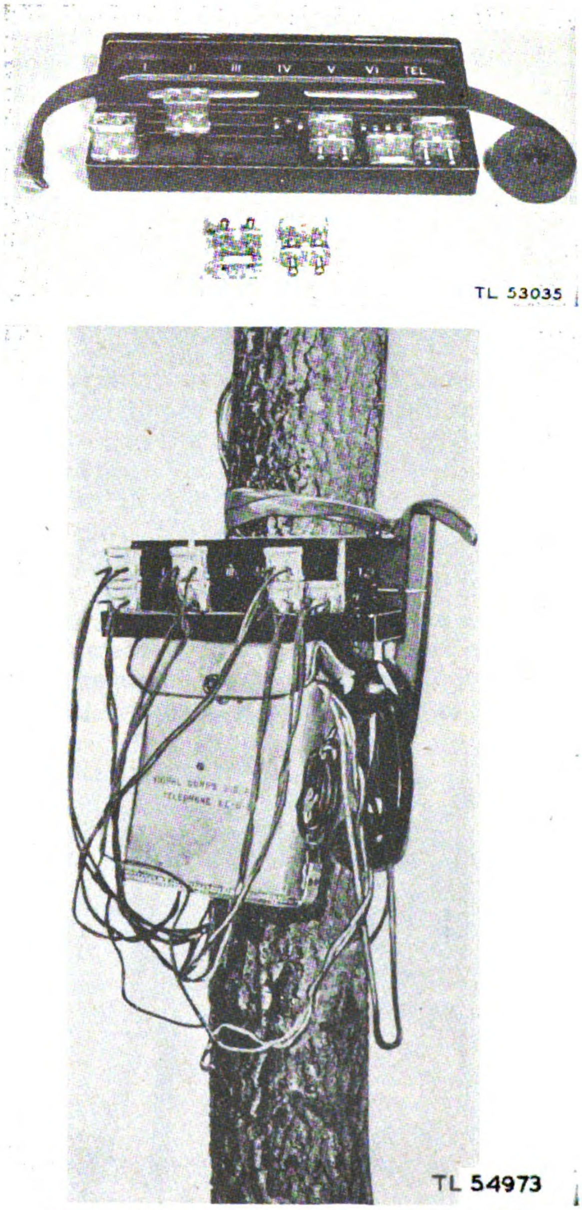


Figure 2-23. Emergency Switchboard SB–18/GT (with Telephone EE–8–B).

also the plugs which are inserted in the sockets of another adapter plug to establish a connection between two lines. Several plugs can be connected in tandem for conference connections, or so that an operator's telephone can be connected to a loop while it is also connected to another loop or trunk. Ringing on a loop to which a plug is connected lights the neon glow lamp in the plug. An audible signal is not obtained when the neon lamp lights, except that the ringer of the Telephone EE–8–( ) will sound if it is connected to a loop while ringing occurs. A luminous dot is provided on each side of the plug to facilitate locating and handling in darkness. The number of the line to which a plug is connected can be written in pencil or ink on a luminescent backed designation strip which is embedded in the surface of the plug. Such numbers are visible in silhouette against the luminescent background under black-out conditions. The uses of these plugs are described in TB SIG 61 (to be superseded by TB SIG 147 when published).

219. MONOCORD MAGNETO SWITCHBOARDS.

The smallest switchboards are of the magneto monocord type. These switchboards are available in capacities from four loops as provided by Switchboard BD–9 up to 12 loops as provided by Switchboard BD–72. The latter switchboard is shown in figure 2-24. The equipment for each loop or trunk is principally a cord, a jack, a drop, and a 2-way lever-type key. Ringing from the distant end of the loop operates the drop. The operator's telephone is connected to the loop by the operation of the key in one direction. Operation of the key in the other direction connects the hand generator to the loop. A connection between two loops is established by connecting the cord of one loop to the jack of the other loop.

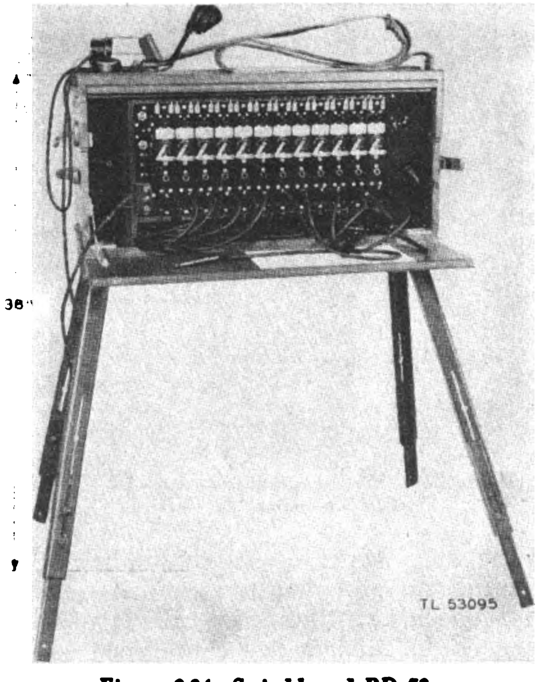


Figure 2-24. Switchboard BD–72.

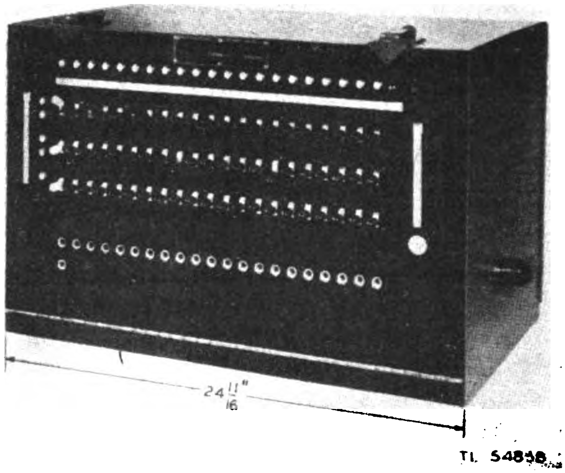


Figure 2-25. Switchboard BD–95.

220. MANUAL CORDLESS SWITCHBOARDS.

Two types of manual cordless switchboards are used in Army communication systems. One is switchboard BD–95 (fig. 2-25) which has capacity for 20 magneto loops or trunks. The other is the Western Electric Company No. 506B switchboard which has a capacity for 12 common battery loops and five common battery trunks. Each of these has five connecting paths which permit five simultaneous calls. However, Switchboard BD–95 has means for readily splitting the connecting paths in the middle of the switchboard by changing cross-connections in the back of the switchboard, thus providing two groups of 10 loops with five connecting paths for each group. A common battery Telephone EE–91 with a Handset TS–12–( ) is normally used with this switchboard. This equipment, however, is not a component of Switchboard BD–95. Under the split condition, the operator's telephone is patched to the last group of 10 loops or trunks, by connecting a patching cord between the operator's test jack and the line test jack of any one of the 10 loops or trunks. A vertical row of three 2-way locking, lever-type keys is provided for each loop or trunk and a similar row of keys is provided for the operator's telephone. Each key can be operated up or down from normal; thus there are six operated key positions for each loop or trunk. Five of these positions are associated with the five connecting paths, respectively. The sixth position on the keys for loops and ringdown trunks is used for ringing. This sixth position on the keys for common battery trunks is used for holding connections to other switchboards. A connection from one loop or trunk to another loop or trunk is established by operating the associated keys to the same connecting path. Ringing signals are indicated on lamps in Switchboard BD–95; it is equipped with one lamp for each loop and one lamp for each trunk. Ringing on common battery trunks in the Western Electric Company No. 506B switchboard operates drops. Switchhook supervisory signals from common battery telephones are indicated in this switchboard on magnetic signals, one of which is provided on each loop and on each connecting path.

221. CORD SWITCHBOARDS.

a. The manual switchboards larger than those of the monocord and cordless types are of the cord type. Connections through these switchboards are established by cord circuits terminated in pairs of cords. To establish a connection, one cord of a pair is connected to the jack of a calling loop or trunk and the other cord of the pair is connected to the jack of the called loop or trunk. Supervisory signals during connections over the cord circuits are indicated on drops or lamps associated with the cords. Signals on loops and trunks, while the cords are disconnected, are indicated on drops or lamps associated with the jacks. Connections to the operator's telephone are established through cord circuit keys. Similar keys are provided in the cord circuits for ringing on the loops and trunks. Further information on cord-type switchboards is given in paragraphs 222 and 223.

b. The smallest cord switchboard is the tactical magneto Switchboard BD–91–( ) with 20 magneto loops, 4 manual and dial common battery trunks, and 8 cord circuits. A similar switchboard with 40 loops and 12 cord circuits is Switchboard BD–96 shown in figure 2-26. The smallest common battery cord switchboard is Switchboard BD–89–( ) (part of Telephone Central Office Set TC–2) with 20 magneto loops, 37 common battery loops, 1 dial trunk, 2 common battery manual trunks, and 13 cord circuits. A substitute for the TC–2 is Telephone Central Office Set AN/TTC–1 (TM 11–2002) which includes switchboard SB–27/TTC–1 (Western Electric Company No. 551B PBX, X–66070A) with 20 magneto loops, 40 common battery loops, 3 manual and dial common battery trunks, and 10 cord circuits. The latter switchboard is also used in fixed plant service. Most of the other switchboards have 15 cord circuits per position. The largest multiple switchboards have 17 cord circuits per position.

Figure 2-26. Switchboard BD–96.

c. The cord circuits are of various types, but all in a particular switchboard are the same. The principal distinguishing features among cord circuits in different switchboards are related to the signaling and battery supply conditions. Magneto cord circuits provide signaling by ringing only and do not include battery supply circuits (par. 224). Common battery cord circuits include battery supply circuits (par. 227) and provide signaling in response to the flow of the battery supply currents. These cord circuits are classified as local cords (par. 230), universal cords (par. 231), and PBX cords (par 232). Cords may be connected to outside conductors through the jacks of various line and trunk circuits. Some of the line circuits are described in paragraph 223. Some of the trunk circuits are described in paragraphs 233, 234, and 235.

222. NONMULTIPLE SWITCHBOARDS.

a. **Positions.** A switchboard having not more than one or two positions is of the nonmultiple type in which each loop and each trunk appears on only one jack. A single-position nonmultiple fixed plant switchboard is shown in figure 2-27. A 2-position nonmultiple tactical switchboard is shown in figure 2-28. All of the jacks are located in the face of the switchboard within the reach of the operators. The maximum practical reach for an operator is a little less than 3 feet. The width of each position is about 2 feet. Consequently, the size of a nonmultiple switchboard is practically limited to two adjacent positions. If three nonmultiple switchboard positions were installed in a line-up, the loops and trunks appearing at one end of the line-up could not be reached by the cords at the other end of the line-up, and even if longer cords were provided, the operators could not efficiently reach so far. In installations with only two nonmultiple positions, the length of the switchboard cords is greater than that in installations of only a single position and with these longer cords the positions are raised on platforms so that the cord weights will not hit the floor.

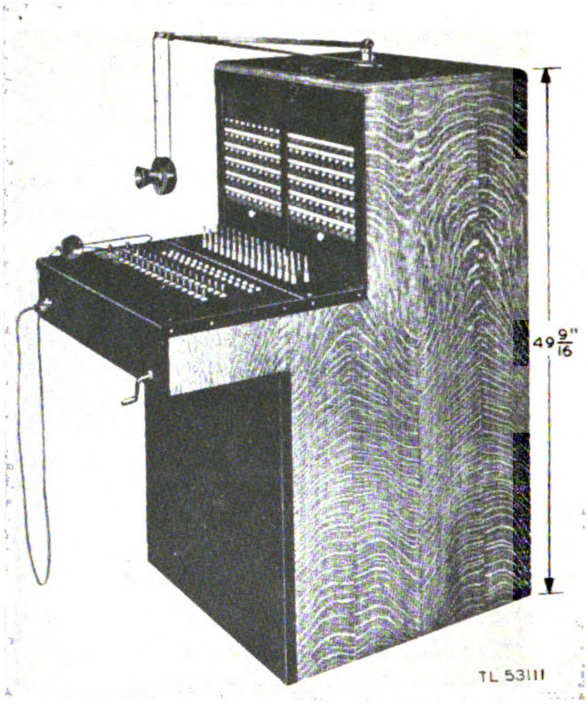


Figure 2-27. K100 switchboard (Kellogg Switchboard & Supply Company).

b. Cut-off Jacks. The jacks connected to loops in nonmultiple switchboards are of the cut-off type shown in figure 2-29. Each of these jacks has two cut-off springs in addition to the tip, ring, and sleeve springs. Each cut-off spring is in contact with its associated tip or ring spring when a plug is not in the jack; but the circuit through each of these contacts is opened when a plug is in the jack. The loop from the telephone is connected to the tip and ring springs. The line lamp, line relay, or drop is connected to the cut-off springs so that it is cut off from the loop while a plug is in the jack.

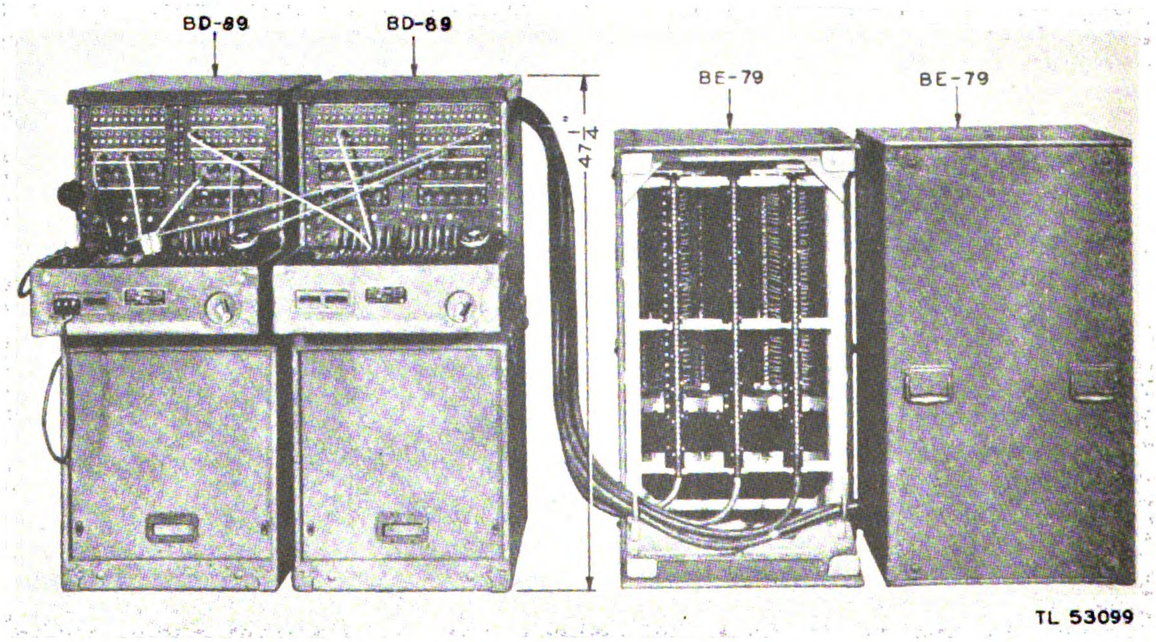


Figure 2-28. Two Switchboards BD-89 and Cabinets BE-79, assembled.

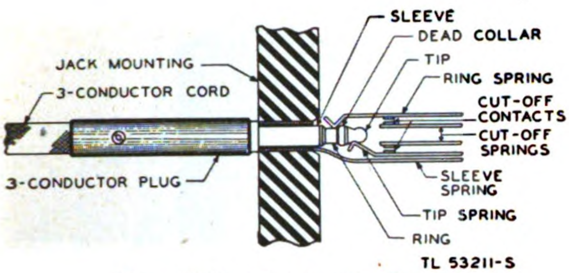


Figure 2-29. Plug in cut-off jack.

223. MULTIPLE SWITCHBOARDS.

a. Multiple Jack Appearances. Switchboards having three or more positions are of the multiple type with some or all of the loops and trunks connected to two or more jacks. A tactical multiple switchboard is shown in figure 2-30. A large fixed plant multiple switchboard with a typical floor plan is shown in figure 2-31. The multiple jack appearances of each loop and trunk are located in different positions with a distance between successive appearances equal to the width of approximately two positions, which is about 4 feet. In the smaller multiple switchboards, two jack panels are provided at each position and multiple appearances of the loops and trunks are in every fourth panel. In the large multiple switchboards with relatively small jacks, three jack panels are provided at each position and the loops and trunks are multipled to appear in every sixth or seventh panel. The relatively large jacks which are provided in most of the multiple switchboards are of the cut-off type (fig. 2-29) similar to those in nonmultiple switchboards. The smaller jacks provided in the larger switchboards have only two plug springs and a sleeve and are not equipped with cut-off springs. A relay connected to the sleeves of the jacks is required for the cut-off function with these smaller jacks (subpar. c).

b. Series Multiple. The multiple switchboards with cut-off jacks are known as series multiple switchboards because the circuit between each loop and its associated lamp or line relay is connected in series with the cut-off springs of all the jacks on the loop (fig. 2-32). The lamp or relay is cut off from the loop when a plug is inserted in any one of the jacks. Switchboard BD–110–( ) (fig. 2-30) is an example of the series multiple type. The contacts between springs in the cut-off jacks may become dirty and cause open circuits. However, series multiples are generally satisfactory with less than about 10 jacks on each loop. In the larger switchboards having a greater number of multiple jacks per loop, the bridged multiple arrangement is generally provided.

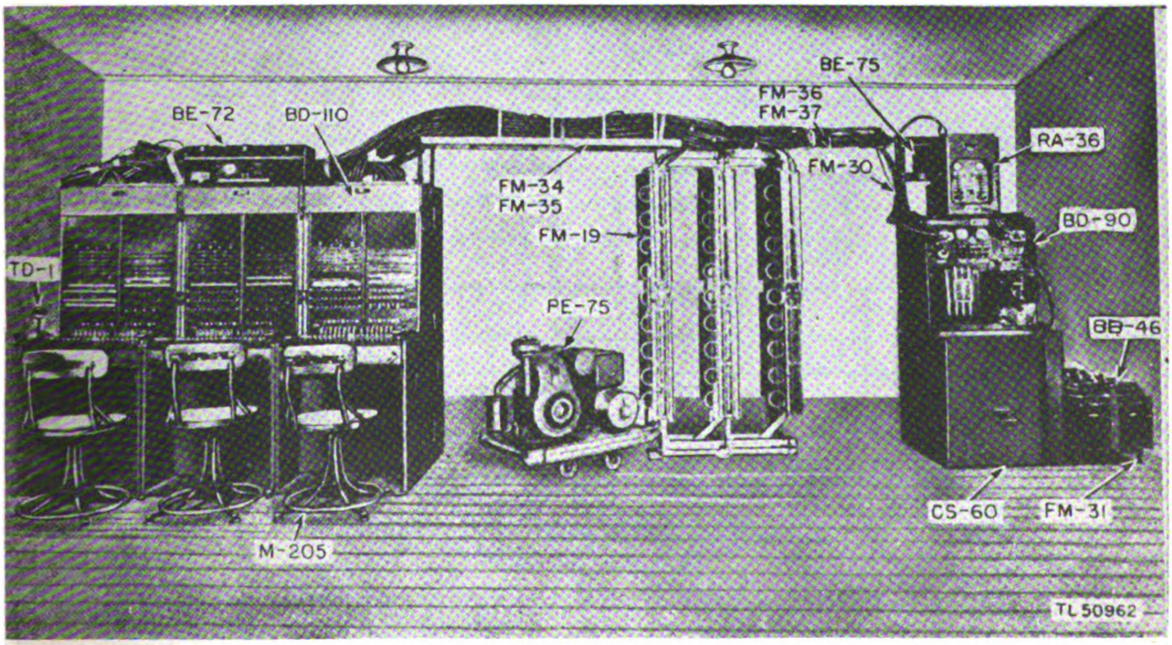
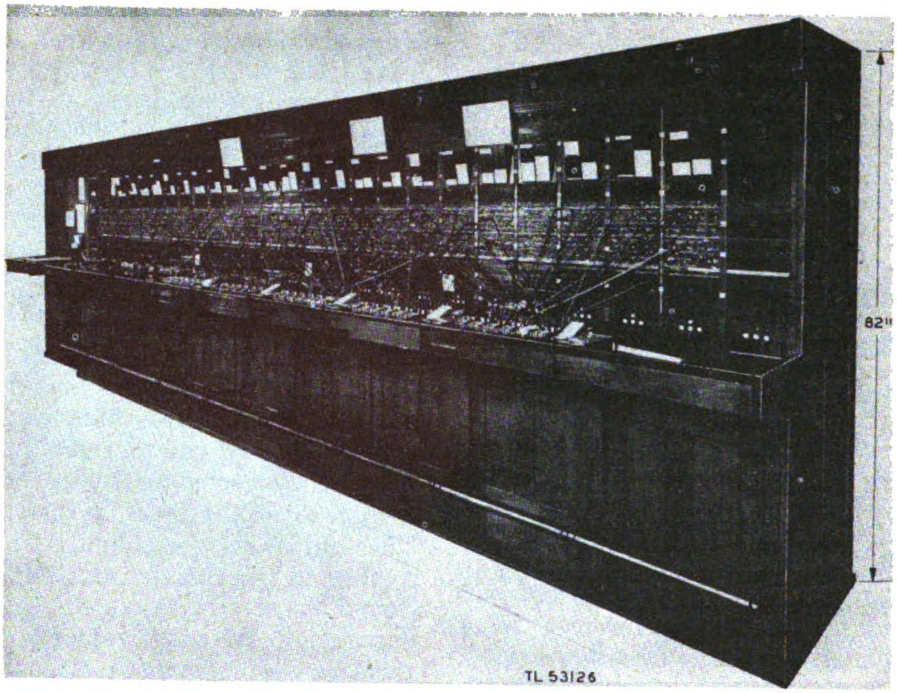


Figure 2-30. Telephone Central Office Set TC-10, assembled.



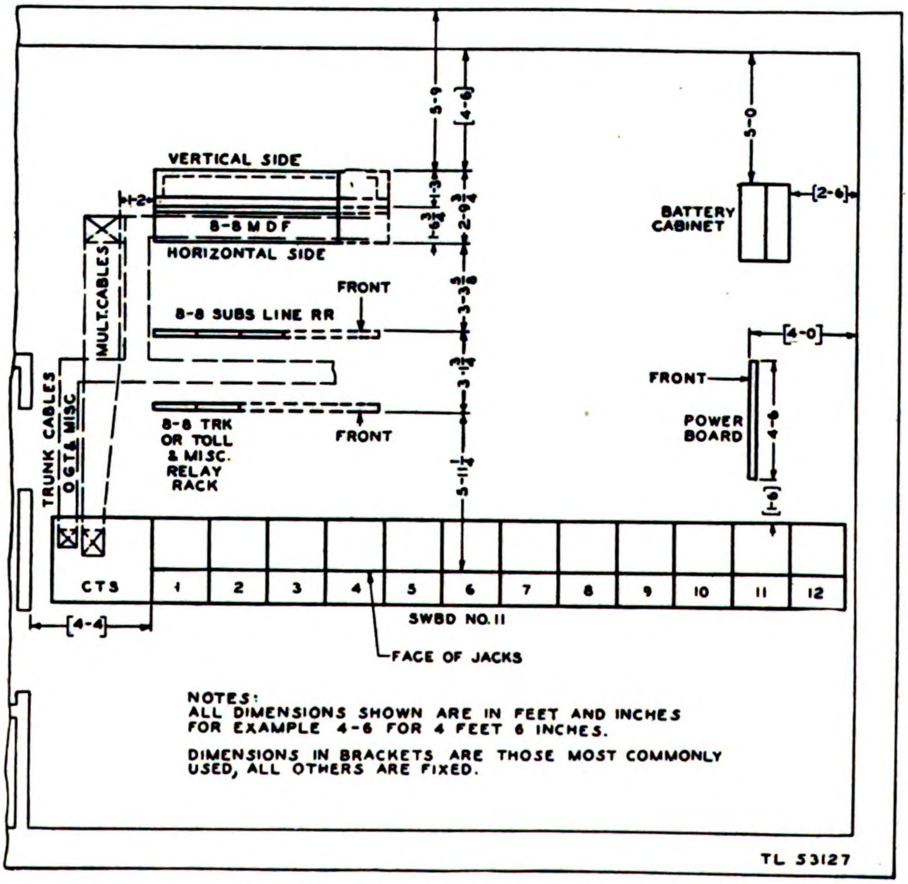


Figure 2-31. No. 11 switchboard and floor plan (Western Electric Company).

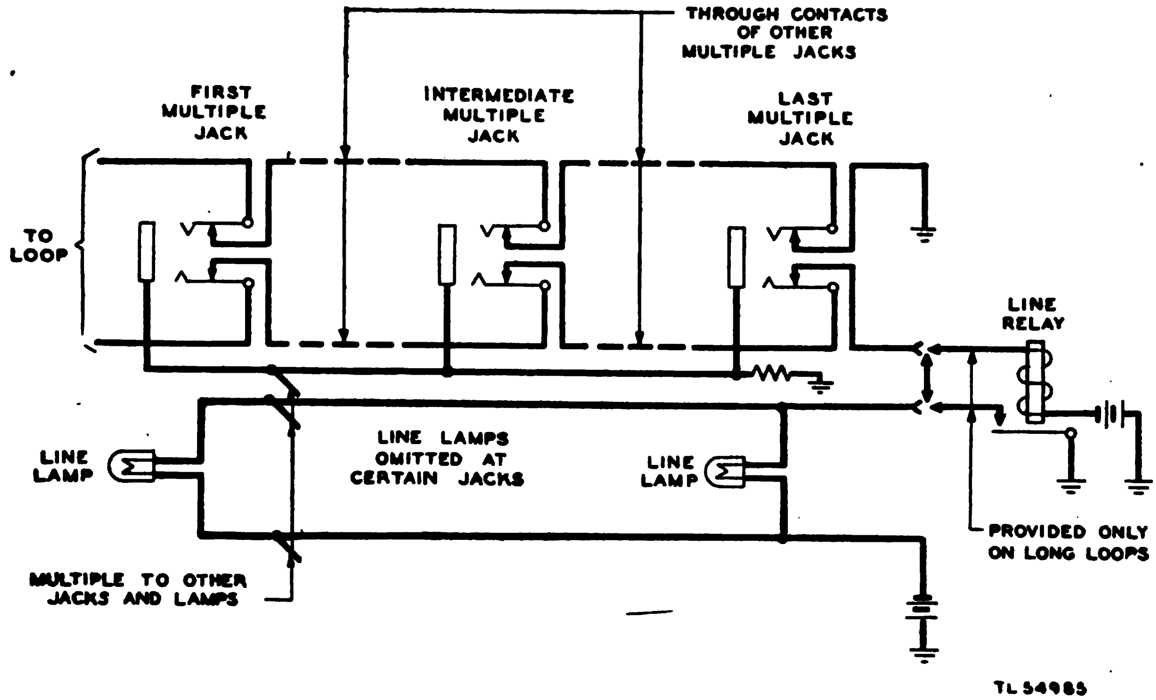


Figure 2-32. Series multiple line circuit.

c. Bridged Multiple. The large multiple switchboards which are equipped with the smaller jacks without cut-off springs are known as bridged multiple switchboards because all of the jacks on each loop are bridged in parallel (fig. 2-33). A line relay is connected to each loop through normally closed contacts of a cut-off relay. This relay is operated when a plug of a cord is connected to any one of the associated jacks. The operating circuit for the cut-off relay is from battery over the sleeve of the cord to the sleeve of the jack, and then through the winding of the cut-off relay to ground. A typical example of a bridged multiple switchboard is the Western Electric Company No. 11 switchboard illustrated in figure 2-31. The advantages of a bridged multiple in comparison with a series multiple are in the elimination of the cut-off springs in the jacks. This simplifies installing, reduces contact maintenance, and permits conference service between three or more telephones by

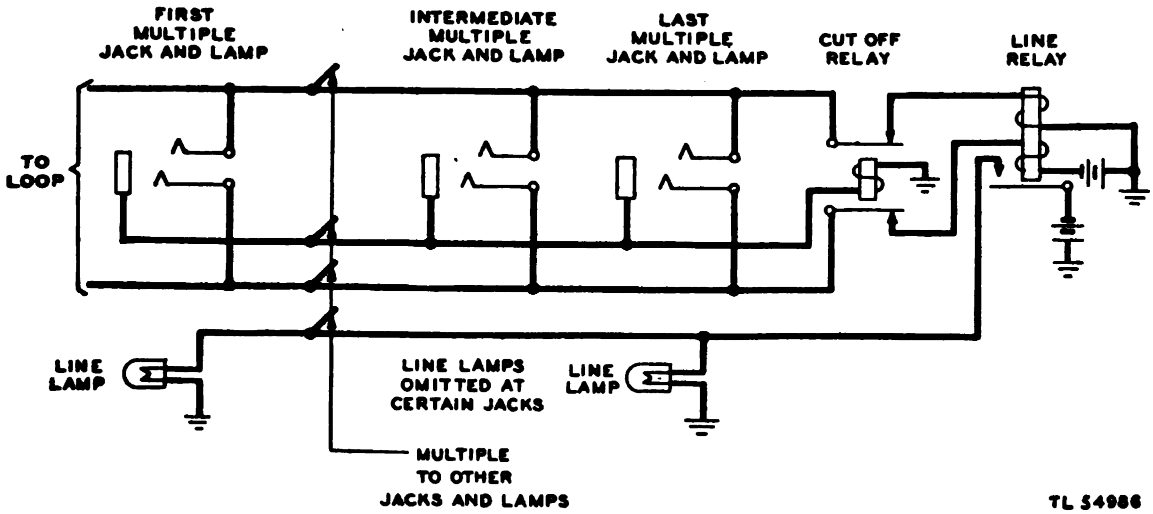


Figure 2-33. Bridged multiple line circuit.

means of two or more cord circuits connected to multiple jacks on the same loop.

d. Lamp Sockets. Lamp sockets are provided with all multiple jacks in some common battery switchboards but lamps are placed in these sockets only at positions where it is desired to have the incoming calls answered. The maximum number of line lamps permissible on each loop is generally not more than two without a line relay (series multiple) nor more than five with a line relay (series or bridged multiple); three are most generally provided.

e. Multiple Wiring. The wiring between multiple jacks and between lamp sockets is in fabric-covered cables which are laid on long pins or a shelf. The individual wires (called *skinners*) which extend from the cables to the terminals of the jacks and sockets are flexible enough to permit removal of the jacks to the rear of the switchboard for maintenance, replacements, or cable extensions.

224. MAGNETO SWITCHBOARDS.

a. Magneto switchboards are the simplest types of switchboards, principally because they are arranged for local battery telephones and for signaling by means of hand generators and drops. The smallest magneto switchboards are of the monocord type described in paragraph 219. These are available with capacities of 4, 6, or 12 loops or trunks. Emergency Switchboard SB–18/GT consisting of Adapter Plugs U–4/GT can be used instead of small magneto switchboards (par. 218). A cordless magneto Switchboard BD–95 (par. 220) has a capacity of 20 loops or trunks. Tactical cord-type magneto switchboards are available in capacities of 20 or 40 loops or trunks. Similar fixed plant switchboards are available with a capacity of 100 loops or trunks. All magneto switchboards supplied for Army communication systems are of the nonmultiple type.

b. All signaling to and from magneto switchboards is by means of ringing. Thus a telephone user must exert conscious effort at the beginning and end of each call to signal the switchboard operator. When one loop is connected through a magneto switchboard to another loop, the ringing from one telephone will ring the bell at the other telephone unless the switchboard cord circuits are of the nonring through type.

c. Dry batteries are required at magneto switchboards for the operators' telephones and for audible signals associated with the drops.

225. COMMON BATTERY SWITCHBOARDS; GENERAL.

A common battery switchboard is distinguished, principally, by its storage battery which is common to all of the battery supply and automatic signaling circuits in the switchboard. Battery supply for telephones on the loops is obtained from the cord circuits except in the cordless switchboard where it is obtained from the switchboard connecting paths. Other battery supply circuits are provided for the operators' telephones. Automatic signaling circuits are associated with the line and cord lamp signals which are controlled from the switchhooks of the telephones on the loops. Similar signals are controlled from ringing on the trunks. These features contribute to high operating efficiency and are particularly desirable in large centrals.

226. COMPARISON OF COMMON BATTERY SWITCHBOARDS WITH MAGNETO SWITCHBOARDS.

a. The advantages of common battery switchboards in comparison with magneto switchboards are principally as follows:

(*1*) Automatic signaling in response to the movements of the switchhooks at the telephones provides fast and reliable signals with almost no conscious effort by the telephone users. This reduces the work of the switchboard operators by eliminating, to a great extent, the need for monitoring and challenging to avoid excessive holding of trunks after conversations are finished.

(*2*) A single storage battery for the switchboard and associated telephones is more desirable than dry batteries.

(*3*) A common battery telephone is lighter than a magneto telephone because it does not contain a hand generator or dry batteries.

b. The disadvantages of common battery switchboards are in the working limits for signaling on the common battery loops. These limits are based on the operating capabilities of the switchboard and require that the insulation resistances of these loops be maintained at more than 10,000 ohms. The insulation resistances on magneto loops can be as low as 1,000 ohms. The higher insulation resistances require greater care in the construction and more labor in the maintenance of the outside plant. The permissible conductor resistances of common battery loops are from 50 ohms to 1,000 ohms depending on the particular switchboard, whereas magneto loops can generally have 2,000 or 3,000 ohms, provided that voice transmission considerations permit. Working limits are discussed further in paragraph 237 and in TM 11–487. On long loops, transmission is poorer with common battery telephones than with local battery telephones (par. 208e).

227. BATTERY SUPPLY CIRCUITS.

a. Repeating Coil Type. The battery supply circuits in the cord circuits of some switchboards such as the Western Electric Company No. 11 switchboard are of the repeating coil type with a 24-volt battery, as illustrated in figure 2-34. In this circuit, the battery is connected in series with the windings of the repeating coil and the voice currents follow the same path as the battery supply currents through the battery. Although the voice currents from many different circuits pass through the same battery, these currents do not produce crosstalk because the impedance of the battery is very low (less than 0.1 ohm), provided that the leads to the battery are arranged properly.

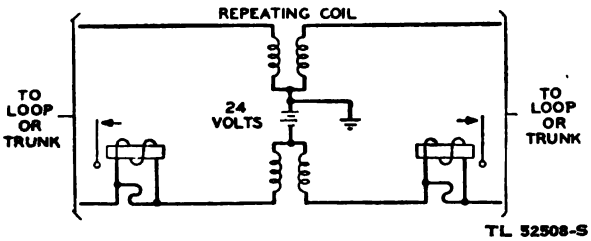


Figure 2-34. Repeating coil 24-volt battery supply circuit.

b. Bridged Impedance Types. Battery supply circuits of the bridged impedance types are arranged with the battery connected in series with retardation coils or relays which are bridged across the voice channels in the cord circuits. A battery supply circuit with a single bridged impedance is illustrated in figure 2-35-A. A similar circuit with two bridged impedances is illustrated in figure 2-35-B. The d-c resistance of each of the inductors is small enough to permit the flow of an adequate amount of battery supply current for the telephone. However, their impedance to voice-frequency currents is high enough to avoid excessive transmission loss. In cord circuits such as those of the Western Electric Company No.

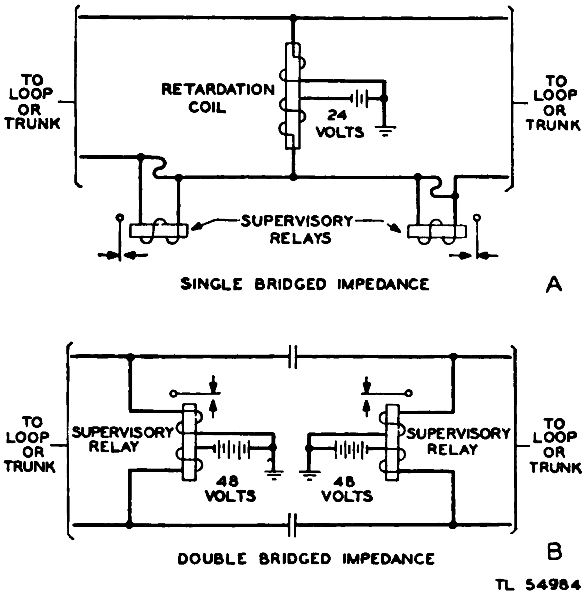


Figure 2-35. Single and double bridged impedance battery supply circuits.

551 switchboard, a single bridged impedance circuit is provided. In cord circuits such as those of Switchboard BD–110–( ), two bridged impedances are provided, one for the front cord and the other for the back cord, and capacitors are connected in series with the voice channels between the bridged impedances (fig. 2-35). In the double bridged impedance type of battery supply circuit, each loop connects to a separate relay while in the single bridged impedance circuit both loops connect to a single retardation coil. The single bridged impedance type of circuit is suitable only where most of the loops are relatively short because the shunting effect of a short loop reduces the battery supply to a longer loop on the same cord circuit.

228. SIGNALING ON COMMON BATTERY LOOPS.

When a call to a cord switchboard is originated at a common battery telephone, direct current flows from the switchboard line circuit such as that shown in figure 2-32 or figure 2-33. This causes the lighting of all line lamps connected to that line. When the call is answered by an operator, the flow of current from the line circuit is cut off by the connection of a cord to a jack, but then the battery supply current flows over the loop from the cord circuit. Battery supply currents flow through the windings of relays, the contacts of which control the supervisory lamps or signals. Telephones are signaled from the switchboard with ringing current applied to the loop by the operation of a ringing key in the cord circuit.

229. COMMON BATTERY CORD CIRCUITS.

The cord circuits in common battery switchboards contain the battery supply circuits described in paragraph 227; they also contain relays and lamps for producing supervisory signals; and they include keys for ringing on loops and trunks, and for connecting the circuits to the operator's telephones. The different types of common battery cord circuits are broadly classified *local* cords, *universal* cords, and *PBX* cords. All cords in a single type of switchboard are of the same type.

230. LOCAL CORD CIRCUITS.

The battery supply circuits in the local cords are of the 24-volt repeating coil type (fig. 2-34) or 48-volt double-bridged impedance type (fig. 2-35-B). These battery supply circuits are always connected to the plugs of the cord circuit. Local cord circuits are the same on connections to magneto loops as on connections to common battery loops. The magneto loops and ringdown trunks associated with these cord circuits are terminated in relays which convert the incoming ringing signals into common battery signals before they are transmitted to the cord circuits. An example of a switchboard with this type of cord circuit is the Western Electric Company No. 11 switchboard.

231. UNIVERSAL CORD CIRCUITS.

a. Principal Features. Universal cord circuits are provided in switchboards which are designed for use with a considerable number of magneto loops in addition to the common battery loops. A universal cord circuit has its battery supply circuit in use only when the cord is connected to a common battery loop. At other times, such as when the cord circuit is connected to a ringdown trunk or to a magneto loop, a ringing bridge, instead of the battery supply circuit, is provided in the cord circuit. The transfer from the ringing bridge to the battery supply circuit is accomplished by a relay which is operated over the sleeve of the cord in combination with the sleeves of the jacks. In a typical switchboard with universal cords such as Switchboard BD–110–( ), the circuits from the sleeves of the jacks on magneto lines are open and the circuits from the sleeves of jacks on common battery loops are closed to the battery. When a cord is connected to one of these closed circuits, the sleeve relay in the cord circuit operates and connects the battery supply circuit. When a cord is connected to a ringdown trunk or a magneto line with an open sleeve, this sleeve relay does not operate, thus providing the circuit arrangement for receiving ringing signals without the battery supply circuit. The ringing signals are indicated on cord circuit recall supervisory lamps. In Switchboard BD–110–( ), a recall ringing signal is provided in addition to two common battery supervisory lamps for each cord circuit. In some other switchboards, only two lamps are provided for each cord circuit and these are arranged for recall ringing signals in addition to common battery signals.

b. Nonlocked-in versus Locked-in Recall Signals. The recall ringing signals on the universal cord circuits in some switchboards such as Switchboard BD–110–( ) are *nonlocked-in*, that is, the recall supervisory lamps are lighted only for the duration of ringing. The recall ringing signals in other switchboards are *locked-in;* that is, the lamps remain lighted after ringing ceases until the associated operator's talking key is operated. The nonlocked-in signals may be somewhat undesirable under conditions where it may be necessary to ring several times to attract the attention of an operator. The locked-in signals avoid the necessity for ringing more than once to produce a steady signal. At switchboards in which the same cord lamps are used for recall ringing signals and for common battery signals, the locked-in recall signals may tend to delay the operators in disconnecting cords from common battery loops because they will have to challenge and be sure that each call is finished before the cords are disconnected; or they will have to trace the cords to the jacks and ascertain whether it is connected to a magneto loop or common battery loop. This situation could be avoided in such switchboards by handling the magneto lines at positions which are different from those where the com-

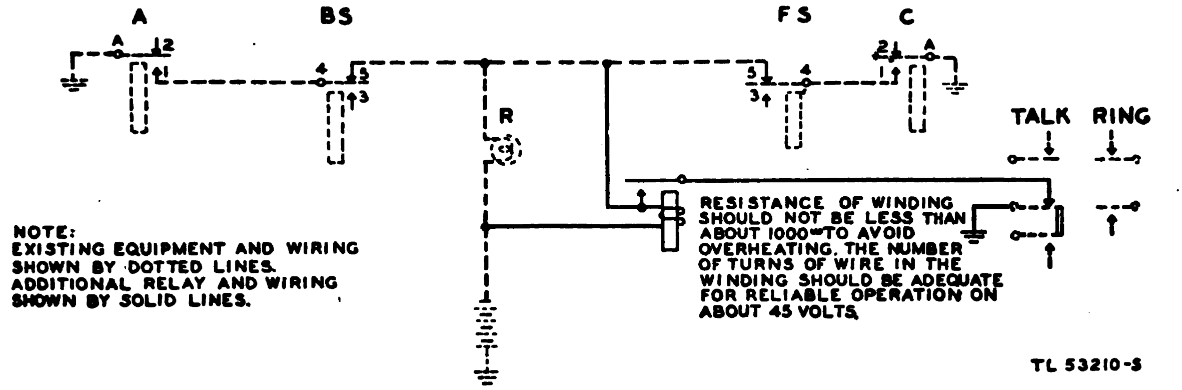


Figure 2-36. Part of universal cord circuit in Switchboards BD–80–( ) and BD–110–( ) showing additional relay and wiring for locked-in recall ringing signals.

mon battery lines are handled. In switchboards such as the BD–110–( ), having separate lamps or drops for recall ringing signals, the locked-in feature would be satisfactory from an operating standpoint.

c. Conversion from Nonlocked-in to Locked-in Signals. The nonlocked-in ringing signals on Switchboards BD–80–( ) and BD–110–( ) can be converted to locked-in signals by adding one relay and associated wiring to each cord circuit as shown in figure 2-36. Any relay having at least one pair of make contacts and a winding suitable for operation on 48 volts is usually satisfactory for this addition. The resistance of this winding should not be less than about 1,000 ohms to avoid overheating while operating. The winding of this relay is connected in parallel with the lamp and its contacts are connected in series with a normally closed pair of contacts on the associated talk key. The circuit through these two pairs of contacts is connected to ground so that when the added relay operates it will lock operated until the talk key is operated. This relay operates from the same voltage that lights the lamp when ringing is received. It remains operated until the operator answers the ringing signal by operating the talk key. The extra contacts on the talking key have been provided in all Switchboards BD–80–( ) and BD–110–( ) but are not used with nonlocked-in signals. The details of these modifications are described in MWO SIG 28 (when published).

232. PBX CORD CIRCUITS.

a. The designation *PBX* is derived from the words *Private Branch Exchange* which is used to describe a civil telephone switchboard located on a subscribers premises and arranged to connect the loops on the same premises to each other and to trunks extending to a telephone central. A PBX may also be connected to tie trunks extending directly to other PBX's and to *off-premise extensions* to distant telephones. The operating features of a PBX are designed for maximum efficiency on the most common types of connections occurring on subscriber premises, namely: those from one short loop to another short loop and those between such a loop and a trunk to a central (called PBX trunk) which terminates at the central in a common battery station line circuit. These line circuits are designed primarily for connections to common battery telephones. Therefore the signaling arrangements utilize ringing outgoing from the central to signal the PBX operator and direct current, also from the central, for supervision between the PBX or telephone and the central. The trunk circuits from Army PBX's which use these signaling arrangements are called *common battery trunks* and are described in paragraph 234.

b. Switchboards such as the Western Electric Company No. 551 switchboard which were originally designed for PBX's in commercial telephone systems are equipped with cord circuits similar to universal cord circuits. Each cord circuit has two different transmission conditions. One is the battery supply condition like that shown in figure 2-34 which is used on loop-to-loop connections. The other condition is a bridged impedance without connections to the battery and with a ringing bridge like that shown in figure 2-37. This is used on connections from loops to common battery trunks. The bridged inductor has a relatively low d-c resistance but its impedance to voice currents is high enough to avoid excessive transmission loss. When this d-c bridge is connected to a common battery trunk, current flows from the distant switchboard, over the trunk and through this bridge. This current controls the supervisory signals in the distant switchboard. A ringing bridge which consists of a relay in series with a capacitor is connected in parallel with the d-c bridge. It indicates ringing signals which are sent from the distant switchboard. The supervisory relay adjacent to the d-c bridge controls the supervisory signals from the switchhook of the telephone on the loop.

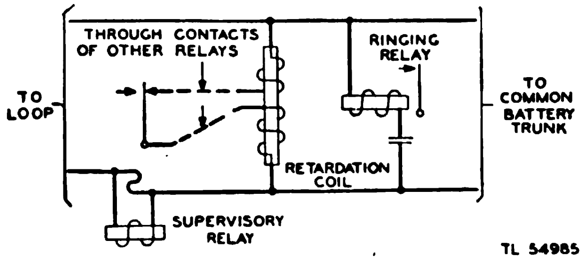


Figure 2-37. PBX cord circuit, cut-through condition.

c. A cord circuit of the type shown in figure 2-37 is known as a *cut-through* cord because battery supply currents from the common battery trunk flow through the cord circuit to the telephone on the loop. With such circuits, in combination with common battery trunks which are similarly cut-through, the battery supply currents through the telephones on the loops depend on the battery supply circuits in the central. This battery supply condition may be troublesome on trunks to some foreign civil centrals having high resistances in their battery supply circuits as described in chapter 8. Cut-through cords are generally advantageous on trunks to American civil centrals because they provide practically the same battery supply for PBX telephones as is obtained by other common battery telephones connected to the central. The cut-through cords also minimize the current drain from the PBX battery. Some common battery trunks are equipped with repeating coils and associated arrangements which include battery supply circuits so that the battery supply currents to the telephones on the PBX loops are derived from the PBX batterv even though the cord circuits are of the cut-through type.

d. Switchboards having cords of the non-cut-through type may be used as PBX's when equipped with suitable common battery trunk circuits (par. 234).

e. Each PBX cord also has a *night and through-dial* key which is not supplied with other types of cord circuits. The operation of this key permits incoming and outgoing, manual or dial calls to pass directly to and from the station and the central, through the cord circuit, without the assistance of the PBX operator. This key is used in Army telephone systems only on night calls and through-dial calls to civil centrals. The operation of this key converts the cord circuit practically into a patching cord. Only the winding of the supervisory relay remains connected in series with the cord, and in most PBX's the ringing bridge also remains connected across the cord but without the d-c retardation coil bridge shown in figure 2-37.

233. TWO-WAY RINGDOWN TRUNK CIRCUITS.

The switchboard circuits for 2-way ringdown trunks are the same as those for magneto loops. In magneto switchboards, each of these circuits contains a drop for indicating the ringing signals. In common battery switchboards equipped with universal cord circuits, each of these trunk circuits contains either a drop like that of a magneto switchboard, or a relay which operates and locks when ringing is received and lights the lamps connected to it. In common battery switchboards equipped with local cord circuits, each ringdown trunk circuit contains several relays; some are used for converting incoming ringing signals into common battery signals to the cord circuit and others are used for transmitting ringing signals from the cord circuit through the trunk circuit to the outside conductors. These trunks are arranged to respond to 20-cycle ringing.

234. COMMON BATTERY TRUNK CIRCUITS—OUTGOING AUTOMATIC AND INCOMING RINGDOWN.

Common battery trunk circuits are provided in common battery switchboards on trunks to civil common battery central offices. These circuits are designed to be connected to common battery station line circuits in the civil central. Each trunk circuit includes a relay which responds to ringing on an incoming call from the civil central and lights the associated lamps in the switchboard. When the call is answered by connecting a cord to the trunk, a d-c bridge is connected across the trunk to cause the flow of direct current over the conductors to control the supervisory signals. The simplest common battery trunk circuit is that provided in PBX switchboards such as the Western Electric Company No. 551 switchboard. When such a switchboard is connected to a dial central, the dial provided in the operators telephone circuit connects through the cord circuit to the trunk circuit on outgoing calls. The common battery trunks in switchboards having local or universal cord circuits are equipped with dial jacks whereby calls may be completed through dial centrals. With such a trunk circuit the operator connects a dial cord to a dial jack, dials the desired number, and removes the dial cord immediately.

235. TWO-WAY AUTOMATIC TRUNK CIRCUITS.

The supervisory signals on 2-way automatic trunk circuits are controlled by the flow of direct currents over the outside plant conductors without ringing. These trunks are not used extensively in Army communication systems. The simplest circuits for a 2-way automatic trunk consist of a regular common battery line circuit at one switchboard connected to a similar line circuit at the other switchboard. However, a reversal is made in the tip and ring conductors between the two line circuits and each circuit is modified by disconnecting the path from the tip side of the line through the cut-off jack or relay to ground (figs. 2-32 and 2-33). With this arrangement the line relay at one switchboard is operated from the connection of ground to the tip side of the trunk through the cord circuit at the other switchboard. When the call is answered, the supervisory signals in the cord circuits are controlled from the flow of the battery supply currents from both the cord circuits in series. These currents flow because the two batteries in the different switchboards are connected in series aiding as a result of the reversal in the trunk conductors. At the end of the call, when a cord is disconnected at one switchboard, the cord supervisory lamp lights at the other switchboard. The line lamp at the switchboard where the cord is disconnected lights and remains lighted until the cord at the other switchboard is disconnected. This relighting of the line lamp is somewhat undesirable on trunk circuits of this type. It is avoided in more complicated types of trunk circuits. This simple type of automatic trunk circuit may also be undesirable because of noise induction in areas where the trunk conductors are adjacent to power circuits.

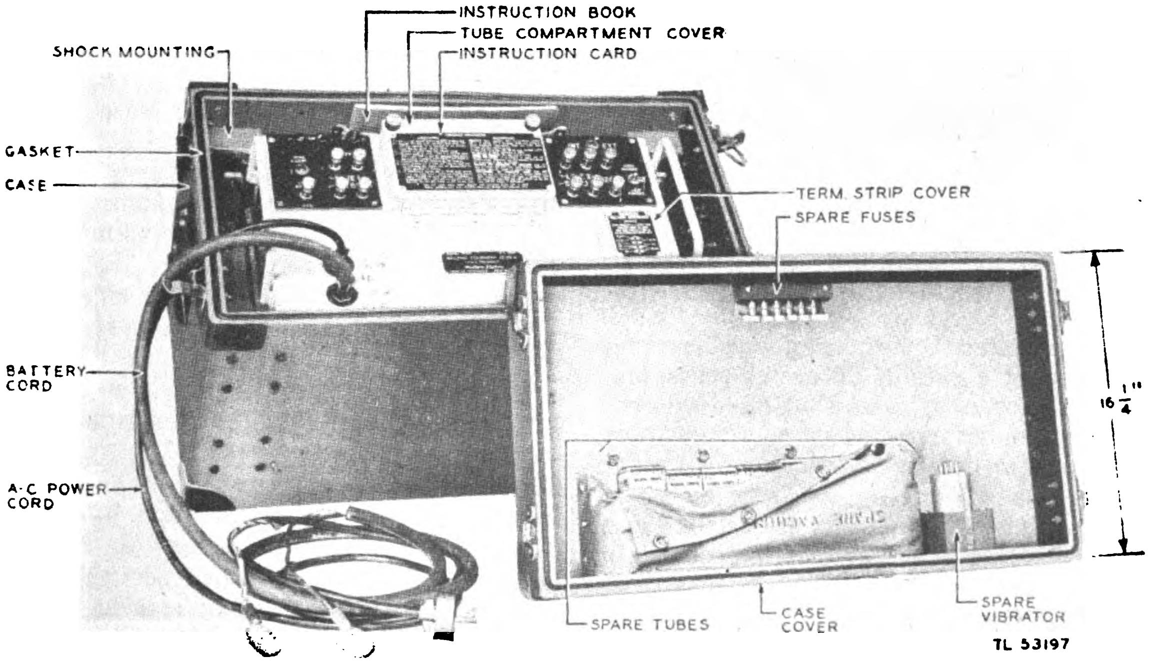


Figure 2-38. Ringing Equipment EE-101-A.

236. VOICE-FREQUENCY RINGERS.

Voice-frequency ringing must be used on trunks operating over carrier channels and on trunks equipped with composite sets or voice-frequency repeaters which are not arranged for 20-cycle operation. Twenty-cycle ringing may be used on nonrepeatered, noncomposited voice-frequency trunks and on repeatered voice-frequency trunks arranged to relay or bypass the 20-cycle ringing at the repeaters. On 2-way ringdown trunks requiring voice-frequency ringing, 20-cycle ringing is used between each of the trunk circuits and the nearest voice-frequency ringer. The ringing between two voice-frequency ringers at opposite ends of the same trunk is by means of either 500 cycles or 1,000 cycles, interrupted

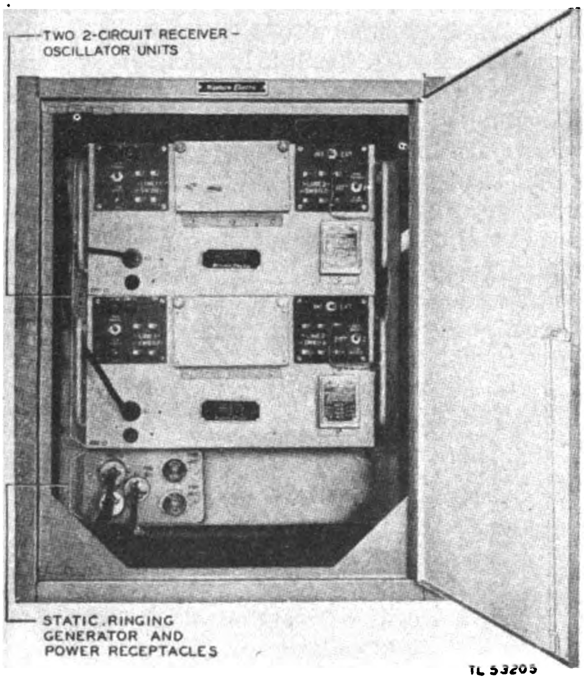


Figure 2-39. Ringer package; voice frequency; 4 circuit X-61820A.

or noninterrupted. One-thousand cycle ringing interrupted at a rate of 20 cycles per second is standard for Army use. Five-hundred cycle ringing, either interrupted or noninterrupted, may be used on interconnections with foreign systems. The allowable loss between voice-frequency ringers is about 30 db. This, in general, permits satisfactory ringing over any Army long distance trunk which is satisfactory for speech transmission. The ringers at opposite ends of a circuit must use the same frequency interrupted at the same rate. Figure 2-38 shows Ringing Equipment EE–101–A which consists of two 1,000/20-cycle ringers. This is a part of Ringer Set TC–24 and is designed for use with tactical equipment such as Telephone Terminal Set TC–21. Figure 2-39 shows the packaged voice-frequency ringer which consists of four 1,000/20-cycle ringers arranged for fixed plant applications. The individual ringers in this package are electrically the same as Ringing Equipment EE–101–( ). These and other available ringers are described in TM 11–487.

237. WORKING LIMITS.

a. **General.** The lengths and gauges of the wires in the loops and trunks are limited by transmission and signaling conditions. The transmission limits are established by the transmission plan discussed in section II of this chapter and are expressed in terms of the maximum loss in db which can be tolerated. The signaling limits are controlled by the type of signaling and the type of switchboard. Signaling limits are expressed in terms of the ohms resistance permissible in the conductors of the loops and trunks. The signaling limits of the various switchboards are specified in TM 11–487. The actual working limit of a loop or trunk is determined by the signaling limit or the transmission limit, whichever is the smaller. The conductor loop resistances and transmission losses of various lengths and gauges of conductors are enumerated in figure 2-40. For example, consider the problem of determining the proper kind of wire for a loop from a Telephone Central Office Set TC–1 to a Telephone EE–8–( ) over a distance of 10,000 feet with common battery signaling and local battery talking. Assume that the transmission plan permits a maximum loss of 6 db in the loop. Reference to the table of working limits for this central office set in TM 11–487 indicates that the resistance of the conductors in the loop should not exceed 500 ohms. Reference to figure 2-40 indicates that Wire W–110–B will be satisfactory for this loop because the length of this wire producing 6–db loss is between 11,300 and 12,800 feet and its resistance is between 400 and 450 ohms. Of course, wire having less transmission loss and less resistance per unit length such as Wire W–143 would also be satisfactory. Wire W–130–A would not be satisfactory because 10,000 feet of this wire would

Switchboard working limits, resistance of loop* (ohms)	Thousands of feet											
	Nonloaded wires (wet)							Nonloaded cables				
									Paper insulated			
	083 GI	109 GS	080 40% C-S	104 40% C-S	W-130-A WD-3/TT	W-110-B	W-143	CC-345 CC-355-A	16 ga.	19 ga.	22 ga.	
50	2.0	3.5	6.2	10.0	0.4	1.4	7.4	2.9	6.3	3.1	1.5	
75	3.2	5.2	9.7	15.6	0.7	2.1	11.3	4.4	10.0	4.6	2.3	
100	4.1	7.0	12.3	20.8	0.9	2.8	15.3	5.9	13.3	6.1	3.1	
125	5.1	10.5	15.4	26.0	1.1	3.5	18.9	7.3	16.7	7.7	3.8	
150	6.1	10.5	18.5	31.2	1.3	4.2	22.7	8.8	20.4	9.2	4.6	
175	7.1	12.3	21.6	36.4	1.6	5.0	26.5	10.3	23.3	10.7	5.3	2-db
200	8.1	14.0	24.7	41.6	1.8	5.7	30.3	11.8	26.7	12.3	6.2	limit
225	9.1	15.8	27.7	46.8	2.0	6.4	34.1	13.2	30.0	13.8	6.9	
250	10.2	17.6	30.9	52.0	2.2	7.1	37.9	14.7	33.4	15.3	7.7	
275	11.2	19.4	34.0	54.2	2.4	7.8	41.7	16.2	36.7	16.9	8.5	
300	12.2	21.1	37.2	62.5	2.7	8.5	45.5	17.6	40.1	18.4	9.2	
325	13.2	22.9	40.2	67.7	2.9	9.2	49.3	19.1	43.4	19.9	10.0	
350	14.2	24.6	43.8	72.8	3.1	9.9	53.1	20.6	46.7	21.5	10.8	
375	15.3	26.4	46.4	78.1	3.3	10.6	56.9	22.1	50.1	23.0	11.6	4-db
400	16.3	28.2	49.4	83.2	3.6	11.3	60.7	23.5	53.4	24.5	12.4	limit
450	18.3	31.7	55.6	93.6	4.0	12.8	68.2	26.5	60.1	27.6	13.9	
500	20.3	35.2	61.7	104.1	4.5	14.2		29.4	66.7	30.7	15.5	
550	22.4	38.7	67.8	114.4	4.9	15.6		32.4	73.4	33.7	17.0	6-db
600	24.4	42.2	74.1	125.8	5.3	17.0		35.3	80.1	36.8	18.5	limit
650	26.4	45.8	80.2	135.3	5.8	18.4		38.3	86.7	39.8	20.1	
700	27.4	49.3	86.4	145.7	6.2	19.9		41.2	93.5	42.8	21.7	
750	30.5	52.8	92.6	156.2	6.7	21.3		44.1	100.0	45.9	23.6	
800	32.5	56.3	98.7	166.4	7.1	22.7		47.1	106.6	49.1	24.7	
850	34.5	59.8	104.9	176.9	7.6	24.1		50.0	113.4	52.2	26.3	
900	36.6	63.3	111.1	187.5	8.0	25.5				55.2	27.8	
950	38.6	66.8	117.3	197.5	8.5	26.9				58.2	29.4	
1,000	40.6	70.4	123.5	208.0	8.9	27.4				61.3	30.9	
1,100	44.7	77.5	135.9	239.0	9.8	31.2				67.6	34.0	
1,200	48.8	84.5	148.4	249.5	10.7					74.0	37.1	
1,300	52.8	91.5	160.6	270.6	11.6						40.2	
1,400	56.8	98.6	173.0	291.4	12.5						43.3	15-db
1,500	60.9	105.0	185.4	312.5							46.5	limit
2,000	81.3	141.0	247.0	416.5								
2,500	102.0	176.0	309.0	522.0								
3,000	122.0	211.0	371.0									

* The data given in this table are based on the following wire characteristics:

Item	Nonloaded wires (wet)							Nonloaded cables			
									Paper insulated		
	083 GI	109 GS	080 40% C-S	104 40% C-S	W-130-A WD-3/TT	W-110-B	W-143	CC-345 CC-355-A	16 ga.	19 ga.	22 ga.
ohms/mile	130.0	75.0	42.8	25.3	590.0	186.0	35.0	90.0	42.0	86.0	171.0
ohms/M ft	24.6	14.2	8.1	4.8	112.0	35.2	6.6	17.0	8.0	16.2	32.3
db/mile (wet)	0.37	0.31	0.25	0.18	6.50	2.80	1.20	1.70			
db/M ft (wet)	0.07	0.06	0.05	0.03	1.23	0.53	0.23	0.32			
db/mile									0.73	1.08	1.79
db/M ft									0.14	0.20	0.34

Figure 2-40. Lengths of station line wire and cable for various switchboard transmission and working limits.

have a loss of more than 12 db and a resistance of more than 1,100 ohms.

b. Limits for Ringdown Loops and Trunks. The working limit for 20-cycle signaling on ringdown loops and trunks without repeating coils or other intermediate line equipment is generally about 3,000 ohms. This is established by the ringing voltage and the sensitivity of the ringers, drops, or relays which respond to the 20-cycle ringing voltage. On similar trunks equipped with a ring-through repeating coil at each end, the working limit is reduced to about 2,000 ohms. Insulation resistances down to about 1,000 ohms can generally be tolerated on these trunks. On trunks equipped with telephone repeaters or carrier terminals, the signaling is by means of 500 cycles or 1,000 cycles between ringers and is by means of 20 cycles between the ringers and the terminals (par. 236).

c. Limits for Common Battery Loops. The working limits for common battery loops are established principally by the transmission losses, including the battery supply losses (par. 208), and the supervisory relays in the cord circuits. On loops connected to line circuits without line relays, the brilliancy of the line lamps may also be controlling. The insulation resistance of the loops is sometimes a limiting factor because the supervisory relays must release while current is flowing through the insulation resistance. In general, the insulation resistance of common battery loops should be greater than 10,000 ohms. To obtain such insulation resistance, a high grade of maintenance on the outside wires, cables, and terminals is required.

238. DISTRIBUTING FRAMES.

The connections from outside wires to a switchboard having a capacity for 40 loops or more, are completed through a separate distributing frame such as Frame FM–19 shown in figure 2-30. This frame consists of terminals, some for the outside wires and others for the inside wires. Cross-connecting wire is used to connect the outside terminals to the inside terminals. This wire can be readily transferred between terminals, thereby providing flexibility in the assignments of the outside wires to various switchboard circuits.

239. PROTECTORS.

Protectors are provided in telephone centrals on the wires coming in from outside for the purpose of protecting the switchboards and associated equipment from damage which might otherwise result from lightning or accidental contacts between communication circuits and high-voltage power lines. Protectors are frequently located on distributing frames. Protection is discussed in chapter 10 and various kinds of protective equipment are described in TM 11–487.

240. POWER EQUIPMENT.

The storage batteries in telephone centrals are charged by rectifiers connected to 50– or 60–cycle engine-driven generators or commercial power sources. The 20–cycle ringing voltage is obtained from ringing vibrators, static ringing machines, or rotating ringing generators. Power equipments are described in chapter 7 and in TM 11–487.

241. MONITORING, OBSERVING, AND RECORDING EQUIPMENT.

Equipments which may be installed in centrals for use in monitoring, observing, and recording on local and long distance telephone connections are described in TM 11–487. One of the observing cabinets is designed for connection to a long distance trunk and includes arrangements to prevent the completion of each call until cleared by the observer. A group of these cabinets can be associated with a group of long distance trunks by means of a patching cabinet having a capacity of 10 trunks. Another cabinet is arranged for monitoring on any one of 30 loops or trunks. This cabinet includes lamps which respond to common battery or ringdown signaling to indicate when calls are in progress. Another cabinet is designed for observing on any one of five common battery loops. A film-type recorder, which embosses the sound track on cellulose acetate tape, may be used for recording conversations in connection with the monitoring and observing cabinets.

242. TESTING AND MAINTENANCE.

a. When outside wires develop faults such as contacts with ground, short circuits, crosses with other wires, or open circuits, the service on these wires can be restored by using testing equipment to locate the troubles. This equipment includes voltmeters or Wheatstone bridges or both, in combinations with tones, ringing voltages, and d-c voltages.

Types of such testing equipment which may be used in centrals are Test Set EE–65–( ), Test Set TS–27/TSM, Test Board BD–101, Cabinet BE–70, Test Set AN/FCM–4 (mobile test unit X–63699A), and Test Set AN/FCM–5 (test and control board X–66034A). This equipment is also used to locate faults on wires and equipment inside the centrals. After troubles have been located, they can be cleared by the use of various types of maintenance equipment. The features of these test sets, test equipments, and maintenance equipments are described in TM 11–487. Information on testing and maintenance procedures is given in chapter 11.

b. The tests which can be performed with test equipment installed in telephone centrals are briefly as follows:

(*1*) Test calls can be originated and answered on magneto and common battery loops.

(*2*) Tests can be made with a voltmeter or voltohmmeter to check the continuity of a circuit and detect accidental grounds, short circuits, crosses, and opens.

(*3*) Ringing voltage can be applied to a circuit as a step in detecting grounds, short circuits, or opens.

(*4*) The capacitance from a line to ground or to another line can be indicated by the swing of a voltmeter needle in combination with the initial application of a potential through the voltmeter to the line.

(*5*) Voltages can be measured.

(*6*) Conductor loop resistance and insulation resistance can be measured with a voltohmmeter or Wheatstone bridge.

(*7*) Approximate locations of open circuits on open wire lines can be estimated from capacitance tests with a voltmeter.

c. A small central with a fixed plant switchboard will ordinarily be equipped with a portable Wheatstone bridge such as Test Set I–49 for use in locating faults on outside lines and for miscellaneous measurements of resistance. A central at a terminal of a main cable route will generally contain a Test Set AN/FCM–4 (mobile test unit X–63699A) for use in locating and analyzing faults on the wires. In large centrals a Test Set AN/FCM–5 (test and control board X–66034A) will generally be provided.

d. When a loop or trunk goes out of order, the following procedures may be adopted to clear the trouble. The trouble is analyzed by making over-all ringing and talking tests. Then specific tests are made to trace the trouble step by step. In the smaller centrals, these tests may be made with a voltmeter at the switchboard. In the larger centrals, they may be made with the test unit or test board. The line is sectionalized and analysis tests are made on each section. When the section with the trouble is determined, the test board or testing equipment nearest to the trouble is used for locating it more closely. Finally the trouble is found by physical inspection.

e. Test and control board equipment provides jacks and paching cords for removing circuits from service such as may be required for trouble tests, routine tests, or transmission measurements. It also provides arrangements for monitoring and talking on the lines. The monitoring jacks may be arranged in some test boards to make the circuits test busy at the associated switchboards so as to avoid interference between the regular traffic and test calls and give full control of the circuits to the testers. In centrals where these automatic make-busy features are not provided, it will be necessary for the tester to ask an operator to make the circuit busy at the switchboard. The latter procedure is followed in centrals with Switchboards BD–80–( ), BD–110–( ), or smaller switchboards.

Section V. AIRCRAFT WARNING SYSTEMS

243. INFORMATION AND OPERATIONS CENTERS.

Information and operations centers are used in aircraft warning systems to receive information on activities of enemy and friendly forces in different areas, to plot this information so that it can be readily visualized and analyzed, and to transmit it and operational orders to the organizations concerned for their information and action. This equipment consists of telephones, relays, jacks, lamps, power plants, and furniture arranged to be quickly unpacked and installed and subsequently packed and transported in motor vehices. Several different types of equipment which are

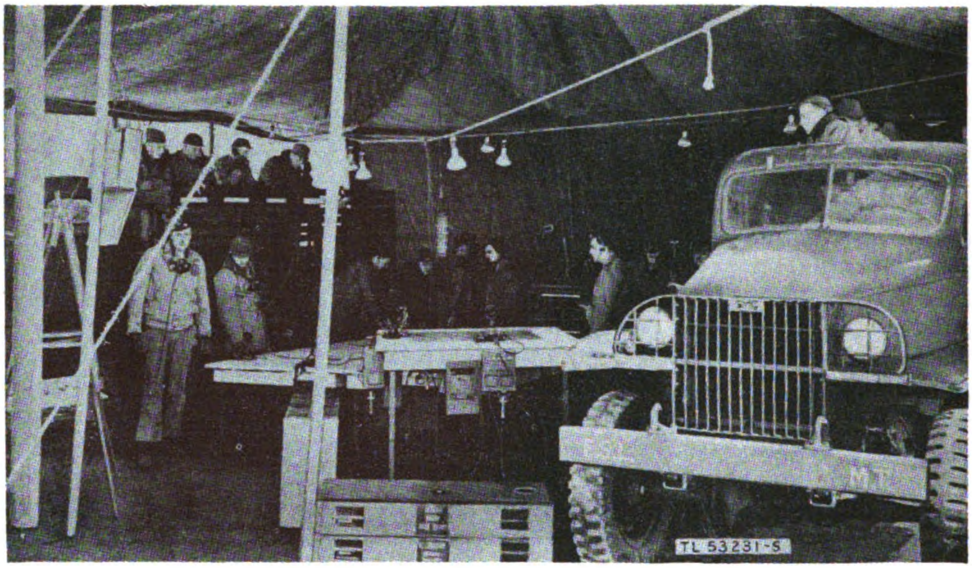


Figure 2-41. Operations Center AN/TTQ-1, mobile use.

used for these centers are described in TM 11–487. A typical arrangement is shown in figure 2-41. This is an Operations Center AN/TTQ–1 assembled for mobile use with the plotting tables on the ground and the other equipment in two trucks on opposite sides of the plotting tables. A tent to protect the equipment is shown in this figure. However, it can also be installed in a shelter or building separate from the trucks. The telephone equipment can be connected to wire lines and radio channels. Facilities are provided for automatic remote control of various types of radio sets. The furniture consists of tables, benches, and platforms. The communication channels are terminated on jacks or keys at the operating positions so that an officer or plotter can directly select the particular line to which he connects his telephone. Most of the communication channels provide point-to-point service. A small tactical switchboard however, is included for a few interconnections over trunks to centrals in Army communication systems.

Section VI. RAILWAY TRAIN DISPATCHING TELEPHONE SYSTEM

244. GENERAL.

a. A train dispatcher controls the movement of trains on a definite length (division) of each railway and transmits train orders by telephone to the way-station operators for control of trains. The length of railway controlled by one train dispatcher varies with the traffic density and geography of the railway. It may be any length up to 200 miles or more. A telephone circuit with connections to every way station along the railway division is provided for transmission of the train orders. Two telegraph wires, also with connections at every way station, are provided, which can be used for transmitting train orders in case of failure of the telephone circuit.

b. The railway communication system is provided and installed by the Signal Corps and, after installation, it is operated and maintained by the Military Railway Service. This communication system, with some of the principal features and limitations, is described in this section.

245. REFERENCES.

Technical manuals to be prepared by the Transportation Corps will describe the components, operation, and maintenance of railway communication systems. Technical manuals prepared by the Signal Corps on the principal items of dispatching equipment are available for such specific apparatus as: amplifiers, rectifiers, etc. A booklet entitled Maintenance of Way Manual; Military Railway Service; Supplement A; Telephone, Telegraph, and Signals is available from The Director General, Military Railway Service, Washington 25, D. C. In the past, commercial literature such as Western Electric Company's Bulletin No. 672A has been furnished with some of this equipment. T/O and E 55–227 lists the communication personnel and equipment of the Maintenance of Way Company of a Railway Operating Battalion. The following field and technical manuals also contain pertinent information:

FM 55–50, Military Railroads and Military Railway Service
FM 55–55, Railway Operating Battalion (superseding TM 5–405)
TM 11–2256, Amplifier No. 3BLH
TM 11–2257, Rectifier Power Units No. 1152 and No. 1161

246. TELEPHONE SYSTEM.

a. A railway train dispatching telephone system is a special form of long distance telephone party line with selective ringing, which enables a train dispatcher to call individually any one of the way stations on the line. The lines usually are open wire, and the Military Railway Service has purchased No. 9 B&S gauge (114-mil) copper wire such as that used in commercial train dispatching installations. If it is planned to use cable for any part of the line, it may be necessary to obtain cable which is specially designed to withstand the high signaling voltages which may be used, as the normal telephone cables are not designed to withstand these voltages. The operating limits of the equipment provided are such that a 114-mil copper open wire line may be as long as about 500 miles and have as many as 60 way stations; if any substantial amount of cable is used, the range will be less.

b. The dispatcher listens continuously on the line by loudspeaker or head receivers, and he talks to way stations through a chest microphone. He rings the bell at the individual way station by means of selector calling keys which control the application of 200- to 500-volt 3½-cycle alternating current to the line. This 3½-cycle alternating current operates the way-station selectors.

c. The way-station operators do not listen constantly because they have various duties to perform. When they have occasion to talk to the dispatcher, as for example, to report the passing of a train, they listen on the line and if it is idle they talk to the dispatcher. The telephones at the way stations are of a special push-to-talk type which cause relatively small transmission loss to other way stations when in the listening condition. Low loss under this condition is important because a large number of stations may listen on a line simultaneously.

247. EMERGENCY SERVICE.

Emergency communication service is required when the telephone train dispatching circuit is out of service because of trouble. The Military Railway Service plan provides two separate wires for single Morse manual telegraph operation. At each station each wire is equipped with suitable station equipment. These telegraph wires parallel the train dispatching telephone wires and are used for both regular telegraph service and emergency train dispatching.

248. DISPATCHERS' EQUIPMENT.

a. **Dispatchers' Telephone Equipment.** Telephone equipment with a head receiver which is provided for each dispatcher is shown in figure 2-42. During periods when the dispatcher does

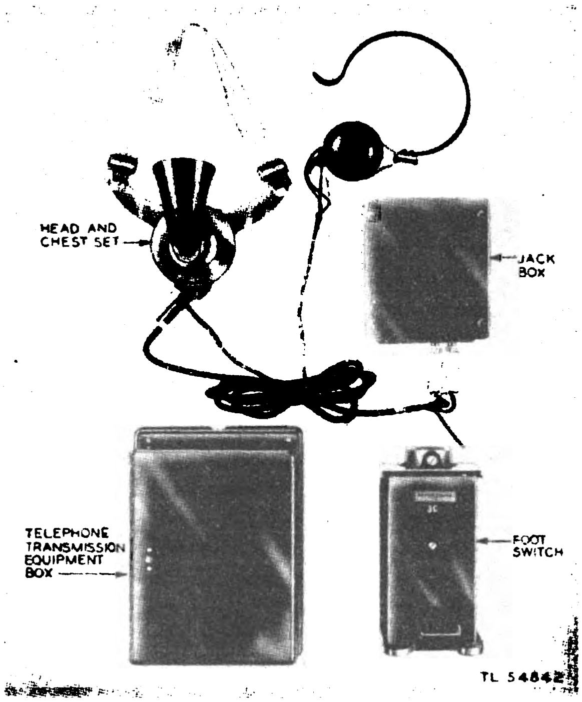


Figure 2-42. Dispatcher's station telephone equipment.

not wish to wear the head receiver, a loudspeaker instead of the head receiver can be connected to the line. A contact on the foot switch provides means for reducing the loudspeaker volume so that the transmission path through the loudspeaker and microphone will not howl when the dispatcher is speaking.

b. Selector Keys. Two different types of keys are provided to enable a dispatcher to call individual way stations: the individual type and the master type. One of the individual type selector keys is used to call each of the way stations. A group of these keys is installed in a selector key case which is mounted on the dispatcher's table. The selector key and a case which has a capacity for 24 keys is shown in figure 2-43. The master type selector calling key (fig. 2-44) is provided for emergency use. When this key is used, the three levers are placed opposite the numbers that make up the code of the way station to be called. Then the fourth lever, which is equipped with a handle, is pulled down and is allowed to return to nor-

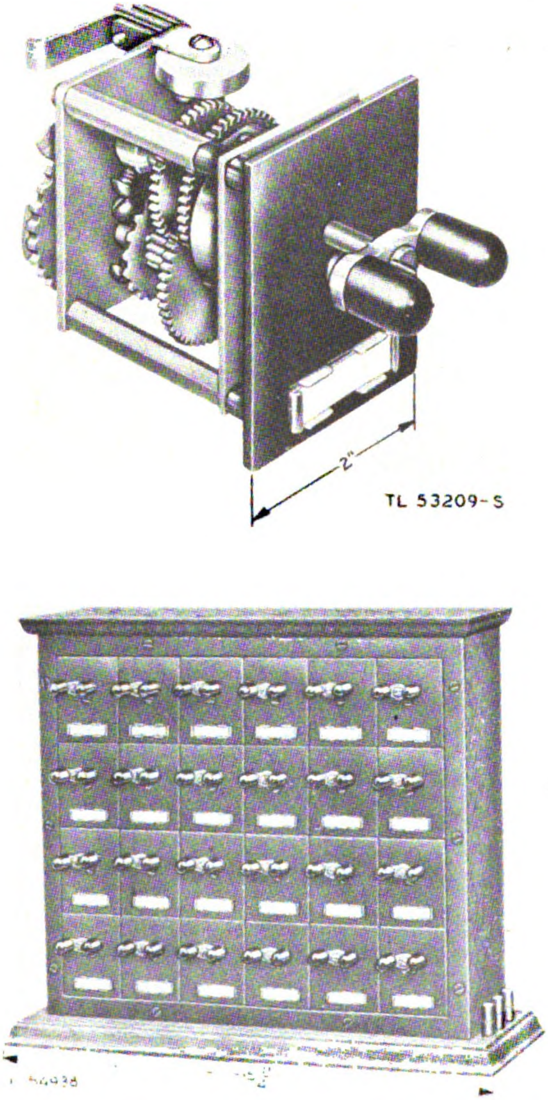


Figure 2-43. Individual type selector key and case (Western Electric Company No. 60A key).

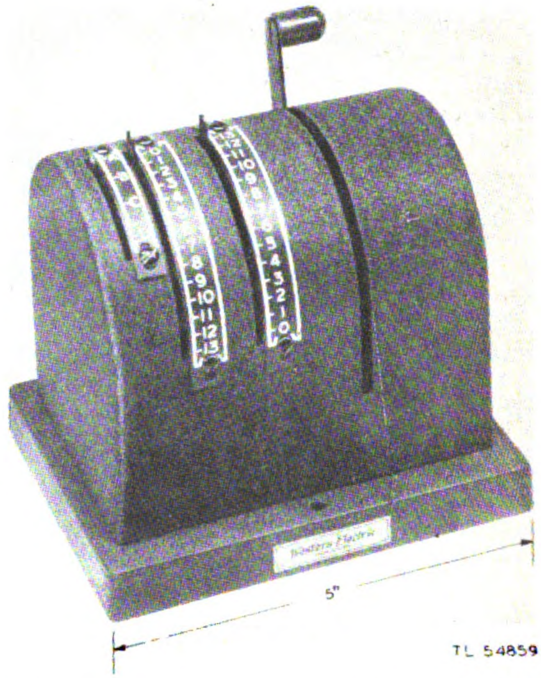


Figure 2-44. Master type selector key (Western Electric Company No. 61A key).

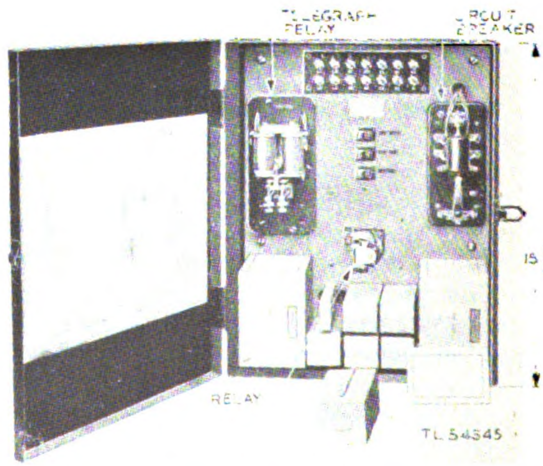


Figure 2-45. Selector apparatus case (Western Electric Company No. 62B).

mal. Thus, this one key can be used for calling any of the way stations.

c. Selector Apparatus Case. The selector calling keys are connected to a selector apparatus case shown in figure 2-45, which contains the apparatus by which the d-c impulses from the keys control the 3½-cycle alternating current for transmission to the line.

d. Power Supply. The 3½-cycle alternating current is derived from direct current by means of a reversing relay in the selector apparatus case. The d-c voltage is obtained from a power supply unit that can be set to produce various potentials between 200 and 500 volts dc. The voltage is adjusted for proper operation of the way station selectors and is governed by the length of line and number of selectors on the line as explained in paragraph 251.

249. WAY-STATION EQUIPMENT.

a. Telephone Equipment. The telephone provided in each way station is shown in figure 2-46. It uses a microphone and head receiver which are similar in their electrical characteristics to the microphone and receiver of Telephone TP–6. A push-to-talk button is provided in the associated desk set box.

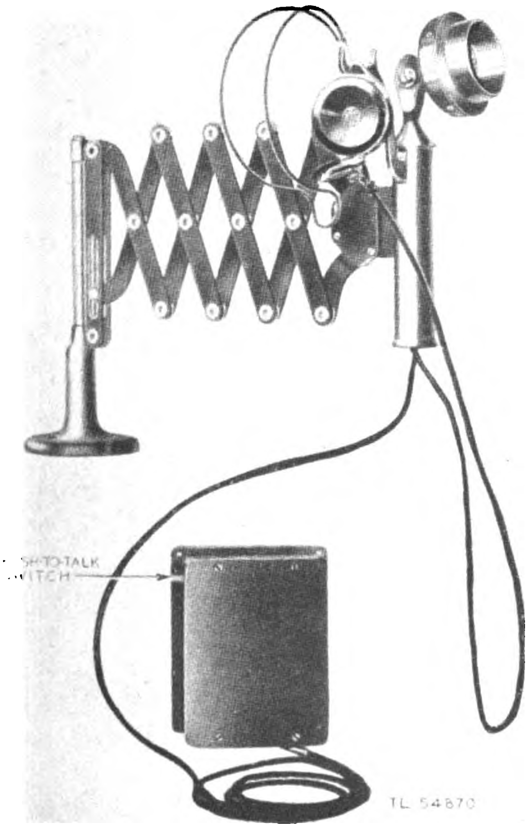


Figure 2-46. Way-station telephone.

b. Selector Set.

(*1*) A selector set is provided at each way station. The selector and the selector set of which it is a part are shown in figures 2-47 and 2-48 respectively.

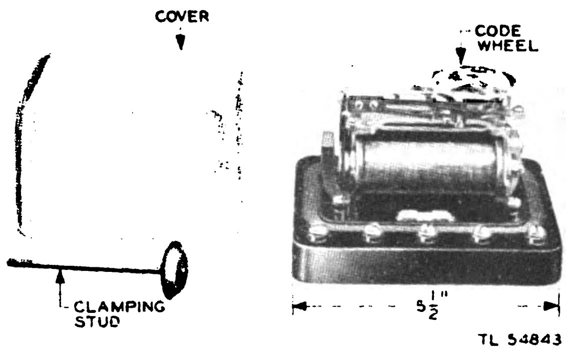


Figure 2-47. Selector (Western Electric Company No. 60AP).

(*2*) The selector has a toothed code wheel and when this wheel has advanced to the 17th step it closes a local battery circuit which rings the way-station bell. Each station has assigned to it a 3-digit code, and the sum of the three digits of each station code is 17. The dispatcher's calling keys introduce short pauses between the three digits.

(*3*) The selector code wheel at each way station is advanced by the 3½-cycle impulses which are sent by the calling key at the dispatcher's station. Only those code wheels stay in the advanced position, during the pause,

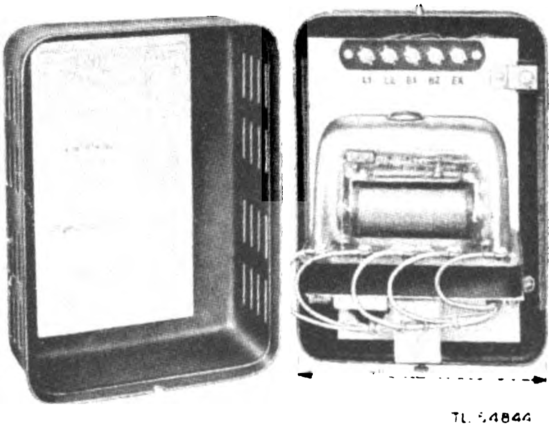
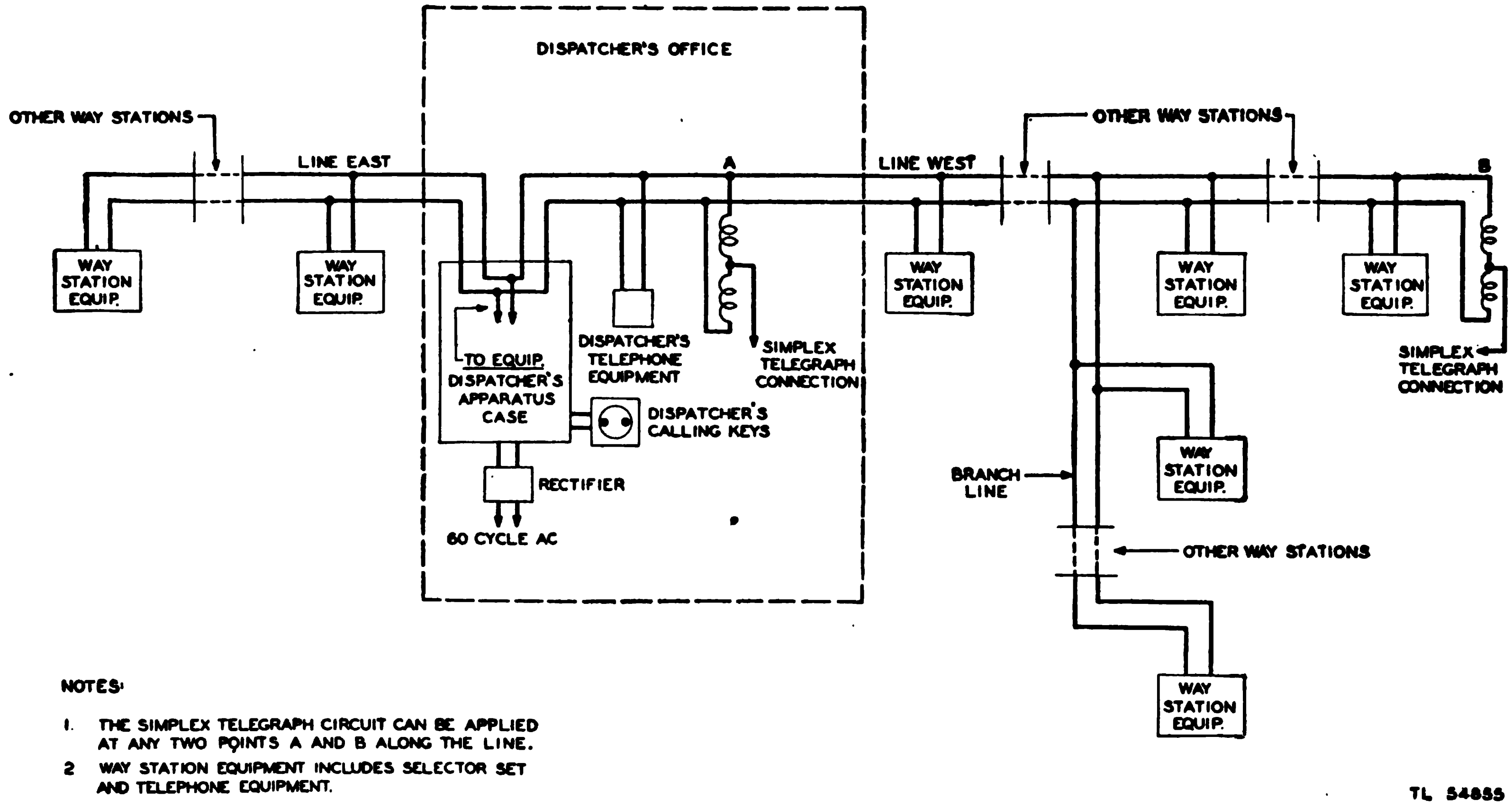


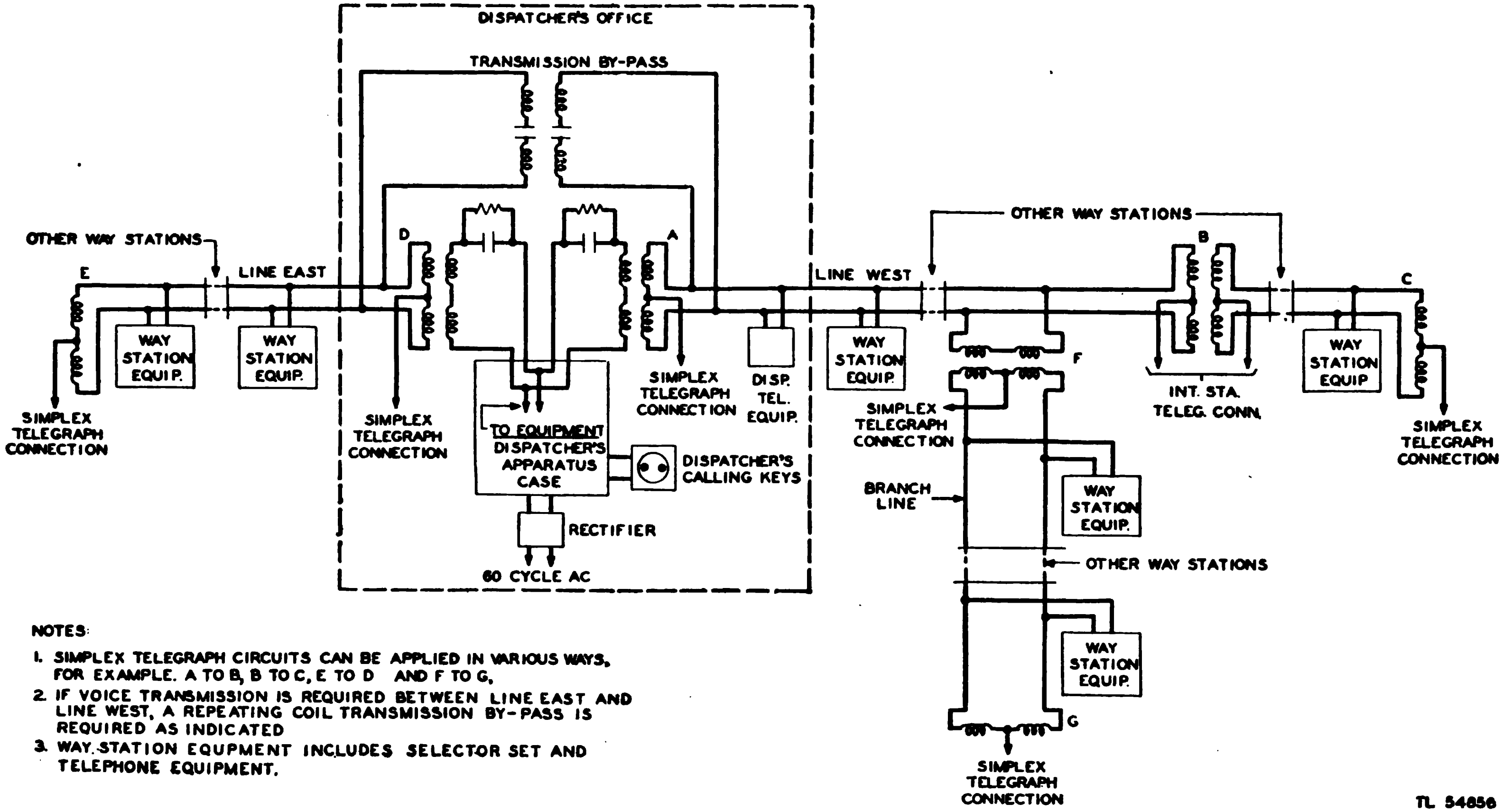
Figure 2-48. Selector set (Western Electric Company No. 162C).



NOTES:

1. THE SIMPLEX TELEGRAPH CIRCUIT CAN BE APPLIED AT ANY TWO POINTS A AND B ALONG THE LINE.
2. WAY STATION EQUIPMENT INCLUDES SELECTOR SET AND TELEPHONE EQUIPMENT.

Figure 2-49. Principles of standard method for operating train dispatching telephone system.



NOTES:

1. SIMPLEX TELEGRAPH CIRCUITS CAN BE APPLIED IN VARIOUS WAYS, FOR EXAMPLE. A TO B, B TO C, E TO D AND F TO G,
2. IF VOICE TRANSMISSION IS REQUIRED BETWEEN LINE EAST AND LINE WEST, A REPEATING COIL TRANSMISSION BY-PASS IS REQUIRED AS INDICATED
3. WAY STATION EQUIPMENT INCLUDES SELECTOR SET AND TELEPHONE EQUIPMENT.

Figure 2-50. Principles of transformer method for operating train dispatching telephone system.

which have a code pin inserted in the code wheel at the step which corresponds to the number of impulses sent from the dispatcher's key. The code wheels of selectors at all other stations return to the zero position during the pause.

(4) The impulses of the second and third digits sent from the dispatcher's key again advance the code wheels, some from the advanced position and others from zero. However, only the selector which has code pins to hold the code wheel during the pauses between the first and second and between the second and third digits will advance to step 17 and ring the bell.

(5) For example, a way station with a ringing code 8-5-4 has code pins set at steps 8, 13, and 17 on the code wheel.

(6) After a ringing interval of about two seconds, the dispatcher's key sends a release impulse which restores the way station selector to normal.

(7) As the bell is rung, a tone is also sent onto the line which is called the *answer-back*. This indicates to the dispatcher that the bell is ringing.

(8) The code pins can be set for 78 different combinations.

250. SPECIAL ADJUNCTS.

Train dispatching telephone circuits can be arranged to provide for the following features:

a. A simplex telegraph circuit can be obtained between two or more places along a line without interfering with telephone service. This circuit can be operated single or duplex, manual, or teletypewriter.

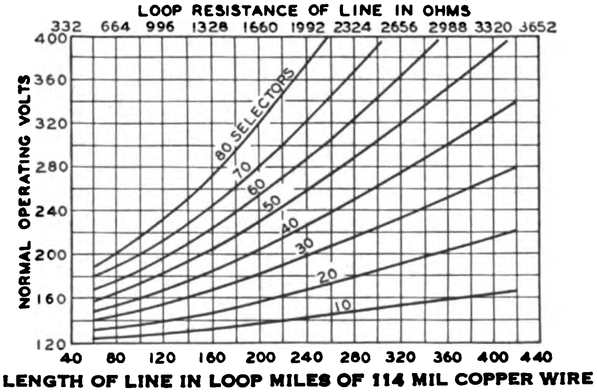


Figure 2-51. Range of No. 160 type selectors for various line voltages and numbers of bridged selectors (no transformer).

b. Branch or spur lines can be connected.

c. Way-side telephones in pole boxes or portable telephones with a line pole for making connections to line wires can be used at points along a line for telephoning the dispatcher.

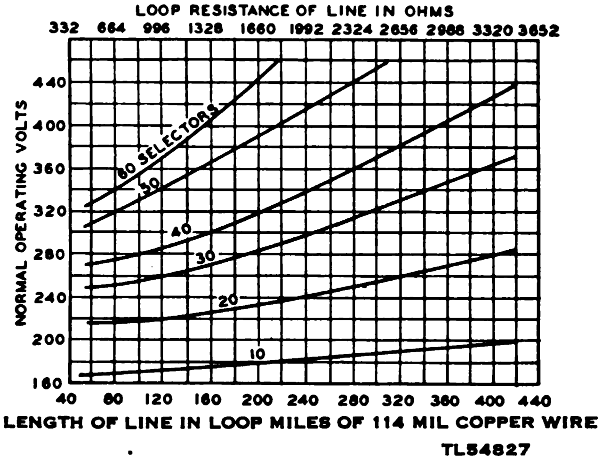


Figure 2-52. Range of No. 160 type selectors for various line voltages and numbers of selectors (one No. 341A transformer).

251. OPTIONAL METHODS OF SELECTOR OPERATION.

a. Two arrangements are available for connecting selectors at the dispatcher's station and way stations to the telephone line, namely: the *standard arrangement* and the *transformer arrangement*. The standard arrangement provides a greater range and more stations for a given line voltage. However, with the transformer arrangement other desirable features such as additional telegraph circuits between way stations can be obtained.

b. The circuit operating principles of these two arrangements are illustrated in figures 2-49 and 2-50. Signaling range data corresponding to these two circuit arrangements are shown in figures 2-51 and 2-52 respectively. In the latter range chart, one No. 341A transformer is assumed to be in the circuit. If the circuit includes more than one transformer, the ranges will be less than those indicated.

252. PROTECTION.

Because of the high voltages present, protector blocks with higher than normal breakdown voltage must be used at the dispatcher's station and at all way stations. Normal fuses (7-amp.) are used at all stations

CHAPTER 3

TELEGRAPH SYSTEMS

Section I. WIRE AND RADIO TELEGRAPH SYSTEMS

301. MAJOR COMPONENTS OF TELEGRAPH SYSTEMS AND NETWORKS.

Telegraph systems serving areas of moderate extent include central office and station equipment operating in conjunction with wire or radio transmission circuits or a combination of wire and radio. Comparatively simple facilities which would be characterized as telegraph circuits rather than systems are shown by figures 3-1 and 3-2, the connecting circuits between the teletypewriter stations being direct (point-to-point) wire and radio connections, respectively. A system is made up of numerous components, including stations with their individual extensions (local lines), main transmission circuits, terminal and repeating equipment, retransmitting equipment, switchboards, and branch circuits extending to outlying localities. A relatively simple system involving such components is shown in figure 3-3. Furthermore, systems utilizing wire and radio facilities are combined to form a rather extensive network to provide communication throughout a theater of operations as illustrated in figure 3-4.

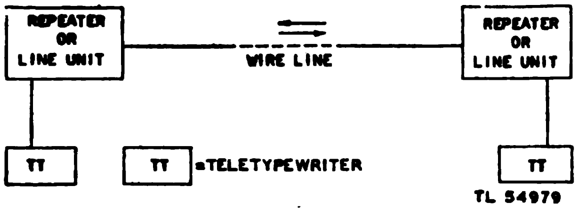


Figure 3-1. Direct (point-to-point) d-c wire teletypewriter circuit.

302. MESSAGE HANDLING METHODS.

Messages may be sent directly from a station to one or more distant stations over fixed circuits or over built-up circuits involving one or more switchboards. Messages may also be relayed semiautomatically or manually from one circuit to another, that is, received at an intermediate point and retransmitted to one or more other points. Teletypewriter operation with semiautomatic relaying is used to handle practically all of the traffic in the Army Command and Administrative Network which is discussed in chapter 11. Teletypewriter equipment should be manned by personnel having some degree of skill. Messages sent by all forms of telegraph usually are written out before transmittal and before delivery; this written record is a very valuable feature. Telegraph circuits, particularly those using teletypewriters, may be used also for interchanging infor-

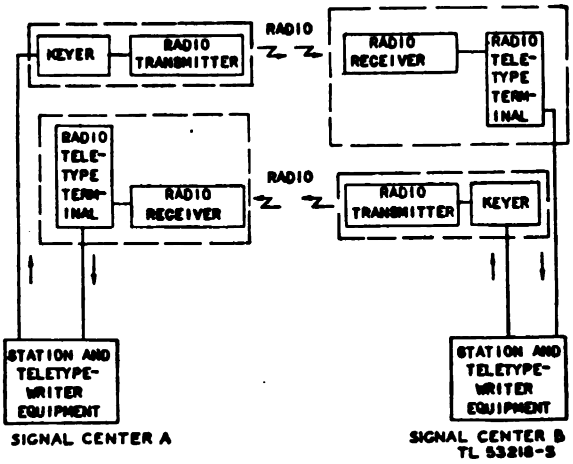


Figure 3-2. Direct (point-to-point) radio teletypewriter circuit.

mation in a conversational manner. Automatic switching to a very limited extent and on a specially engineered basis is used whereby a connection is established by switches actuated by certain teletypewriter characters.

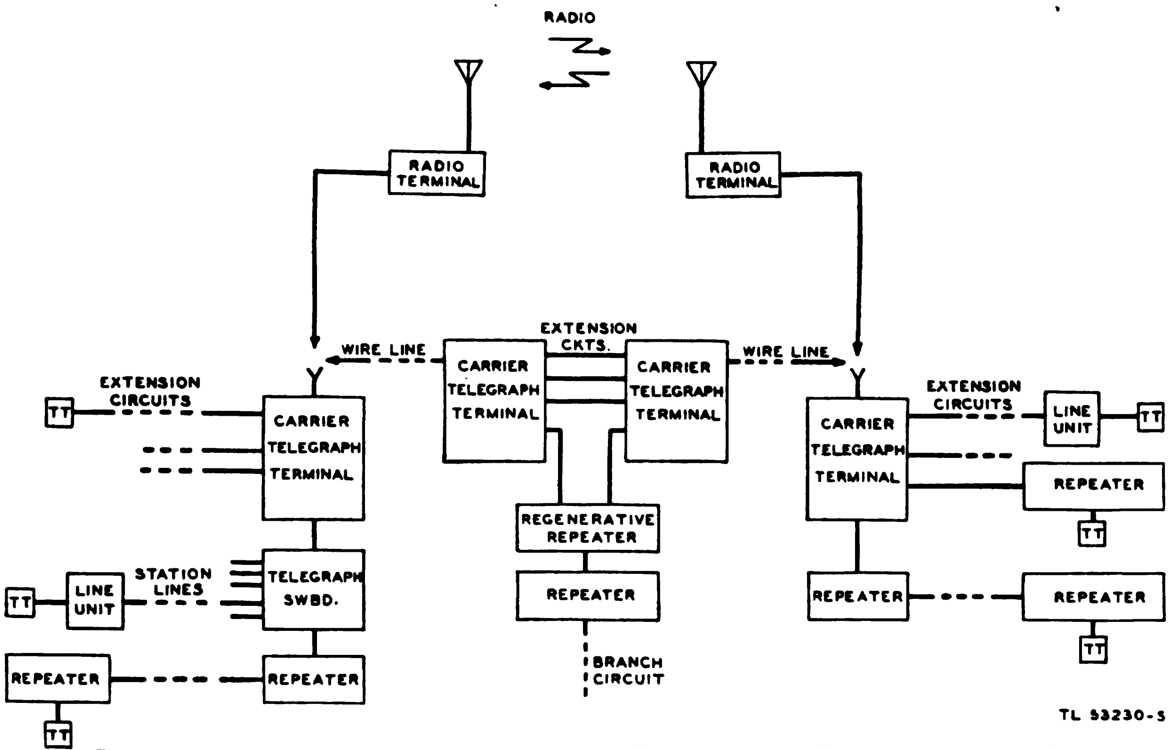


Figure 3-3. Teletypewriter system with wire (d-c and carrier) and radio transmission circuits.

303. INTERNATIONAL MORSE-CODE VERSUS TELETYPEWRITER OPERATION.

a. International Morse-code Methods and Speeds.

(*1*) In manual telegraphy the signals are formed as dots and dashes by the operation of a telegraph key by a trained operator. They are received as audible tone signals and recorded by hand or on a typewriter. The signals shown in figure 3-5-A illustrate the formation of typical characters. As indicated, a dot signal followed by a space of equal length is called a *dot-cycle* or sometimes simply a *cycle*. Certain administrations use a unit of speed called the *baud*, which is a rate of ½ cycle per second. Thus a speed of 23 dot-cycles per second may be expressed as 46 bauds. Since the baud is a *unit of speed*, it is incorrect to speak of a character or word as consisting of so many bauds. With average operators, a speed of 10 to 15 words per minute may be expected and perhaps twice as much with skilled operators.

(*2*) The International Morse Code is also used with automatic sending equipment, particularly where speeds up to about 400 words per minute or more are desired, such as on certain long-haul radio circuits. In this case, a punched tape is prepared by operating a keyboard; this tape is fed into a keying head capable of sending at a readily adjustable speed which is in accordance with circuit capabilities and traffic requirements. It is customary to assume that the average word consists of six characters, including one for a space at the end of the word. Use is being made of the test word CODEZ as a standard-length word in determining military speeds; on this basis a speed of 100 words per minute corresponds to 50 dot-cycles per second.[1] At comparatively low speeds, the signals may be received by ear. Generally, at speeds over about 25 words per minute, the signals are received by means of an ink recorder and transcribed by one or more operators at an average speed of about 35 words per minute for each operator. Sent and received tapes are illustrated in figure 3-6. Automatic equipment used for International Morse-code operation is described in paragraph 330.

[1] The transmission of the word CODEZ and the following space utilizes a transmission time equivalent to that of 30 dot-cycles. Therefore, a speed of 100 words per minute is 3,000 dot-cycles per minute or 50 dot-cycles per second.

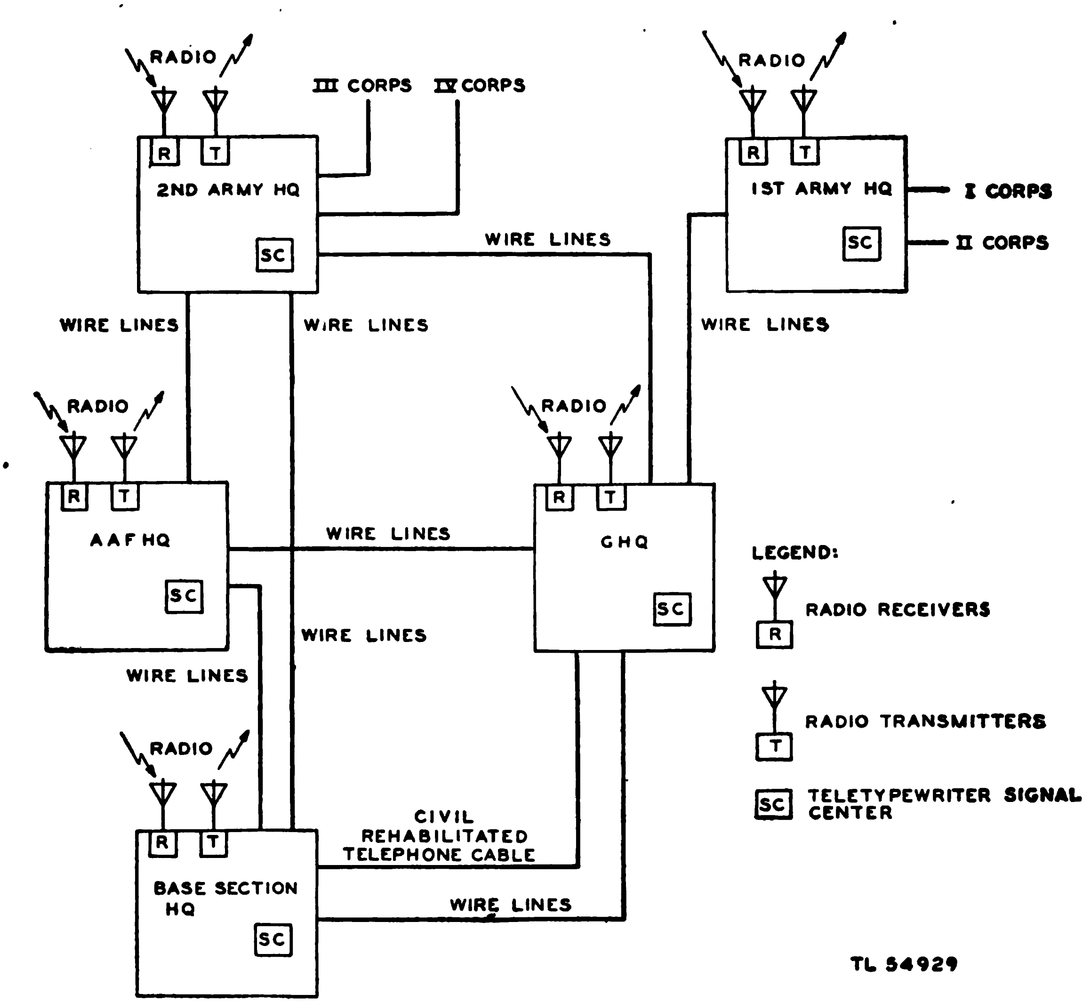


Figure 3-4. Typical theater teletypewriter network.

b. Teletypewriter Methods and Speeds.

(*1*) The form of teletypewriter signals is shown in figure 3-5-B; these signals are discussed in more detail in chapter 12. The letters and the space between words are all of equal length and the code is slightly more efficient in the use of line time than the International Morse code. Signals are produced by the operation of a teletypewriter keyboard similar to that of a typewriter, and the corresponding characters are typed in page form or on tape by machines at both sending and receiving stations. Signals may also be sent from a punched tape prepared locally by a *perforator* which

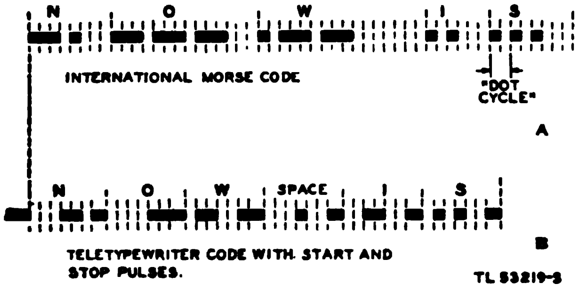


Figure 3-5. Telegraph codes, typical characters.

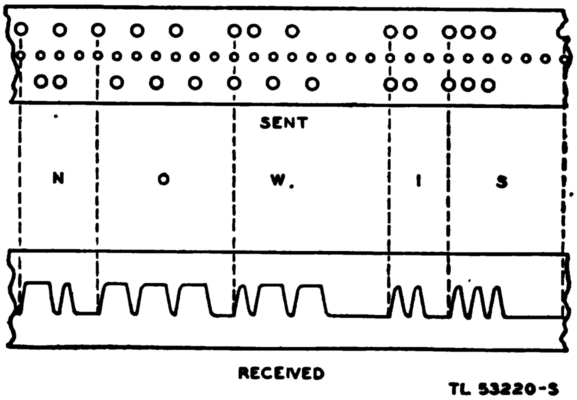


Figure 3-6. International Morse-code tapes.

has a keyboard similar to that of the teletypewriter. A sample of this tape is shown in figure 3-7. Teletypewriter signals may be received over a line by a *typing reperforator*, which records the message as partial perforations and as typed characters on the same tape. Some typing reperforators have keyboards from which

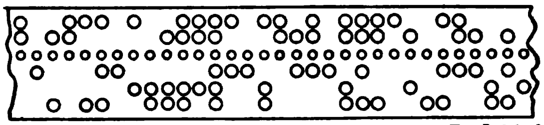


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Figure 3-7. Perforated teletypewriter tape.

tape may be prepared locally. The typing reperforator may also be used as a teletypewriter in sending messages. The form of tape, illustrated in figure 3-8, is called *chadless* and may be used for retransmitting the message. As a general rule, American Army teletypewriter equipment operates at a nominal speed of 60 words per minute, that is, 368 operations[2] per minute (opm). This speed may be increased to a nominal speed of 66 words per minute (404 operations per minute) to work with British teleprinters. However, for interoperation, other factors are important (par. 350). When sending directly to a circuit from a keyboard, the average operator will type at a nominal rate of 25 to 30 words per minute; because of the transmission of headings, nontyping selections, etc., the corresponding net message (text) speed is about 23 words per minute. When sending from tape at normal machine speed of 60 words per minute the average message (text) speed is about 50 words per minute.

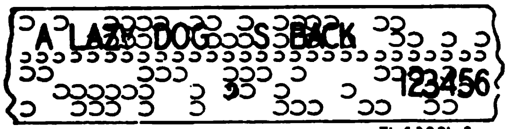

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Figure 3-8. Chadless (partially perforated) teletypewriter tape with typing.

(*2*) A few teletypewriter circuits, wire and radio, are being operated on a provisional basis at 100 words per minute. Operation at this speed requires modifications of teletypewriter equipment and associated testing arrangements. The modifications consist of introducing certain new parts and changes in adjustments. Also, new requirements, are imposed on transmission facilities because the signaling speed is about 37 cycles per second as compared with about 23 cycles per second for 60 word-per-minute service.

c. Relative Advantages.

(*1*) The advantages of teletypewriter operation as compared to manual telegraph operation are: high average speed, automatic reception of multiple copies in typed form at one or more points, use of operators with a lower degree of skill, possibility of regenerating signals automatically, and relaying of messages from circuit to circuit by means of tapes. The main disadvantages as compared to manual telegraphy are: size and weight of the equipment, complexity requiring skilled maintenance forces, need for high grade circuits, and need for about 100 to 300 watts of power per station.

(*2*) In the manual Morse method, the operators may reduce speed to meet the capabilities of the circuit. The use of manual Morse generally permits operation under more adverse circuit conditions than either teletypewriter or voice. Its main disadvantages are relatively slow speed and the need for more skillful operators. For operation on wire lines, manual telegraph uses simple sets which are readily portable and operable from batteries. These sets are relatively inexpensive, small in size, and light in weight (seven pounds without typewriter). The weight is roughly 1/50 that of teletypewriter station equipment.

(*3*) Automatic Morse operation is particularly advantageous in the case of a circuit which is operable for only a small part of the time, for example, on certain h-f radio circuits operating over paths near a magnetic pole a large amount of traffic can sometimes be moved in a few hours, using a speed of several hundred words per minute. The speed of automatic Morse operation may be regulated to suit the capabilities of the circuit. However, this equipment is complicated, requires about 500 to 600 watts of power, is heavier and larger than comparable teletypewriter equipment, and trained personnel is required to transcribe the signals from the received tape.

[2] An operation is considered to be a typing character or a nontyping selection. Examples of nontyping selections are *carriage return* and *line feed*.

Section II. WIRE AND RADIO TELEGRAPH TRANSMISSION

304. TRANSMISSION.

a. Dotting Speeds. Telegraph signals are sent at different rates, depending on the method of working and on circuit conditions. In manual International Morse the rate of sending dot-cycles is from about 6 to 15 cycles per second, the average being about 8 cycles per second. In teletypewriter operation, the line speed in dot cycles per second is set by the machine independently of the rate at which the keyboard is operated. The speeds are approximately 23 and 25 cycles per second for nominal word speeds of 60 and 66 per minute (368 and 404 operations per minute), respectively. In automatic Morse-code operation, the speed of signaling may reach 100 dot-cycles or more.

b. Frequency Band Widths. Although telegraph signals are made up of pulses during which the operating current substantially reaches a steady value, they also contain alternating-current components of different frequencies; the range of essential frequencies from the lowest to the highest is called the signal frequency band. It is necessary to provide a circuit having the proper characteristics to transmit this band. In the case of a d-c telegraph circuit, this band ordinarily extends from zero cycles per second, that is, direct current, up to about three times the maximum speed in dot-cycles per second. Thus, in manual telegraphy a band of about 50 cycles in width would ordinarily be adequate. In teletypewriter operation (60 word-per-minute speed) a band about 75 cycles wide is desirable; in high-speed automatic Morse-code operation, a band several hundred cycles in width may be required for the highest speeds. In carrier and radio telegraph, when current of a single tone or frequency is keyed on and off, the required band is twice as wide, extending in each direction from the carrier frequency by the amount required for the d-c case. When two frequencies (one for marking and another for spacing[3]) and two channels are used, the band width is again doubled. With tone modulated radio telegraph, the whole voice band is generally used.

[3] A signaling interval during which current flows through the teletypewriter receiving magnet is called a mark, and the circuit is said to be marking. When no current flows through the magnet, the signal is called a space, and the circuit is said to be spacing.

c. Wire Transmission. The two general types of wire telegraph circuits are dc and carrier. Carrier telegraph facilities operating in the voice range between 300 and 2,400 cycles per second generally form the main transmission circuits for long and medium distance communication on land lines. D-c circuits are used especially for the shorter facilities, including extensions to stations and branch circuits to outlying offices. Wire telegraph circuits will, in general, furnish dependable and accurate service if reasonable standards of circuit layout and maintenance are adhered to.

d. Radio Transmission. Although radio transmission provides a high degree of flexibility for point-to-point communication from a station to any one of a large number of stations and for broadcasting to a plurality of stations, transmission is, on the whole, less dependable than that over wires. This is because of variable conditions in the transmission medium and the possibility of accidental or intentional jamming. The transmission impairment is not only in the form of displacements of transitions between marks and spaces (*time distortion*) but also in variations in strength of received signals and the occasional obliteration of the received signals by interference. Single-channel and multichannel teletypewriter circuits are operated satisfactorily over radio links within limits of distances from a few thousand yards to many thousands of miles. International Morse-code operation is being replaced in some cases by teletypewriter operation. Most of these applications make use of radio facilities operating within either the h-f or v-h-f range, but in polar latitudes radio frequencies in the order of 50 to 200 kilocycles are used. For operation in the h-f range over radio circuits using sky-wave transmission, it is generally desirable to use diversity operation. Thus signals may be received simultaneously at two or more locations separated by several wavelengths (*space diversity*), or each signal may be sent simultaneously at two or more frequencies to be combined at the receiving station (*frequency diversity*). Where space is limited, two different adjacent antennas, such as vertical and horizontal, or differently-oriented horizontals, may give some improvement by providing *polarization-diversity* reception. Further information regarding teletypewriter operation over radio will be found in section VII. Refer to chapter 6 for general information on radio transmission, including antennas.

e. Repeaters. The limiting length of a telegraph circuit, either wire or radio, is generally reached when a signal becomes so weak as to be incapable of actuating the receiving apparatus properly, when the waveshape is modified so that the time distortion of the telegraph impulses is excessive, or when the received signal strength is too low to override the interference. Usually the circuit can be extended by inserting a repeater before the limiting length is reached. In d-c telegraphy, such a repeater involves reception of the signals by means of a relay and automatic retransmission using a local source of energy, such as a set of batteries or rectifiers. In carrier or radio telegraphy, the signals may be converted to d-c form before retransmission, or the repeater may be a vacuum-tube device merely to amplify them. In teletypewriter operation, a regenerative repeater may be used at an intermediate point. This repeater will automatically retransmit the received signals in practically perfect form if they have not suffered an amount of distortion which would cause errors in the copy in a teletypewriter at that point. The punching of a tape by a reperforator and retransmission from a transmitter-distributor is also a means of regenerating signals. This method is applicable to both wire and radio circuits.

f. Single and Duplex Methods of Operation.

(*1*) Over wire circuits, telegraph operation which is limited to one direction at a time is known as *single-* or *half-duplex* operation; a break feature is provided to enable the receiver to stop the sender. In radio operation, such to-and-fro service using only one radio frequency assignment is called either *simplex* or *one-way reversible*; in teletypewriter service, no break feature is provided but in manual circuits there may be a break-in feature. The term *half-duplex* as applied to radio is used to describe to-and-fro teletypewriter service using two radio-frequency assignments with a break feature. As noted in paragraph 305d, the term *simplex* also applies to a method of using wires to obtain d-c telegraph simultaneously with telephone.

(*2*) In any telegraph circuit (wire or radio) in which independent transmission paths are provided for the two directions of transmission, it is possible to transmit messages in both directions simultaneously. This is known as *duplex operation,* and is also called *full-duplex operation.* This method involves certain inconveniences from an operating standpoint, but allows moving approximately twice as much traffic as the single method. Carrier telegraph is particularly suited to the duplex method. With radio circuits, the duplex method requires different frequency assignments for the two directions of transmission.

305. D-C WIRE TELEGRAPHY.

a. Neutral. D-c neutral circuits operate on the basis of current for marking and no current for spacing. A metallic pair or a wire with ground return may be used between the sending and receiving points. Figure 3-9 shows schematically a manual neutral circuit. Simple open-and-close operation is sometimes used between teletypewriters connected directly to the line without line relays; in such cases, operation between teletypewriters is limited to distances in the order of a mile when field wire is used. This limitation is imposed primarily

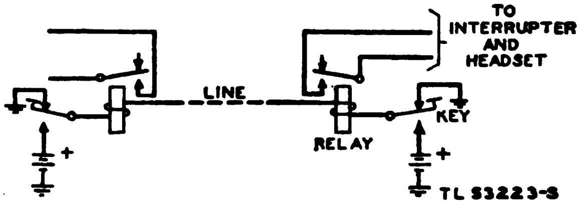


Figure 3-9. Neutral telegraph circuit (manual operation).

by signal distortion resulting from varying weather conditions. This distortion cannot be readily compensated for in the adjustment of the teletypewriter mechanism. However, this form of signal distortion can be overcome to a certain extent by interposing an adjustable receiving relay between the line and the teletypewriter, as shown in figure 3-10. At A the relay is biased mechanically; at B the bias is electrical.

b. Polar. In d-c polar circuits, approximately equal values of positive and negative voltage are applied alternately to the line at the transmitting end. At the receiving end, a polar relay responds to the direction of the current rather than to its magnitude. A one-way polar telegraph circuit (fig. 3-11) generally uses one line conductor with ground return,

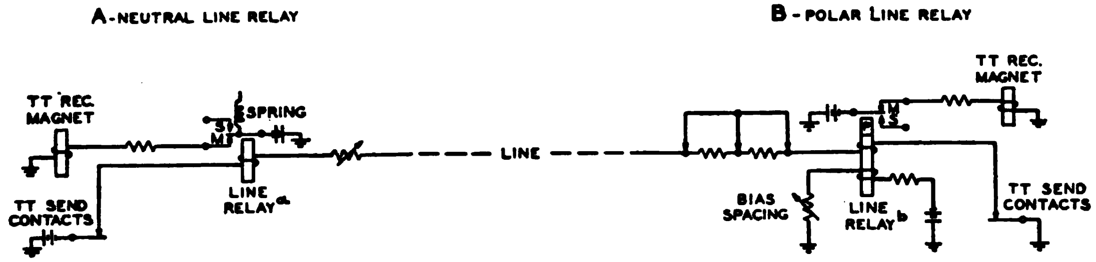


Figure 3-10. Neutral telegraph circuit (teletypewriter operation).

but two conductors may be used on a metallic-return basis. A 2-path polar circuit consists of two one-way polar circuits and is suitable for duplex operation provided the local circuits are so arranged. The British have a reversible one-way polar arrangement which uses one wire and reverses the direction of transmission by switching, which is automatic in the case of teletypewriter operation. This reversible arrangement does not lend itself to duplexing or multisection connections, and it is also subject to false operation when idle. American

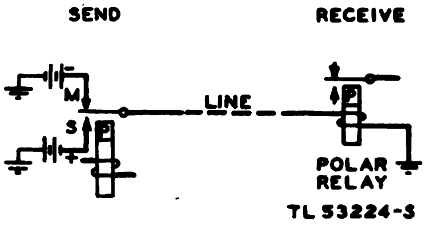


Figure 3-11. One-way polar telegraph circuit.

teletypewriters are not arranged for reversible one-way polar operation. See paragraph 350 for interoperation of British and American teletypewriters.

c. Polarential. A polarential circuit (fig. 3-12) provides practically the equivalent of a half-duplex 2-path polar circuit and uses only one line conductor instead of two. In a polarential circuit, the transmission in one direction is polar, and in the other direction it is equivalent to polar as far as the receiving relay is concerned. This polar equivalent is attained by providing the receiving relay at the polar-sending end with a local bias current which in magnitude is midway between the marking line current and the spacing current. The transmitting arrangments at the two terminals of a polarential circuit are dissimilar; one end, referred to as the polar-sending end, applies equal voltages of opposite polarities for marking and spacing and the other end, referred to as the differential-sending end, applies ground for marking and positive polarity for spacing. The operating ranges of polar and polarential circuits are substantially the same, and exceed

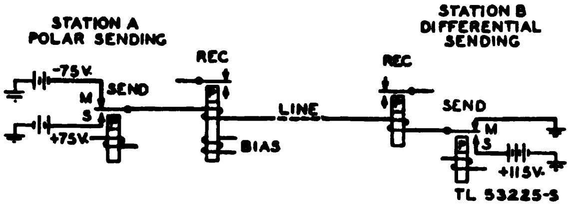


Figure 3-12. Polarential telegraph circuit.

that of a neutral circuit provided with an adjustable receiving relay. No adjustment is required in equipment operating on a polar or polarential basis to compensate for varying weather conditions. In the case of distributed leakage, there is little difference between the transmission capabilities of a polar and polarential circuit. However, a polar circuit will tolerate somewhat more leakage concentrated at one part of the line, and somewhat more difference of ground potential between the terminal points, than a polarential circuit.

d. Simplexed Circuits. D-c telegraph circuits are generally obtained from conductors which are used simultaneously for telephone purposes rather than by the use of conductors exclusively for telegraph purposes. One method of doing this is by simplexing (fig. 3-13), wherein one winding of a repeating coil or transformer is connected across the line pair and a point midway between the coil terminals of this line winding is connected to the telegraph equipment. With reasonably good impedance balance between the two wires of the pair, telegraph currents will divide approximately equally between the two wires and hence will not interfere with telephone transmission. A noise killer is often included in the transmitting branch of the telegraph repeater to reduce noise in the telephone circuit. The telephone currents will not introduce any material voltage in the telegraph circuit since they are transmitted on a metallic basis.

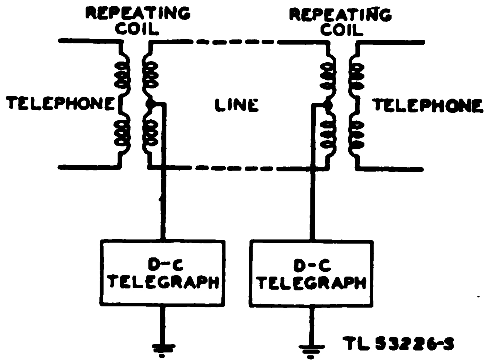


Figure 3-13. Simplexed circuit.

e. Composited Circuits. The compositing method for deriving d-c telegraph circuits from wires used for telephone circuits is based on frequency discrimination, that is, filtering, which is a method of selecting the desired electrical frequencies and rejecting others. A composite set (fig. 3-14) consists of a retardation coil and capacitors, and provides a low-pass filter (0 to about 80 cycles) for the telegraph currents and a high-pass filter for the telephone currents. The compositing method has the advantage of providing

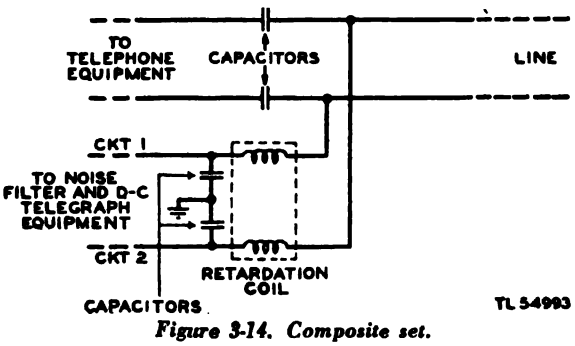


Figure 3-14. Composite set.

two telegraph channels from a pair of wires. A composited circuit can be phantomed but not simplexed. Compositing is usually applied to open wires in order to derive as many d-c facilities as possible. Generally the effect of leakage is less on composited telegraph circuits than it is on simplexed circuits.

f. Telegraph Extension Circuits. Circuits of this type, sometimes referred to either as local extensions, d-c extensions, or loop circuits, are operated on a d-c basis. They are used to extend circuits from the local side of carrier telegraph line terminals and d-c telegraph repeaters to teletypewriter equipments located in stations or signal centers. Furthermore, this type of circuit is used to interconnect the local sides of line equipment, that is, carrier terminals and d-c repeaters, at an intermediate point with or without teletypewriter equipment. Extensions may be operated neutral half-duplex, neutral full-duplex, 2-path polar, or polarential. Neutral full-duplex and 2-path polar extension circuits require two independent transmission paths to the teletypewriter station. Extensions operating on a neutral basis may use either a metallic or a ground-return circuit. To minimize interference, metallic return is preferable, when conductors are available. When interference is not the controlling factor, ground return would be used in some cases because of the lower total line circuit resistance.

306. MULTICHANNEL VOICE-FREQUENCY CARRIER WIRE TELEGRAPHY.

a. General.

(*1*) In general, carrier telegraphy uses an alternating current of fixed frequency for each channel, which is switched on and off at the sending end by a sending relay actuated by d-c signals. Frequencies in the voice-frequency band which are used for carrier telegraph systems (roughly 300 to 2,400 cycles) are given in the frequency allocation chart in chapter 5. The carrier currents are transmitted through their respective channel filters, and at the receiving end are separated by filters and then rectified in detectors to reproduce the original d-c signals. Circuits suitable for telephone transmission are used, and only a small part of the total voice band width available is required for each telegraph channel. Simultaneous operation of several (2 to 12) telegraph circuits may be obtained in the voice range, each circuit being capable of duplex operation.

(*2*) Carrier telegraph systems are operated sometimes on 2-wire circuits and sometimes on 4-wire circuits or the equivalent in which the transmission in the two directions is independent. In 2-wire carrier telegraph operation, different frequencies are used for the two directions of transmission. In the 4-wire case, the same frequencies may be used for both directions. When using the same frequencies in this manner the requirements as regards crosstalk between the two sides of the circuit are more severe for full-duplex telegraph operation than they are for telephone operation. Excessive crosstalk coupling between the two sides of the circuit will cause serious impairment of telegraph signals transmitted in one direction because of the telegraph currents sent in the opposite direction on the other side of the circuit.

(3) The power levels used in carrier telegraph systems must be properly coordinated with the telephone transmission levels. If the net loss from the originating long distance telephone switchboard to a point in the circuit is 0 db, this point is said to be at 0-db transmission level. The power in dbm (db referred to one milliwatt) per carrier telegraph channel, at a point of 0-db transmission level, is known as the *specific telegraph level.* Typical specific telegraph levels for various types of circuits are given in the following table for general information purposes. Various particular adjustments of telephone and telegraph equipment gains or losses are made in order to realize such telegraph levels. For specific information, see the manuals on particular telegraph and telephone equipments.

Type of telephone system (ch. 5)	*Specific telegraph level (dbm)*
Telephone Terminal CF-1-( ) (carrier)	
4-channel v-f telegraph	−10
6-channel v-f telegraph	−10
12-channel v-f telegraph	−18
Type C or H carrier telephone	
6-channel v-f telegraph	−12
12-channel v-f telegraph, on type C	−15
11-channel v-f telegraph, on type H	−15
Voice-frequency loaded cable (4-wire)	
6-channel v-f telegraph	−18
12-channel v-f telegraph	−21

b. Carrier Telegraph on Spiral-four Cable. Carrier telegraph systems are available for operation on one or more of the four telephone channels of a spiral-four cable system using Telephone Terminal CF–1–( ). This equipment can also be used on other wire telephone circuits, and on radio circuits as covered by paragraph 342. A schematic of a 4-channel carrier telegraph terminal (Telegraph Terminal CF–2–( )) is shown in figure 3-15. Telegraph Ter-

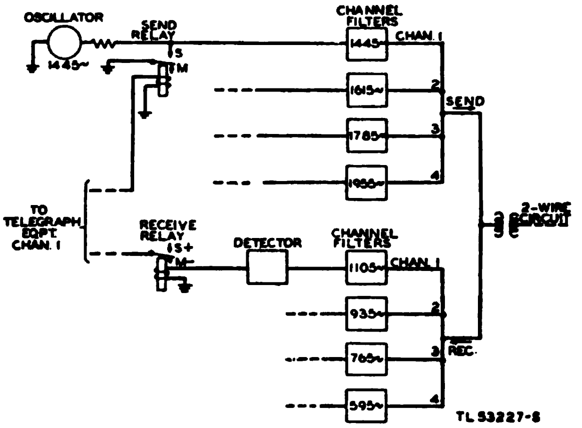


Figure 3-15. Elementary Schematic of Telegraph Terminal CF–2–( ).

minal CF–2–( ) with or without the addition of Telegraph Terminal CF–6 may be operated on either a 2-wire or a 4-wire basis and are normally associated with Telephone Terminal CF–1–( ). In this case the method of operation is designated 2-wire or 4-wire, depending upon whether the connection between Telephone Terminal CF–1–( ) and Telegraph Terminal CF–2–( ) uses 2 wires or 4 wires. If a 2-wire connection is used, four telegraph circuits can be obtained, using four frequencies for one direction of transmission and four for the opposite direction. The addition of Telegraph Terminal CF–6 to Telegraph Terminal CF–2–( ), connected 2-wire, provides two additional 2-way circuits making a total of six 2-way circuits. If a 4-wire connection is used between the CF–1–( ) and two CF–2–( ) terminals, the eight available telegraph transmission frequencies can be used in each direction of transmission, thereby providing eight 2-way telegraph circuits. In this case, the addition of two Telegraph Terminals CF–6 will increase the number of 2-way telegraph circuits to 12. Telegraph Terminal CF–2–( ) may be operated on channels of the British Apparatus Terminal Carrier Telephone (1 + 4), on types C or H carrier telephone systems, or in general over any good telephone channel.

c. Carrier Telegraph on Type C or H Carrier Telephone System. Another telegraph system (packaged equipment), providing 6 or 12 channels on a 4-wire basis, is also available for operation on type C or H carrier telephone circuits or on 4-wire cable circuits with suitable loading. The same frequencies are used in both directions of transmission. Channel 2 of a type C system is normally used for telegraph when only one telegraph system is required; two or all three channels of a type C system may, however, be used for telegraph if desired. In a type C system carrying telegraph, the channels used for telephone service must be equipped with volume limiters to prevent interference with the telegraph. In the case of type H, the number of telegraph channels or the quality of transmission for a given number of channels is somewhat restricted, depending principally on the stability of the system from a level standpoint. Telegraph channel 1 is generally not usable. Channels 2 to 12 can be operated simultaneously provided line variations are very small. Best results are obtained by using channels 2 to 6 inclusive, or 7 to 12 inclusive.

307. SPEECH-PLUS-SIMPLEX AND SPEECH-PLUS-DUPLEX SYSTEMS.

a. General. These systems are designed to derive carrier telegraph from a portion of the frequency band used by a telephone channel while retaining the use of the channel for speech transmission. The speech-plus-simplex (S + SX) system, which is British, provides service in both directions on a circuit but in only one direction at a time. The speech-plus-duplex (S + DX) system is used by the British and the American Army, and provides full-duplex service but may be operated half-duplex if required.

b. S + SX. The British speech-plus-simplex equipment is furnished in three types: S+ SX Nos. 1, 2, and 3. Nos. 1 and 2 are arranged to use carrier frequencies of 300, 900, and 2,300 cycles per second. The No. 3 equipment uses frequencies of 300, 1,740, and 2,300 cycles per second. With any one of these three types of equipment, two telegraph circuits, together with a speech channel, may be obtained by using the 300-cycle and the 2,300-cycle channels for telegraph and the intervening band of frequencies for the telephone channel. One S + SX system normally uses either the 300-cycle or the 2,300-cycle frequency and uses the same frequency in both directions of transmission. Two such systems are therefore required to obtain two telegraph circuits from one speech channel. When adverse line conditions interfere with transmission, the telephone can be abandoned and the telegraph worked at one of the emergency frequencies of 900 cycles or 1,740 cycles. In the S + SX equipment, the carrier is transmitted for spacing and interrupted for marking.

c. S + DX. In the speech-plus-duplex system (British and American), a band from about 1,500 to 2,000 cycles is eliminated from the

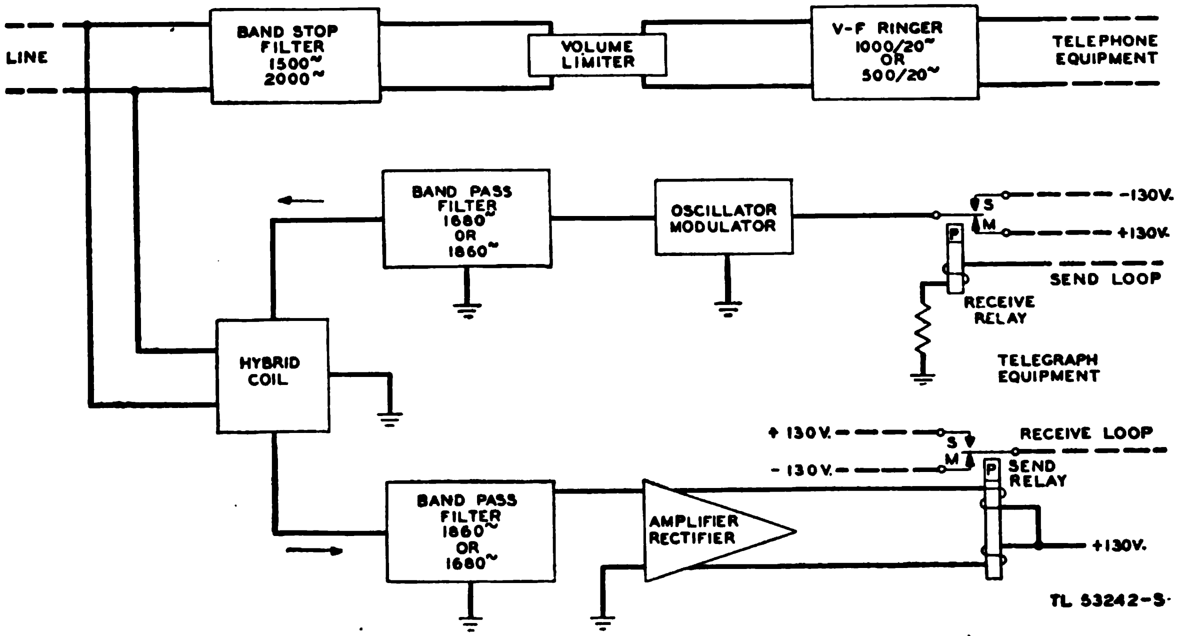


Figure 3-16. Speech-plus-duplex system.

speech transmission circuit and used for telegraph purposes. The carrier midband frequencies employed are 1,680 cycles for one direction of transmission and 1,860 cycles for the other direction. Carrier is transmitted for marking and interrupted for spacing. The British equipment is known as British Apparatus, V.F. Telegraph, S +DX. The American equipment, Telegraph Terminal TH–1/TCC–1, is shown schematically in figure 3-16. Further information on Telegraph Terminal TH–1/TCC–1 and its use will be found in paragraph 333. Interoperation of the British and American speech-plus-duplex equipment is described in paragraph 351. The British S + SX equipment is not operable with S +DX equipments since the two use different frequencies.

d. Use of S + SX and S + DX Systems. These systems have the advantage that the telegraph circuit can be set up quickly without arranging for simplexing or compositing, or setting up intermediate telegraph repeaters. The removal of the 1,500– to 2,000–cycle band from the speech circuit and the losses at other frequencies caused by the S + DX apparatus often produce impairment in speech transmission as discussed in paragraph 333h. It is generally desirable to confine the use of speech-plus-duplex equipment to cases where facilities and time are insufficient to provide a telegraph circuit by other means. When these systems are used, telegraph levels must be coordinated with the telephone layout, and telephone net losses for the S + DX system are restricted, as discussed in paragraph 333.

308. METHODS OF OPERATING RADIO TELETYPEWRITER CIRCUITS.

a. Single Channel.

(*1*) *General.* Single-channel teletypewriter operation over h-f or v-h-f radio may be accomplished by modulating or keying the radio transmitter in a number of ways, depending upon the type of radio transmitter, radio receiver, and teletypewriter terminating equipment used, and upon the distance of transmission. The more common methods are described in subparagraphs (2) to (6) below, and transmission comparisons relative to these methods of operation are given in paragraph 309. C–w and single-tone modulation are applicable to manual and automatic Morse operation as well as to teletypewriter operation. Two-tone modulation and frequency-shift methods are used especially for teletypewriter operation.

(*2*) *Cw* (*Keyed Carrier*). This is a method in which the radio transmitter emits a radio-frequency wave during closure of the teletypewriter contacts (marking signal) and emits nothing during spacing signals. For reception of this type of signal, the radio receiver includes a beat-frequency oscillator to provide the audible tone from the output of the receiver to the teletypewriter receiving circuit whenever a marking signal is received. There is no tone during a spacing signal. A teletypewriter receiving circuit, capable of amplifying and rectifying the tone signals obtained from the output of the receiver and of operating the receiving teletypewriter in response to these tones is required for operation with the radio receiver.

(*3*) *Single-tone Modulation.* In this method, the radio-frequency carrier emitted by a radio telephone transmitter is generally modulated with an audible tone during teletypewriter marking signals and unmodulated during spacing signals. In some cases, however, the carrier wave may be modulated for the spacing signal instead of for the marking signal. The term tone-modulation is applied to this method of modulation.[4] It is applicable to either an amplitude-modulation or frequency-modulation radio system suitable for speech transmission. A teletypewriter sending circuit that furnishes, for example, an audible tone for marking and no tone for spacing is required for operation with the transmitter. A teletypewriter receiving circuit that amplifies and rectifies the tone signals and operates the receiving teletypewriter in response to these tone signals is required.

(*4*) *Two-tone Modulation.* With this method the radio-frequency carrier emitted by a radio telephone transmitter is modulated with one audible tone during marking signals and by another audible tone during spacing signals. It is applicable to either an amplitude-modulation (a-m) or a frequency-modulation (f-m) radio system suitable for speech. A teletypewriter sending circuit that furnishes one audible tone for marking and another for spac-

[4] The term mcw is not used in this chapter since in radio parlance its use is rather indefinite and is related to a number of different methods of keying. It is sometimes used to mean single-tone modulation. For further discussion of tone-modulation and mcw, see chapter 6.

ing is required for operation with the transmitter. A teletypewriter receiving circuit, equipped with band filters, a fast-acting wide-range current limiter, an amplifier-detector for receiving marking signals, an amplifier-detector for receiving spacing signals, and a receiving relay, is used with the radio receiver to provide the operating currents to the teletypewriter in response to the tones obtained from the output of the receiver.

(*5*) *Frequency Shift.* This is a method in which a radio wave having a particular frequency is emitted by the radio transmitter during teletypewriter marking signals and another radio wave of the same amplitude but slightly different frequency is emitted during spacing signals. This method is sometimes called carrier shift. Radio transmitters capable of c-w emission operating in the h-f range may be arranged for use with this method. A suitable transmitter keying arrangement must be provided to shift the radio frequency. A conventional h-f receiver can be used provided that suitable radio teletype terminal equipment is available. The radio receiver is equipped with a beat-frequency oscillator to provide the two tones, one for marking and the other for spacing, from which the marking and spacing teletypewriter pulses are derived. A teletypewriter receiving circuit, equipped with band filters, a fast-acting current limiter, an amplifier-detector for marking signals, an amplifier-detector for spacing signals, and a receiving relay, is used with the radio receiver to supply the operating currents to the receiving teletypewriter in response to the tones obtained from the output of the receiver.

(*6*) *Diversity Operation.* If reception is on a space-diversity basis, two receiving antennas spaced a few wavelengths apart, two radio receivers, and two teletypewriter receiving circuits with one polar relay for operating the receiving teletypewriter equipment are used. If reception is on a frequency-diversity basis, the transmitter is modulated with two audible tones during marking signals and by two other audible tones during spacing signals. In this latter case, both the teletypewriter sending and receiving circuits become more complicated than for space-diversity reception, but only one receiving antenna and one radio receiver are required. Two-tone modulation operation may use space diversity with or without frequency diversity. Frequency-shift operation is commonly on a space-diversity basis.

b. Multichannel.

(*1*) *General.* Where multichannel teletypewriter operation is required over radio, the single-tone modulation method may be used where the transmission is by ground wave, as is ordinarily the case with v-h-f radio circuits. The 2-tone modulation method is used primarily to aid in overcoming the effects of fading which is experienced on h-f radio circuits using sky-wave transmission (ch. 6). Transmission comparisons of the single-tone modulation and the 2-tone modulation method for multichannel teletypewriter operation will be found in paragraph 310.

(*2*) *Single-tone Modulation.* In multichannel radio teletypewriter operation using the single-tone modulation method, the carrier emitted by the radio telephone transmitter may be modulated simultaneously by a number of audible tones, one for each teletypewriter channel. In each channel, the tone is usually sent when the teletypewriter sends a marking signal and in this case no tone is sent for spacing. The teletypewriter connecting circuits are fundamentally the same as for single-channel single-tone modulation operation.

(*3*) *Two-tone Modulation.* In the case of 2-tone modulation multichannel operation, each channel is arranged fundamentally in the same manner as for 2-tone modulation single-channel operation. The teletypewriter connecting circuits are basically of the same design as for single-channel 2-tone modulation operation.

309. TRANSMISSION COMPARISON OF SINGLE-CHANNEL TELETYPEWRITER METHODS OF OPERATION.

a. Relative Transmitter Power Required for Morse, Teletypewriter, and Voice. Various types of radio transmitters and receivers and methods of operation have different effectiveness in overcoming electrical interference or noise.

Method of operation	*Relative transmitter carrier power required*
Manual Morse, c-w	1
Automatic Morse, c-w	10
Teletypewriter, c-w	20
Teletypewriter, single-tone, a-m	40
Teletypewriter, 2-tone, a-m	10
Teletypewriter, frequency-shift	5
Voice, full transmitter modulation, a-m	25

Therefore, different amounts of transmitter power are required for overcoming a given strength of interference. Some order-of-magnitude comparisons of relative power required per channel, based largely on experience, are given in the above table in which it has been assumed that the receiver band-width is roughly the same throughout and that the transmitter is approaching full modulation. In this table manual Morse, automatic Morse, and voice are listed for reference purposes only. Furthermore, the table applies more particularly to ground-wave than to sky-wave transmission; that is, little or no fading is assumed. These figures are to be considered as general guides only, and do not necessarily apply exactly to any particular case, since much depends on the design of the transmitter and receiver, the radio frequency used, the band width of the receiver, and the skill of the operating personnel, as well as the nature of the interference. With c-w manual telegraphy, results depend, to a large extent, on the skill and experience of the receiving operator in copying signals through interference and in adjusting the radio receiver; for example, a particularly good operator may receive signals successfully through 5 to 15 times as much interference as an ordinary operator. The above estimates assume that the operator has fair or moderate skill. It is assumed that in teletypewriter service comparatively few errors are permissible and that in automatic Morse-code operation an easily legible tape record is required.

b. Relative Transmitter Power Required, Further Comparisons for Teletypewriter Operation. Figure 3-17 gives some data for various methods of operating single-channel teletypewriter circuits over radio. These are intended to indicate, as a first approximation, the relative transmitter power required for representative

Method of operation	*H-f or v-h-f radio equipment*[a]	*Assumed pass band of receiving teletypewriter circuit (cycles)*	*Estimated relative amounts of transmitter power required for satisfactory teletypewriter operation (db)*		
			Ground-wave h-f or v-h-f transmission nondiversity reception[b]		*Sky-wave h-f transmission space-diversity reception*[b]
Cw	Tg or a-m tp type, with c-w keying of transmitter, and c-w (beat-frequency) oscillator in receiver	1,000[g]	0[c]		0[c]
Single-tone modulation	A-m tp type transmitter and receiver	100	+10 to 0[d]	*Do not*	not recommended
		2,000	+16 to +6[d]	*compare*	
	F-m tp type transmitter and receiver	100	+ 2 to −2[e]	*these*	not recommended
		2,000	+ 4 to 0[e]	*columns*	
Two-tone modulation	A-m tp type transmitter and receiver	200[f]	+ 6 to −4[d]	*horizontally*[b]	−5 to −15
	F-m tp type transmitter and receiver	200[f]	0 to −4[e]		No data
Frequency shift	Tg or a-m h-f tp type, with c-w (beat-frequency) oscillator in receiver	2,000[g]	−4		−17

[a] A-m = amplitude modulation; f-m = frequency modulation; tp = telephone; tg = telegraph; c-w = continuous wave.

[b] Figures in ground-wave column should not be compared with those in sky-wave column as the data do *not* indicate the relative efficiencies of ground-wave and sky-wave transmission.

[c] The 0-db figure is chosen arbitrarily as a reference for comparison with the other methods.

[d] First figure assumes 30 percent modulation of transmitter; second figure assumes 100 percent.

[e] First figure assumes 30 percent of full degree of modulation for which transmitter was designed; second figure assumes full modulation.

[f] Assumes marking and spacing filters each having a pass band of 100 cycles.

[g] By closely regulating the oscillator frequency in the radio transmitter and receiver these pass-band widths may be reduced with an attendant reduction in transmitter power.

Figure 3-17. Comparison of various methods of operating single-channel teletypewriter circuits over radio.

receiver pass bands under average conditions. It will be noted that the differences are not large with ground-wave transmission, whereas with sky-wave transmission the frequency-shift and 2-tone a-m methods offer a great advantage.

c. Audio Pass-band Widths. As regards the width of audio pass bands of receiving circuits, the single-tone and 2-tone modulation methods have the practical advantage over the other methods in that frequencies of audio signals delivered to the teletypewriter connecting circuits do not vary appreciably, and narrow band filters may, therefore, be inserted in the receiving teletypewriter circuits to eliminate some of the noise that would otherwise interfere with reception. For 60-word-per-minute teletypewriter service, a filter having a pass band of 100 cycles (6-db point[5]) may be used with the single-tone modulation method; and for 2-tone modulation two 100-cycle filters will permit satisfactory operation. With the c-w and frequency-shift methods, where frequency drift of transmitter and receiver oscillators becomes a factor, such narrow filters cannot ordinarily be used. The width of the pass band of the receiving circuit with the c-w method may be as narrow as about 1,000 cycles, and with the frequency-shift method it may be about 2,000 cycles, with the average types of radio sets. A greater degree of protection against noise can be obtained by further narrowing these pass-band widths, if stable oscillators are used in the radio sets or if proper compensation is provided for the frequency drifts of transmitter and receiver oscillators; this may require automatic frequency control or frequent monitoring by skilled operators.

d. Degree of Modulation. In comparing the various methods from the standpoint of their ability to overcome the effects of noise, with the single-tone and 2-tone modulation methods, best results are obtained if the transmitter is fully modulated. Under this condition a larger portion of the total power transmitted is contained in the intelligence-bearing sidebands than when the transmitter is only partially modulated. For example, with only 30 percent amplitude modulation 10 times as much power is required to maintain the same signal-to-noise ratio as with full modulation. With the c-w and frequency-shift methods, this problem is not present because both are essentially 100-percent modulation schemes.

e. Radio Relay Operation. Where it is desired to transmit beyond the limit of a single radio section with ground-wave transmission, v-h-f radio equipments suitable for speech transmission, such as Radio Sets AN/TRC–1, –3, or –4, may be used to provide operation over several radio sections in tandem. In this case the single-tone modulation method is used. Multisection operation is, of course, more complicated than single-section operation, as radio relay equipment is introduced. The length of each section may also have to be reduced below that for single-section operation, because the noise present in each section contributes to over-all degradation of transmission. H-f radio equipment is not recommended for multisection ground-wave transmission because of the relatively large amount of interference from noise in the h-f range.

f. Ground-wave Transmission. Any of the methods described in paragraph 308a may be used to provide a single-channel teletypewriter circuit over a radio link where ground-wave transmission is used. With ground-wave transmission the permissible distance for satisfactory teletypewriter operation with any of the methods will depend on the power transmitted, the radio frequency used, the antennas used, the terrain, and the amount of noise in the radio path. The distance ranges can be estimated from the information in chapter 6, together with the table in paragraph 309a and figure 3-17. Since transmission is on a ground-wave basis there should be little or no trouble from fading.

g. Sky-wave Transmission.

(*1*) *General.* For distances beyond the ground-wave transmission range, sky-wave transmission may be used with radio sets operating in the h-f range. The permissible distance of transmission will depend on the power transmitted, the radio frequency used, the types and directivity of antennas used, and the amount of noise in the radio paths. In addition, the distance will depend largely upon the severity of fading encountered in the sky-wave paths. The frequency-shift, 2-tone modulation, or c-w methods may be used in that order of preference from a transmission standpoint.

[5] This a rough measure of the boundaries of a band-pass filter. The 6-db points are the two frequencies at which the loss in the filter is 6 db greater than the minimum loss in the pass band.

The single-tone modulation method is not recommended.

(*2*) *Overcoming the Effects of Fading.* Various methods may be used to cope with fading. To overcome the effects of rapid fading prevalent in sky-wave transmission, and particularly of *flat* fading (uniform over the frequency range of the receiver pass band) of the telegraph channel, a preferred method is to use either frequency-shift or 2-tone modulation transmission in combination with a compensating arrangement such as a wide-range fast-acting constant-output current limiter in the receiving circuit. The limiter attenuates high currents and amplifies weak currents so as to practically eliminate amplitude variations and thereby furnish the detectors with signals of a constant amplitude. In either the frequency-shift or 2-tone modulation cases, the limiter may be used effectively because a radio wave is emitted at all times. In the c-w system, it would cause considerable trouble by amplifying the noise energy received during the no-signal or spacing intervals. Either the frequency-shift or 2-tone method of working with a limiter reduces the effects of flat fading and is of some advantage for *selective* fading (nonuniform over frequency range of the receiver pass band). Furthermore, noise components superimposed on the received signals will cause little interference as long as they are materially less in amplitude than the signals. The effects of fading (either flat or selective) may be substantially reduced by using space diversity, in which the receiving arrangement consists of two or more antennas spaced a few wavelengths apart, with individual radio receivers and receiving circuits connected to a common receiving relay.

310. TRANSMISSION COMPARISON OF MULTICHANNEL TELETYPEWRITER METHODS OF OPERATION.

a. General.

(*1*) In multichannel operation, it is expedient to use the tone modulation methods of operation. In the case of ground-wave transmission systems, single-tone modulation is preferable because of its simplicity; for sky-wave transmission, the 2-tone modulation method should be used to combat fading. In the v-h-f range, single-tone can be used on multisection radio circuits.

(*2*) As regards relative transmitter power required, receiver band width, etc., the transmission comparisons given in paragraph 309 and figure 3-17 for single-channel operation are generally applicable. However, there is an additional limitation that may materially reduce the ability of a multichannel system to operate satisfactorily. Since several different audio-frequency currents are applied simultaneously to the radio transmitter, it is necessary in a multichannel system to reduce the input level of current delivered by each channel to the transmitter sufficiently to prevent the composite current, made up of currents from all channels, from having peaks that will overload the transmitter. This reduction is a function of the number of channels and the type of equipment used; for example, with four channels it is 6 to 12 db. The resulting signal-to-noise ratio in this case is correspondingly less per channel than it would be with the same system lined up and operated on a single-channel basis.

(*3*) In the single-tone modulation case, when all teletypewriter channels are marking, the radio-frequency carrier is modulated by all the channel tones; when all channels are spacing the carrier is unmodulated. Therefore, the degree of modulation varies with signaling on the various channels. This is not true with 2-tone modulation operation. In the case of 2-tone modulation multichannel operation, each channel is arranged fundamentally in the same manner as for 2-tone modulation single-channel operation.

b. Twin-channel Single-sideband System. A suitable though elaborate arrangement for obtaining multichannel radio teletypewriter operation over long distances makes use of twin-channel single-sideband radio telephone equipment operating in the h-f range. Two radio telephone circuits are normally obtained over such a radio link, one telephone circuit using the spectrum of the lower sideband and the other using the spectrum of the upper sideband. Each sideband, therefore, carries intelligence independently of the other. In addition, a large portion of the radio-frequency carrier is suppressed, which further increases the efficiency of the transmitter from a radio transmission standpoint. Such a telephone channel may be used for multichannel teletypewriter operation. When a telephone channel of a twin-channel single-sideband system is used for multichannel telegraph service, the other telephone channel can be used for telephone, multichannel telegraph, or other service; however, some sacrifice in the power per channel will be required. The system is many db better than the single-tone modulation method described in paragraph 308b from the standpoint of transmitter power required for satisfactory teletypewriter operation over long distances. To care for the fading problems prevalent in long distance sky-wave transmission, limiters are provided in the receiving teletypewriter circuits and frequency diversity is used. Frequency diversity rather than space diversity was chosen for this particular system mainly because sufficient radio receivers were not available initially to provide space-diversity reception. From a transmission standpoint, there is apparently little difference between the two schemes as regards their effectiveness in overcoming selective fading.

311. RADIO TELETYPEWRITER ARRANGEMENTS; FIXED PLANT AND TACTICAL.

a. Radio teletypewriter arrangements available for fixed plant installations include:

(*1*) A single-channel system using space-diversity with frequency-shift transmission and using Radio Teletype Terminal Equipment AN/FGC–1 at the receiving point. This equipment may be used on circuits up to several thousand miles in length.

(*2*) A multichannel system using 42B1 carrier telegraph equipment which provides six single-tone modulation wide-band telegraph channels. This equipment, described in paragraph 341b, is generally used with short-haul v-h-f radio circuits.

(*3*) A 2-tone modulation multichannel carrier telegraph arrangement for application to single-sideband radio telephone systems operating in the h-f range. Such a system is in use between theater headquarters and continental United States.

b. Multichannel radio teletypewriter circuits can be set up, using tactical radio sets operating in the v-h-f range, together with Telegraph Terminals CF–2–A, CF–2–B, and CF–6.

c. Except for Radio Set AN/MRC–2 (par. 347c), standard arrangements for single-channel radio teletypewriter circuits using tactical radio sets are not at present generally available. Arrangements can be improvised, based upon the use of Telegraph Terminal CF–2–B, fixed plant Radio Teletype Terminal Equipment AN/FGC–1, or British Telegraph Apparatus Mark III 2-Tone.

d. For use of speech-plus-duplex systems on radio, refer to paragraph 333i.

e. Both fixed plant and tactical radio teletypewriter arrangements are discussed in more detail in section VII of this chapter.

Section III. LAYOUT OF WIRE TELEGRAPH CIRCUITS

312. GENERAL.

a. Telegraph circuit layouts are formed by combining line sections and extensions. A line section includes terminal repeater equipment as well as line conductors. Extensions are defined in paragraph 305f.

b. In planning circuit layouts, it is essential to have information on the maximum operable lengths of the various types of line sections and extensions. Furthermore, it is important to evaluate the transmission capabilities of the individual line sections and extensions so as to select suitable facilities and properly locate repeaters, including the regenerative type. The use of transmission ratings, known as coefficients, will aid in the efficient use of available facilities and in planning additions.

c. This section provides general information regarding laying out wire telegraph circuits. For further information, reference should be made to TM 11–2001, TM 11–2022, and TM 11–2037.

d. With manual operation using Morse code, the circuit layout problem is usually comparatively simple. The circuits are usually short and nearly always on a single-section basis since they are generally confined to the forward area. Except for paragraph 316, this section discusses the layout of telegraph circuits for teletypewriter service only.

313. MAXIMUM LENGTHS D-C TELEGRAPH LINE SECTIONS.

a. The distances which can be operated satisfactorily are limited by different considerations for different types of circuits and

Type of circuit and equipment	*Type of wire*	*Maximum length per section (miles)*	
		One section	*Each of two sections in tandem*[c]
Neutral operation			
Simplexed field wire with Line Unit BE-77, BE-77-A, BE-77-B	W-110-B	40	Not used
	W-143	35[a]	Not used
Simplexed field wire with Switchboard BD-100 and Line Unit BE-77, BE-77-A, or BE-77-B	W-110-B	Not used	25
	W-143	Not used	25
Polar or polarential operation with Repeaters TG-30 or X-61824			
Simplexed field wire	W-110-B	50	40
	W-143	75	40
Simplexed lead sheath cable	16 B.&S. ga.	135	125
	19 B.&S. ga.	125	125
	22 B.&S. ga.	80	75
Simplexed open wire	open wire	[b]	[b]
Composited open wire	165 copper	200	200
	128 copper	200	200
	104 copper	200	200
	80 copper	150	135
	128 40% C-S	150	135
	104 40% C-S	135	100
	80 40% C-S	95	50
	125 30% C-S	135	100
	104 30% C-S	100	75
	109 GS	45	25
	83 GS	25	15

[a] The recommended lengths are for average leakage and capacitance conditions and should be reduced when these conditions are extreme. The recommended length of Wire W-143 is below that for Wire W-110-B with these line units on account of the method of limiting line current used in these units. The resulting distribution of capacity and resistance produces an unfavorable waveform with Wire W-143. The operating range with Wire W-143 would be greater if lower voltages and terminating resistances were used.

[b] For maximum lengths of simplexed open wire, use 100 miles or *twice* the maximum length for composited wire, whichever is less.

[c] The two sections are joined without using a regenerative repeater and the intermediate repeating arrangement is a Telegraph Repeater TG-31, two Repeaters TG-30, two X-61824 d-c repeaters, or a Switchboard BD-100 connection.

Figure 3-18. Recommended maximum lengths for d-c telegraph line sections.

operating conditions. Important factors are leakage, capacitance, and resistance of the line, ground resistance, waveshape distortion, and interference. Figure 3-18 gives recommended maximum section lengths for single-section and 2-section teletypewriter operation of d-c telegraph line sections without regeneration. These are intended to be used as a guide in laying out circuits and should not be considered as exact figures. The line section lengths given are independent of the lengths of the extensions. The data are for 60-word-per-minute teletypewriter service. For 66-word-per-minute service, reference should be made to subparagraphs e and f below. The lengths given in figure 3-18 are based on the following assumed conditions:

(*1*) Field Wires W–110–B or W–143 on wet ground or in water with a capacitance to ground of 0.8 mf per mile and a leakage to ground of 0.25 megohm per mile.

(*2*) Open wire leakage of 0.25 megohm per mile to ground.

(*3*) Open wire leakage of 3.5 megohms per mile between wires of a pair (ungrounded).

(*4*) Resistance of ground connection (as for example, one or more ground rods to earth) about 200 ohms for one telegraph circuit and 20 ohms for a common ground connection used by more than one telegraph circuit.

(*5*) Little or no interference or ground potential.

(*6*) Maximum temperature of 130° F.

(*7*) Standard paper-insulated lead-sheath cable of a commercial grade.

b. Under average or better than average conditions it may be possible to use greater lengths. Field wire may be suspended on poles or trees or laid on dry ground; this will not permit greater lengths of Wire W–110–B to be used except where consistently low temperatures exist, since the maximum length given is set by line and ground resistance. With Wire W–143, however, resistance is not the limiting factor and the lengths may be increased materially, perhaps by a factor of 2 or 3, under consistently good conditions. With copper open wire 104 mil and larger, the maximum length is determined mainly by leakage. Under consistently dry conditions the length of a single section of large gauge copper open wire may be increased considerably. With open wire lines of small gauge copper and lines of poorer conductivity than copper, such as 080- and 104-mil copper-steel, the lengths are limited by distortion introduced by the line resistance and the characteristics of composite sets and noise filters; these lengths should not be materially increased under any condition. If there is material electrical interference, such as severe lightning or more than 5 to 10 volts of a-c power induction or d-c ground potential difference, the maximum lengths may need to be reduced, depending upon the amount of interference.

c. The maximum lengths for each section of a 2-section d-c circuit are generally lower than that for a single section. With copper open wire lines 104 mil and larger, however, the limit is determined mainly by the leakage, and the maximum section lengths are about the same for both cases. In many cases, particularly with cable, the maximum lengths are influenced by other factors, such as interference between telegraph circuits and telephone repeater spacing.

d. Ground return is assumed for operation of d-c line sections. With metallic return, using two simplexed pairs, the distance between stations with Wire W–110–B for one section should be reduced from 50 miles to about 30 miles. The lengths given for other types of wire apply to both methods of operation.

e. It is recommended that for 60-word-per-minute circuits no more than two d-c line sections should be used in tandem for teletypewriter service without a regenerative repeater. At 66 words per minute, a regenerative repeater may be required at every intermediate office.

f. At 66 words per minute, a reduction in length of section is required in order to maintain the same transmission quality as at 60 words per minute. A number of factors contribute to this reduction, and not all wires are equally affected; but as a general engineering rule the reduction should be in the order of 20 percent.

314. MAXIMUM LENGTHS FOR CARRIER TELEGRAPH LINE SECTIONS.

The maximum lengths for carrier telegraph sections are generally set by the requirement that the telephone circuits involved be suitable for furnishing good telephone service. However, in the case of Telegraph Terminals

Type of operation	*Line transmission equipment*	*Circuit, simplexed or two wires in parallel*	*Maximum length (miles) one section*
Polar or polarential, ground-return	Terminal CF-2-A, CF-2-B, CF-6, X-61822, TH-1/TCC-1	Field Wire W-110-B to TG-30 or X-61824 repeaters	25[a]
		Field wire W-143 to TG-30 or X-61824 repeaters	40[a]
		Open wire or cable to X-61824 repeater	100[a] (not to exceed 1,250 ohms)
Neutral, ground or metallic return	Terminal CF-2-A, CF-2-B, CF-6 X-61822, TH-1/TCC-1	Any type wire, to a teletyepewriter[b]	10
	Terminal CF-2-A, X-61822	Any type wire to line unit or Switchboard BD-100	25
	Terminal CF-2-B, CF-6, TH-1/TCC-1	Any type wire to line unit	16
	Terminal CF-2-B, CF-6, TH-1/TCC-1	Any type wire to Switchboard BD-100	12
	Repeater TG-30, X-61824	Field wire or cable to a teletypewriter[b] or line unit or Switchboard BD-100	5
	Repeater X-61824	Open wire to a teletypewriter[b] or line unit or Switchboard BD-100	10
Polar, ground-return	Repeater X-61824	Any type wire to a 2-path polar termination	10
Neutral, ground or metallic return. Signals regenerated to and from station	Regenerative repeater X-66031 (east ext neut to pos batt, or west ext)	Field wire or cable to a teletypewriter[b]	20
		Open wire to a teletypewriter[b]	30
Neutral, ground or metallic return. Signals not regenerated to and from station	Regenerative repeater X-66031 (east ext neut 3-way)	Wire W-110-B or W-143 or cable to a teletypewriter[b]	5
		Open wire to a teletypewriter[b]	10

[a] If an intermediate d-c repeater is used to increase the length of the extension circuit of a v-f carrier telegraph terminal, for the first section use the length given in this table; the second section may use any of the lines of figure 3-18 and corresponding mileage given in the column headed *Each of two sections in tandem.*

[b] With a line relay having a modified bias circuit. Refer to TM 11-2022.

Figure 3-19. Recommended maximum lengths for telegraph extension circuits.

CF-2-( ) and CF-6, the maximum loss should not exceed about 25 db between telegraph terminals. If extensions from Telephone Terminal CF-1-( ) to the telegraph terminals are involved, these should be relatively quiet and should not have a loss in excess of about 8 db each. Packaged carrier telegraph equipment is installed in the same office as the carrier telephone equipment, consequently the loss in the extension is practically zero. Several carrier telegraph sections may be included in a multisection network provided the over-all limiting coefficient (par. 317) is not exceeded.

315. MAXIMUM LENGTHS FOR TELEGRAPH EXTENSIONS.

a. Recommended maximum lengths for extension circuits are given in figure 3-19. The data are for teletypewriter service at a speed of 60 words per minute (wpm). For 66-word-per-minute service reference should be made to subparagraph d below. They are based on the same assumptions as those used for the lengths given for d-c line sections in figure 3-18 with respect to leakage, capacitance to ground, temperature, and interference.

b. Where there is a teletypewriter station at an intermediate point (such as the intermediate station at C in figure 3-23), the maximum distance to the station is 10 miles when the station is located between carrier telegraph terminals and 5 miles when it is located between d-c repeaters or between a carrier terminal and a d-c repeater.

c. When lengths greater than those shown in figure 3-18 for simplexed operation are required, a single wire may be used for ground-return operation using no simplex coils. The other side of the pair may be used for telegraph in the case of open wire lines. This precludes the use of these wires for telephony. The lengths given for simplexed circuits may then be about doubled if the resistance of the wire plus ground resistances will permit the required current to be obtained.

d. If the maximum lengths given in figure 3-19 are used for operating at a speed of 66 words per minute, transmission will be slightly inferior to that at 60 words per minute. In the case of the longer lengths, it may be worth while to make a reduction of about 10 percent in length to overcome this.

316. MAXIMUM DISTANCES FOR MANUAL TELEGRAPH ON WIRES.

It is in general possible to operate Morse-code manual telegraph over greater distances and over poorer circuits than any other form of electrical communication available. However, field telegraph sets are designed to meet a variety of line conditions and some sacrifices in the transmission possibilities have been made to secure flexibility, simplicity, and light weight. Telegraph Set TG–5–A has much lower impedance and its line relay is less sensitive than that of Telegraph Set TG–5–B (par. 329). With low-impedance lines, such as field wire on wet ground and open wires in wet weather, Telegraph Set TG–5–A is preferable to Telegraph Set TG–5–B. The latter set is preferable for use on dry, high-resistance lines and those having high ground-connection resistance. It is also preferable in cases where Telegraph Set TG–5–A does not have sufficient sensitivity. It should ordinarily be possible to operate over simplexed field wire on wet ground up to 40 or 50 miles with reasonably low ground resistance; with specially skilled operators, the distance might be about doubled. With field wires suspended from trees or poles, the maximum distance will probably be about 100 miles except in case of unusually heavy leakage, such as might be experienced with damaged insulation. Wire W–143 will generally permit manual operation over a length materially in excess of that of Wire W–110–B. Best results with the TG–5–B will be secured if the transmitting operator takes a good grip on the key and manipulates it in a forceful snappy manner with moderate spring tension so as to minimize travel time of the key. This will tend to eliminate false signals at the transmitting end caused by transients. Tactical d-c repeaters (pars. 327c and d) are supplied with a manual Morse operating arrangement. This feature is intended for emergency use when teletypewriters are not available. Regenerative repeaters can not be included in a manual telegraph layout.

317. TELEGRAPH TRANSMISSION COEFFICIENTS.

a. A figure or coefficient may be assigned to each part of a network so that, by adding the figures for the parts operated in tandem, it can be predicted whether or not transmission over the circuit will probably be satisfactory. In teletypewriter operation, the use of regenerative repeaters effectively breaks the network into independent circuits as far as the computation of coefficients is concerned. A further explanation of telegraph transmission coefficients will be found in chapter 12.

b. The limiting value of the sum or over-all coefficient for sections in tandem depends somewhat upon the grade of service desired. The recommended limit for high-grade military teletypewriter service is 15. Circuits having this limit should have no more than about one error in about 1,500 characters (one in 4 minutes of continuous operation at 60 words per minute) as a long-time average. This should not be considered a hard and fast limit. If a lower grade of performance is acceptable, particularly if occasional periods of unserviceability are permissible, it may be found practicable to use a limiting coefficient as large as 20.

c. The coefficient values given in figure 3-20 are estimates of the probable service performance of the circuits including the line conductors and terminating equipment. They apply for either 60 or 66 words per minute, the effect of the higher speed being compensated for by a reduction in the recommended maximum lengths of d-c line sections and extensions as shown in paragraphs 313f and 315d. It will be noted that the coefficient values in this manual are not on precisely the same basis as those in TM 11–2022. The principal difference is that in TM 11–2022, one figure is given for a particular circuit whereas in figure 3-20 minimum and maximum figures are given to cover a wide range of conditions. The smaller of the coefficients for a given case is intended for comparatively short lengths operating under favorable conditions while the larger figure applies to longer lengths operating under less favorable conditions. The larger figures should be applied whenever there is doubt that the equipment and lines will be maintained properly, or when it is suspected that interference might be a factor of importance.

	Type of circuit	*Coefficient*
Telegraph line sections	Carrier section	2.5-5
	One d-c section	5-7
	Two d-c sections in tandem	9-12
	Three or more d-c sections in tandem	Not recommended
Switchboard BD-100 lines	Each line	2-7
Extension circuits	Polar or polarential from a carrier terminal to the line side of a d-c repeater	5-7
	Neutral to a teletypewriter or to a line unit from a d-c telegraph repeater.........	0-2
	Neutral to a teletypewriter or to a line unit from a carrier telegraph terminal	0-5

Figure 3-20. Telegraph coefficients.

d. Operation of carrier telegraph over spiral-four cable and operation of carrier telegraph by means of speech-plus-duplex should generally be assigned a higher coefficient than operation over 16-, 19-, or 22-gauge cable or type C or H carrier on open wire.

e. In the case of d-c line sections, two sections in tandem provide partial cancellation of bias but there will be more likelihood of interference. This case has a higher rating than the single section case but not twice as much.

f. A d-c telegraph section consists of a repeater, a line to a distant point, and a repeater at that point. A carrier telegraph section similarly consists of a telegraph channel terminal, a line to a distant point generally equipped with vacuum-tube carrier telephone repeaters, and the distant telegraph channel terminal.

318. APPLICATION OF TELEGRAPH COEFFICIENTS TO CIRCUIT LAYOUTS.

a. In using the coefficients, a diagram is drawn for a tentative layout and a coefficient is selected for each part of the telegraph circuit. Then a computation is made of the over-all coefficient from each station to every other station, assuming no regeneration. If any such over-all figure materially exceeds the desired limit, it will then be necessary either to substitute better transmission sections or to divide the circuit into parts by the insertion of one or more regenerative repeaters. Since such a repeater reforms and retimes the signals, it is necessary only to compute the over-all coefficient from each terminal to a regenerative repeater and from one regenerative repeater to another and then see whether or not the limit is exceeded. Where a regenerative repeater is used at a 3-way point to derive a branch circuit, it may be connected to provide complete regeneration either in the main circuit or in the branch circuit but not in both circuits. It is necessary to take this into account in applying coefficients to such a circuit.

b. Comparatively large values, sometimes in excess of those given in figure 3-20, should be applied where any one of the following conditions is extreme or where several exist in combination:

(*1*) Lines at or somewhat above the mileage limits given.

(*2*) Lines seriously affected by moisture (continued rain, slush, or immersion).

(*3*) Poor maintenance.

(*4*) Excessive ground-connection resistance.

(*5*) Serious interference, such as that from power systems, other communication circuits, frequent thunderstorms, or ground-potential differences.

c. The smaller values should be applied for favorable conditions, such as with:

(*1*) Short line sections under good conditions, such as, in dry climates.

(*2*) Unusually well-maintained and adjusted equipment.

d. Intermediate values should be applied for average conditions.

319. EXAMPLES OF TELEGRAPH CIRCUIT LAYOUT.

a. The following examples illustrate the use of coefficients in circuit layout work.

b. The layout in figure 3-21 is a simple one, consisting of two line sections for service

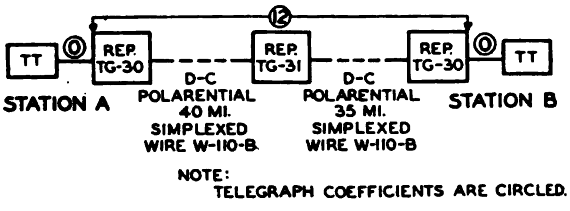


Figure 3-21. Use of telegraph coefficients, simple layout.

between stations A and B. Two d-c polarential line sections using Wire W–110–B simplexed are used with two terminal repeaters and one intermediate repeater. A teletypewriter is connected with short cords to the station terminal repeaters. The sections are at or near their maximum lengths and moderate interference is present, so that the maximum coefficient 12 (fig. 3-20) is assigned for the two d-c sections. The coefficient for the teletypewriter connections at the terminals is 0; therefore the total coefficient is 12 and the circuit should be satisfactory.

c. An example of a layout for switched service is shown in figure 3-22, which illustrates a switched connection to three stations, A, B, and C.

(*1*) Service to A is given over a d-c polarential section using 30 miles of simplexed Wire W–143. This is well below the maximum length but is assumed subject to leakage and interference, so a coefficient of 6 is assigned. The teletypewriter at station A is connected directly to the repeater; this connection has a coefficient of 0. The office connection from the switchboard to the Repeater TG–30 takes a coefficient of 2.

(*2*) Service to station B is on a neutral basis over 25 miles of simplexed Wire W–143 to a Line Unit BE–77–A and then direct to a teletypewriter. This operates under severe conditions and takes a coefficient of 7.

(*3*) Service to station C is over an office connection to a carrier terminal, over a 100-mile carrier telegraph section on spiral-four cable and a 5-mile neutral extension to a Line Unit BE–77–A, and then directly to a teletypewriter. The coefficient for the connection from the switchboard to the carrier terminal is 2 and that for the carrier section is 3.5. The neutral extension is short, 5 miles, and a coefficient of 2 is assigned. The teletypewriter is connected directly to the line unit and the coefficient for this is 0.

(*4*) The sum of the coefficients from station A to station B is 15; from station B to station C is 14.5; and from station A to station C, is 15.5. This layout would accordingly be considered satisfactory for usual service requirements.

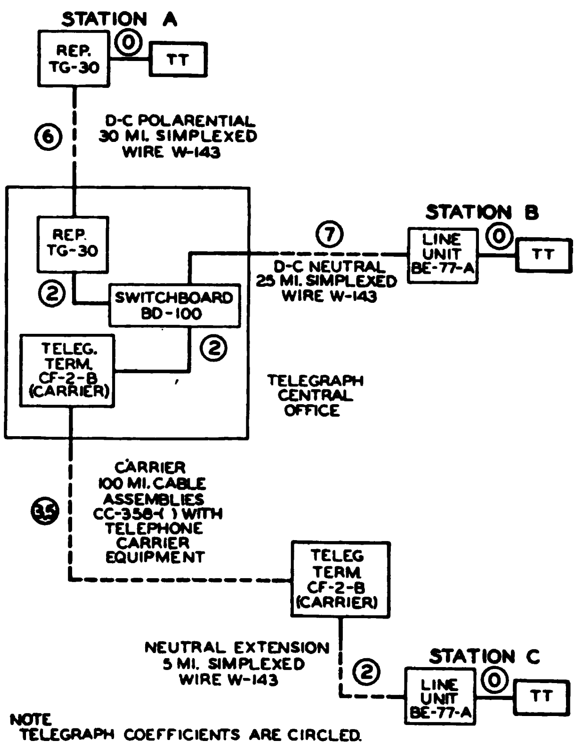


Figure 3-22. Use of telegraph coefficients, switched connection.

d. An example of a more complicated layout, including fixed plant and tactical equipment, is given in figure 3-23. The circuit from station A to station B, together with a branch to stations C and D, involves the following:

(*1*) At station A, a teletypewriter with a line relay is connected by a 5-mile local extension circuit over 19-gauge cable to a d-c repeater. A coefficient of 2 is assigned to this extension circuit.

(*2*) A 50-mile line section of composited 104-mil 40 percent copper-steel operates on a 2-path polar basis. The length is well below

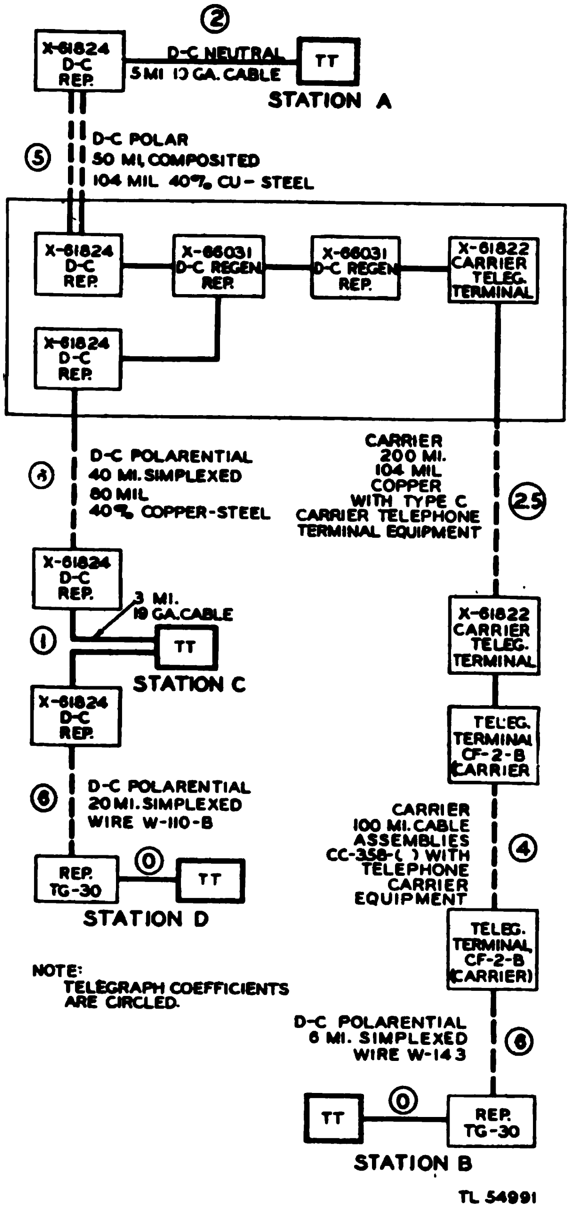


Figure 3-23. Use of telegraph coefficients, fixed layout.

the limit and interference and leakage are assumed to be small, so the minimum cofficient of 5 is selected.

(*3*) A carrier section operates over 200 miles of 104-mil copper open wire in tandem with a 100-mile section of Cable Assembly CC–358–( ) (spiral-four). The open wire section is good, and a coefficient of 2.5 is assigned. The spiral-four section is given a coefficient of 4.

(*4*) An extension circuit from the carrier terminal to B operates on a polarential basis over 6 miles of simplexed Wire W–143. Although this is short, leakage and maintenance conditions are assumed to be below average and a value of 6 is assigned.

(*5*) The branch extending to stations C and D comprises a polarential section using 40 miles of simplexed 80-mil 40-percent copper-steel wire, coefficient 6; a 3-mile 19-gauge cable loop (6 miles of wire) to an intermediate station C, coefficient 1; a polarential line of 20 miles simplexed Wire W–143 to station D, coefficient 6. The lengths and operating conditions are such that a low coefficient value was assigned to the extension circuit and intermediate values for the line sections.

(*6*) The over-all coefficient for the circuit from station A to station B via the 3-way point is 19.5; from station A to station D it is 20; and from station B to station D it is 25.5. Since the coefficient is greater than 15 between any two stations it will be necessary to use regenerative repeaters to divide the circuits into parts. To provide full regeneration; that is, signals sent from any station will be regenerated before reception by the other stations, two regenerative repeaters have been included in the layout representing the central office at the 3-way point. The total coefficient for any part of the circuit from any station to a regenerative repeater will now be less than 15.

320. EMERGENCY LAYOUTS BASED ON TELETYPEWRITER ORIENTATION RANGES.

a. In certain cases it will be necessary to set up teletypewriter circuits on nonstandard facilities, or on conductors of unknown type and condition, or with abnormal interference, leakage, vacuum-tube repeater adjustment, or the like; this might occur particularly in making use of more-or-less damaged facilities. When a section becomes available, a fair idea as to its transmission capabilities may be obtained quickly (assuming teletypewriters to be available) by measurement of the orientation range at each end, as explained in chapter 12.

b. With this knowledge, a decision may be reached as to whether a circuit is likely to be suitable for service on a single-section basis or in tandem with other sections. The following table gives figures which should generally be met in order for a section to be suitable for various cases.

No. of sections to be operated in tandem	*Minimum orientation range per section (percent)*
1	35
2	50
3	55
4	60

c. Thus, if the range as measured on each of two sections is at least 50 percent, the two sections may be used in tandem; if each measures 60 percent, four sections should generally work satisfactorily. This assumes that the centers of range coincide within a few divisions and that the extensions at the terminals are short. It will be desirable to make occasional range checks to determine whether there has been material change in the transmission quality of the facilities.

Section IV. STATION AND SIGNAL CENTER EQUIPMENT

321. GENERAL.

a. This section pertains to station and signal center equipments used essentially by operators for sending and receiving. In some cases the station or signal center equipment will be connected over d-c telegraph circuits to line transmission equipments located in nearby offices; and in other cases the line transmission equipment may be located in the station or signal center.

b. The equipments referred to in this section are classified, in a general way, as tactical and fixed plant equipment. Electrically these two classes are interchangeable. However, tactical equipment is characterized by its portability and ease of installation. Fixed plant equipment is not as readily moved from one location to another and considerably more time is required for installation and greater protection against weather must be provided. On the other hand, fixed plant equipment is normally capable of handling a greater volume of traffic.

c. Equipment information on telegraph sets, teletypewriter sets, and repeater sets, including information on their major components, will be found in TM 11–487 and the information therein includes weights, dimensions, displacements, and stock numbers.

322. TELETYPEWRITER EQUIPMENT.

a. Types of Keyboards. Two types of keyboard and type-bar arrangements are available. These are known as *communication* and *weather*. Both are the same in lower case but differ in some of the upper case characters. The communications arrangement has punctuation marks where the weather arrangement has symbols, such as arrows to indicate wind direction, for transmitting weather data.

b. Basic Forms of Recording and Sending. Two basic forms of teletypewriter recording are used. One of these is type copy on a page; the other is perforations in tape with or without typing on the tape. Equipment which records the message in typed characters and in perforations in a tape is a typing reperforator. The basic forms of sending are direct sending manually from a keyboard or sending automatically by means of perforated tape from a transmitter-distributor.

c. Use of Perforated Tape.

(*1*) *Without Typing.* Figure 3-24 represents equipment such as a model 19 teletypewriter set which has facilities for locally perforating a tape which does not carry typing. A sample of this tape is illustrated in figure 3-7. After the tape is prepared by operating a keyboard, it is passed through a transmitter-distributor which sends the message signals to the line. A page copy of the message may be made on the teletypewriter of the set simultaneously with perforation of the tape, or alternatively as the message is sent to the line. As another alternative, the teletypewriter keyboard may be used for sending directly to the line without perforating tape and with a home copy made simultaneously. A page copy of any incoming message may be made on the teletypewriter. The model 19 teletypewriter set is described in paragraph 325b.

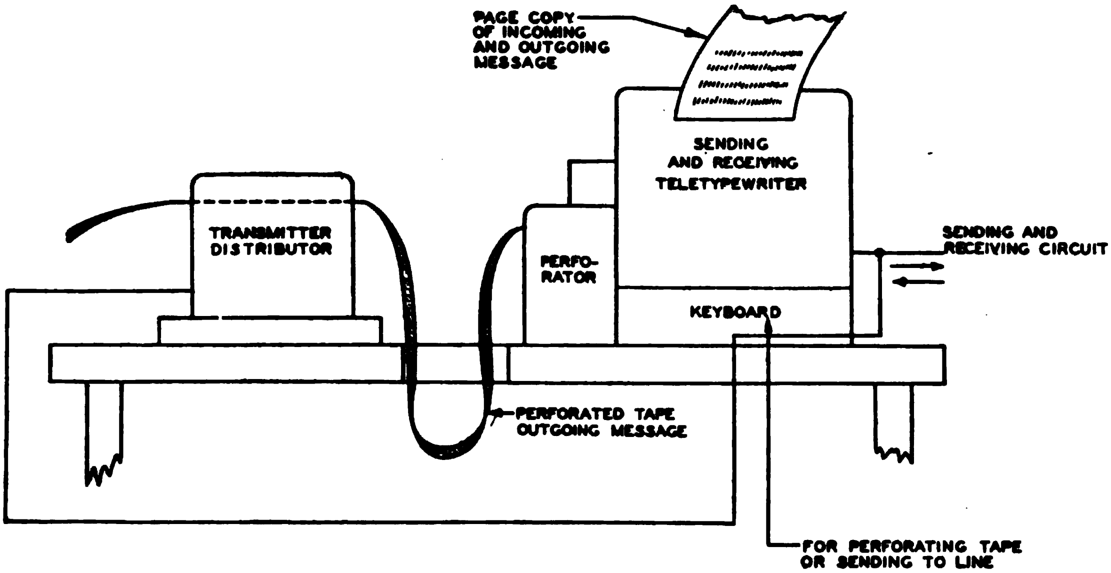


Figure 3-24. Page teletypewriter with perforator and transmitter-distributor.

(2) *With Typing.* Figure 3-25 represents equipment such as Reperforator Transmitter TG-26-A. The typing reperforator perforates tape and types on it at the same time; this can be done locally from the keyboard, or from incoming line signals. Also, the set includes a transmitter-distributor for transmitting from the tape. This form of tape is called *chadless,* the perforations being partial in order to retain paper for the typed symbols. The perforations for a character are offset 6 spaces to the left of the printed character. A sample of this tape is illustrated in figure 3-8. If required, tape perforated in accordance with incoming line signals may be passed directly to a transmitter-distributor associated with another

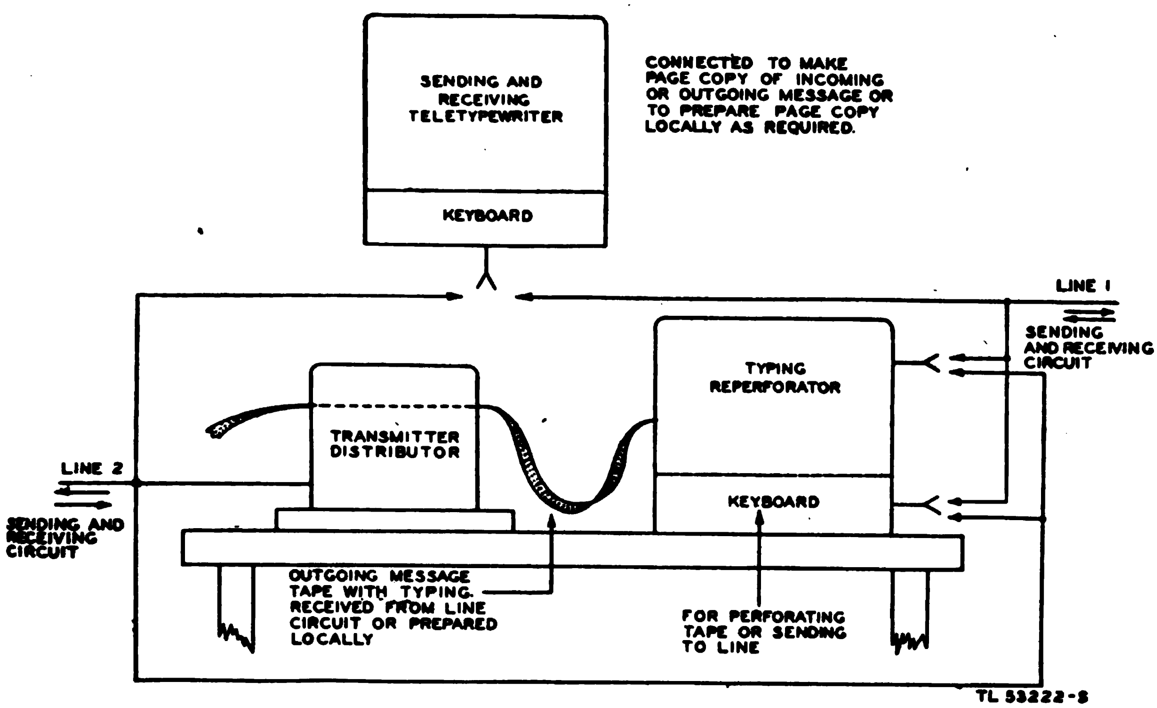


Figure 3-25. Typing reperforator with keyboard and transmitter-distributor.

line. Thus, arriving signals which are somewhat distorted but still suitable for producing a correct copy on the typing reperforator are retransmitted undistorted, with the same quality as signals originating at that point. As shown in figure 3-25, a teletypewriter may be connected in the circuit with the typing reperforator or transmitter-distributor to make a page copy of an incoming or outgoing message. Reperforator Transmitter TG–26–A is described in paragraph 324b.

(3) *Usage Comparison.* Both of these arrangements meet the requirements for signal centers where it is often necessary to handle a large volume of traffic, because the tapes may be prepared locally and characters sent to the line automatically at the maximum line circuit signaling speed which may be 60 words per minute or higher. A set with a typing reperforator has the advantages that messages may also be received on perforated tape and the characters are printed on the tape, which facilitates handling the message. For retransmission, the transmitter-distributor may be connected to the proper outgoing line by patching, or the tape may be taken from the typing reperforator and inserted in a transmitter-distributor associated with the proper line.

323. SIGNAL CENTER SEMIAUTOMATIC TELETYPEWRITER OPERATION.

a. A *signal center* is a unified collection of several agencies of signal communication equipped to transmit and receive messages by electrical means and by other means if required. The term signal center includes a message-center section and a cryptographic section if required. A signal center may be established at a point, fixed or mobile, and will be charged with the receipt, transmission, and delivery of official messages. The traffic engineering and management of signal centers is discussed in chapter 11.

b. In signal centers with heavy traffic loads, messages are normally handled by teletypewriter equipment. Typing reperforators are used for receiving messages and transmitter-distributors for sending. This basic plan is known as semiautomatic tape-relay operation and such installations are specially engineered. Sending and receiving equipments are physically disassociated so as to concentrate similar work operations. Typing reperforators are grouped in receiving cabinets, and transmitters are arranged on sending tables and driven by a common motor.

c. Message and channel numbers, for identification and for making a record of the passage of the message through relay offices, are transmitted automatically from previously prepared tapes. Monitoring equipment is used to make a tape record of outgoing messages, and this tape may be used for rerunning a message if required.

d. On certain lines in large signal centers where the traffic load is especially heavy, two transmitters are associated with one circuit in such a manner that a message tape inserted in the idle transmitter will automatically be numbered and sent as soon as the working transmitter becomes idle.

324. TACTICAL TELETYPEWRITER STATION EQUIPMENTS.

a. Teletypewriters TG–7–A, TG–7–B, and TG–37–B. Teletypewriter equipments for tactical usage are arranged so that connections

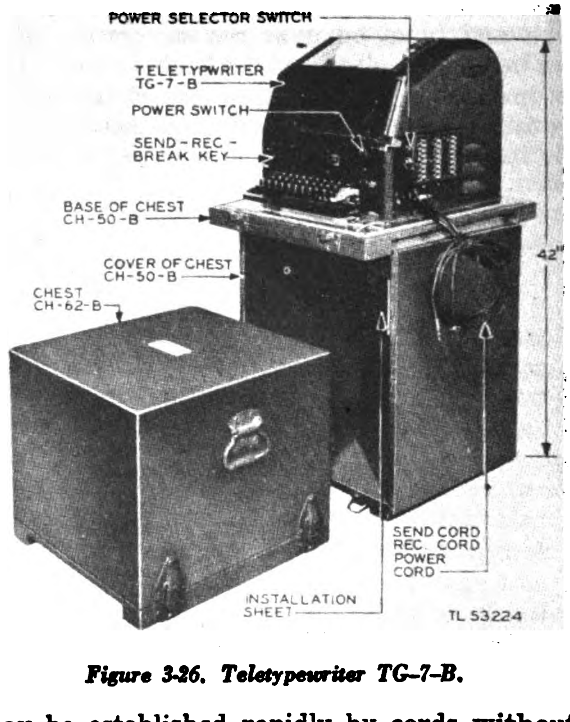


Figure 3-26. Teletypewriter TG–7–B.

may be established rapidly by cords without the use of tools. The equipments are portable and transported in wooden chests. Tactical teletypewriters require more protection from the weather than is provided by their carrying chests. Page-type teletypewriters supplied with communications symbols are Teletypewriters

TG–7–A or TG–7–B. These are electrically interchangeable, but certain minor parts not required for tactical applications are not included in Teletypewriter TG–7–B. The governed series motor in Teletypewriter TG–7–A requires a source of 115 volts, either dc or 25 or 50 to 60 cycles ac. The motor in Teletypewriter TG–7–B operates on these sources and also on 115v, 40-cycles ac. Teletypewriter TG–7–B is shown in figure 3-26. Teletypewriter TG–37–B is equivalent to Teletypewriter TG–7–B except that it is equipped with weather keyboard and type bar symbols.

b. Reperforator Transmitter TG–26–A and TG–27–A. Where tape transmission with communication characters is required, a reperforator-transmitter set, consisting of a typing reperforator and a transmitter-distributor, known as Reperforator Transmitter TG–26–A, is used. This set is shown in figure 3-27. For weather circuits, Reperforator Transmitter TG–27–A is used. This is equivalent to the Reperforator Transmitter TG–26–A except that the typing reperforator is equipped with weather keyboard and typebar symbols (par. 322a).

c. Teletypewriter Sets and Repeater Sets.

(*1*) Station arrangements using neutral line transmission circuits are available in the form of *teletypewriter sets*. Some of these sets include all equipment and accessories required to establish a teletypewriter station. In general, they consist of a page-type teletypewriter or reperforator transmitter, a line unit, a rectifier, ground rods, and in some cases, a gasoline-engine-operated generator as a power source. Teletypewriter Set EE–97–A which includes a page-type teletypewriter and Reperforator Teletypewriter Set TC–16, which includes a transmitter-distributor and typing reperforator, are shown in figures 3-28 and 3-29.

(*2*) Station arrangements using 2-path polar or polarential operation are available as

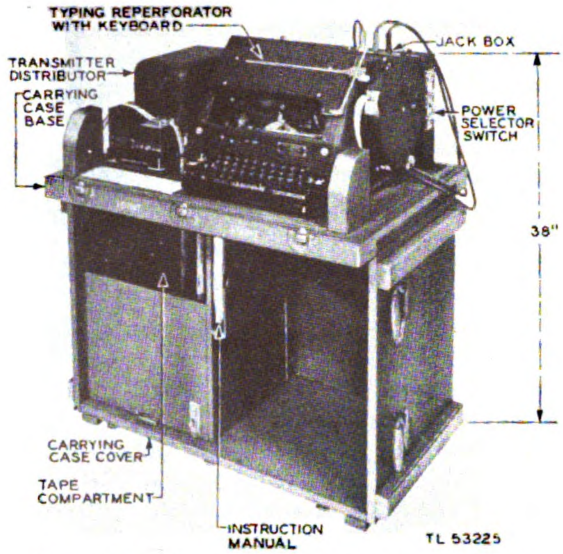


Figure 3-27. Reperforator Transmitter TG–26–A.

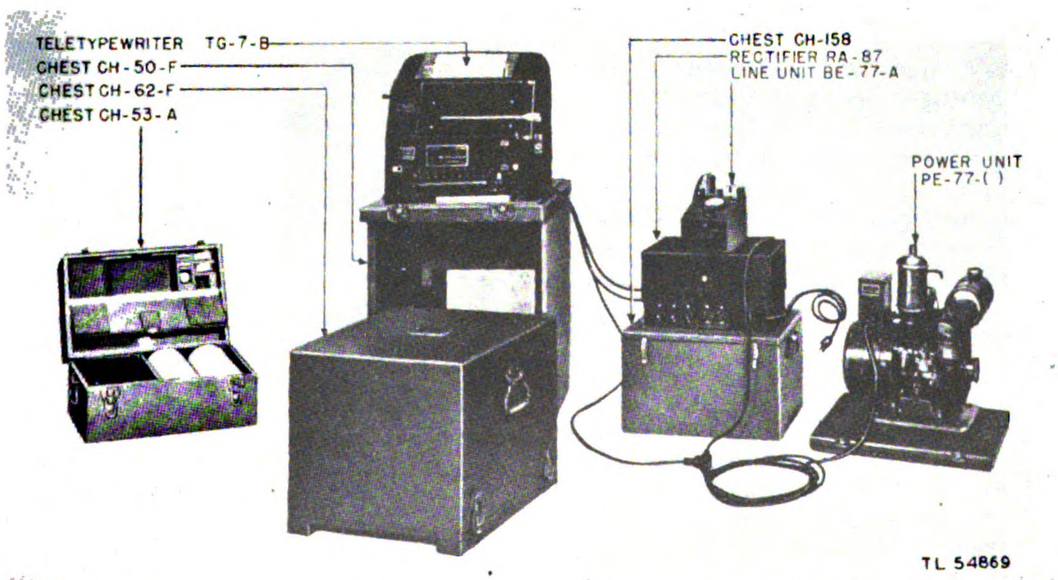


Figure 3-28. Teletypewriter Set EE–97–A.

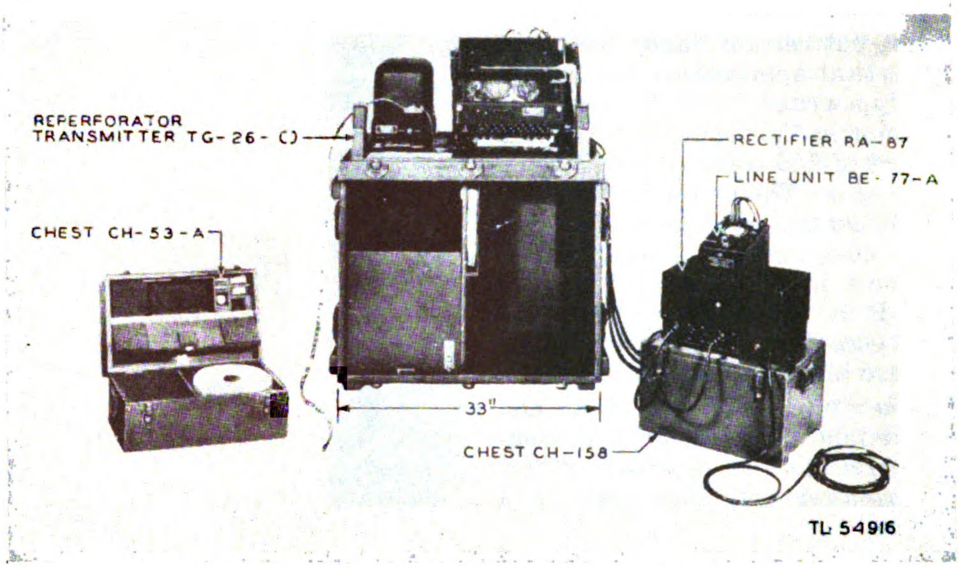


Figure 3-29. Reperforator Teletypewriter Set TC-16.

repeater sets. Repeater Sets TC–18 (terminal, 2-path polar or polarential) and TC–19 (intermediate, polarential) each consist of a repeater with built-in rectifier and ground rods; they do not include a teletypewriter or a power unit.

325. FIXED PLANT TELETYPEWRITER STATION AND SIGNAL CENTER EQUIPMENTS.

a. Model 15 Teletypewriter Set. Teletypewriters used in fixed plant installations are commercial equipment procured to meet Signal Corps requirements. Model 15 teletypewriter when supplied with a metal table and rectifier is known as a model 15 teletypewriter set (fig. 3-30). This is a sending and receiving page-type teletypewriter equipped with a line relay and a governed series motor. Either communications or weather keyboard teletypewriters may be obtained. The table is equipped with a combination terminal and jack box for making external connections and for connecting the teletypewriter cords. Rectifiers may be obtained for various voltages and frequencies. Since the teletypewriter is supplied with a line relay, it may be connected to a neutral loop or extension circuit without the use of a line unit or a telegraph repeater. The tactical Teletypewriter TG–7–A or –B, in combination with a line unit, may be used in extension circuits in place of a model 15 teletypewriter equipped with a line relay.

b. Model 19 Teletypewriter Set. Where tape transmission is required, a model 19 teletype-

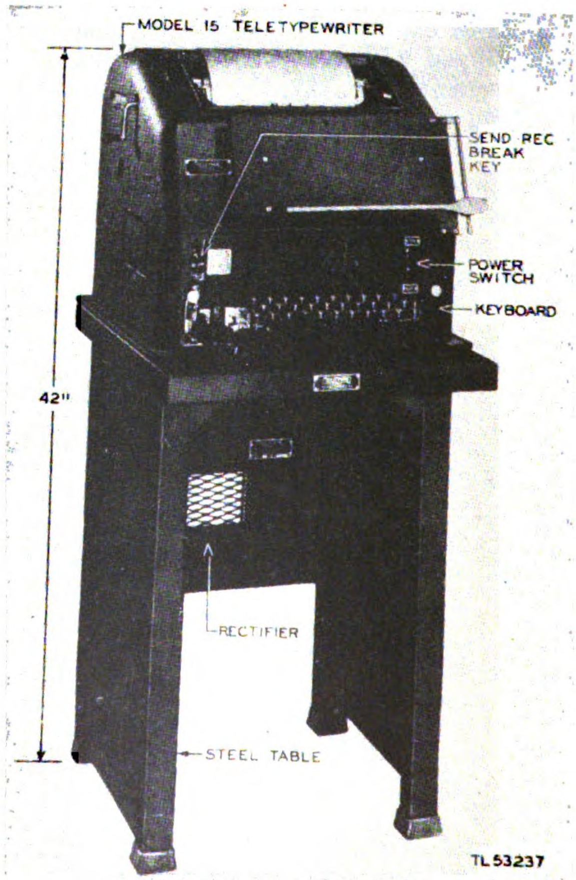


Figure 3-30. Model 15 teletypewriter set.

writer set (fig. 3-31) is often used. The set consists of a page teletypewriter, the keyboard of which may be used to send to the line or to perforate the tape, a transmitter-distributor for tape sending, and a rectifier for furnishing

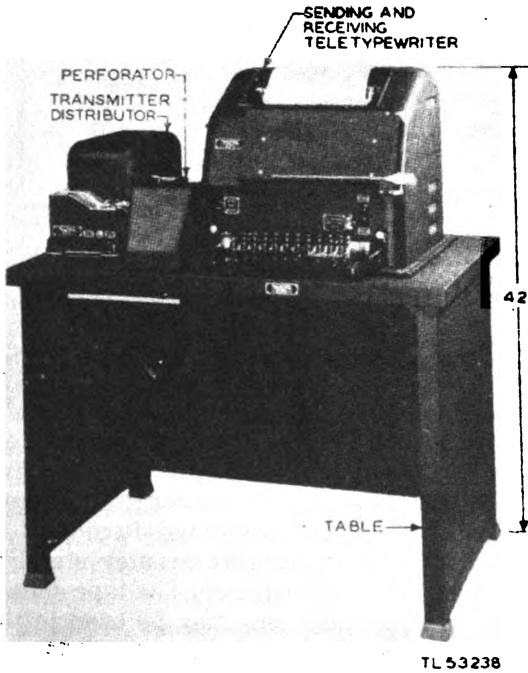


Figure 3-31. Model 19 teletypewriter set.

dc for local circuits. The teletypewriter supplied with a model 19 teletypewriter set is equipped with a line relay. The motor in the teletypewriter and the motor in the transmitter-distributor is a governed series motor. The teletypewriter is supplied with either a communication or a weather keyboard.

c. Signal Corps Nomenclature for Model 15 and Model 19 Teletypewriter Sets. Joint Army-Navy nomenclatures for models 15 and 19 teletypewriter sets which have been assigned recently are given in the following table. Sets

Joint Army-Navy nomenclature	*Commercial description, Teletype Corporation*
Teletypewriter TT-5/FG (communications keyboard).....	Code 2.18A-1 (model 15 printer set)
Teletypewriter TT-6/FG (weather keyboard)............	Code 2.16A-1 (model 15 printer set)
Teletypewriter TT-7/FG (communications keyboard).....	Code 4.15A-1 (model 19 printer set)
Teletypewriter TT-8/FG (weather keyboard)............	Code 4.13A-1 (model 19 printer set)

furnished according to these nomenclatures include tables and rectifiers in addition to the teletypewriter equipments.

d. 132A2 Teletypewriter Set.

(*1*) This equipment, for use especially on radio teletype circuits, includes a typing reperforator (without keyboard) and a transmitter-distributor, mounted on the top of a cabinet-type table. The exterior appearance of this equipment is similar to that of the 133A2 set shown in figure 3-32. A synchronizing circuit, a power supply rectifier, miscellaneous control apparatus, and a tape storage bin are located inside of this cabinet. The typing reperforator records the incoming message on a tape in the form of perforations and printed characters. The outgoing message, in the form of perforated tape, is sent from the transmitter-distributor.

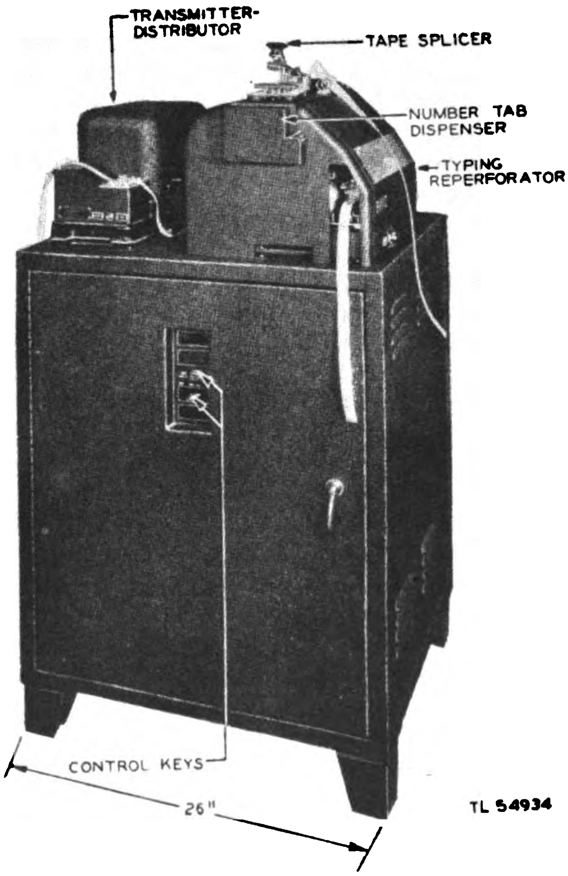


Figure 3-32. 133A2 teletypewriter set.

(*2*) The synchronizing circuit keeps the typing reperforator in synchronism with automatic signals received from the distant sending station in case a start or stop pulse,

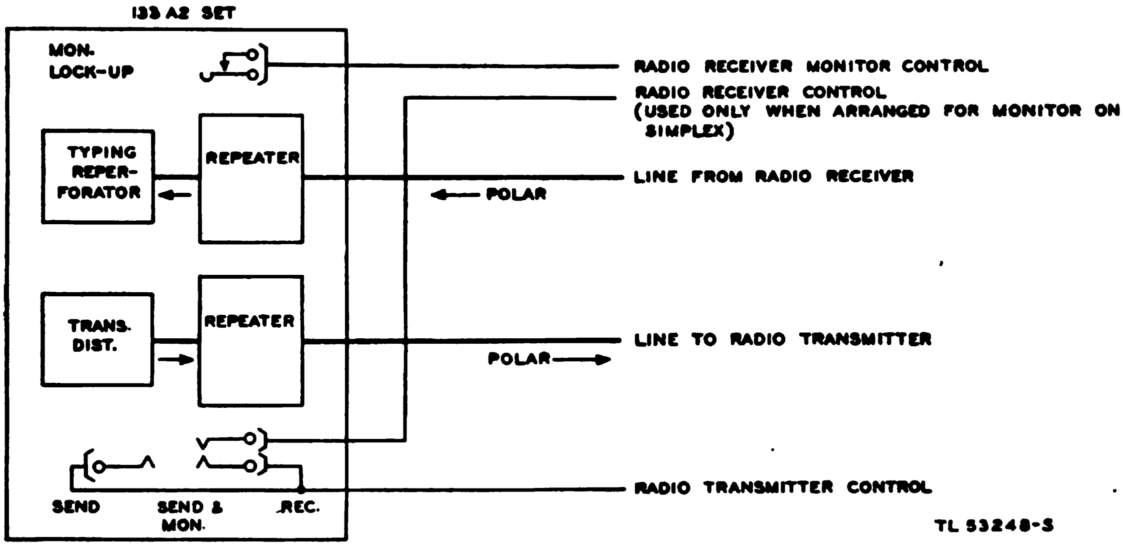


Figure 3-33. 133A2 teletypewriter set connected to a radio circuit, simplex or duplex operation.

or even several characters are lost because of interference or fading on the radio channel. A key is provided for cutting out the synchronizing circuit when radio transmission conditions do not require its use, or when the set is used on wire circuits.

(3) A tape splicer may be mounted on top of the typing reperforator and a number-tab dispenser may be located on the side of the typing reperforator beneath the tape splicer. These are designated in figure 3-32. The tape splicer is used to join message tapes so that continuous transmission of a number of teletypewriter messages may take place. The splicer is also used to splice message-identifying numbers in the message tapes. The number-tab dispenser contains these message-identifying numbers in the form of a roll of perforated tape with consecutive numbers preceded by and followed by a number of "letters" characters. The letters characters provide space on the tape for tearing and splicing.

e. 133A2 Teletypewriter Set.

(1) This set, used on radio or wire circuits, includes a typing reperforator (without keyboard) and a transmitter-distributor, mounted on a cabinet-type table as shown in figure 3-32. These units perform the same functions as the typing reperforator and transmitter-distributor of the 132A2 set described in subparagraph d above. The 133A2 set contains two polar-relay repeaters, a power supply rectifier, and two control keys. These control keys are used with the single-channel radio teletype system using Radio Teletype Terminal Equipment AN/FGC-1 as the receiving teletype terminal. The synchronizing circuit supplied in the 132A2 set is not furnished in the 133A2 set and therefore greater stability of the radio circuit is required. The tape splicer and number-tab dispenser may be used in the same manner as described for the 132A2 set.

(2) A diagram of the 133A2 set connected to a radio circuit is shown in figure 3-33. The repeaters provide polar transmission to and from the radio transmitter and radio receiver, respectively. The control features permit turning the radio transmitter on and off, monitoring when transmission is taking place on a simplex basis, and arranging the Radio Teletype Terminal AN/FGC-1 sc that noise and interference will not cause extraneous operations of the typing reperforator when the distant radio transmitter is off-the-air.

(3) A diagram of two 133A2 sets operating over a wire circuit is shown in figure 3-34. One of the 133A2 sets might be replaced by a 133A1 set (subpar. f below) or a Teletypewriter Set AN/TGC-1 (subpar. h below) or similar equipment, with or without intervening line transmission equipment.

f. 133A1 Teletypewriter Set. Like the 132A2 and the 133A2 sets, the 133A1 set includes a typing reperforator and transmitter-distributor for receiving and sending messages in perforated tape form and has the same general appearance as the 133A2 set shown in figure 3-32.

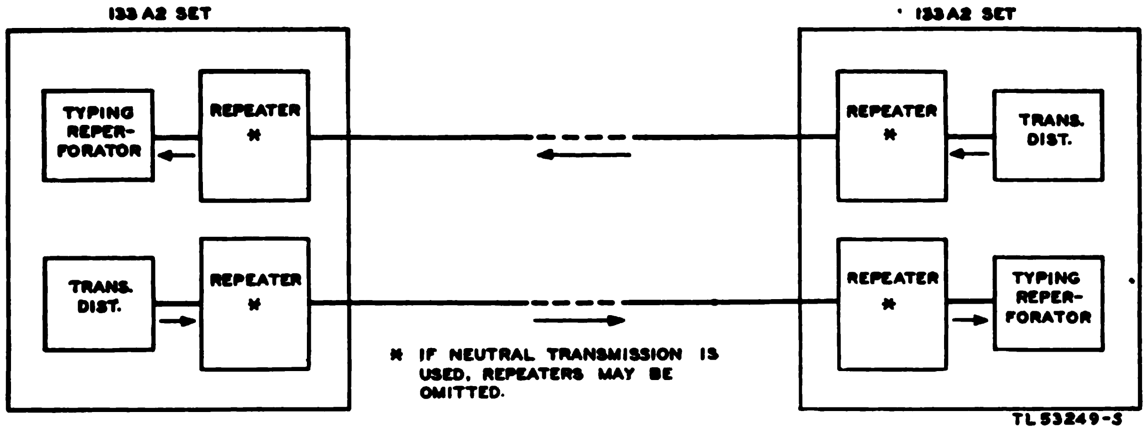


Figure 3-34. 133A2 teletypewriter sets connected to a wire line, duplex operation.

The set contains one repeater unit, for sending or receiving polar signals. By the use of a second repeater unit, it may be arranged both to send and to receive on a polar basis. A common use of the 133A1 set is in local circuits (called room circuits), but it may be used with certain limitations in connection with wire or radio circuits. The radio receiver and transmitter control features of the 133A2 set are not provided. A tape splicer and number-tab dispenser may be used if required.

g. XD91 Transmitter-distributor (Two-channel Start-stop).

(*1*) The traffic capacity of circuits operating either simplex or duplex may be doubled under favorable conditions by the use of a 2-channel XD91 transmitter-distributor (fig. 3-35) to send to the radio channel. This requires that the channel be capable of transmitting 46-cycle signals, which may be done on systems having sufficient band width, such as those using Radio Teletype Terminal Equipment AN/FGC-1. Any d-c or extension circuits which may be involved must also be capable of transmitting 46-cycle signals. This method of operation is called *diplex*. In diplex operation the normal start and stop pulses are transmitted, but each of the five selecting pulses is divided in half. The first half of each of the five normal pulses carries the intelligence of one channel (Transmitter B, fig. 3-35), while the second half carries the intelligence of the other channel (Transmitter A, fig. 3-35). A second typing reperforator, connected in series with the typing reperforator of the 132A2 set or the 133A2 set, is used to receive the second channel. The two typing reperforators are kept in synchronism by the start and stop pulses. One typing reperforator is oriented to receive the first half-pulses while the other is oriented to receive the second half-pulses. The traffic capacity in doubled, for example, from a nominal 60 words per minute to 120 words per minute for simplex operation. The capacity is 120 words per minute in each direction or 240 words per minute in the two directions combined on a duplex basis.

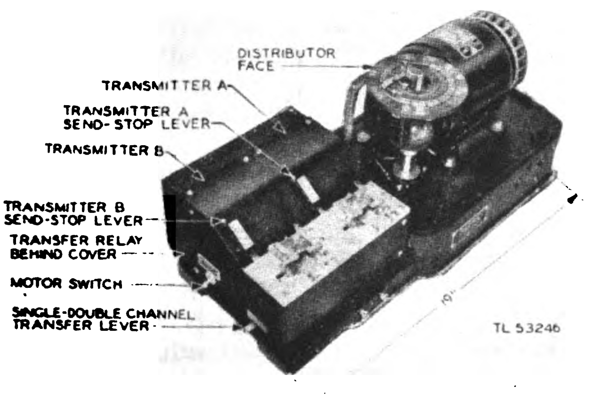


Figure 3-35. XD91 transmitter-distributor.

(*2*) The 2-channel transmitter-distributor is substituted for a single-channel transmitter-distributor on the 132A2 set, the 133A1 set, or the 133A2 set. Two tapes may be sent from the unit simultaneously, and either tape may be started and stopped independently of the other. Since the same start and stop pulses are used, the synchronizing unit of the 132A2 set is effective on each channel. When the traffic is light, or if the radio channel temporarily deteriorates so that it will not transmit 120 words per minute, the transmitter-distributor may be switched to single-channel operation, in which case it sends 60-word-per-minute signals. The second typing reperforator is then shut down.

h. Teletypewriter Set AN/TGC–1.

(*1*) This equipment, known as a semiautomatic packaged unit, is for use in signal centers where a number of teletypewriter lines terminate. It provides a means for receiving messages from any line on perforated tape with typing, and permits tearing the tape into message tapes for manual insertion in transmitter-distributors for sending to other lines, as may be required. Teletypewriter Set AN/TGC–1 is supplied in a console-type cabinet 65 inches high and 24 inches wide, and includes a multiple transmitter-distributor (two message transmitters and one number transmitter, subparagraph (2) below) driven by a common motor and two typing reperforators without keyboards. It also includes a motor-driven tape winder, a rectifier, and tape feed-out arrangement, together with the necessary controls and alarms. This unit (fig. 3-36) may be used to terminate two separate circuits which may be operated either single or duplex. Duplex operation may be either neutral or polar. Typical line circuit connections for Teletypewriter Set AN/TGC–1 are shown at A and B in figure 3-37. At A the set is shown operating duplex on one line, and at B operating on two lines, one single and one duplex.

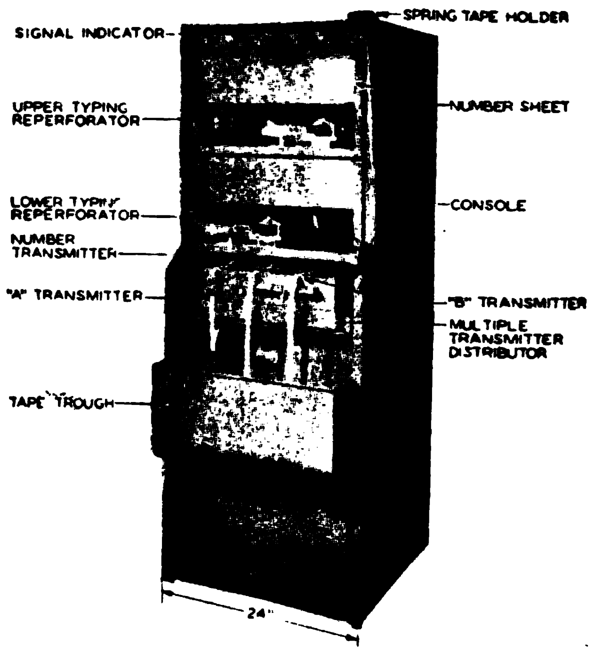


Figure 3-36. Teletypewriter Set AN/TGC–1.

(*2*) When the unit is used for terminating one circuit, one typing reperforator is used for recording the received message and the other for monitoring on the sending side of the circuit to provide a copy of the transmitted message. With this circuit arrangement both message transmitters are used and the message numbers are inserted automatically and trans-

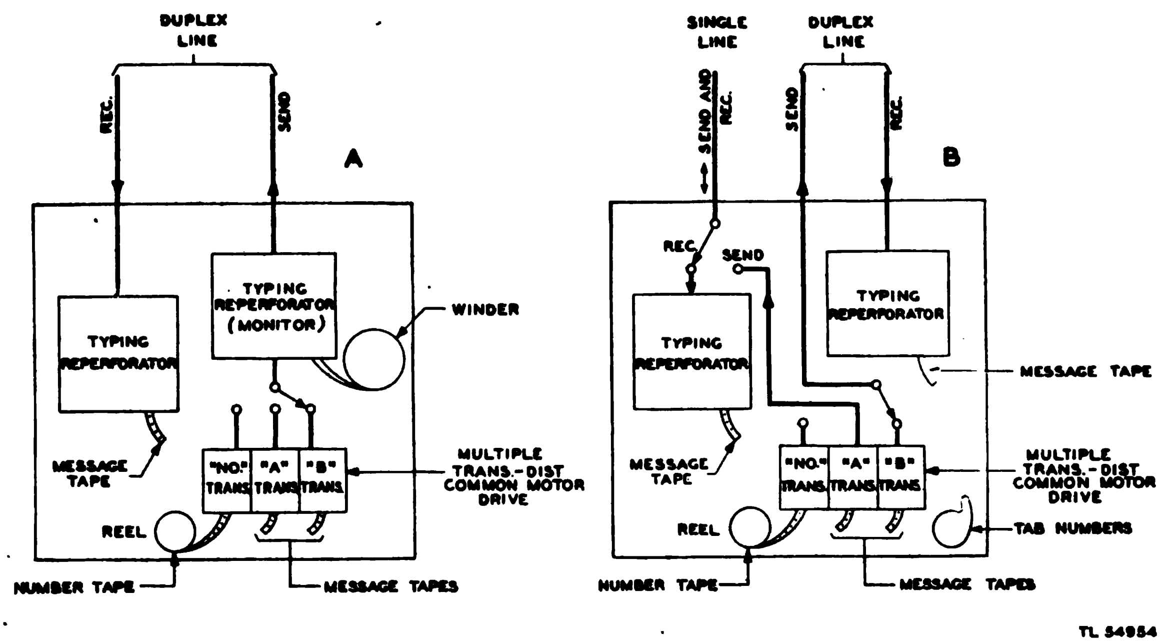


Figure 3-37. Teletypewriter Set AN/TGC–1, typical line circuit connections.

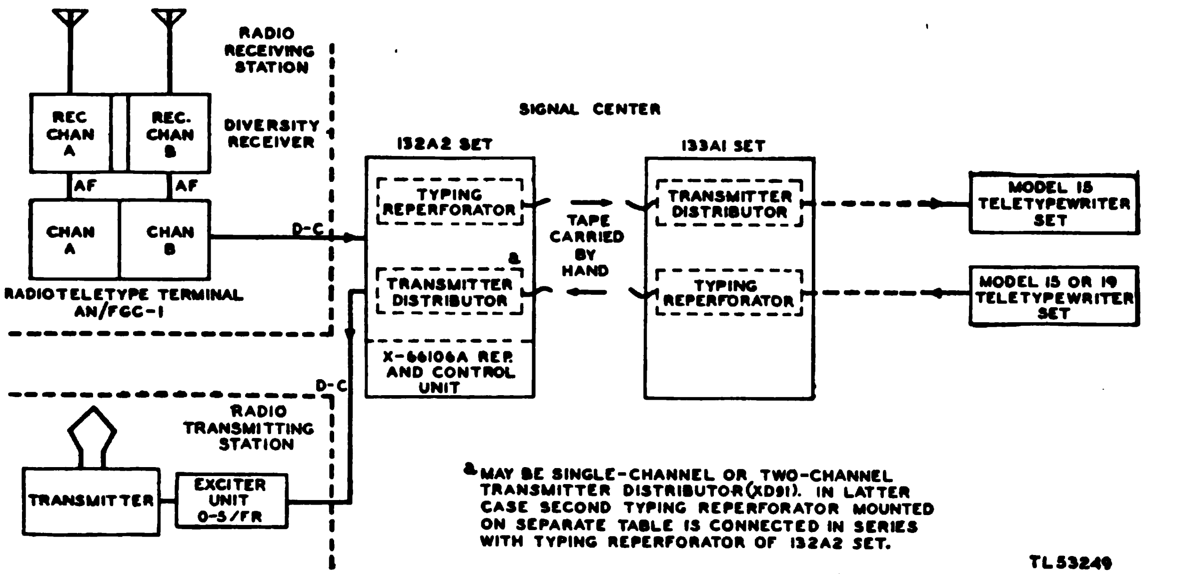


Figure 3-38. Elements of a single-channel radio teletype terminal and signal center.

mitted by the number transmitter. When both message transmitters are used on one circuit, they are arranged for tandem operation whereby a tape inserted in the idle transmitter will be automatically numbered and sent when the working transmitter becomes idle. The numbers sent from the number transmitter are prepared as perforations in a tape and stored on a number-tape reel, the capacity of which is about 750 numbers.

(*3*) When used for terminating two circuits, a typing reperforator is assigned to each circuit. The number transmitter may be associated with one of the message transmitters, and short lengths of perforated tape with tab numbers are sent from the other message transmitter. These numbers are stored on the tab-number reel.

(*4*) The transmitter-distributor and reperforators operate at 60 words per minute.

326. SIGNAL CENTER TELETYPEWRITER EQUIPMENT USED WITH RADIO TELETYPE TERMINAL EQUIPMENT AN/FGC–1.

a. Teletypewriter Equipment. Reception at the signal center may take place on the typing reperforator of a 132A2 teletypewriter set (par. 325d) or on the typing reperforator of a 133A2 teletypewriter set (par. 325e). Transmission may be from a single-channel transmitter-distributor normally supplied with these sets or from an XD91 transmitter-distributor (2-channel start-stop) described in par. 325g. The elements of a single-channel radio teletype terminal (AN/FGC–1) and associated signal center are shown in figure 3-38. TM 11–2207 covers a radio teletype signal center.

b. Circuits between Radio Stations and Signal Center. The circuits from the radio receiving and radio transmitting stations to the signal center operate on a d-c basis. Normally a metallic circuit is used between the radio receiving station and the signal center, although a metallic or ground return circuit may be used between the signal center and the radio transmitting station. The allowable length of circuit varies greatly, depending on the type of line facility used. Reasonable maximum distances for single-channel (23-cycle signals) ground return operation are 15 miles of cable or 100 miles of open wire with average ground-potential and ground-resistance conditions. For single-channel metallic operation, these distances might be doubled providing the line resistances do not exceed 4,150 ohms (sending) or 3,700 ohms (receiving). In the case of diplex operation (par. 325g), these distances will have to be reduced in most cases for satisfactory operation because of the use of 46-cycle signals.

327. TELETYPEWRITER LINE UNITS AND D-C TELEGRAPH REPEATERS.

a. General Comparison.

(*1*) In tactical teletypewriter systems, either a line unit or a d-c telegraph repeater (terminal or intermediate) should be used between the line and the teletypewriter sending and receiving equipment. Jacks are provided on line units and d-c repeaters for the send and receive cords of the teletypewriter equipment which is generally placed close by. The personnel in the station or signal center maintain the service adjustments, required for line circuit operation by means of the external controls on the line unit or d-c telegraph repeaters. Line units provide neutral line transmission and d-c telegraph repeaters provide polarential or two-path polar line transmission.

(2) In fixed plant teletypewriter systems the station teletypewriter equipment usually contains a receiving relay in the teletypewriter, in which case no line unit or d-c repeater is required at the station. Transmission to and from the station is usually on a neutral basis. The station personnel make no line circuit or extension circuit adjustments, since they are made by the maintenance personnel at the repeater equipment located at the central office (sec. V).

(3) A line unit contains a line relay which receives signals from the line and operates the receiving selector magnet of the teletypewriter in a local circuit. The sending contacts of the teletypewriter, when connected to a line unit, open and close the line circuit directly for sending. The line relay in the line unit responds to these outgoing signals and operates the receiving magnet to provide a local copy in the same manner as it operates the receiving magnet on incoming line signals.

(4) In the tactical d-c telegraph repeater the receiving relay operates the receiving selector magnet on incoming signals but it does not respond to outgoing signals. The sending contacts of the teletypewriter operate sending relays in the repeater, and the contacts of these relays send signals to the line circuit. Arrangements are made to provide a local copy of the sent signals.

b. Line Units BE–77, BE–77–A, and BE–77–B. Line units are used generally to connect Teletypewriter TG–7–A or –B or the typing reperforator of Reperforator Transmitter TG–26–A to a neutral line transmission circuit or a neutral extension circuit. All line units contain, in addition to the line relay, a rheostat for adjusting and a meter for measuring the line current. Line Unit BE–77–A (fig. 3-39) and Line Unit BE–77–B contain, in addition to these features, a bias measuring circuit for use in adjusting the line relay and a means for measuring the voltage of the power supply. Line Unit BE–77–B is the same as Line Unit BE–77–A except for minor apparatus differences. Line Unit BE–77 does not contain the

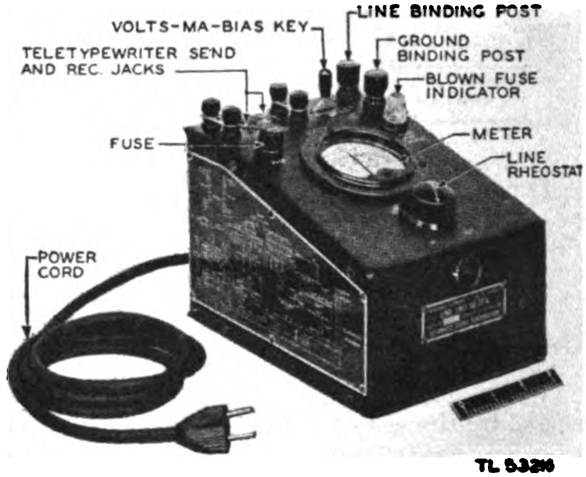


Figure 3-39. Line Unit BE–77–A.

bias measuring feature or a means for measuring the voltage of the power supply, these features being obtained by using Bias Meter I–97–A and Voltmeter IS–170 in combination with the line unit. Line units are equipped with jacks for connecting the teletypewriter send cord and receive cord and binding posts for making line and ground connections.

c. Repeater TG–30 (Terminal). This repeater, shown in figure 3-40, is used for making connections from a polarential or 2-path polar line circuit to Teletypewriter TG–7–A or –B, or to a neutral type local circuit, such as that used in Switchboard BD–100, Line Unit BE–77, BE–77–A, or BE–77–B, Telegraph Terminal CF–2–A or –B, Telegraph Terminal CF–6, and Telegraph Terminal TH–1/TCC–1. The polarential or 2-path polar line side may extend to another Repeater TG–30 or similar polarential or 2-path polar termination such as furnished in the carrier telegraph terminals. Repeater TG–30 is commonly used for point-to-point teletypewriter circuits on long field wire lines with or without a Repeater TG–31 (Intermediate) described in subparagraph *d* below. The 2-path polar line operating feature is intended primarily for operating to British terminal units referred to in section IX. The local sides of two Repeaters TG–30 may be connected for intermediate operation and, if required, a teletypewriter may be used in the local circuit for sending and receiving, but the connection between the repeater and teletypewriter should be limited to the length of the teletypewriter cords. The repeater operates on 115- or 230-volts, 50-60-cycle ac, or on a nongrounded source of 115-volts dc, such as supplied by a gasoline-engine-driven power unit. A-c power is converted to dc by a built-in rectifier. Repeater TG-30 pro-

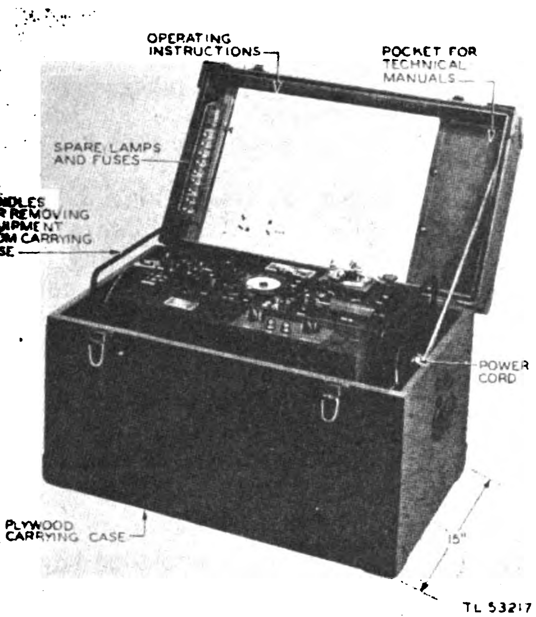


Figure 3-40. Repeater TG-30 (terminal).

vides half-duplex service only. A manual telegraph set utilizing an oscillating circuit with an adjustable tone is built into the equipment, and a telephone headset is supplied. The repeater is supplied complete in a wooden carrying case.

d. Repeater TG-31 (Intermediate). This equipment repeats directly from one line circuit to another and provides a means for connecting a teletypewriter to send simultaneously to both lines and to receive from either line, one at a time. The repeater is arranged for polarential line operation only and it is always a differential sending repeater. It may be used to extend the operating range of certain circuits on which the terminal equipment is arranged for polarential (polar sending) operation. This repeater may be used on an unattended basis with power supplied by dry batteries or storage batteries or other stable power sources. The battery voltages should be checked every 2 or 3 days. The power source may be 115- or 230-volts, 50-60-cycle ac, 12-volt storage batteries, 115-volt dry-battery, or 115-volt dc from a gas-engine power unit. If some other d-c source is used the positive side must not be grounded. The a-c or a 12-volt storage-battery source is converted to the required d-c voltage by a built-in rectifier and a vibrator is included for use when the power source is 12-volts dc. This is the only d-c telegraph repeater available for storage-battery and dry-battery operation. A teletypewriter cannot be used with the repeater when the power source is dry batteries or storage batteries. Like Repeater TG-30, Repeater TG-31 is supplied in a wooden carrying case and includes a manual telegraph set.

e. X-63638 Telegraph Repeater. This repeater, which is no longer in production, is arranged for 2-path polar line operation. The local side may be connected to teletypewriter equipment located nearby. One local pair of wires is required for the sending circuit and another pair for the receiving circuit. This equipment was produced in small quantities pending the development of Repeater TG-30. The X-63638 telegraph repeater is arranged for operation only on 115-volt, 50-60-cycle ac. A built-in rectifier converts ac to dc. The receiving relay 209FG per D-163120 may be adjusted without using a polar relay test set, as covered in Western Electric Company instruction book X-63639.

328. TELETYPEWRITER POWER AUXILIARIES AND TELETYPEWRITER SUPPLIES.

a. Rectifiers. Selenium dry-disc rectifiers, such as Rectifier RA-37 and Rectifier RA-87, are used as one means of supplying the direct current required for line and local circuits when the primary power supply is alternating current. These rectifiers are components of tactical teletypewriter sets. They are portable and supplied in wooden chests from which they are removed for service. Fixed plant teletypewriter sets also use selenium-disc rectifiers which are electrically similar to the tactical rectifiers but mechanically designed for mounting on teletypewriter tables. The d-c voltage output of the rectifiers may be adjusted to compensate for normal a-c voltage variations; automatic regulation to compensate for short period a-c voltage variations is not provided. The rectifiers are available for frequencies of 25 and 50-60 cycles and for a-c input voltages of 115 volts or of 230 volts with provision for a 115-volt, a-c source for teletypewriter motors.

b. Power Units. When no other power source is available, gasoline-engine-driven generator sets may be used at outlying teletypewriter stations and, in some cases, in signal centers to supply power for line and local circuits and for teletypewriter motors. At a station consisting of a line unit or repeater and one teletypewriter, Power Unit PE–77 with a rated output of 250 watts may be used. Power units of a higher rating are available for larger groups of teletypewriters and for use in signal centers. For example, Power Unit PE–75 with a rating of 2,500 watts is a typical unit.

c. Teletypewriter Supplies. All teletypewriter equipments require lubricating oil and lubricating grease for proper operation. The one type of oil and one type of grease which are available (TM 11–487) are obtained through normal supply channels. Page teletypewriters require rolls of paper and inking ribbon. Typing reperforators require rolls of tape and inking ribbon. Keyboard perforators require tape. The chest for Line Unit BE–77, BE–77–A, or BE–77–B may be obtained with a supply of paper and ribbon for use with a teletypewriter. The chest for Line Unit BE–77–A or –B, when furnished with Reperforator Transmitter TG–26–A or TG–27–A, may be obtained with a supply of tape and ribbon. Teletypewriter rolls of paper may be procured for single copies, or with carbon paper for duplicate or triplicate copies.

329. MANUAL TELEGRAPH SETS.

a. Telegraph Sets TG–5–A and TG–5–B are tone telegraph sets of the open-circuit d-c type used for telegraph communication. A few intermediate stations may be used between terminal stations. These sets consist essentially of an electromechanical oscillator also known as an interrupter or howler, a line relay, a telegraph key, and a headset. The oscillator is used only to convert the d-c line signals to an audible tone in the headset. Telegraph Set TG–5–B is shown in figure 3-41. The line relay in Telegraph Set TG–5–A is a 600-ohm relay and about 1.0 to 1.5 milliamperes minimum operating current is required. It has airgap and spring tension adjustments. The line

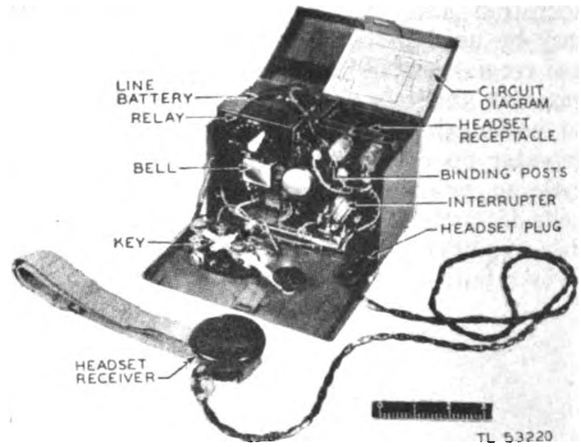


Figure 3-41. Telegraph Set TG–5–B.

relay in Telegraph Set TG–5–B is a 4,400-ohm relay and requires about 0.2 milliampere minimum operating current. It has spring tension adjustment only. The line battery is normally a 22.5-volt dry battery and the local battery for operating the interrupter is normally a 3-volt battery. Two batteries may be used to provide a 45-volt line battery when required. The sets are equipped with a calling-in bell which is disconnected when the headset is plugged in.

b. By the use of an adapter cord, a manual telegraph set may be used as a tone keyer for the transmitter of certain radio sets designed for voice operation. This adapter cord may be used with Radio Sets SCR–508, SCR–510,

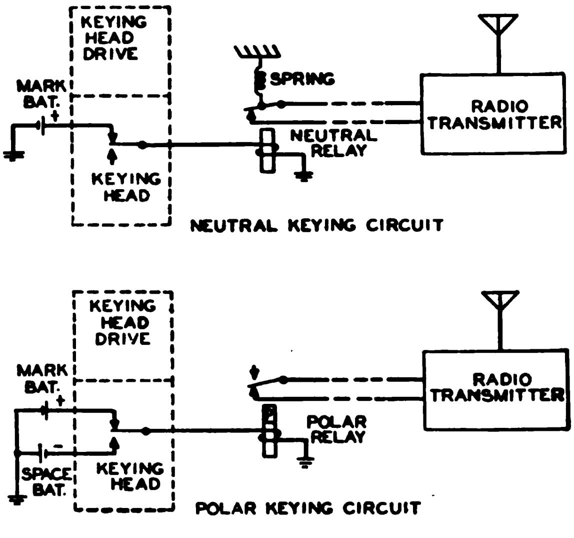


Figure 3-42. Neutral and polar keying circuits, automatic keying head.

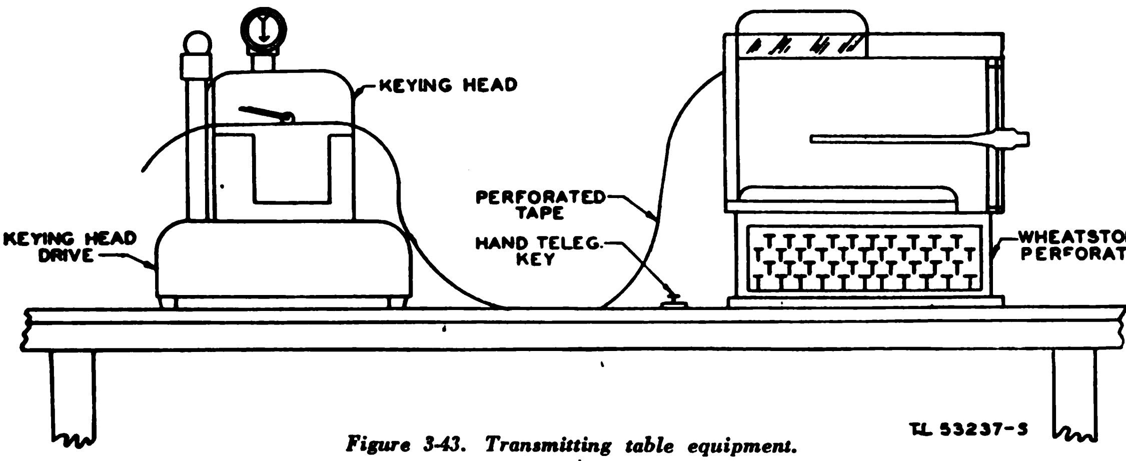


Figure 3-43. Transmitting table equipment.

SCR–608, SCR–610, or SCR–619. It is furnished with a Plug PL–55 containing a 400-ohm resistor for connecting to the telegraph set and a Plug PL–68 for connecting to the radio set.

330. AUTOMATIC KEYING AND RECORDING EQUIPMENT.

a. Boehme equipment is generally used to automatically transmit and receive International Morse-code telegraph signals primarily on radio. The operating speed is adjustable and it may be operated up to about 400 words per minute. The equipments are arranged on tables at the transmitting and receiving points.

b. At the transmitting point the equivalent of dots and dashes are perforated in tape (fig. 3-6) by the use of a Wheatstone perforator which has a typewriter keyboard. The tape is then run through a keying head mounted on a keying head drive. The keying head, controlled by the perforated tape, sends mark and space signal conditions to the external circuit to the radio transmitter. The basic principles of a neutral keying circuit and a polar keying circuit are illustrated in figure 3-42. Figure 3-43 is a diagram of the principal units used on a transmitting table. Figure 3-44 is a photograph of a Boehme keying head, type 4-E with keying head drive, type 4-D.

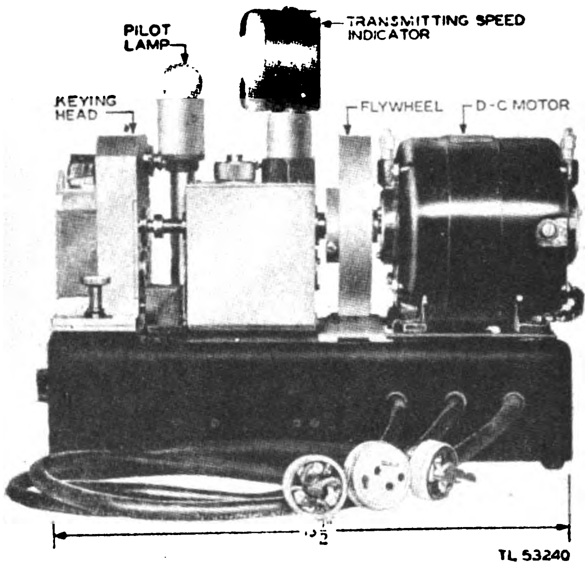


Figure 3-44. Boehme keying head, type 4-E with keying head drive, type 4-D.

c. At the receiving point, the principal equipments are a Boehme ink recorder and recorder driving unit, a tape puller with magnetic release attachment, a tape puller with rewind reel attachment, and a tape bridge. Recorder BC–1016, instead of Boehme recording equipment, is sometimes used for receiving signals. The Boehme recorder driving unit

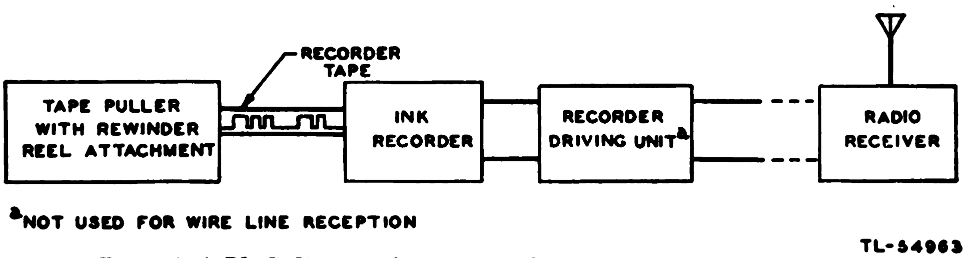


Figure 3-45. Block diagram of equipment elements at a receiving terminal.

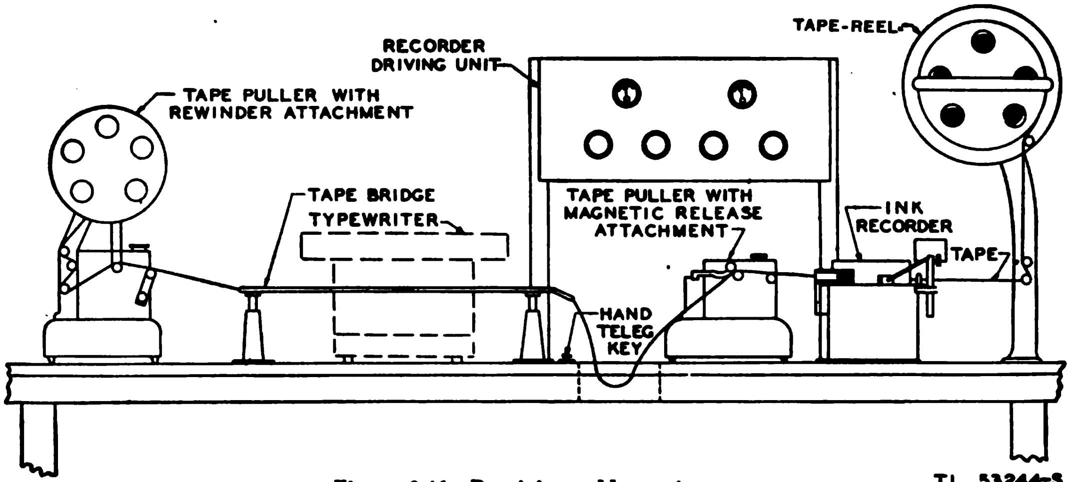


Figure 3-46. Receiving table equipment.

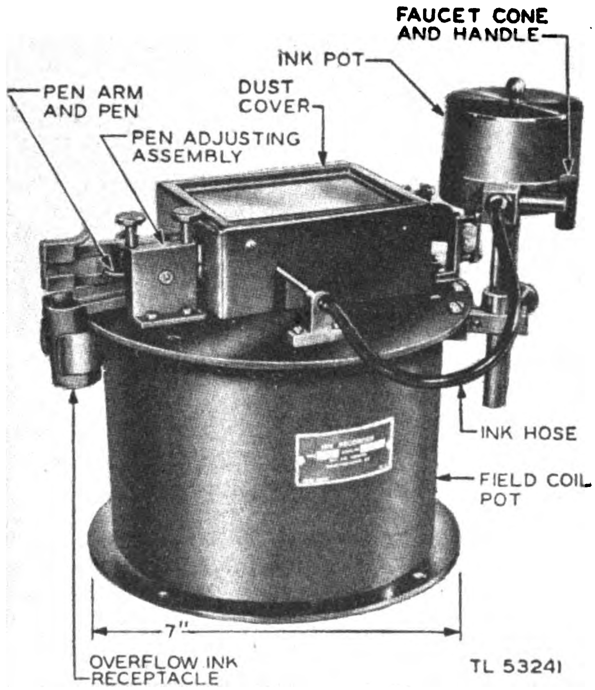


Figure 3-47. Boehme ink recorder, type 4-G.

receives keyed-tone dot and dash signals from a radio receiver or similar source and converts the signals to direct current to operate the ink recorder. The coil in the ink recorder actuates a fountain-type pen which makes a record on the tape symbolic of dot and dash signals. The elements of a typical arrangement at a receiving terminal are shown in figure 3-45. Receiving table equipment is illustrated in figure 3-46. A photograph of a Boehme ink recorder, type 4-G is shown in figure 3-47.

d. Boehme operating equipment is employed in Radio Set AN/MRC-1 which provides facilities for high-speed automatic International Morse-code c-w transmission and reception in addition to the normal functions of Radio Set SCR-399 (component of AN/MRC-1). Radio Set AN/MRC-1 is housed in two shelters, a transmitting Shelter HO-17 and an operating Shelter HO-17 or HO-27. The transmitting shelter includes the radio transmitter, amplifier, and one receiver. The operating shelter includes three radio receivers and the Boehme equipment. The Boehme equipment consists of a keying head and a hand keying circuit, a Wheatstone tape perforator, a recorder driving unit, an ink recorder and associated tape puller, two tape bridges, and two tape pullers with winding reels. Running spares for each major component of Radio Set AN/MRC-1 are supplied in their respective shelters.

Section V. TELEGRAPH LINE TRANSMISSION EQUIPMENT

331. GENERAL.

a. This section pertains to equipments which are generally located at an office at the termination of a line transmission section, such as an open wire line, spiral-four cable, or field wire. Extension circuits may extend from the offices to signal centers and stations. As explained in paragraph 321, office equipments, like station and signal center equipments, may be used by either tactical or fixed plant organizations. Equipment information on carrier telegraph terminals, d-c telegraph repeaters, telegraph switchboards, and test sets will be found in TM 11–487.

b. Newly assigned joint Army-Navy nomenclature for packaged telegraph line transmission equipment is as follows:

Commercial nomenclature	*Joint Army-Navy nomenclature*
V-f carrier telegraph terminal (1-6) X-61822A	Carrier Terminal OA-4/FC
V-f carrier telegraph terminal (7-12) X-61822B	Carrier Terminal OA-5/FC
D-c telegraph repeater X-61824A	Telegraph Repeater OA-6/FC
D-c regenerative telegraph repeater X-66031A	Regenerative Repeater OA-3/FC

332. CARRIER TELEGRAPH EQUIPMENT.

a. Telegraph Terminal CF–2–A (Carrier).

(*1*) Telegraph Terminal CF–2–A is tactical equipment and is contained in two carrying cases which are referred to as bays. Each bay provides channel terminals for two telegraph circuits, and two different bays are required at each terminal for four telegraph circuits. This equipment is supplied by the manufacturer for 2-wire operation only but may be modified in the field for 4-wire operation as covered in TM 11–2001. Telegraph Terminal CF–2–A is used in conjunction with Telephone Terminal CF–1–( ) as discussed in paragraph 306b.

(*2*) The telephone channel must be reasonably free from interference and rapid changes in net loss. Generally, any channels suitable for telephone may be used, but the telegraph system is usually operated over the No. 3 telephone channel of the spiral-four carrier system (Telephone Terminal CF–1–( )). The No. 2 telephone channel of the spiral-four system provides transmission which is nearly as satisfactory as the No. 3 channel and may be used.

(*3*) Each extension from a telegraph channel can be used for half- or full-duplex neutral operation, or for 2-path polar or polarential operation. Regulated tube rectifiers operable on 115-volts, or 230-volts, 50-60 cycles ac and a polar relay test circuit are built into the equipment.

b. Telegraph Terminal CF–2–B (Carrier). Telegraph Terminal CF–2–B, shown in figure 3-48, is practically the electrical equivalent of Telegraph Terminal CF–2–A but the equipment has been reduced in size and weight so that the 4-channel terminal occupies one bay of the same size and about the same weight as one 2-channel bay of Telegraph Terminal CF–2–A and no modification for 4-wire operation is required. Figure 3-49 shows a typical spiral-four terminal with telegraph and telephone equipments including Telegraph Terminal CF–2–B.

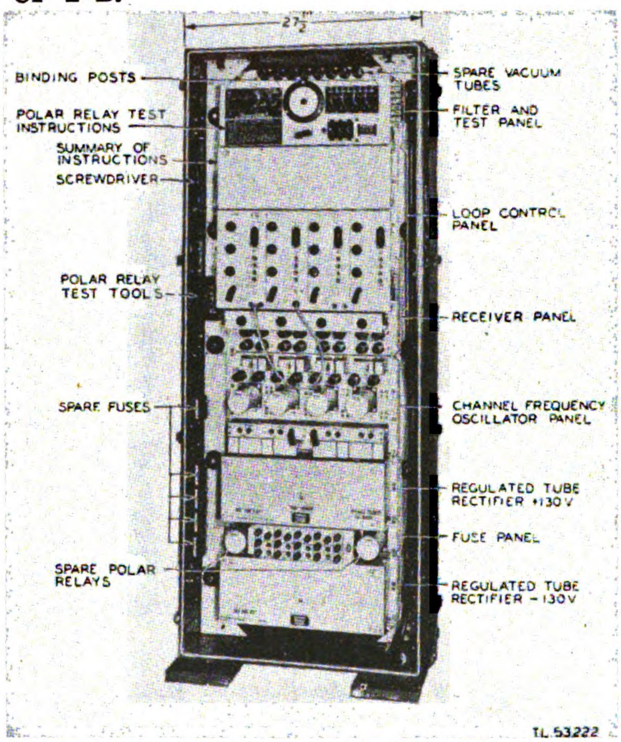


Figure 3-48. Telegraph Terminal CF-2-B (Carrier).

c. Telegraph Terminal CF–6 (Carrier). Telegraph Terminal CF–6 contains two circuit terminations and is for use primarily in combination with Telegraph Terminal CF–2–( ) to increase the number of telegraph circuits from 4 to 6 (2-wire operation) or from 8 to 12 (4-wire operation). These extra telegraph circuits are generally called channel 5 and channel 6. Extension circuits are equivalent to those used in Telegraph Terminal CF–2–( ). When Telegraph Terminal CF–6 is used with Telegraph Terminal CF–2–( ), the sending and receiving frequencies range from 425 to

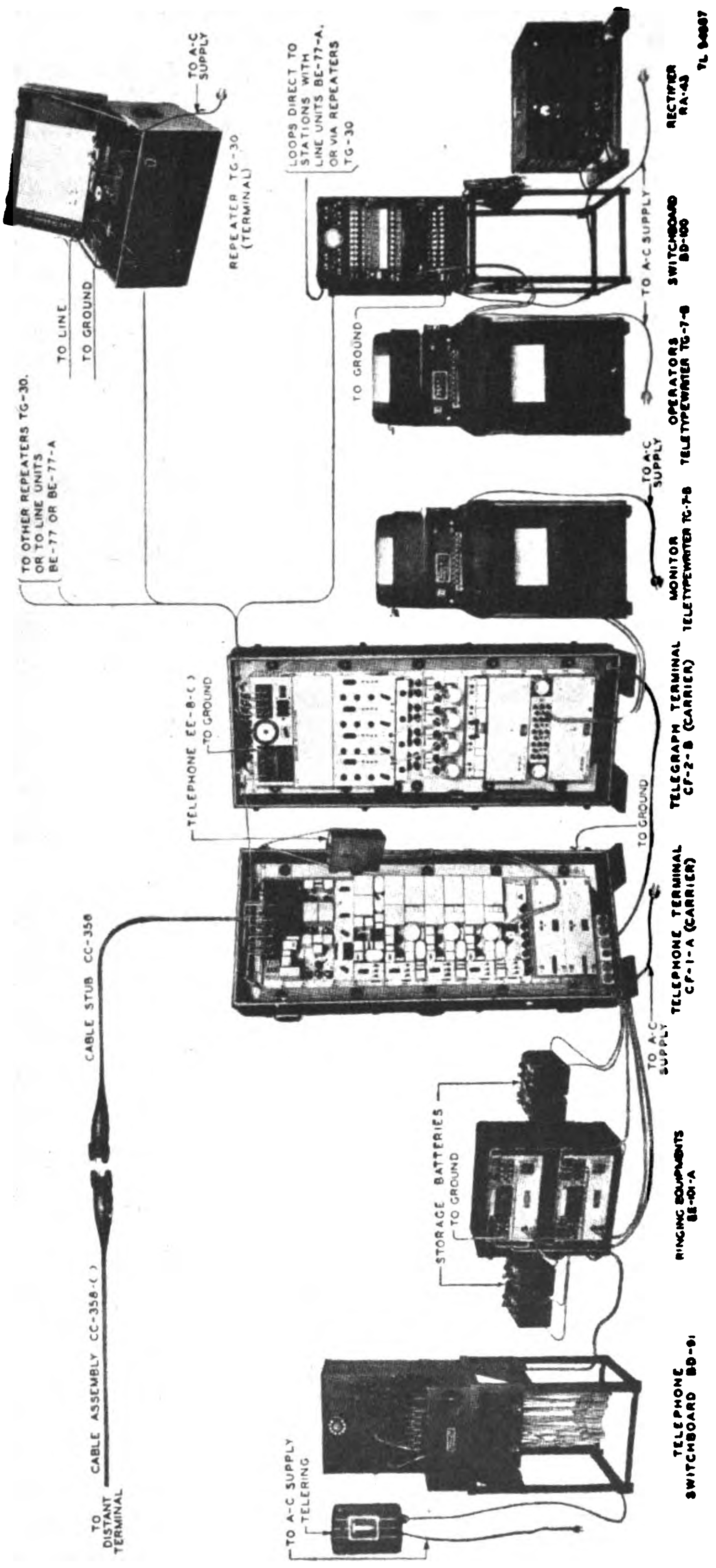


Figure 3-49. Typical spiral-four terminal.

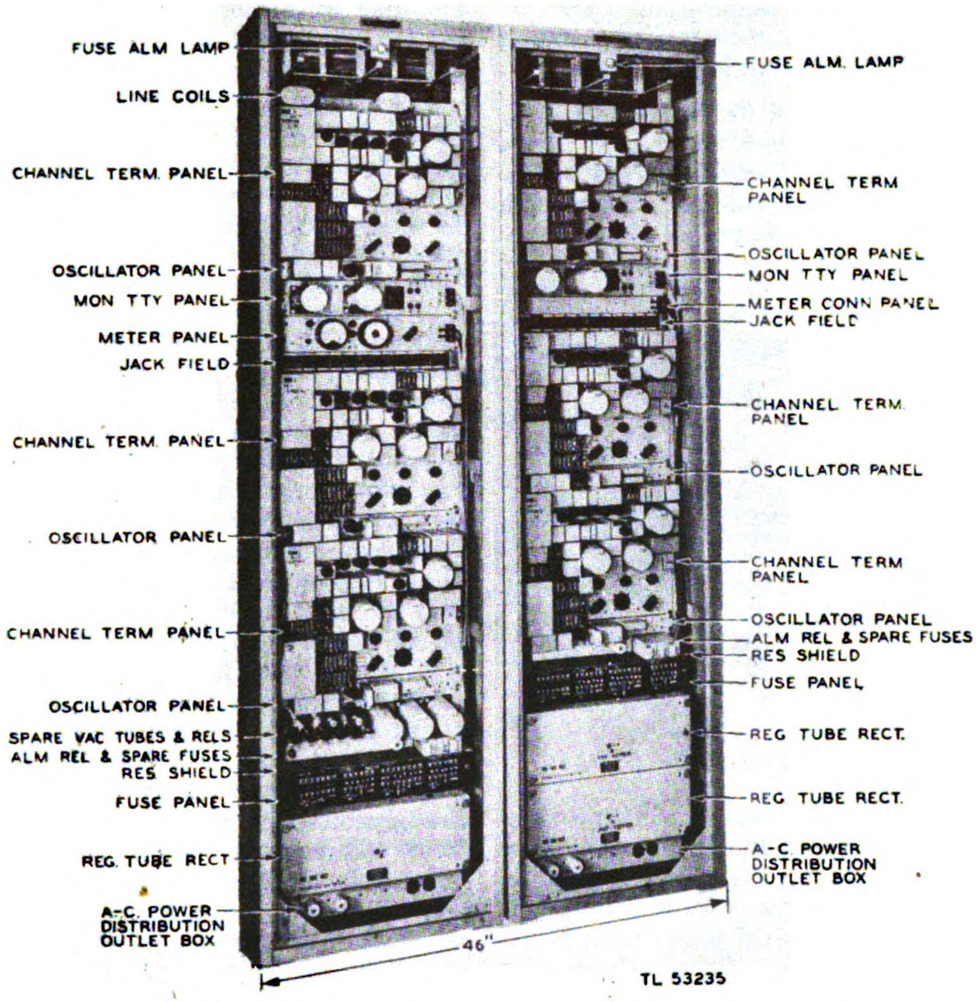


Figure 3-50. X–61822A or X–61822B v-f carrier telegraph repeater package.

2,295 cycles and the spacing is 170 cycles. The volume of the equipment is slightly more than one-half that of Telegraph Terminal CF–2–B. Like the Telegraph Terminals CF–2–( ), this equipment is supplied with rectifiers and a relay test circuit.

d. X–61822 Carrier Telegraph Equipment. This equipment was designed as part of the packaged system for fixed plant installations. It provides a maximum of 12 2-way telegraph circuits. The equipment is arranged in 7-foot metal cabinets, and one cabinet contains three telegraph circuit terminals. Six channel terminals, that is, two cabinets, shown in figure 3-50, are the minimum number operable as a unit. Four cabinets are required for a 12-channel telegraph system. This system operates on a 4-wire basis over a type C or type H carrier telephone system or over small gauge cable circuits with suitable loading. This carrier telegraph terminal is normally connected to channel 2 of the X–61819 type C carrier telephone terminal package. Telegraph equipment may, however, be connected to all three channels of the carrier telephone terminal and thereby provide a total of 36 telegraph circuits by sacrificing all carrier telephone channels. Volume limiters are provided on telephone channels but are not used when the channel is used for telegraph. The same v-f telegraph frequencies are used for both directions of transmission. Rectifiers operating from 115-volts, 50- to 60-cycle power are mounted in the cabinets to furnish direct current. The d-c extensions are arranged for neutral half-duplex and neutral full-duplex, and for 2-path polar and polarential operation. Channels 1 to 6 are furnished in the X–61822A package and channels 7 to 12 in the X–61822B package[6].

333. SPEECH-PLUS-DUPLEX SYSTEM USING TELEGRAPH TERMINAL TH–1/TCC–1.

a. A general description of this system including a schematic diagram is in paragraph 307. Figure 3-51 is a photograph of the equipment.

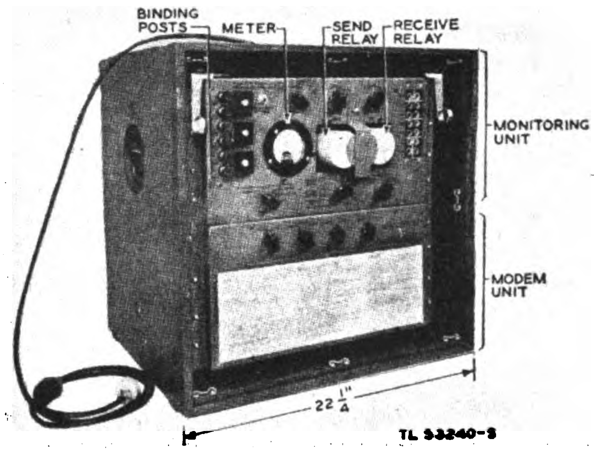


Figure 3-51. Telegraph Terminal TH–1/TCC–1.

b. The telegraph and speech channels derived from the common telephone circuit are entirely independent on the office side of the terminal. The d-c telegraph loop options are neutral half-duplex, neutral full-duplex, polarential, and 2-path polar. Carrier is on for mark and off for space.

c. The telegraph terminal may be stacked with telephone and telegraph packaged equipments. The equipment contains a power supply unit using a selenium-disc rectifier. Running spares are included.

d. The telephone branch of the terminal includes a 1,000- or 500-cycle voice-frequency ringer for ringing over the common circuit. The telephone branch also includes a neon tube limiter circuit designed to prevent interference into the telegraph, caused by peaks of signaling or speech voltages originating in the telephone branch of the system and acting on nonlinear elements, such as amplifiers, in the common branch. The limiter should be included, and voice-frequency ringing used, when the common circuit includes a repeater or other amplifier or a modulator. In other cases, 20-cycle or d-c signaling may be employed as an option without the limiter.

e. Telegraph Terminal TH–1/TCC–1 is designed to transmit either one of two values of telegraph power: —3 dbm and +4 dbm (ch. 12). The values of —3 dbm will always be used except on telephone lines containing no repeater, amplifier, or modulator or where a long connection, equivalent to approximately 7-db attenuation, is used between Telegraph Terminal TH–1/TCC–1 and the telephone or radio terminal.

f. The *1,800-cycle loss* between two Telegraph Terminals TH–1/TCC–1 ordinarily should not exceed about 25 db. The telegraph receiving terminal has sufficient gain to permit reception of powers as low as —53 dbm at 1,800 cycles (that is, over a loss of 50 to 57 db), but powers as small as this will be usable only if circuit noise and interference from telephone into telegraph are very low.

g. A separate filter, Filter F–2/GG, can be used to bypass the telegraph circuit from one telephone circuit to another without any other telegraph equipment. If this filter is located near a 2-wire intermediate telephone repeater, the impedance irregularity introduced by the filter will tend to restrict the repeater gain obtainable without repeater singing.

h. When Telegraph Terminal TH–1/TCC–1 is applied to a telephone circuit, allowance should be made in the circuit layout for resulting impairment to speech transmission. The suppression of the band of frequencies between 1,500 and 2,000 cycles in the speech branch, impairs intelligibility because of the distortion and loss in volume. Tests have indicated that on circuits of good quality, this suppression is equivalent to increasing the net loss of the telephone branch by about 5 db. Qualitative observations on a long wet Wire W–110–B circuit indicated that the transmission impairment is less for such a circuit. The 1,000-cycle attenuation through each terminal, including the limiter, is about 1.5 db. Hence, the total transmission impairment in ordinary cases is about 1.5 + 1.5 + 5 = 8 db for a pair of terminals. When telephone circuits equipped with this apparatus are connected together, the transmission impairment, as compared to that without apparatus, is about 8 db for the first link, plus 3 db for each additional pair of terminals or of Filters F–2/GG.

[6] The frequencies used are shown in the telegraph frequency allocation chart in chapter 5.

i. Telegraph Terminal TH-1/TCC-1 can be applied to multichannel radio relay systems using carrier telephone terminals. It cannot be used on radio circuits operating on a push-to-talk basis since it requires that the circuit be capable of simultaneous transmission in both directions. Modification of radio circuits normally push-to-talk, in order to use this terminal, is not recommended. It would involve the use of two radio-frequency assignments, one for each direction of transmission, equipment changes, and new operating procedures to prevent singing, since Telegraph Terminal TH-1/TCC-1 is on a 2-wire basis.

334. D-C TELEGRAPH REPEATERS.

a. General. D-c telegraph repeaters are classified broadly as terminal repeaters, intermediate repeaters, and regenerative repeaters. Terminal repeaters are arranged for connections to a line on one side and to an extension, including teletypewriter equipment, on the other side. Intermediate repeaters are arranged for direct repetition between two line sections, and their use on certain kinds of wire increases the allowable over-all circuit length between terminals. Since regenerative repeaters reform and retime the signals, they extend the over-all allowable circuit lengths of teletypewriter networks by increasing substantially the number of sections operable in tandem. Regenerative repeaters (par. 335) do not increase the length of a line section.

b. Tactical D-c Repeaters. Repeater TG-30 (Terminal) and Repeater TG-31 (Intermediate) are suitable for office installations as well as for stations and signal centers. If desired, these repeaters may be removed from their wood carrying cases and mounted on 19-inch relay racks or the equivalent. Office installations of Repeater TG-30 will generally consist of connecting the local side to a carrier telegraph terminal or to Switchboard BD-100, in order to provide longer circuits than can be obtained with the polarential circuit termination integral in the carrier terminal or the neutral circuit termination in Switchboard BD-100. Such applications require use of Repeater TG-30 at the outlying end of the circuit. Repeaters TG-30 and TG-31 are described in paragraph 327.

c. X-61824 D-c Telegraph Repeater. This repeater is packaged equipment for use in fixed and semifixed plant and lacks the portable features of tactical d-c repeaters. A photograph of this packaged equipment is shown in figure 3-52. The line side is electrically equivalent to the line side of Repeater TG-30 and hence provides polarential or 2-path polar operation. This equipment is operable over a line circuit to a Repeater TG-30. The extension side is arranged for neutral half-duplex, neutral full-duplex, and 2-path polar operation. The neutral half-duplex and neutral full-duplex terminations are suitable for interconnection with other packaged telegraph equipment, such as the X-61822 v-f carrier telegraph terminal and the X-66031 d-c regenerative telegraph

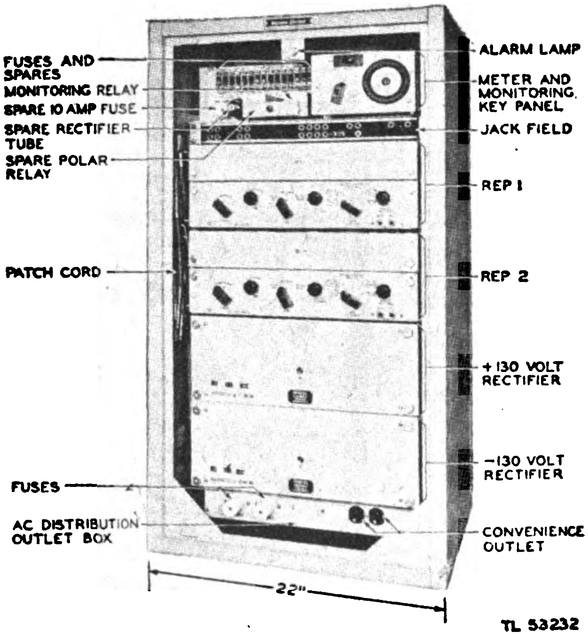


Figure 3-52. X-61824A d-c telegraph repeater package.

repeater. Two d-c repeaters are supplied in a 3-foot 6-inch metal cabinet which also contains positive and negative 130-volt d-c regulated rectifiers for operation on 115-volts 50-60-cycles ac. Two repeaters in the metal cabinet comprise the X-61824A d-c telegraph repeater package. The two repeaters in one cabinet, or two repeaters in different cabinets, may be interconnected locally to provide the equivalent of an intermediate repeater, and a teletypewriter, regenerative repeater, or both may be inserted in series in the extension circuits. The line operating range of the X-61824 d-c telegraph repeater is the same as Repeater TG-30, and they may be operated on the same types of conductors.

335. D-C REGENERATIVE TELEGRAPH REPEATER.

a. X–66031 D-c Regenerative Telegraph Repeater. This equipment is arranged especially for fixed plant use in combination with packaged d-c telegraph repeaters and packaged carrier telegraph terminals. The extension circuits operate neutral, half-duplex, or full-duplex. Two repeaters are supplied in a 3-foot 6-inch metal cabinet which also contains an orientation indicator circuit required for adjusting the regenerator units. The complete cabinet arrangement with the two repeaters is the X–66031A d-c regenerative telegraph repeater package. Each repeater in the package contains two regenerator units, and the four regenerator units in a cabinet are driven by a common a-c series-governed motor requiring 115-volts 50- to 60-cycle a-c power. D-c power for the transmission circuits is required; this is generally obtained from the rectifiers in the d-c repeater package. The rectifiers in Repeaters TG–30 and TG–31 are not suitable as a source of d-c power for the regenerative repeater. Figure 3-53 is a photograph of the equipment package with the front door removed and the cover of the regenerator panel removed in order to show the four regenerator units.

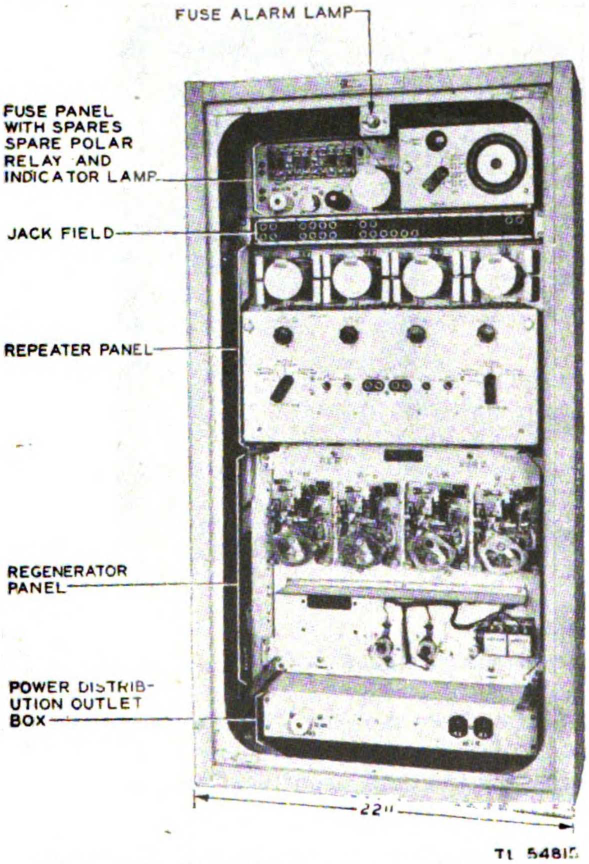


Figure 3-53. X–66031A. d-c regenerative telegraph repeater package.

b. Application.

(*1*) The X–66031 d-c regenerative telegraph repeater is used basically for two different reasons. One is to provide regeneration of teletypewriter signals to increase the number of line sections operable in tandem, and the other is to provide 3-way operation. A 3-way connection involves a branch circuit from a main line circuit, generally at an intermediate office. The branch circuit may be extended to a line-relay-equipped teletypewriter at an outlying office, or a telegraph repeater located in the intermediate office may be connected to the regenerative repeater and the circuit then extended over one or more line sections as required. Two regenerative repeaters are required at a 3-way point to provide regeneration with the branch circuit and the main line circuit. Some typical uses for regenerative repeaters with fixed plant equipment are shown in figure 3-54.

(*2*) The proper location for regenerative repeaters in different kinds of circuits can be determined by the combined use of telegraph coefficients and line operating ranges.

(*3*) This repeater will operate at 368 opm or 404 opm. At 404 opm the motor speed is increased about 10 percent by adjusting its speed with a No. 104984 tuning fork (marked BRITISH SPEED—404 OPM) (Stock No. 4T104984). The repeater is oriented by use of biased signals obtained from Test Set TS–2/TG which is the major component of the X–66031B d-c regenerative telegraph repeater testing package.

336. USE OF D-C REGENERATIVE TELEGRAPH REPEATERS WITH TACTICAL EQUIPMENT.

a. General. Occasions may arise where it is desirable to interconnect the X–66031 d-c regenerative telegraph repeater with tactical repeaters, tactical carrier equipment, and Switchboard BD–100. The following subparagraphs describe briefly some of the possible arrangements. For illustrative purposes, the west side of the regenerative repeater is shown connected to the tactical equipment (figs. 3-55 to 3-57). The east side of the regenerative

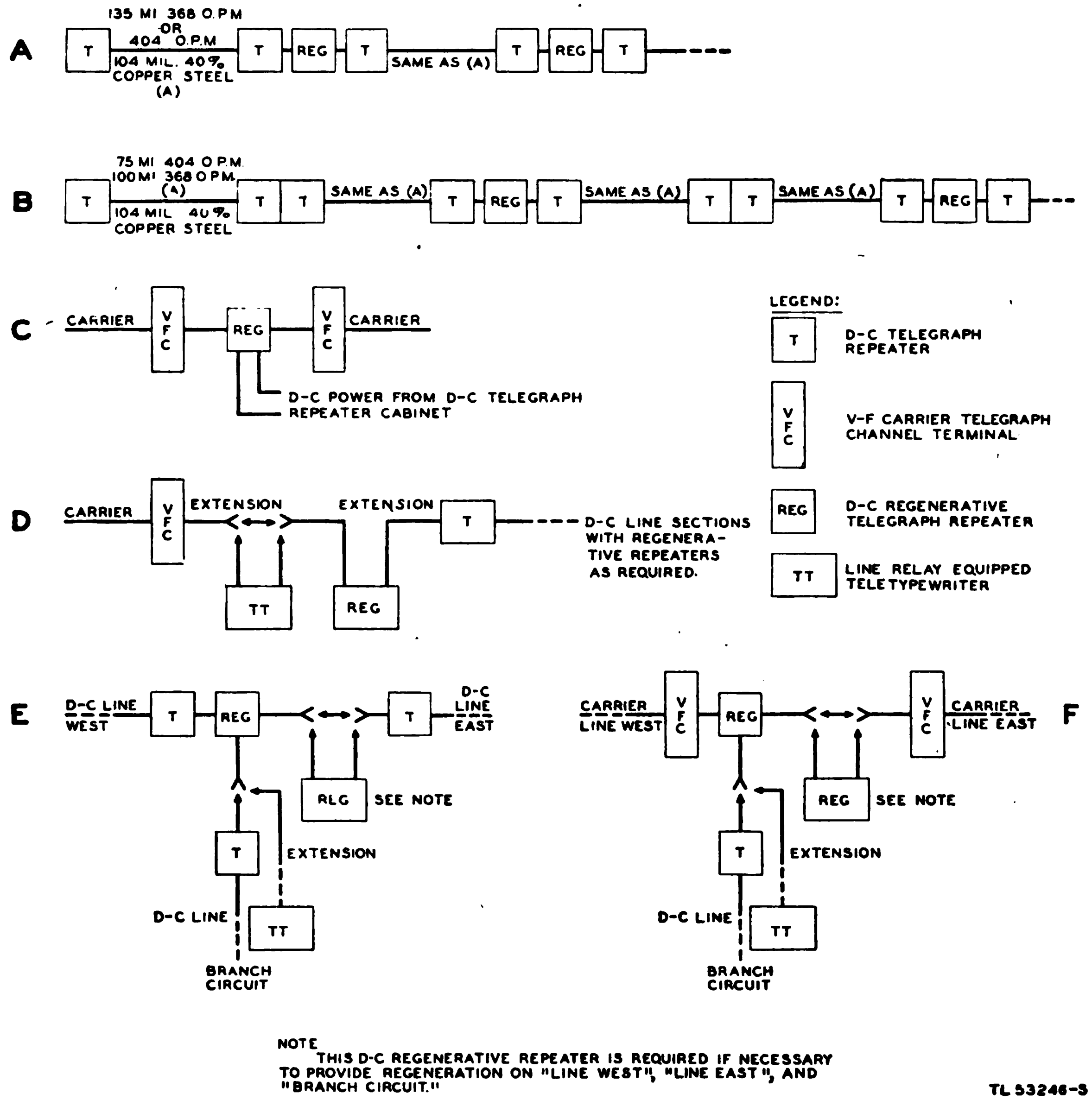


Figure 3-54. Typical uses for regenerative repeaters.

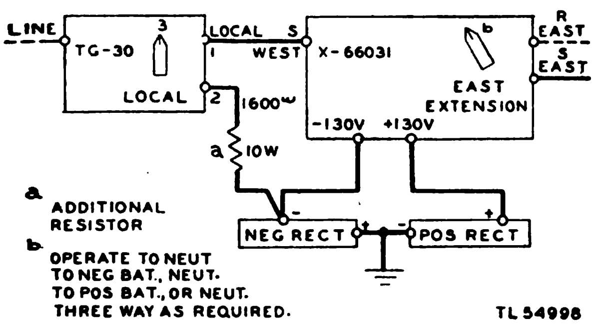


Figure 3-55. Repeater TG-30 connected to X-66031 d-c regenerative telegraph repeater.

repeater may be arranged for balanced loop or open and close loop operation to meet particular service requirements. Service will be on a half-duplex basis except with carrier telegraph terminals which may be arranged for either half- or full-duplex service. In practically all cases standard operating practices and line-up procedures are used throughout.

b. Use with Repeater TG-30. The X-66031 d-c regenerative telegraph repeater may be used with Repeater TG-30 as shown in figure 3-55. A separate 1,600-ohm resistor connected to negative battery is required for connection to the No. 2 LOCAL binding post of each Repeater TG–30. The 1,600-ohm 10-watt fixed resistor (Stock No. 3Z6160–15) which is a replacement part for Line Units BE–77–A and –B may be used. An external source of positive and negative 130-volt battery is required as described in subparagraph e below.

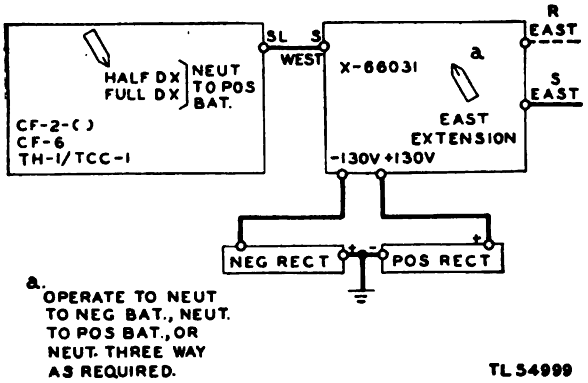


Figure 3-56. Telegraph Terminal CF–2–( ), CF–6, or TH–1/TCC–1 connected to X–66031 d-c regenerative telegraph repeater.

c. Use with Carrier Telegraph Terminals. The regenerative repeater may be used between any combination of Telegraph Terminals CF–2–( ), CF–6, or TH–1/TCC–1. The carrier terminal extension circuits (loops) are electrically equivalent to those in the X–61822 packaged carrier telegraph terminal. A source of positive and negative 130-volt telegraph battery is required for the regenerative repeater as described in subparagraph e below. Figure 3-56 shows a block diagram of a typical connection.

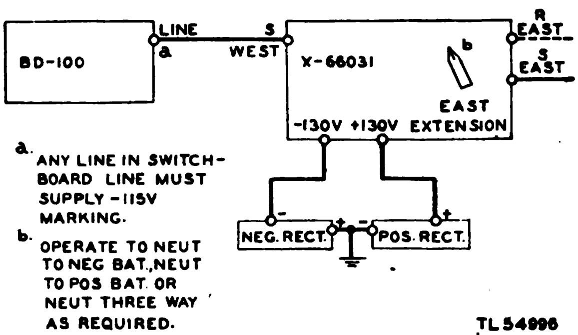


Figure 3-57. X–66031 d-c regenerative telegraph repeater connected to a line in Switchboard BD–100.

d. Use with Switchboard BD–100. The regenerative repeater may be used with any line circuit terminating at a Switchboard BD–100 as shown in figure 3-57 or it may be used as a cord circuit repeater as shown in figure 3-58 to regenerate all signals received and retransmitted in a switchboard connection. A cord, for example Cord CC–68 (modified), can be used to connect the regenerative repeater into the vacant lower jack of a Switchboard BD–100 connection. Any or all of the four regenerator units in an X–66031A cabinet may be modified. The 1,600-ohm resistor required for connection to terminal 5 may be secured as described in subparagraph b above.

e. Power Supply for Regenerative Repeaters. The motor on the regenerator panel requires about 150 watts at 105- to 125-volts, 50- to 60-cycles ac and the alarm circuits require about 6.6-volts ac. The transmission circuits require low-impedance positive and negative rectifiers, each capable of supplying about 0.4 amperes dc regulated to 130 volts. The 130-volt regulated tube rectifiers in an X–61824A d-c telegraph repeater cabinet are the normal source or d-c power for this purpose. Similar rectifiers of the type supplied in Telegraph Terminals CF–2–( ), CF–6, and the X–61822A and B packaged telegraph terminals may be

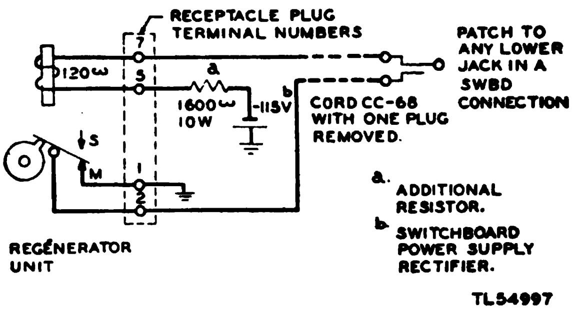


Figure 3-58. Use of a regenerator unit in X–66031 d-c regenerative telegraph repeater as cord circuit repeater for Switchboard BD–100.

used for this purpose, provided that they are not supplying a load in their normal operation such that the rated output of 0.8 ampere at 130 volts is exceeded. If these rectifiers are used exclusively for supplying the d-c regenerative repeater, a dummy load resistor of 2,000 to 3,000 ohms (10 watts) should be connected across the output of each rectifier. If the above rectifiers are not available, two 115 volt Rectifiers RA–87 or RA–43–( ) may be used. The rectifiers in the TG–30, TG–31, or TH–1/TCC–1 are not suitable for supplying the regenerative repeater.

Section VI. TELEGRAPH SWITCHBOARDS

337. SWITCHBOARD BD–100.

a. Switchboard BD–100, shown in figure 3-59, is available for teletypewriter switched service. Teletypewriter stations and trunks are interconnected in much the same manner as in telephone practice. This teletypewriter switchboard has a capacity of 10 lines, which may be station lines or trunks as required. The lines terminate in neutral type circuits, each containing a mechanically biased demountable sending and receiving relay. The line circuits are interconnected by a parallel-type circuit which readily permits conference connections. The switchboard includes a bias measuring circuit for use in adjusting the relays on repeat space-bar signals; means for measuring line current and voltage are included.

b. The switchboard requires 115-volt dc, generally obtained from regulated tube Rectifier RA–43–A or –B. This rectifier may be operated from Power Unit PE–75–D or an equivalent source of alternating current. The rectifier output is sufficient for operating three switchboards in a single installation.

c. Patch cords 18-inches and 72-inches long are supplied for making interconnections. Teletypewriter TG–7–A or –B is used as an operator's teletypewriter for answering calls and for general communication purposes. Stations call by momentarily opening the line, and the stations are called by the operator sending a

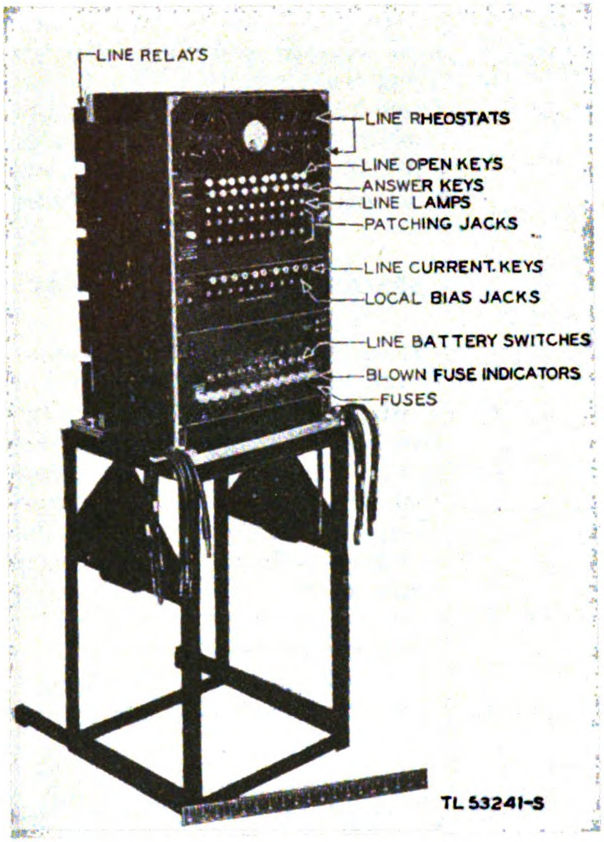


Figure 3-59. Switchboard BD–100.

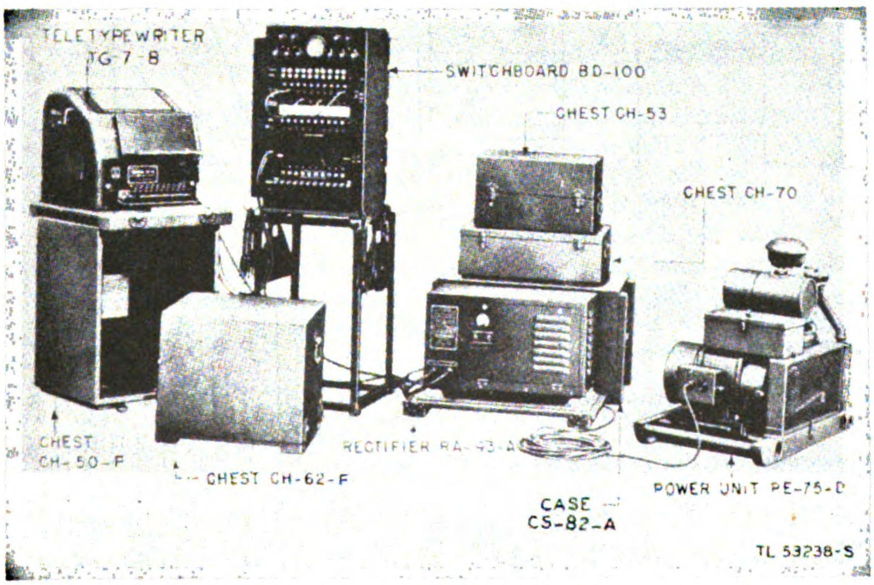


Figure 3-60. Telegraph Central Office Set TC–3 prepared for operation.

break signal followed by a bell signal to attract the attention of the station operator.

d. The equipment is mounted in a metal cabinet supplied with an iron framework for protection during transportation. This framework is removed from the board and used as a mounting while the board is in service. Switchboard BD–100 is the major component of Telegraph Central Office Set TC–3 shown in figure 3-60.

338. GROUP OPERATION OF SWITCHBOARDS BD–100.

a. Purpose. In large signal centers, arrangements for group operation of the 10-line Switchboards BD–100 have been used to improve operation and increase the traffic handling capacity of the switchboard. This paragraph describes briefly one of the arrangements devised in the field for a group of five switchboards. Figure 3-61 shows the over-all equipment arrangement.

b. Principal Features.

(*1*) It is possible to make direct connections between any two of 48 teletypewriter station line circuits. The remaining two line circuits are required to terminate two regular operators' teletypewriters.

(*2*) All the circuits can be answered and connected by either of the two regular operators' teletypewriters. A third operator's teletypewriter is provided to handle overflow traffic, to line up circuits, and for general maintenance work. For switched connections, the operator at this auxiliary teletypewriter position uses regular patch cords and standard operating procedures.

(*3*) The five positions of switchboard are mounted adjacent to each other on a plank platform directly above the three operators' teletypewriters (fig. 3-61).

(*4*) The patching jacks are made more accessible by interchanging panel positions and lowering the patching jacks on the face

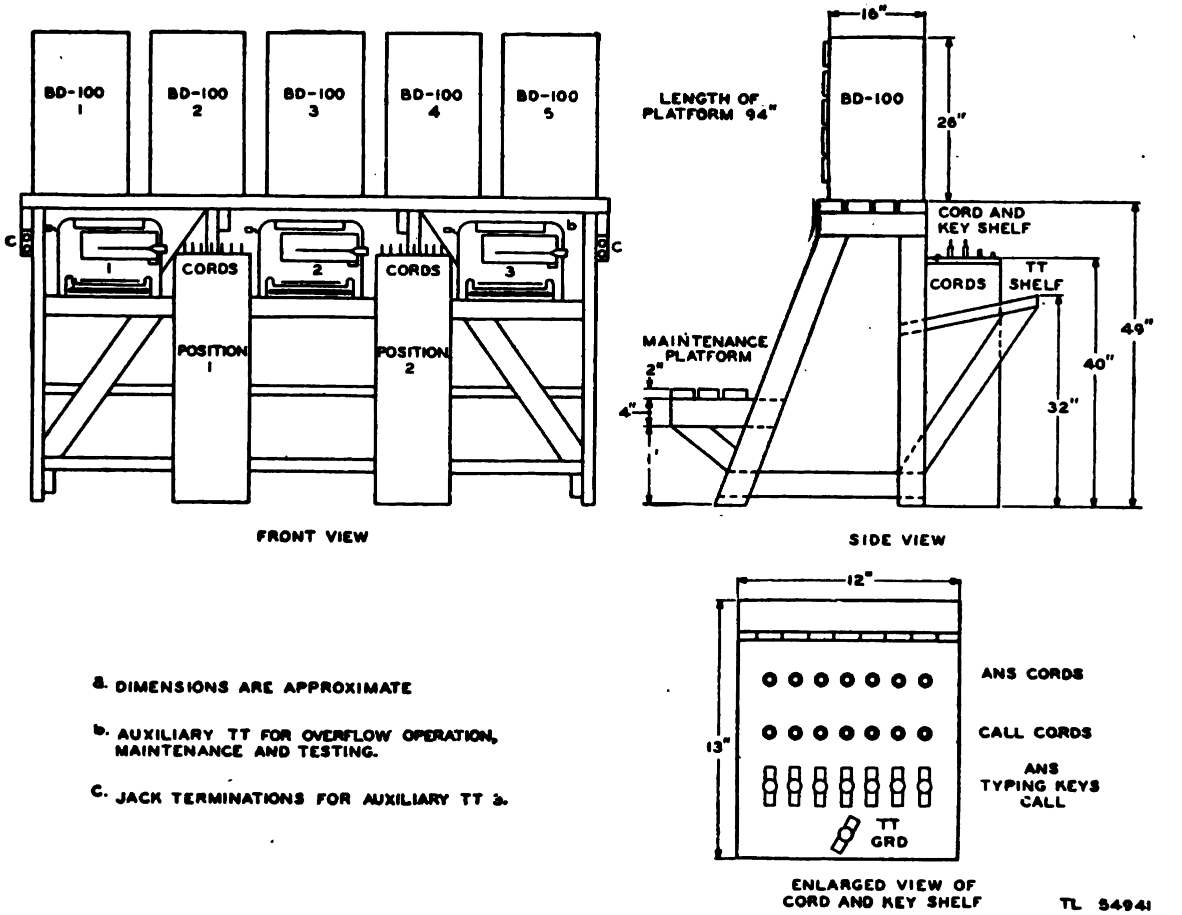


Figure 3-61. Installation of Switchboards BD–100 arranged for group operation.

of the switchboard. A rearrangement of the panels is shown in figure 3-62. The local cable is long enough to permit relocating the panels, but it will be necessary to drill and tap the framework.

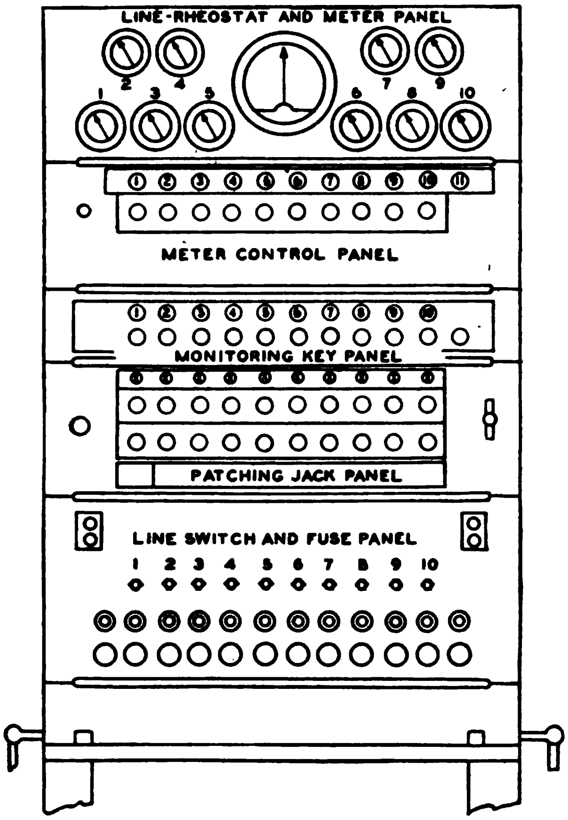


Figure 3-62. Front view of Switchboard BD-100, panels rearranged for group operation.

(*5*) A cord and key shelf is located immediately to the right of each of the two regular operators' teletypewriters. Each key shelf contains 7 pairs of cords, so that a total of 14 simultaneous connections can be made. An enlarged view of the cord and key shelf is shown as part of figure 3-61. Additional scheduled or overflow connections may be set up with the normal patching cords.

(*6*) Each pair of cords has an associated 3-position typing key for answering a call, completing a connection, or monitoring a connection. A teletypewriter ground key (TT GRD) is located in each key shelf. This key is operated during the idle periods to prevent the operator's teletypewriter running open. Figure 3-63 is a schematic of one key of the cord circuit. Other keys are wired in the same manner. This figure also shows a connection between two station line circuits.

(*7*) A permanent patch is made from each group of cords to the station line circuit selected as the operator station. This patch is shown in figure 3-63. When the typing key is operated, the operator's station line is connected electrically as a member of a conference connection.

c. Method of Operation.

(*1*) *To Answer an Incoming Call.*

(*a*) Release TT GRD key.

(*b*) Operate typing key of next idle cord to ANS (back) position.

(*c*) Connect ANS (back) cord of the selected pair to the lower line-patching jack of calling station.

(*d*) Momentarily partially depress the LINE OPEN key to put out the call lamp.

(*e*) Acknowledge call in the regular manner.

(*2*) *To Complete an Incoming Call.*

(*a*) With typing key in ANS (back) position, insert calling (front) cord in upper line-patching jack of the called station.

(*b*) After 2-second interval operate the typing key to the CALL or Monitor (front) position. During the 2-second interval, an open signal is sent to the station to start teletypewriter motor.

(*c*) Call the station operator in the prescribed manner.

(*d*) After calling station acknowledges call, leave the connection by restoring key to the normal (upright) position.

(*e*) Operate the TT GRD key to stop the operator's teletypewriter running open.

(*3*) *To Call a Station from Operator's Teletypewriter.*

(*a*) Proceed as in the first three steps of subparagraph (1) above.

(*b*) Operate cord circuit key to normal for 2 seconds and return it to the CALL position to start the motor of the called station.

(*c*) Call the station operator in the prescribed manner. Bell signals may be used for this purpose.

(*4*) *To Monitor Connection.*

(*a*) Only one connection can be monitored in each position at a time.

(*b*) To monitor connection in same position: Release TT GRD key; operate typing key to CALL, or monitor (front) position.

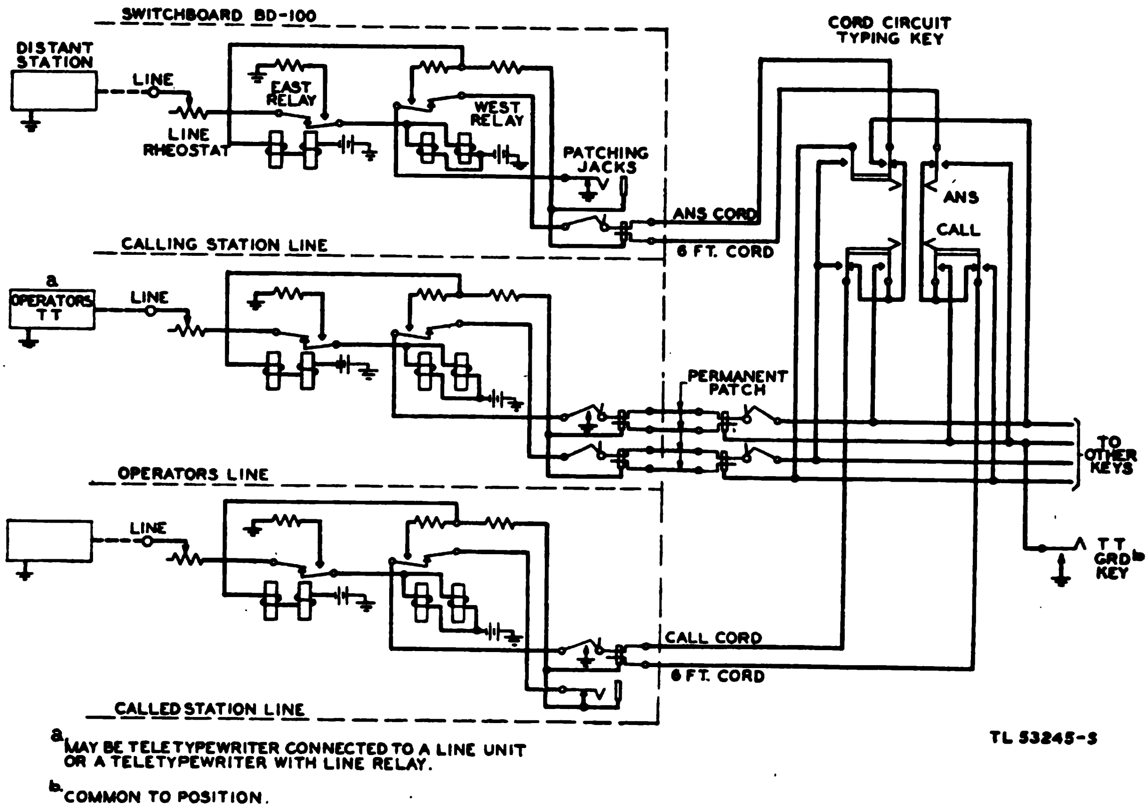


Figure 3-63. Schematic of Switchboard BD-100 connection with two stations connected by means of cord circuit.

(*c*) To monitor connection of next position: Release TT GRD key; operate typing key of an idle cord pair to ANS (rear position); connect ANS cord (back) to lower line jack of called station. Do not attempt to monitor by using upper line jack of calling station.

(*5*) *To Disconnect on a Connection.*

(*a*) Release TT GRD key.

(*b*) Operate typing key to CALL or monitor (front) position.

(*c*) Challenge connection as specified.

(*d*) Grasp the plugs of both the ANS and CALL cords and pull them from their respective jacks simultaneously.

339. TELEGRAPH SWITCHBOARD SB–6/GG.

A patching board, sometimes called a loop board, differs from a switchboard used for switched service in that no supervisory features are provided and no current is supplied. Telegraph Switchboard SB–6/GG, shown in figure 3-64, is a board of this type. It is normally used for interchanging lines and equipment at signal centers or stations. When the connected equipment is operating on the normally assigned line facilities, no patch cords are up at the board. Patches may be made in some cases to rearrange circuits because of equipment or circuit failures. This switch-

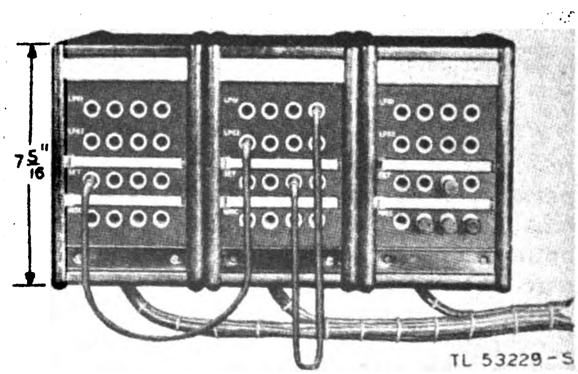


Figure 3-64. Three Telegraph Switchboards SB–6/GG, 12-line installation.

board has a capacity of four lines, each line containing two looping jacks and one set jack. Four miscellaneous jacks are available in each switchboard. As many as four boards may be mounted as a unit to provide up to 16 lines. This board is arranged for wall mounting and is supplied with two 2-foot patching cords and two dummy wooden plugs. Telegraph Switchboards BD–50, –51, –52, and –53, which are now rated obsolete, are replaced by Telegraph Switchboard SB–6/GG. In some installations Switchboard SB–6/GG has been furnished as a 63C2 telegraph loop switchboard (Western Electric Company specification).

Section VII. RADIO TELETYPEWRITER SYSTEMS AND CIRCUITS

340. GENERAL.

a. This section describes single-channel and multichannel fixed plant and tactical radio teletypewriter arrangements. The fixed plant systems are available using standard components. At the time of writing, the tactical arrangements generally involve associating together apparatus units originally designed for other purposes.

b. On account of the growth in military usage of teletypewriters, various arrangements for transmitting teletypewriter signals over single-channel radio circuits have been devised in the field. This section contains a discussion of some factors which should be considered before attempting to devise these arrangements, and describes methods which it is believed will be satisfactory if undertaken where the necessary physical facilities and qualified personnel are available.

341. FIXED PLANT EQUIPMENT USED IN RADIO TELETYPEWRITER SYSTEMS, SINGLE CHANNEL AND MULTICHANNEL.

a. Single-channel Frequency-shift System Using Radio Teletype Terminal Equipment AN/FGC–1.

(*1*) The AN/FGC–1 is used for single-channel operation at the *receiving* end of a teletypewriter system using space-diversity reception and frequency-shift transmission. Operation may be over distances from a few hundred to several thousand miles. The circuit arrangement of the complete system is shown schematically in figure 3-65 and a photograph

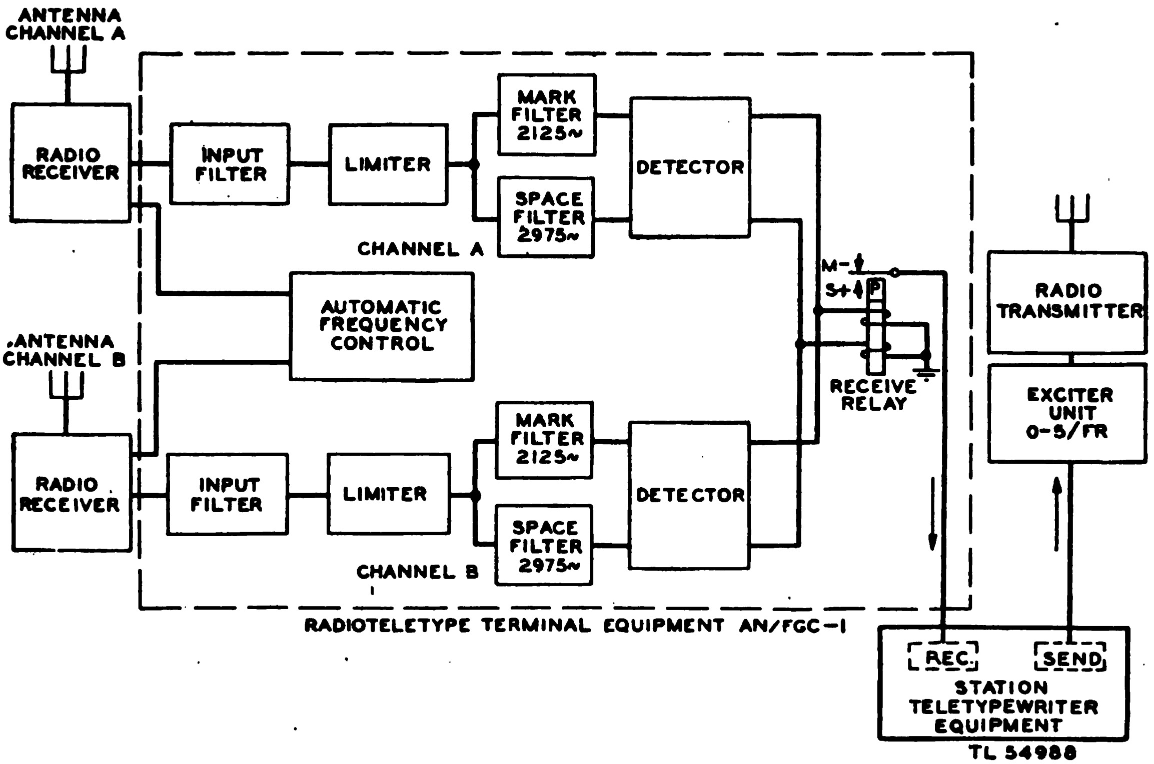


Figure 3-65. Single-channel radio teletype system using Radio Teletype Terminal Equipment AN/FGC–1.

of the AN/FGC-1 equipment is shown in figure 3-66. When the sending contacts of the teletypewriter at the transmitting station are in the marking position, an unmodulated carrier frequency is radiated by the transmitter;

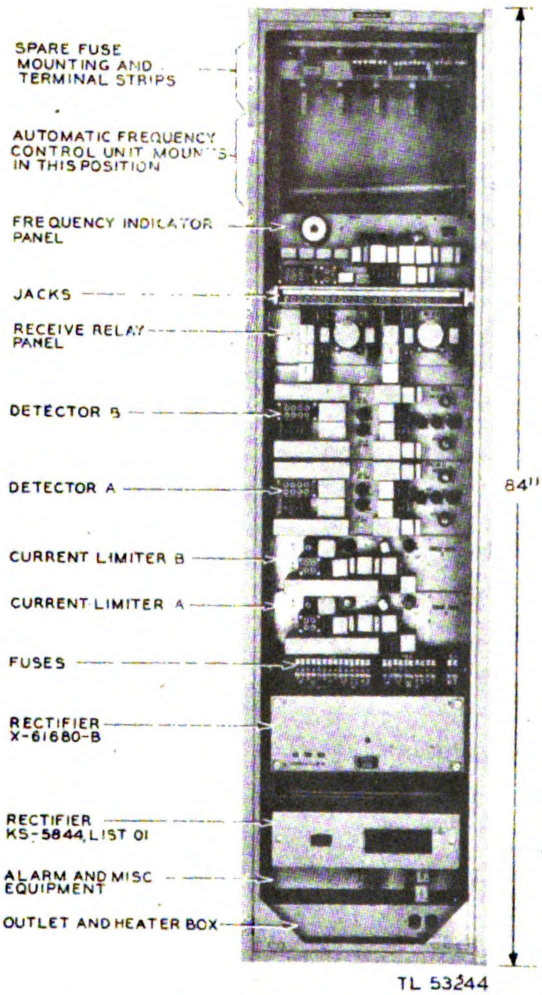


Figure 3-66. Radio Teletype Terminal Equipment AN/FGC-1.

when in the spacing position, this frequency is lowered (850 cycles usually), the amplitude remaining unchanged. Radio receivers for channels A and B provide space-diversity reception. In each channel the receiver converts the signals to two audio frequencies, 2,125 and 2,975 cycles, for marking and spacing respectively. The input filter (1,600 to 3,500 cycles at 6-db points[7]) excludes noise frequencies outside the working band and passes both marking and spacing frequencies into a fast-operating wide-range limiter which prevents the currents from exceeding a prescribed maximum value and largely eliminates the effects of amplitude variations (fading) which are normally experienced in long distance h-f radio operation. The marking and spacing frequencies then pass through their respective filters, into a double detector which actuates the receiving relay. The marking filter passes the frequency band from about 1,700 to 2,500 cycles and the spacing filter 2,600 to 3,400 cycles. The outputs of space-diversity channels A and B are combined in the receiving relay on a d-c basis in order to avoid distortion from variable phase differences between the tones of the A and B channels. The radio teletype terminal equipment is located adjacent to the radio receivers.

(2) The two radio receivers have separate antennas located several wavelengths apart so that fading will seldom cause the loss of signals in both simultaneously. This space-diversity feature adds stability to the circuit; interconnection between the detectors for favoring the channel having the better signal-to-noise ratio effects a further increase in stability. It is generally desirable to use rhombic antennas since their directive effect gives additional improvement in signal-to-noise ratio. If it is not practicable to provide space diversity antennas, satisfactory results may be obtained in some cases by using polarization diversity (sec. V of ch. 6).

(3) Operation may be on a simplex or duplex basis. In the first case, the same radio frequency is generally used for transmission in each direction; in the latter case, different transmitting frequencies are required.

(4) Suitable transmitter power and frequency assignment are required. In other than

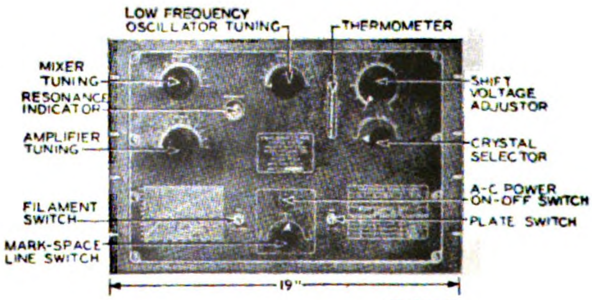


Figure 3-67. Exciter Unit 0-5/FR.

[7] This is a rough measure of the boundaries of a band-pass filter. The 6-db points are the two frequencies at which the loss in the filter is 6 db greater than the minimum loss in the pass band.

polar regions, some frequency between 2 and 20 megacycles will usually be satisfactory, depending largely upon the time of day. On routes which lie near the magnetic pole, however, a low frequency (in the order of 50 to 200 kilocycles) will be preferable; in this case some modification is required in the receiving radio teletype equipment. Refer to paragraph 326 for station arrangements used with Radio Teletype Terminal Equipment AN/FGC–1.

(*5*) Exciter Unit 0–5/FR, shown in figure 3-67, may be used to key the radio transmitter on a frequency-shift basis. It may be applied to any h-f radio transmitter, replacing the first oscillator section of the transmitter. The crystals are not supplied as a part of Exciter Unit 0–5/FR. The method of determining the proper crystal frequency for a

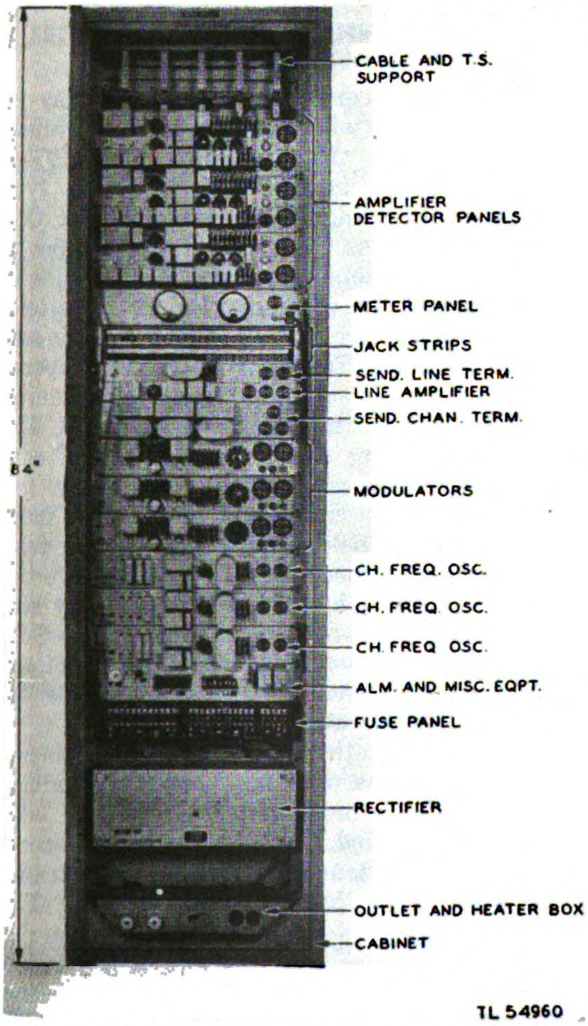


Figure 3-68. 42B1 carrier telegraph equipment, sending terminal cabinet No. 1.

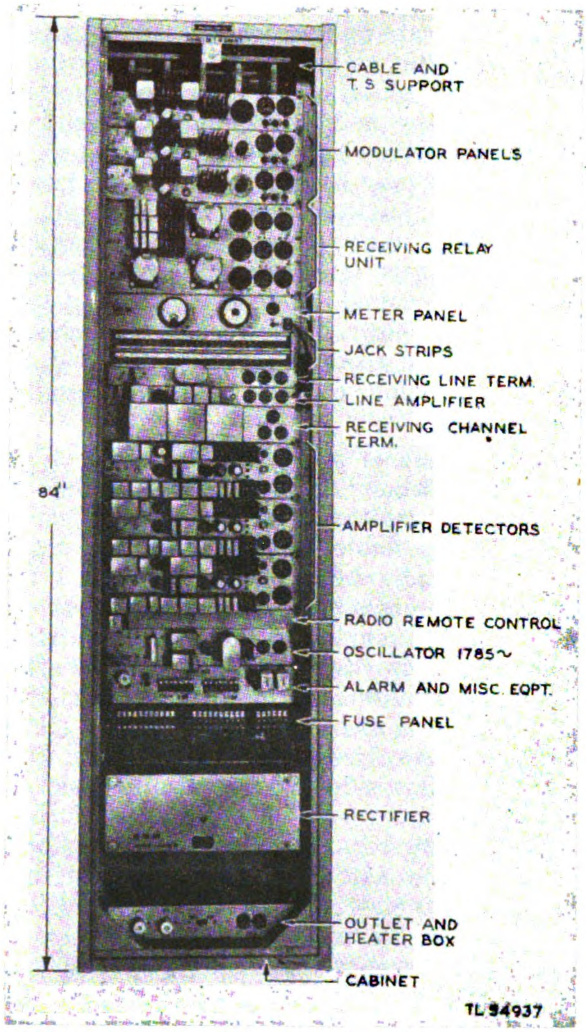


Figure 3-69. 42B1 carrier telegraph equipment, receiving terminal cabinet No. 1.

given transmitter frequency is covered in TM 11–2205.

(*6*) Automatic frequency control has been provided with some receivers to take care of transmitter and receiver frequency variations. Such control can be detrimental, however, when there is strong interference from an adjacent channel, because the interfering signal takes control.

b. 42B1 Carrier Telegraph Equipment Multichannel Single-tone Modulation. This multichannel carrier telegraph equipment provides six wide-band high-speed telegraph channels which may be used for teletypewriter or automatic Morse operation. The frequency spacing is 340 cycles; the lowest frequency is 425 cycles and the highest 2,125 cycles. Each telegraph circuit is limited to one-way service, and a separate and equivalent amount of carrier and radio equipment is therefore required for each direction of transmission. The tones are keyed on and off for teletypewriter or automatic Morse-code operation. A channel of this system may be used as a link in tandem with other facilities, such as long-haul h-f circuit. A sending-terminal cabinet containing three channels is shown in figure 3-68. A receiving-terminal cabinet containing three channels is shown in figure 3-69. A 6-channel 2-way system requires, at each terminal, two sending-terminal cabinets and two receiving-terminal cabinets.

c. Multichannel V-f Carrier Telegraph System on Single-sideband Radio Telephone System.

(*1*) A multichannel h-f radio telegraph system is available for application to a single-sideband radio telephone system. This telegraph and telephone equipment should be procured as a complete system through Army Communications Service. Such systems are in use for communication between various theater headquarters and continental United States. These furnish as many as six high-grade 2-way 60-word-per-minute teletypewriter circuits on either 5,000-cycle sideband of a radio system. The channels may also be used for automatic Morse-code operation at speeds up to about 75 words per minute.

(*2*) At the transmitting end of the circuit in this system, each teletypewriter channel is arranged to send four audio-frequency tones. Two of these are sent for marking and the other two for spacing. The two marking tones and similarly the two spacing tones are separated from each other by about 1,000 cycles, thus providing a frequency-diversity feature. Each marking tone and its corresponding spacing tone are separated by 170 cycles. The sum of the frequency bands allotted to each telegraph channel is $4 \times 170 = 680$ cycles. Multichannel operation is provided in the usual way for carrier telegraph by assigning different frequencies to each channel. All of the carrier telegraph channels combined modulate the radio carrier but only one sideband is transmitted, the other being suppressed. The radio carrier power is transmitted at much reduced strength compared to the sideband power.

(*3*) At the output of the radio receiver, each teletypewriter channel includes four band-pass filters to separate the four tones of that channel from those of the other channels, a limiter, additional band filters to separate the marking from the spacing tones, marking and spacing detectors, and a common polar receiving relay. Two marking tones and two spacing tones, each separated from the other by about 1,000 cycles, are normally received in each channel. Because of the frequency separation, the two tones will seldom fade deeply at the same time, and thus selective fading is largely overcome. The limiter action effectively takes care of those cases where both tones are reduced simultaneously (flat fading) since the detector is supplied with a practically constant input. From the standpoint of reception, each channel of this system is equivalent to a frequency-shift system with frequency-diversity.

342. MULTICHANNEL RADIO TELETYPEWRITER ARRANGEMENTS FOR TACTICAL USE.

a. Telegraph Terminal CF–2–( ) may be applied directly (without Telephone Terminal CF–1–( )) to Radio Sets AN/TRC–1, AN/CRC–3, or similar voice-emission type radio sets operating in the v-h-f range. One to eight full-duplex telegraph channels may be obtained, using separate radio frequencies in the two directions of transmission[8]. The telegraph terminals are connected to the radio sets on a 4-wire basis. To provide 8-channel operation on a 4-wire basis requires at each terminal two Telegraph Terminals CF–2–A or –B. The radio transmitters should be capable of continuous emission and have reasonably flat attenuation characteristics over a range from about 100 cycles below the lowest carrier telegraph frequency used to 100 cycles above the highest. As many as 8 or 10 radio relay sections in tandem can be used with Radio Sets AN/TRC–3 and –4, the individual sections being somewhat shorter than permissible for single-section operation.

b. The input to the radio transmitter should be adjusted to give approximately full modulation with all channels marking. Figure 3-70 gives recommended input levels and approximate input impedance for certain radio transmitters on which tests have been made. The

[8] Four additional channels may be obtained by adding two Telegraph Terminals CF–6 to Telegraph Terminal CF–2–( ). However, for some radio sets, designed for single speech channel operation, the upper and lower frequency telegraph channels may suffer some transmission impairment.

power figures apply to the operation of a 4-channel telegraph system. For a single-channel system, the power may be increased about 12 db over the recommended power per channel for a 4-channel system. For an 8-channel system the power per channel should be made about 5 db less than in the 4-channel system. Proper adjustment must be made to take account of loss in connecting wires between the telegraph and radio equipment.

Radio set or transmitter	*Recommended power into radio transmitter[a] with 4-channel operation (dbm[b] per telegraph channel)*	*Approximate input impedance (ohms)*
AN/TRC-1, -3, and -4	−14[d]	600
AN/CRC-3[c]........	−21	50
AN/CRC-3A[c].......	−13	50
BC-640.............	−27	600
TDQ (Navy)........	−15	600
TDG (Navy)........	−12	600

[a] Microphone jack of AN/CRC-3 or -3A; line terminals of other transmitters.
[b] dbm = db referred to one milliwatt.
[c] Special cooling arrangements required for continuous operation.
[d] Cable compensator on step 12.

Figure 3-70. Power input to radio transmitters, 4-channel telegraph.

c. For f-m operation, the minimum required carrier field strength at the receiving end for 4-channel telegraph is approximately 5 db higher than the minimum required for a single-channel point-to-point telephone circuit, assuming speech to cause practically full modulation of the radio transmitter; for eight telegraph channels, the corresponding value is around 8 db. For a-m operation (ground wave) the corresponding values for four and eight telegraph channels are about +11 db and +16 db, respectively.

d. Telegraph Terminals CF–2–( ) and CF–6 could be applied to suitable tactical radio sets operating in the h-f range for ground-wave use (negligible fading) and with strong enough received signals to override noise. Arrangements for doing this have not been worked out.

e. Telegraph Terminals CF–2–( ) and CF–6 may also be operated using one or more channels of Telephone Terminal CF–1–( ) when the telephone terminal is connected to radio sets capable of 4-channel telephone transmission (sec. II of ch. 6). In such cases, the telegraph levels are limited by Telephone Terminal CF–1–( ) and these levels are not related to the fact that a radio link is involved. The resulting telephone and telegraph circuits may be terminated independently at switchboards.

f. Multichannel systems require that radio carrier be on the air continuously in both directions.

343. SINGLE-CHANNEL RADIO TELETYPEWRITER ARRANGEMENTS FOR TACTICAL USE.

a. General. Situations may arise in the field where single-channel radio teletypewriter circuits and standard radio teletypewriter equipments which are not available could be used to advantage. In these cases, certain sending and receiving radio teletypewriter improvised arrangements may be made by qualified personnel. Ordinarily, the basic equipment for such improvising is the sending and receiving circuits of Telegraph Terminal CF–2–B, and in some cases it may be advantageous to make slight modifications in Radio Teletype Terminal Equipment AN/FGC–1 or the British Mark III 2-Tone equipment. Requirements for different forms of operation, together with a brief description of arrangements which may be made, will be found in paragraphs 344 to 347, inclusive. Arrangements may be made for one-way (simplex) or 2-way (duplex) service. Duplex operation requires a separate radio path and associated equipment, with a different radio frequency for each direction of transmission. A functional diagram of the sending and receiving circuits of one channel in the standard Telegraph Terminal CF–2–B equipment is shown in figure 3-71. Refer to TM 11–355–B for further information on Telegraph Terminal CF–2–B.

b. Impedance Matching and Use of Line Coils. A separate line coil (repeating coil) should be used for each sending and each receiving radio teletypewriter circuit because connections to the radio sets are made on a 4-wire basis. In case a portion of a CF–2–B is arranged for radio and both line coils in the bay are used, the rest of the bay may be used on wire circuits if additional line coils are obtained. This

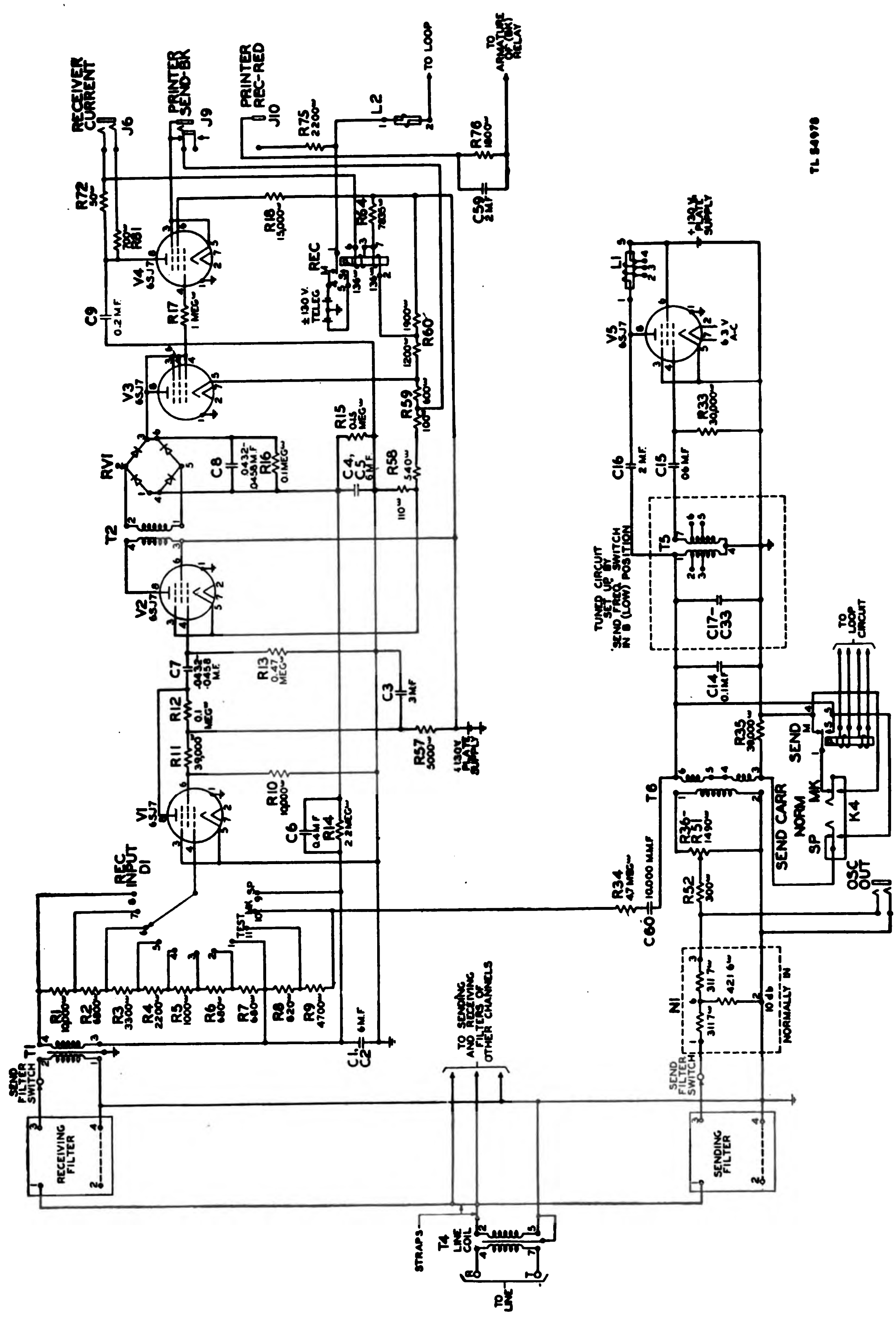


Figure 3-71. Telegraph Terminal CF-2-B, sending and receiving circuits, functional diagram.

line coil (T4, fig. 3-71) has four balanced windings and an impedance ratio of 600 to 600 ohms. This impedance is probably satisfactory for use with many transmitter input or receiver output circuits; if not, a coil of suitable ratio may be substituted for, or placed in tandem with, the line coil in the CF–2–B.

344. ARRANGEMENTS FOR TACTICAL C-W TELETYPEWRITER OPERATION.

a. Radio Sets.

(*1*) Amplitude-modulation type radio sets now in use which operate in the h-f range are frequently equipped with arrangements to permit c-w operation on a *manual* telegraph basis with tone reception (by ear), using a beat-frequency oscillator. This feature is necessary for single-channel c-w teletypewriter operation. Amplitude-modulated type radio sets operating in the v-h-f range are generally not equipped for the c-w method of operation.

(*2*) The determining factor in the use of c-w transmitters for teletypewriter operation is the speed at which they may be keyed. Radio sets where the on-off carrier condition is manually keyed are generally equipped with relays which are not fast enough to follow teletypewriter operation. Teletypewriter operation at 60 words per minute requires arrangements which are reliable for a signaling speed of at least 23 cycles per second. This keying speed requirement is met by electronic keying arrangements. As a rule, the manual telegraph closed-key circuit condition is made the marking condition for teletypewriter operation.

(*3*) No standard arrangements are available to interconnect teletypewriter apparatus to radio transmitters and receivers equipped for c-w operation. The requirements which such apparatus must meet in case it is necessary to provide such arrangements are given in subparagraph b below.

b. Requirements.

(*1*) Since the keying cord may connect to the grid of the oscillator in the transmitter, a short cord similar to the cord used for manual keying is required. A d-c circuit is required between the teletypewriter equipment and the radio set, the teletypewriter circuit being arranged to produce local copy.

(*2*) The audio output of the receiver must be converted to dc to operate the receiving teletypewriter circuit. A circuit will be required at the output of the radio receiver which includes an audio gain control (if not in the radio receiver), an electronic or equivalent rectifying circuit, and a receiving relay (preferably polar) for operating the teletypewriter. It is generally necessary to provide additional audio amplification between the receiver output and rectifying circuit. If the radio receiver is not capable of delivering a fairly constant level of tone, as might be the case if it is not equipped with an automatic volume control circuit, then the teletypewriter receiving circuit should also be provided with a level compensator.

c. Improvised Transmitter Keying Circuit.

(*1*) A transmitter keying circuit for c-w teletypewriter operation may be provided as indicated in figure 3-72. The contacts of the polar relay duplicate electrically the manual telegraph key which is normally used. The polar relay used requires that the line current be adjusted to 60 milliamperes marking.

(*2*) If, for security reasons or to save transmitter power, it is required to remove carrier from the air when the circuit is idle, the line from the teletypewriter to the radio transmitter may be opened, in which case the teletypewriter motor power should be turned off. If this is done, the distant receiving teletypewriter will run open. This will result in an increase in room noise at the receiving station, and in addition the receiving teletypewriter may print extraneous characters because of noise on the radio channel, since the spacing condition increases the gain in the level compensator circuit of the CF–2–B receiving circuit.

d. Improvised Receiving Circuit. The receiving circuit in each channel of Telegraph Terminal CF–2–B includes a level compensator and the other receiving requirements outlined in subparagraph b (2) above. It may be modified in the following manner to make it suitable for the reception of c-w signals for teletypewriter operation. Referring to figure 3-71, select any one of the channels. Disconnect the wires on terminals 1-2 of detector input transformer T1 and run a pair of wires to the output of the radio receiver from terminals 1-2 of T1. The receiving circuit will now contain input transformer T1 and associated receiving circuit shown in the upper half of figure 3-71. The input impedance of the transformer T1 is 600 ohms, which is probably satisfactory for proper matching of many

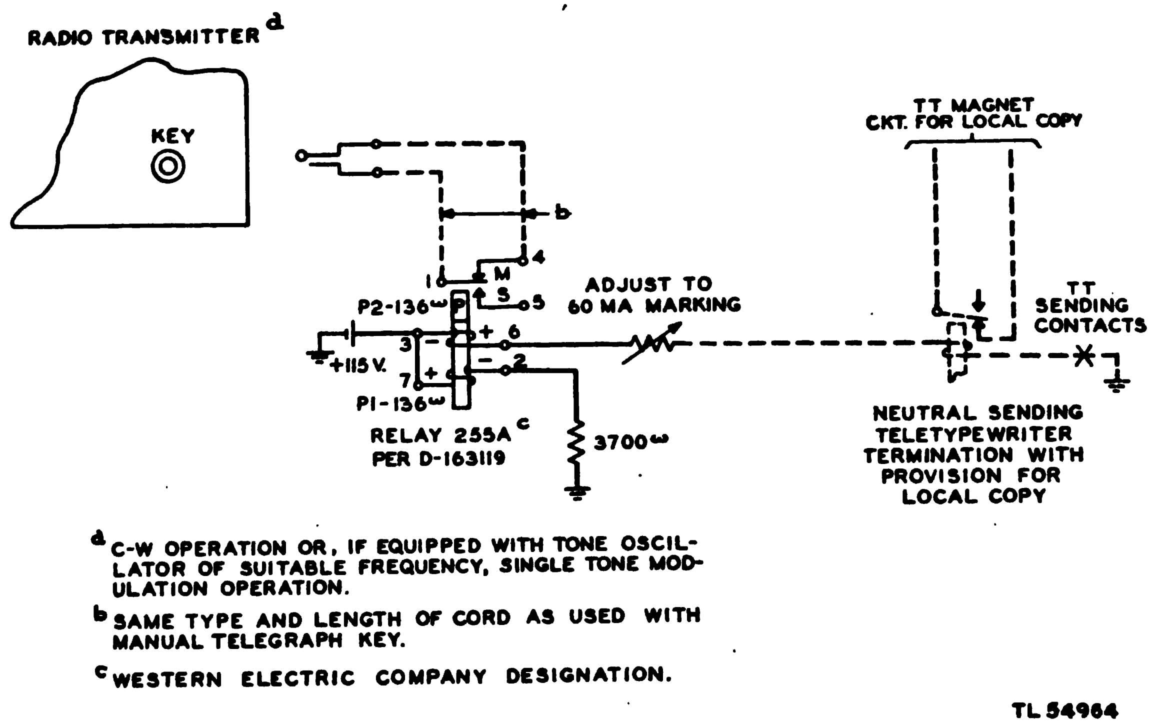


Figure 3-72. Radio teletypewriter polar-relay keying circuit.

radio receiver output circuits. If not, a coil of suitable ratio may be placed in tandem with it. The receiving filter of the CF–2–B channel selected should in general not be used, since the received signal frequency is apt to drift out of its pass band. Operate the loop switch to a full-duplex position and arrange the d-c loop circuit the same as for reception on a wire circuit. Adjust the output tone of the radio receiver to a fairly high pitch, say, around 1,200 cycles.

345. ARRANGEMENTS FOR TACTICAL SINGLE-TONE MODULATION OPERATION.

a. Radio Transmitters. With the single-tone modulation method, either a-m or f-m speech transmission radio systems operating in either the h-f or v-h-f range may be used for single-channel teletypewriter operation at ground-wave distance ranges. Certain of the speech-type transmitters are equipped with an audio-frequency oscillator; if the frequency of this oscillator falls within the pass band of the receiving arrangement, it can be used to key the oscillator by the polar-relay sending circuit shown in figure 3-72. In other cases it is necessary to provide a teletypewriter sending circuit that is capable of sending an audible tone to the tone-keying jack circuit of the transmitter when a marking signal is being sent and no audible tone when a spacing signal is being sent. Such an arrangement (subpar. c below) may be obtained by using the sending circuit of one channel in Telegraph Terminal CF–2–B.

b. Radio Receivers. Speech-type radio receivers provide currents in the speech band currents to headphones or a loudspeaker. The requirements for a teletypewriter receiving circuit are the same as for c-w reception described in paragraph 344b(2). In addition, a narrow-band filter, whose mid-band frequency is the same as the frequency of the radio transmitter tone oscillator is desirable between the output of the receiver and the input to the amplifier. This filter will reduce the effects of noise on teletypewriter reception. The 1,105-cycle filter (FL5) in a CF–2–B channel will serve this purpose if the transmitted tone is at or close to this frequency.

c. Improvised Single-tone Modulation Sending Circuit. The circuit of Telegraph Terminal CF–2–B, shown in figure 3-71 may be modified to obtain a single-tone modulation sending circuit. Select channel 1 and operate the sending frequency switch and the sending filter switch so as to send 1,105 cycles to the radio transmitter for a marking signal[9]. Disconnect from the channel to be modified, the receiving filter and associated receiving circuit of this channel, and the sending and receiving filters of the other channels. Connect a pair of wires from the input of the radio transmitter to the line terminals of line coil T4 (par. 343b). Arrange the d-c loop circuit for a full-duplex sending loop the same as for wire operation.

d. Improvised Single-tone Modulation Receiving Circuit. Telegraph Terminal CF–2–B (fig. 3-71) may be modified for single-tone receiving in the following manner. Disconnect from the channel to be modified, the sending filter of this channel, and the sending and receiving filters of other channels. For reception at 1,105 cycles, the position of the sending frequency switch and sending filter switch should be coordinated with positions of the equivalent switches at the sending terminal. All of the receiving circuit including transformer T4 may be used. Operate the loop switch to a full-duplex position and arrange the d-c loop circuit the same as for reception on a wire line circuit. If transmission is from a radio transmitter equipped with a tone oscillator which is close to the mid-band frequency of some other CF–2–B channel, the receiving filter used should have the same mid-band frequency. Refer to chapter 5 for the channel frequencies available in the CF–2–B. If the tone oscillator does not fall in any CF–2–B channel, the channel filter may be removed from the circuit, with a resulting signal-to-noise impairment.

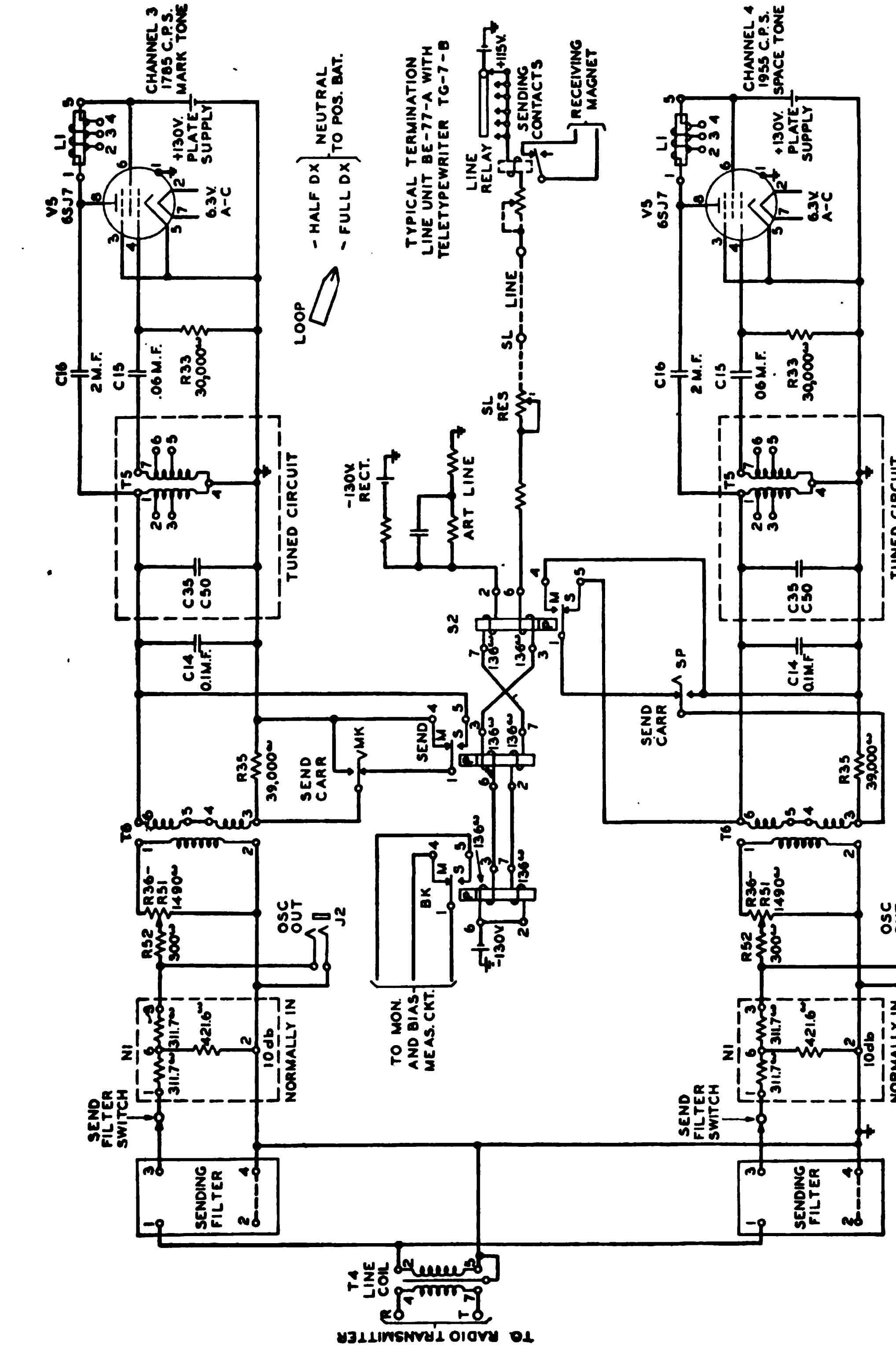
346. ARRANGEMENTS FOR TACTICAL 2-TONE MODULATION OPERATION.

a. Radio Sets. The same types of a-m and f-m radio telephone transmitters and receivers used for single-tone modulation operation may be used for single-channel 2-tone modulation teletypewriter operation. In case of ground-wave transmission, the added complications required to provide 2-tone modulation suggest its use only for cases where somewhat greater ability to overcome noise is important. Comparative data for single-tone modulation and 2-tone modulation are given in paragraph 309. Where transmission is by sky-waves the 2-tone modulation method may give service where the single-tone modulation method will not, because of the ability of the 2-tone method to overcome the effects of flat fading. The use of either frequency- or space-diversity is highly desirable in order to effectively overcome selective fading. The arrangements described in the following subparagraphs cover the 2-tone modulation method with space-diversity.

b. Keying Transmitter for 2-tone Modulation Operation. Although certain h-f telephone type radio transmitters are equipped with an audio-frequency oscillator, which may be keyed by the equivalent of teletypewriter contacts for single-tone modulation, it is unlikely that this oscillator can be readily modified for 2-tone modulation. To key the transmitter, it will probably be more convenient to provide a teletypewriter sending circuit that is capable of sending one audible tone for marking and another audible tone for spacing. This circuit may be connected to the microphone jack or equivalent circuit of the radio transmitter. For this method, a tone of 1,785 cycles has been chosen for marking and a tone of 1,955 cycles for spacing. These frequencies are used so as to be within the band of the input filter of the Radio Teletype Terminal Equipment AN/FGC–1 used to receive 2-tone signals (subpar. d below).

c. Improvised 2-tone Modulation Sending Circuit. A teletypewriter sending circuit of this type may be provided by a modification of the sending circuit of two channels of Telegraph Terminal CF–2–B. By providing two sending circuits, one for sending a 1,785-cycle frequency and the other a 1,955-cycle frequency, and by associating these circuits with two sending relays, as shown in figure 3-73, the 1,785-cycle frequency (channel 3) will be sent to the radio transmitter for a marking signal and the 1,955-cycle frequency (channel 4) for a spacing signal. These modifications should be made in the following manner. Disconnect from transformer T4 the sending and receiving filters of other channels and the receiving filter and associated receiving circuits of channels 3 and 4. Connect the windings of the sending relay of channel 4 in series with the windings of the sending relay in channel 3 as shown in figure 3-73. This rewired relay is designated S2. The SEND CARR key in channel 4 is redesignated SP on the *marking* side of the key. No rewiring of the SEND CARR keys is required.

[9] If other channels in the bay are used on a wire circuit, do not operate these switches without proper coordination of frequencies with distant wire terminal.



NOTES
1. OPERATE (SEND FREQ) AND (SEND FILTER) SWITCH TO A (HIGH) CHANNEL 3 AND CHANNEL 4.
2. RELAY (S2) OBTAINED BY RECONNECTING THE (SEND) RELAY OF CHANNEL 4
3. OPERATE (LOOP) SWITCH OF CHANNEL 3 TO (FULL, DUPLEX, NEUTRAL, TO POS. BAT.)

Figure 3-73. Two-tone modulation sending circuit using Telegraph Terminal CF-2-B.

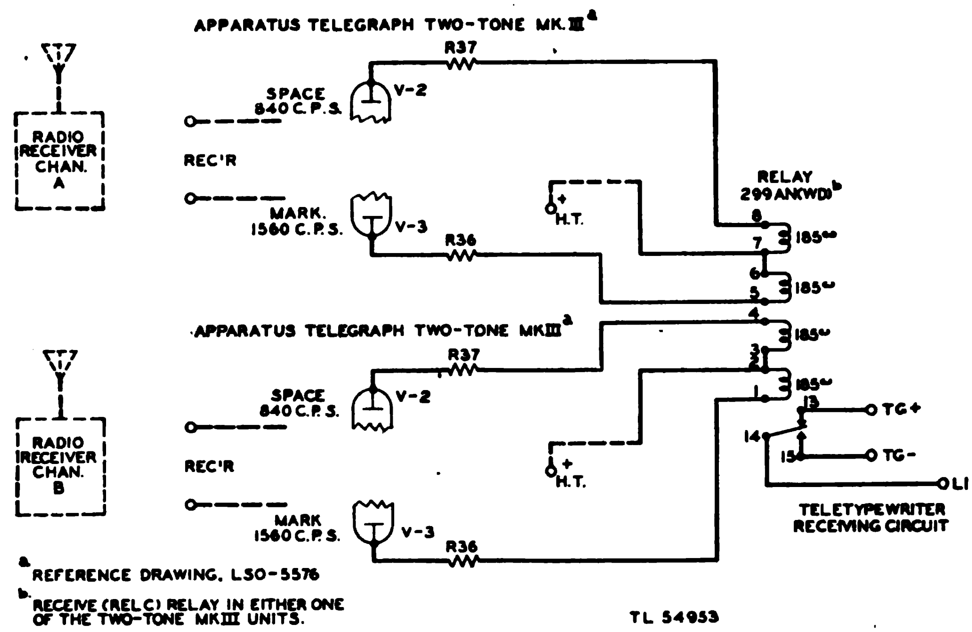


Figure 3-74. Space-diversity reception using two British Apparatus Telegraph Mark III Two-tone.

d. Use of Radio Teletype Terminal Equipment AN/FGC–1 for 2-tone Modulation Reception. Since the 2-tone modulation method is recommended chiefly for sky-wave use, where a limiter in the receiving circuit is needed, a Radio Teletype Terminal Equipment AN/FGC–1 is suggested for receiving, even though it is large and difficult to transport. In order to be able to receive the frequencies available in the sending equipment (subpar. c, above), it is necessary to change the marking and spacing filters in the AN/FGC–1. This may be accomplished by substituting filter FL3 used in CF–2–B equipment for the marking (MCH) filter and the FL4 filter used in the CF–2–B for the spacing (SCH) filter. Two FL3 filters and two FL4 filters are required for one AN/FGC–1 equipment. The narrower filters obtained from the CF–2–B will provide improvement in suppressing noise and are practicable with the 2-tone modulation method because of its inherent frequency stability.

e. British Apparatus Telegraph Mark III 2-tone. (*1*) British Apparatus Telegraph Mark III Two-tone equipment may be available. This is designed to provide service using the 2-tone modulation method. The Mark III equipment contains both sending and receiving circuits for single-channel teletypewriter operation without space-diversity. The marking frequency is set for 1,560-cycle tone and the spacing frequency for 840-cycle tone.

(*2*) The British Mark III equipment contains the necessary apparatus and circuit elements similar to those of the AN/FGC–1 arrangement (subpar. d above), with the possible exception of the current limiter. The characteristics of the Mark III limiters are not well known at present and their performance may or may not be as good as those included in the AN/FGC–1 equipment.

(*3*) To provide space-diversity reception, two Mark III equipments would be required, one connected to each radio receiver; for sending, only one Mark III equipment would be used. The outputs of the two receiving circuits would be combined in a common polar receiving relay, as shown in figure 3-74, for operating the receiving teletypewriter equipment.

347. ARRANGEMENTS FOR TACTICAL FREQUENCY-SHIFT OPERATION.

a. Frequency-shift Keying Methods.

(*1*) High-frequency radio transmitters may be keyed on a frequency-shift basis, using various alternative schemes. The more important ones are described in this paragraph. All of the schemes of keying transmitters on a frequency-shift basis permit control of the keyer on a d-c basis over a pair of wires extending from the teletypewriter sending equipment, either directly or through a relay.

(*2*) The radio transmitter may be keyed by means of a keyer unit which in effect is substituted for the first oscillator section in the radio transmitter. This keyer unit consists of a crystal controlled oscillator with a frequency which differs from the required radio frequency by about 200 kc, and a stable 200-kc oscillator whose tuned circuit frequency can be shifted by about ± 425 cycles. The radio frequency oscillator is modulated by the 200 kc + 425 cycles and 200 kc —425 cycles in response to teletypewriter marking and spacing signals respectively. All modulation products except the sum of the crystal oscillator frequency and of the 200-kc $\pm$ 425-cycle oscillator frequency are filtered out, and the remaining radio-frequency signal with minor sidebands is fed into the first amplifier stage of the radio transmitter. Exciter Unit 0–5/FR (par. 341a (5)) is an arrangement of this type.

(*3*) The frequency of the tuned circuit of some types of r-f crystal oscillators may be varied by adding a capacitor under control of either a diode tube or the contacts of a keying polar relay. The crystal oscillator may be the one normally used in the transmitter. Owing to difficulty in modifying an oscillator not originally designed to include this feature, it is, in most cases, simpler to provide a separate oscillator in an applique frequency-shift keyer rather than use the one in the transmitter. This is especially true if the job is to be done at a depot rather than at the point of manufacturing before the set is shipped. Many types of crystal are unsuitable for such operation; in general it may be said that AT–cut crystals will give best results, BT–cut crystals will be unsatisfactory, and other types may or may not give the desired shift. The proper value of capacitor will have to be determined by test. The amount of shift may be checked by adjusting a receiver with a beat-frequency oscillator to zero beat for the normal crystal frequency, and measuring the frequency of the beat note after shifting, by comparison with tone from a calibrated audio oscillator.

(*4*) A master oscillator (electronic) rather than a crystal oscillator may be used. It may be more practicable to supply an external oscillator as a part of an applique frequency-shift keyer rather than attempt to modify the one normally supplied in the set. A frequency-shift keyer is now being developed for application to Radio Transmitter BC–610 (part of Radio Set SCR–399). This frequency-shift keyer will make use of a master oscillator (electronic) whose frequency will be shifted by a diode tube under control of a polar relay. The output of the keyer will be applied to the radio frequency amplifier in Radio Transmitter BC–610 instead of using the crystal oscillator of the set.

b. Receiving Frequency-shift Signals. For receiving frequency shift signals, a-m type radio receivers, operating in the h-f range and equipped with beat frequency oscillators to provide tone reception of telegraph signals transmitted on a c-w basis, may be used. Either one or two receivers and associated antennas and teletypewriter terminating equipments will be required to take care of reception. Where fading is not present, one receiver only with its associated antenna and terminating equipment will suffice; for longer haul reception two sets will be needed with the antennas separated, one from the other, by a few wavelengths.

c. Radio Set AN/MRC–2.

(*1*) This equipment, as planned for procurement, is described herein for information only.

(*2*) Radio Set AN/MRC–2 will provide a single-channel radio-teletype system using carrier-frequency shift keying and dual space-diversity reception with a modified Radio Set SCR–399. Service may be on a one-way reversible basis using the same radio frequency for both directions of transmission, or on a half-duplex or full-duplex basis using two radio frequencies, one for each direction of transmission. It is proposed to assemble the components of Radio Set AN/MRC–2 in three Shelters (HO–17 or HO–27). In the description which follows, these shelters will be designated as a transmitting shelter, a receiving shelter, and an operating shelter (signal center). Voice communication between shelters may be provided for by use of Telephones EE–8–( ).

(*3*) The equipment proposed for the transmitting shelter includes a modified Radio Set SCR–399, a frequency-shift keyer and a 2-kw radio-frequency amplifier such as that under development for Conversion Kit MC–543. Transmitting Antenna System AS–95/MRC–1 will be furnished.

(*4*) In the receiving shelter, it is proposed to furnish two Radio Receivers BC–342, a space-diversity adapter unit and a monitoring teletypewriter. The adapter unit contains dual-diversity terminating channel equipment, frequency indicator, and power supply. The frequency indicator is furnished to aid the operator in maintaining the proper adjustment of the beat frequency oscillator in each receiver. A receiving antenna with mast sections, guys, wires, coaxial leads, etc., will be supplied.

(*5*) The operating shelter, which will serve as a signal center, will contain a repeater and control unit, teletypewriter sending equipment (manual and automatic), and teletypewriter receiving equipment (page and tape). For teletypewriter equipment, it is planned to furnish one Reperforator Transmitter TG–26–A, two Teletypewriters TG–7–B, together with line units, rectifiers, and necessary operating tables. The repeater and control unit will accept neutral signals from the teletypewriter sending equipment and send polar signals for operation of the keyer. Also, the repeater and control unit will accept polar signals from the dual-diversity adapter and send neutral signals for operating the receiving teletypewriter equipment. This unit will also contain means for manually controlling the radio sets for the desired form of service. Space should be available in this operating shelter for storing a limited quantity of teletypewriter supplies, such as paper, tape, and ribbon.

(*6*) The nomenclature for the frequency shift keyer and the space diversity adapter, together with the repeater and control unit, is Radio Teletype Equipment AN/TRA–7.

(*7*) One Trailer K–52 (Power Unit PE–95) will be used with each shelter as a source of 115-volt 60-cycle power. It is expected that each shelter will include essential maintenance and operating supplies and running spares.

d. Space-diversity Reception Using Two British Apparatus Telegraph Mark III 2-tone Equipments. An alternative dual space-diversity receiving arrangement using British Mark III equipment, may be provided using the *receiving circuits only* of two Mark III units. The input to the receiving circuit of each Mark III unit would be connected to its associated radio receiver and the output of the receiving circuits of the two Mark III units would be combined in a common polar relay (fig. 3-74) for supplying signals to the receiving teletypewriter equipment. Since the filters of the British equipment are separated by 720 cycles (1,560-840) rather than 850 cycles (2,975-2,125), the frequency shift at the transmitter should be 720 rather than 850 cycles; this shift can be obtained with Exciter Unit 0–5/FR. As regards the quality of service rendered with Mark III equipment when arranged for reception of frequency-shift signals on a dual-diversity basis as outlined above, two points will bear mentioning. First, the Mark III equipment is not equipped with a frequency indicator. Such a device will probably be necessary unless the oscillators in the radio sets are stable; otherwise it will be difficult to maintain the beat frequency oscillators in the receivers in proper adjustment to keep the incoming signals within the pass bands of the Mark III filters. Second, the Mark III equipment contains a copper-oxide limiter; it is not known, at the time of writing, whether or not this will perform satisfactorily in frequency-shift systems.

Section VIII. TELEGRAPH TESTING EQUIPMENT

348. POLAR RELAY TEST SETS.

a. Test Set I–193–A.

(*1*) This set, shown in figure 3-75, is portable polar relay testing equipment. It is used to test and adjust the demountable telegraph polar relays used in tactical and fixed plant telegraph and teletypewriter equipment. The relays commonly used in these equipments are relay 255A per D–163119 (fig. 3-76), and relay D–164816 (fig. 3-77). These are moisture-resistant relays. This test set contains, in addition to the polar relay testing features, a source of 10- and 20-cycle dot signals, the latter being used for lining up the carrier circuits of the packaged carrier telegraph terminals. The test set requires a positive polarity of 115 to 130 volts for its operation; this may be obtained from any low impedance rectifier, such as Rectifier RA–37 or Rectifier RA–87, or from the test set battery

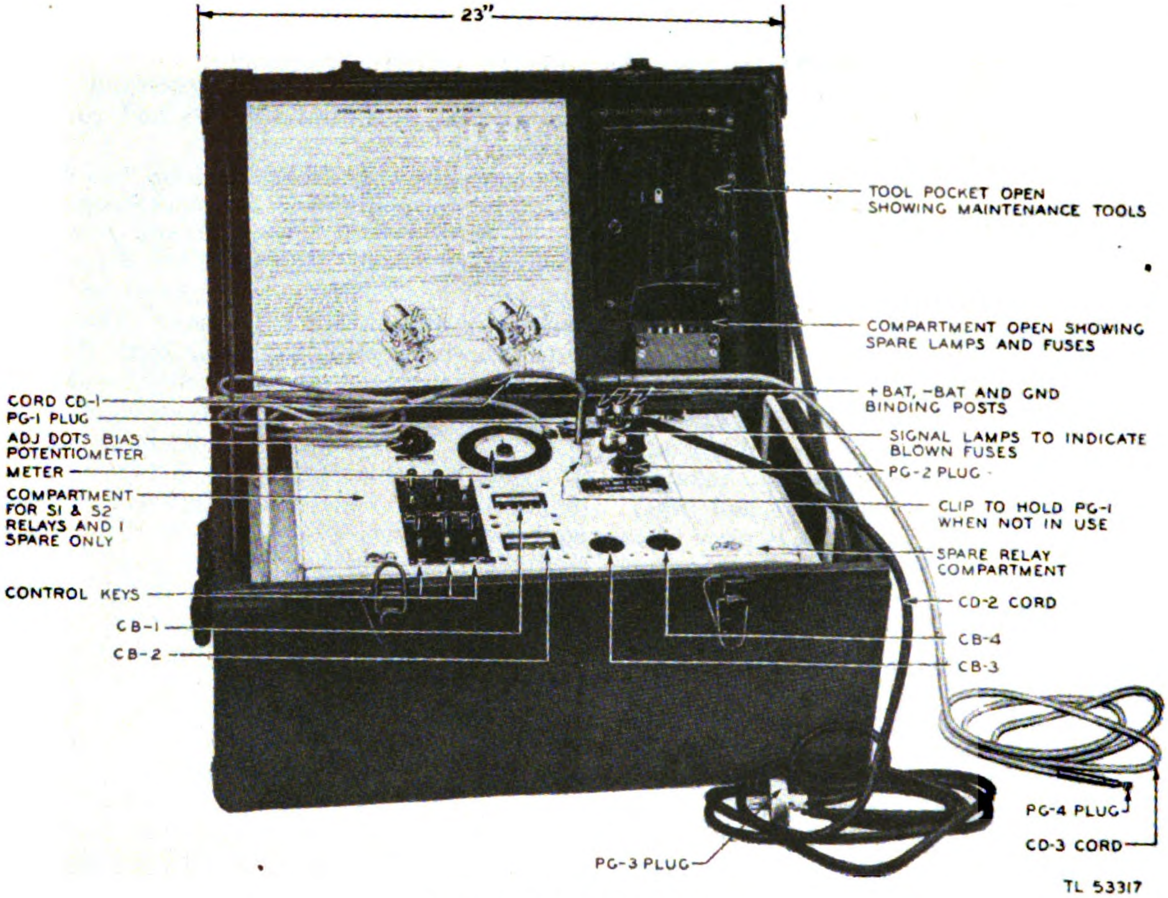


Figure 3-75. Test Set I–193–A.

supply jack in the X–61822 carrier telegraph terminal equipment, the X–61824 d-c telegraph repeater, Repeater TG–30, or Repeater TG–31. A special cord is supplied with the test set for use with Repeater TG–30 and Repeater TG–31. The relay to be tested is inserted in the proper connecting block (CB–1, 2, 3, or 4, fig. 3-75). Relay adjusting tools are furnished with each test set.

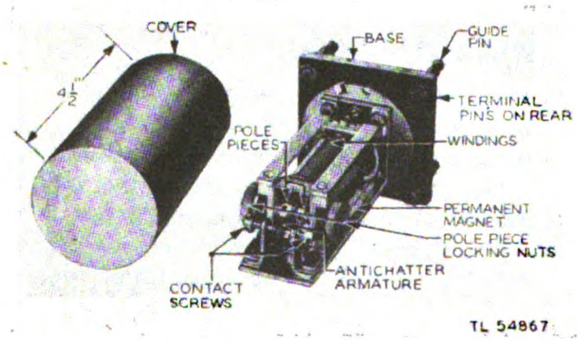


Figure 3-76. Telegraph polar relay 255A per D–163119.

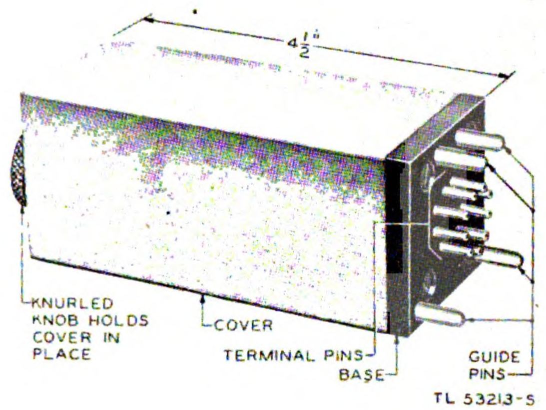
(*2*) Test Set I–193–A is the major component of Test Set AN/FCM–6 (v-f carrier telegraph testing package X–61822C).

b. Test Set X–61809A. A few portable polar relay test sets per X–61809A for testing 255-type relays are now in the field. This test set is no longer in production and is replaced by Test Set I–193–A.

349. TELEGRAPH TRANSMISSION TEST SETS.

a. Test Set TS–2/TG.

(*1*) This test set (fig. 3-78) is for use by tactical and fixed plant organizations. It provides a continuous source of the following neutral (open and close) test signals: letter R, letter Y, repeated space-bar signal, and a test message consisting of THE QUICK BROWN FOX JUMPED OVER A LAZY DOG'S BACK 1234567890 TESTING followed by a *carriage return* and a *line feed.* It can be arranged to transmit undistorted test signals, or test signals with a predetermined percentage of marking or spacing bias, or test signals



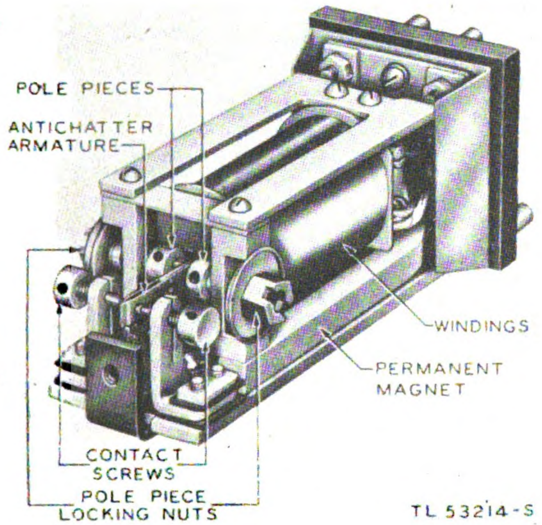


Figure 3-77. Telegraph polar relay D-164816.

with a predetermined percentage of marking or spacing end distortion. The percentage of bias or end distortion can be changed but is not adjustable by external means. The test signals may be used for checking orientation ranges of teletypewriter receiving selectors or for sending over line circuits to distortion measuring apparatus or to teletypewriters in order to check the quality of transmission. The bias and end distortion is used for checking tolerances of teletypewriter equipment and associated line facilities. The space-bar signals may be used with bias meters for adjusting neutral type relays such as those in line units and Switchboard BD–100. The test set is supplied with an a-c governed series motor which may be adjusted for use at 368 or 404 operations per minute. A 60 milliampere test circuit is built into the test set to provide a ready means for measuring the bias tolerances of teletypewriter receiving equipment.

(*2*) Test Set TS–2/TG is the major component of Test Set AN/FCM–3 (d-c regenerative telegraph repeater testing package X–66031B).

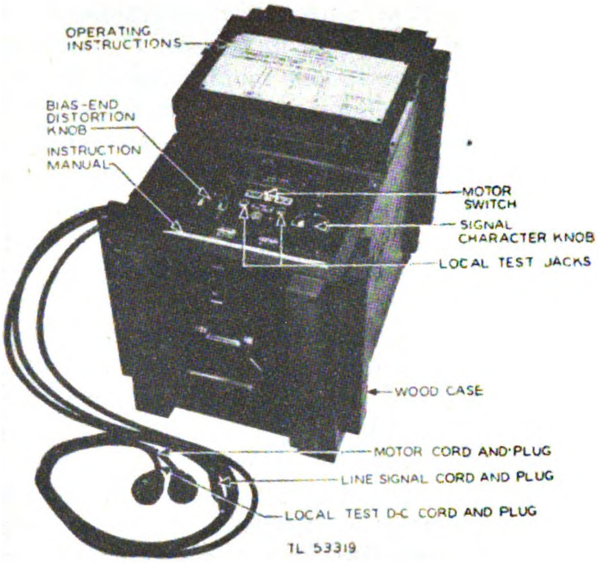


Figure 3-78. Test Set TS–2/TG.

b. Distortion Test Set TS–383/GG. This set (Teletype Corporation nomenclature DXD4) is primarily for maintenance depot use and contains, in general, the sending features of Test Set TS–2/TG but not the 60-milliampere local circuit, and in addition it contains a means for measuring distortion of signals by use of a stroboscopic device. The set (fig. 3-79) is arranged to use an a-c series-governed

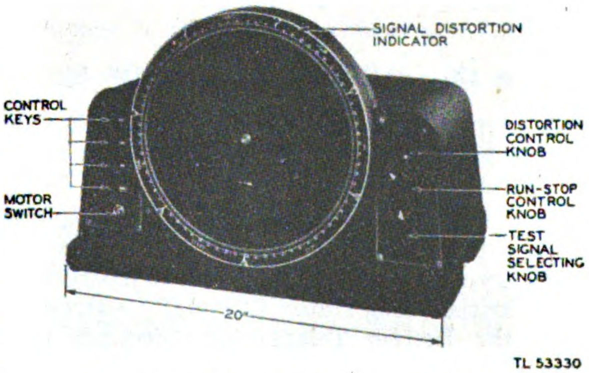


Figure 3-79. Distortion Test Set TS–383/GG.

motor and includes motor unit and gears. It is fundamentally equivalent to its predecessor, Teletype signal distortion test set DXD1 except that it supplies *blank*, T, O, M, V, or *letters* signals in addition to the test message, R, and Y signals.

c. X–66421A Automatic Telegraph-service Monitoring Set. The automatic telegraph-service monitoring set, shown in figure 3-80 provides a means for continuous monitoring of 60, 75, and 100-word-per-minute or 60-word-per-minute double-channel (120 words per minute) teletypewriter circuits. The monitoring set is connected like a teletypewriter in the d-c loop or local circuit of telegraph terminals or repeaters. It observes teletypewriter signals and registers the presence of unit signal elements which have been shortened excessively. If an excessive number of these is registered in a predetermined time, an alarm is sounded, calling in the attendant. By sampling the signals in this way an indication is provided when the transmission has deteriorated to such an extent that service is unsatisfactory or is likely to become so; this is accomplished without requiring continuous monitoring by an attendant. The set is contained in a steel cabinet with full-length doors, front and rear. The dimensions of the cabinet are 22¼ x 17 x 42 inches. The weight is approximately 300 pounds. It operates on a 115- or 230-volt, 50- to 60-cycle power supply.

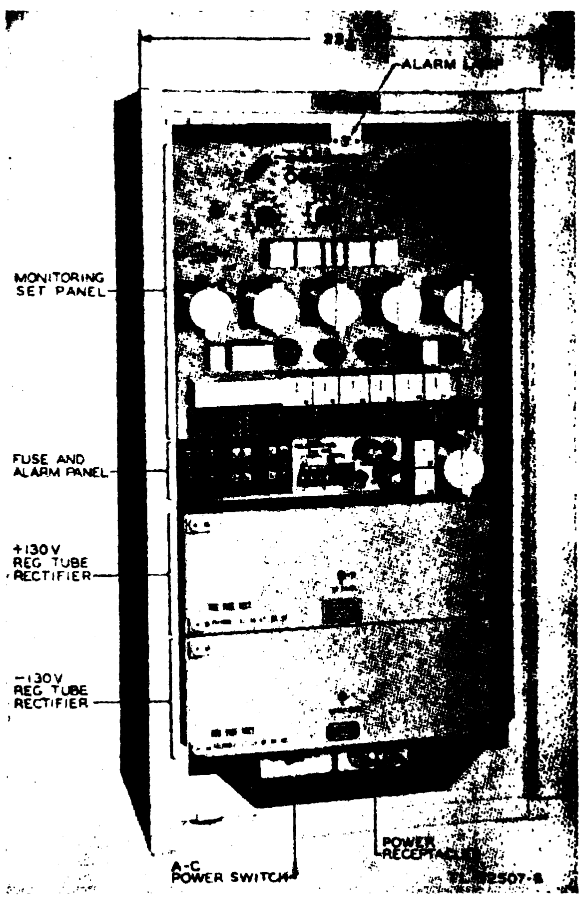


Figure 3-80. X–66421A automatic telegraph-service monitoring set.

Section IX. INTEROPERATION OF BRITISH AND AMERICAN TELEGRAPH APPARATUS

350. INTEROPERATION OF TELETYPEWRITERS USING 2-PATH POLAR OR CARRIER LINE FACILITIES.

a. American teletypewriters and British teleprinters may be operated on the same circuits. Typical circuits are shown in figure 3-81. The British teleprinter is usually associated with the British Teleprinter Terminal Unit Mark IV. It may operate directly over a 2-path polar line to a distant American 2-path polar terminal equipment or on a 2-path polar basis over an extension to a carrier Telegraph Terminal CF–2–( ), CF–6, X–61822, or TH–1/TCC–1 and thence over a carrier channel to the proper American carrier terminal equipment at a distant point. At this point, the extensions may be as required for the American equipment.

b. At the American carrier telegraph terminal, the line current in the extension circuit is adjusted only in the line sending to the British terminal unit. Line current must also be adjusted in the line which receives from the British equipment. In order to do this, a rheostat and meter should be provided at the British equipment.

c. Certain changes are required to permit interoperation of the teletypewriters. The most important is to speed up the American teletypewriter from its standard speed of 368

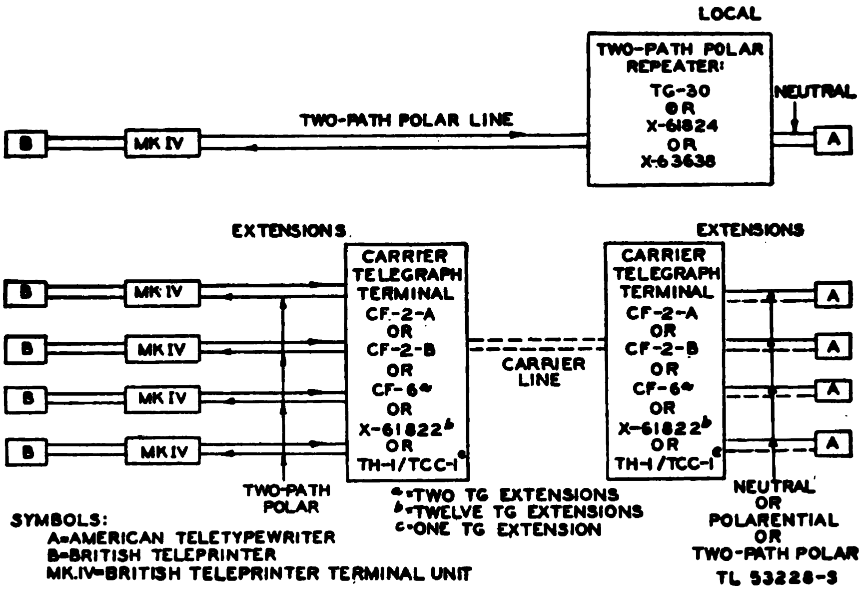


Figure 3-81. Interoperation of American and British teletypewriters.

operations per minute to 404 operations per minute. This is accomplished by the use of a tuning fork (par. 335b(3)) which is a part of Tool Equipment TE–50–A. The standard 10-spot target is retained on the motor governor. Several adjustments are also changed on the American teletypewriter and some differences in the keyboard exist. For information on these points, refer to TM 11–353, Changes No. 3, Appendix (Added), 27 December 1943.

d. In case it is necessary to connect any stations equipped with British teleprinters into a switching network using, for example, Switchboard BD–100, all teletypewriters must be adjusted for 404 operations per minute (subpar. c above) in order to provide interconnections with all stations in the network.

e. The British Teleprinter 7B(WD) is a portable field unit equipped with a polar receiving selecting magnet and polar sending contacts. For single wire 2-way operation, it includes an automatic send-receive switch. This switch is in the receive position when all keyboard levers are normal and it operates to the send position when any key is depressed. The teleprinter may be arranged also for neutral operation by attaching a spring to the selector magnet armature to move it to a spacing position. The automatic send-receive switch is not required for neutral operation. The teleprinters are equipped with a timing device which stops the motors if the line remains marking and idle for about 1½ to 3 minutes. The motors run on 24-volt storage battery and are started by a short spacing signal.

f. American teletypewriters employ a signaling code 7.42 time units in length, each character consisting of a start and five selecting impulses each 1 unit in length, and a stop impulse 1.42 units in length ($6 \times 1 + 1.42 = 7.42$). British teleprinters use the same length start and selecting impulses but the stop impulse is 1.50 units in length, making the signaling code 7.50 units in length. British equipment operates at 400 operations per minute and therefore the American equipment should operate at 404 operations per minute ($400 \times 7.50 \doteq 404 \times 7.42$). The British line signaling frequency is 25 cycles per second.

351. INTEROPERATION OF TELEGRAPH TERMINALS (SPEECH–PLUS–DUPLEX).

The British Apparatus VF Telegraph S + DX and the American Telegraph Terminal TH–1/TCC–1 use the same frequencies for transmission and may be connected on opposite ends of a line circuit as shown in figure 3-82. The filters and v-f ringer are integral in the American equipment, whereas the equivalent apparatus in the British equipment (models 1C and 1W) is in individual cabinets which are interconnected at the time of installation. A later model (S + DX No. 2) is like the American equipment in this respect. The d-c telegraph extension circuits in Telegraph Terminal TH–1/TCC–1 are identical to

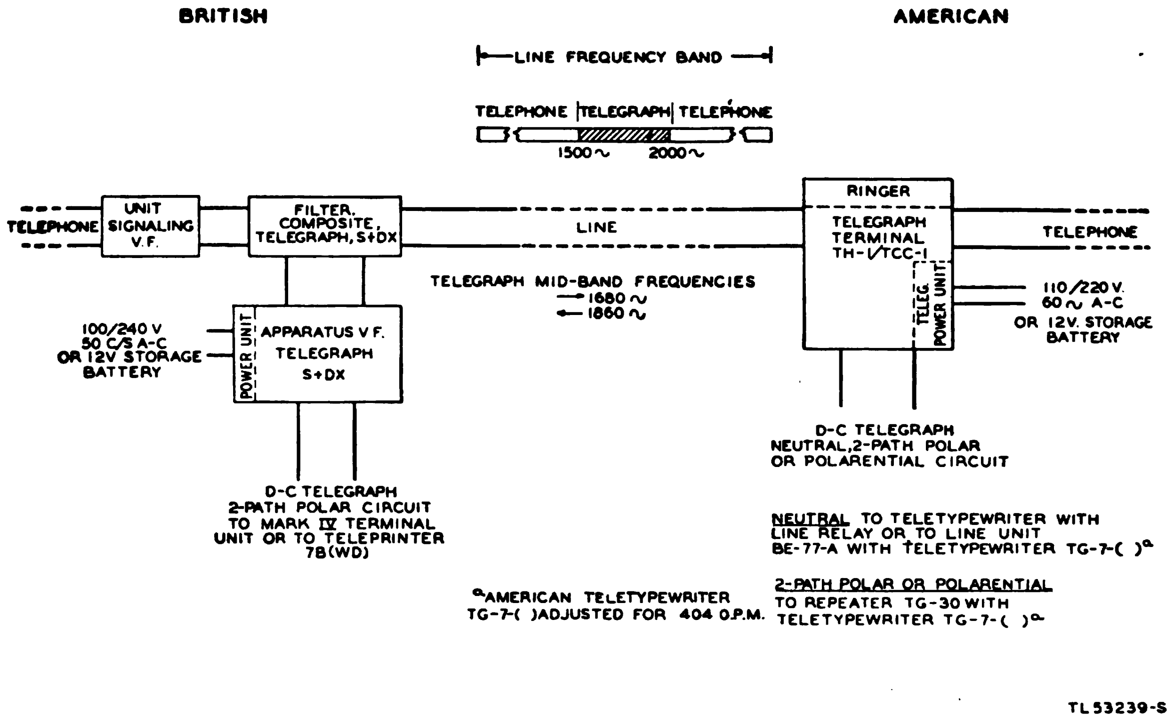


Figure 3-82. Interoperation of British and American S + DX equipment.

those supplied in Telegraph Terminal CF–2–B.

352. TELEGRAPH TERMINAL CF–2–A, CF–2–B, OR CF–6 CONNECTED TO APPARATUS TERMINAL CARRIER TELEPHONE (1 + 4).

The British Apparatus Terminal Carrier Telephone (1 + 4) provides four carrier channels and one voice-frequency channel over either open wire or cable circuits (ch. 5). The voice-frequency channel, also called the physical circuit, is unamplified. The British normally connect their telegraph terminals to the voice-frequency channel (Chan. 1). American terminals may be connected to the British equipment and it is recommended that they be connected to carrier telephone channels (Chan. 2, 3, 4, or 5).

353. TABULATION OF BRITISH ARMY TELEGRAPH APPARATUS.

Figure 3-83, page 114, is a tabulation of the physical and electrical characteristics of British Army telegraph equipment.

Section X. TELEGRAPH PUBLICATIONS

354. REFERENCE LIST.

This section is a list of Technical Manuals and other publications for telegraph and teletypewriter equipments. Other manuals which cover telegraph equipment from the standpoint of systems engineering are given in chapter 1. In the following list, X-numbers are Instruction Books prepared by the Western Electric Company and Instruction Manuals are prepared by the Teletype Corporation.

a. Carrier Telegraph Equipment.

Telegraph Terminal CF-2-A	TM 11-355
Telegraph Terminal CF-2-B	TM 11-355-B
Telegraph Terminal CF-6	TM 11-2009
Telegraph Terminal Set AN/TCC-1, Terminal TH-1/TCC-1, and Filter F-2/GG	TM 11-2206
Voice-frequency Carrier Telegraph (Packaged Equipment)	TM 11-2029 (X-63653) (X-66147)
42B1 Carrier Telegraph Equipment	X-61757
Voice-frequency Carrier Telegraph System Single-sideband High Frequency Radio Telegraph Equipment	X-66578

b. D-c Telegraph Equipment.

Repeater Set TC-18 (Terminal)	TM 11-2004
Repeater Set TC-19 (Intermediate)	TM 11-2005
D-c Telegraph Repeater (Packaged Equipment)	TM 11-2034 (X-66038)
D-c Regenerative Telegraph Repeater (Packaged Equipment)	TM 11-2032
Line Unit BE-77-A and Line Unit BE-77	TM 11-359

c. Teletypewriter Equipment and Sets.

Teletypewriters TT-5/FG and TT-6-/FG (Model 15 Teletypewriter Set)	TM 11-2215 (Instruction Manual No. 7 or 22)
Teletypewriter TT-7/FG and TT-8/FG Model 19 Teletypewriter Set)	TM 11-2216 (Instruction Manual No. 10 or 26)
Teletypewriter Set AN/TGC-1	TM 11-2203
132A2 Teletypewriter set and Associated Equipment	TM 11-2210 (X-66154)
133A1 Teletypewriter Table and Associated Printer Apparatus	TM 11-2211 (X-66152)
133A2 Teletypewriter Set and Associated Equipment	TM 11-2214
XD91 Two-Channel Start-Stop Transmitter-Distributor	X-66355
Reperforator Teletypewriter Sets TC-16 and TC-17	TM 11-2201
Reperforator Transmitters TG-26-A and TG-27-A	TM 11-2220 (Inst. Man. No. 38)
Printers TG-7-A, TG-7-B, and TG-37-B, Chests CH-50-A and CH-50-B, Chests CH-62-A, and CH-62-B. (Teletypewriters)	TM 11-352 (Inst. Man. No. 11)
Telegraph Printer Sets (Teletypewriter) EE-97 and EE-98. Teletypewriter Sets EE-97-A, EE-98-A, and EE-102	TM 11-354
Installation and Maintenance of Telegraph Printer Equipment	TM 11-353 with changes
Instructions for Treatment of Teletypewriter Paper Rolls	TB SIG 28
Interoperation of American and British Teletypewriters in the Field	TM 11-353 Changes No. 3 Appendix (Added)

d. Telegraph Switchboards.

Telegraph Central Office Set TC-3	TM 11-358
Operation of Circuits in Switchboard BD-100	TB 11-358-1
Connection and Line-up Procedure for Switchboard BD-100	TB SIG 52
Telegraph Switchboard SB-6/GG	TM 11-2035

e. Morse-code Telegraph Sets and Equipment.

Telegraph Sets TG-5, TG-5-A, and TG-5-B	TM 11-351 with changes
Instructions for use of Telegraph Set TG-5, TG-5-A, TG-5-B as Tone Keyer	TB 11-351-2
Boehme Automatic Keying and Recording Equipment	TM 11-377
Radio Set AN/MRC-1	TM 11-602
Recorder BC-1016	TM 11-441

f. Radio Teletype and Associated Equipment.

Radio Teletype Terminal Equipment AN/FGC-1	TM 11-356
Exciter Unit O-5/FR	TM 11-2205
Radio Teletype Code Room and Signal center	TM 11-2207

g. Testing and Monitoring Equipment.

Distortion Test Set (Teletype Corp. Models DXD1 and DXD4)	Inst. Man. No. 23 (TM 11-2217 when published)
Test Set I-193-A	TM 11-2513
Test Set TS-2/TG	TM 11-2208 (Inst. Man. No. 43)
Test Set X-61809A	X-63631
Automatic Telegraph-Service Monitoring Set	TM 11-2053
Bias Meter I-97-A	TM 11-2200

Nomenclature	Dimensions and weight				Power[a]	Tubes	D-c extension operation[b]
	Dimensions in use (inches)	Weight (pounds)	Dimensions in case (inches)	Weight in case (pounds)			
Apparatus, VF Telegraph, S+SX No. 3	Terminal 8 x 18 x 14½	47	Same		24v dc, 1.5 amps.	1-ARP7 3-ARP9 Spares 1-ARP7, 1-ARP9	2-line simplex
	Filter composite telegraph 300 or 2,300 cycles 6 x 10 x 6	36	Same				
Apparatus, VF Telegraph, S+DX	Terminal 15 x 23½ x 11¼	94	Same		100/240v ac, 30-40 watts 12-v battery, 3 amps.	5-6V6G	2-line simplex
	Filter 8 x 20 x 7	34	Same				
Apparatus, Terminal, VF Telegraph 3 channel Duplex, Group 1 and Group 2	2 boxes each 22 x 23 x 20	120 each	Same		24v dc, 2¼ amps.	6-VT73 or AR12 6-VT88 or AR13 50% Spares	2-line simplex on each channel
Apparatus, VF Telegraph 6 Channel Duplex	3 bays each 66 x 21 x 16	1,120 total	—	2,465 total	24v dc, 7.5 amps.	1-VT75 or AR11 12-VT73 or AR12 6-VT88 or AR13 20% spares	2-line simplex on each channel

[a] A-c power is 50 cycles.
[b] 2-line simplex similar to American 2-path polar.

Figure 3-83. British
(continued

Max. line loss db	*No. channels*	*Major components required per terminal*	*Remarks*
30 at 1,740 cycles	1	Apparatus VF Telegraph S+SX No. 3, Filter Composite Telegraph 300 cycles, Filter Composite Telegraph 2,300 cycles, Teleprinter 7B (WD), Unit Signaling VF No. 3 with Rectifier No. 7 or No. 2, for voice circuit	Line operation on simplex (half-duplex) basis. Uses frequencies above or below speech band. Carrier 300 or 2,300 cycles. Carrier is transmitted for space. Also may use 1,740 cycle carrier by eliminating voice circuit. 2 separate filters supplied for 300 cycle or 2,300 cycle operation. Voice circuit must use 500/20 cycle ringing. Must provide 24v batteries or Rectifier No. 6; plate supply from rotary transformer in S + SX set. Relay 299AN required to permit remote working to Teleprinter Terminal Unit 80 + 80 Volt connected to a teleprinter.
50 at 1,900 cycles	1	Apparatus, VF Telegraph, S+DX, Filter, Composite, Telegraph, S+DX, Teleprinter 7B (WD), Unit Signaling VF No. 3, Supply Unit Rectifier No. 7 or 12 batteries Dry Refill 8 cell No. 2	Line operation on duplex basis. Uses 1,500 to 2,000 cycles band from speech circuit, equivalent 4-wire carrier frequencies 1,680 cycles and 1,860 cycles. Carrier is transmitted for mark. Consists of oscillators, detectors, power unit, spare tubes. Output +7 db, +2 db, −3 db. Voice circuit must use 500/20 cycle signaling. Portable in metal case. Includes vibrator No. 4. 1 working −1 spare. Requires 24v for tt. Includes neon voltage limiter to keep down voice peaks on associated voice circuit. Models 1C and 1W have filter and signaling unit in separate boxes. Model No. 2 will have them combined with the telegraph apparatus and supplied in a single box similar to the American Telegraph Terminal TH-1/TCC-1.
40 at 1,980 cycles	3 or 6	—	For 3 channels group 2 should be used. Either terminal may be A or B. Group 2 Ch 1 1,980 cycles A-B; 420 cycles B-A Ch 2 1,860 cycles A-B; 540 cycles B-A Ch 3 1,740 cycles A-B; 660 cycles B-A Group 1 Ch 4 1,620 cycles A-B; 780 cycles B-A Ch 5 1,500 cycles A-B; 900 cycles B-A Ch 6 1,380 cycles A-B; 1,020 cycles B-A 2 wire or 4 wire line operation. Includes test transmitter which generates unbiased reversals to line up channels. 4 vibrators No. 2 used plus 4 spare. Must have external power supply for 24v. Built in unit supplies 80 + 80 volts for local extension. Electrically similar to 6 channel systems and will work with it. TT station must be equipped with Teleprinter Terminal Unit 80 + 80 volts. Uses Rectifier No. 6 for A-C operation.
40 at 1,980 cycles	6	Apparatus VF Telegraph Six Channel Duplex, Bays No. 1 and No. 2, Apparatus VF Telegraph Six Channel Duplex, Spare parts case, Apparatus Terminal Carrier Telephone (1+4), Bay No. 3 (Power and Test Bay), Transformer Rotary HT 50 watt No. 1 or No. 2, Teleprinters 7B (WD)	Standard commercial equipment. Electrically similar to VF Telegraph 3 Channel Duplex. May use 2 six channel systems 4 wire to get 12 channels. Max. Receiving Gain 26 db. A and B terminal separate. Filament and plate supply from power and test bay served by 24v office supply. Filament 20.5 volts. Plate 150 volts. One power and test bay may serve 2 VF Telegraph or 2 (1 + 4) Carrier Telephone Terminals.

Army telegraph equipment.

on following page)

Nomenclature	Dimensions and weight				Power[a]	Tubes	D-c extension operation[b]
	Dimensions in use (inches)	Weight (pounds)	Dimensions in case (inches)	Weight in case (pounds)			
Repeater VF Telegraph No. 1	15 x 20 x 73	90	20 x 25 x 15	135	100/240v ac, 12 watts 12-v battery, 1 amp.	2-ARP34 200% spares	—
Teleprinter Terminal Unit Mark IV	8½ x 12¼ x 5½	15	—	—	24v dc, 3 amps.	—	Switched[c] simplex, half duplex, or 2-line simplex all with or without local record
Teleprinter Terminal Unit 80+80 volt	6½ x 8 x 6½	8¼	—	—	80+80 volts dc, 15 to 20 ma	—	2-line simplex with or without local record
Supply Unit Rectifier No. 6	16 x 19 x 7	90	—	—	100/240v ac in steps of 10 volts	—	—
Supply Unit Rectifier No. 7	7⅛ x 7¼ x 9½	12	—	—	100/240v ac in 10-volt steps or 12-volt battery	—	—
Teleprinter 7B (WD)	Floor space—48 x 30 Over-all height 38	210 including 20 for terminal unit	24 x 29 x 14	191	24 volts, 2.5 amps.	—	Switched simplex 2-line simplex

[a] A-c power is 50 cycles.
[b] 2-line simplex similar to American 2-path polar.
[c] American terminology is *reversible one-way polar.* Teleprinter 7B (WD) has automatic *send-receive* switching feature.
[d] Electrically equivalent to Western Electric Company 209 type polar relay.

Figure 3-83. British
(continued

Max. line loss db	*No. channels*	*Major components required per terminal*	*Remarks*
—	—	—	Used with 3 or 6-channel systems. Consists of 2 directional filters and 2 amplifiers. Consists of terminal panel, miscellaneous panel, spare parts panel. Rack mounted. Max. gain 26 db from 300 to 2,400 cycles Directional filters separate bands at 1,200 cycles. Equalization for 7½ or 15 mi. PCQT cable 40 change by U linkstraps. Output +12 dbm. Max. gain 20 db at 2,400 cycles with full equalization. Uses Vibrator No. 4.
—	—	—	Simplification of previous units MK III and uses U links instead of keys to set up connections. Uses 299 AN relay [d] for relayed operation. Teleprinter may operate direct. Requires center tapped 24 volt, 3 ampere d-c supply for telegraph line voltage 12+12 volts. May use higher voltage of suitable battery supplied.
—	—	—	Part of proposed teleprinter network where 80+80 telegraph voltage supplies are available. Relay operates on 15-20 ma. Contacts supply battery to printer magnet. If direct operation of printer magnet is used one Terminal Unit 80+80 volts used. If relayed operation necessary, then it is arranged that 2 Terminal Units 80+80 volts can be used together. Call key included to call Teleprinter switchboard. Must use Rectifier No. 7 for a-c operation.
—	—	—	Provides 22 to 26 volts for operation of equipment requiring 24 volt battery. Furnishes currents up to 6 amps. Intermittent load of 7.5 amps. Full wave metal rectifier.
—	—	—	Provides 80-0-80 volts at 30 ma.; 12 volts d-c 30 ma. filtered; 40 volts, 17 cycle a-c 30 ma. Westinghouse rectifier with vibrator Mallory type G-65.
—	—	Teleprinter 7B (WD), terminal Unit Mark IV or Terminal Unit 80+80 Volts, 24-Volt Storage Battery	This is a Creed machine arranged for portable field use by the Army, It is equipped with polar selecting magnet for receiving and polar transmitting contacts. Can be arranged also for neutral operation. Provided with automatic send-receive switch which is normally in receive position and operates to send position when any key is depressed. Uses 7.5 unit code with a speed of 400 operations per minute equivalent to 66⅔ words per minute which is a line frequency of 25 cycles per second. Timing device stops motor if line is marking and idle for 1½ to 3 minutes. Motor runs on 24-volt storage batterie.

Army telegraph equipment.

on following page)

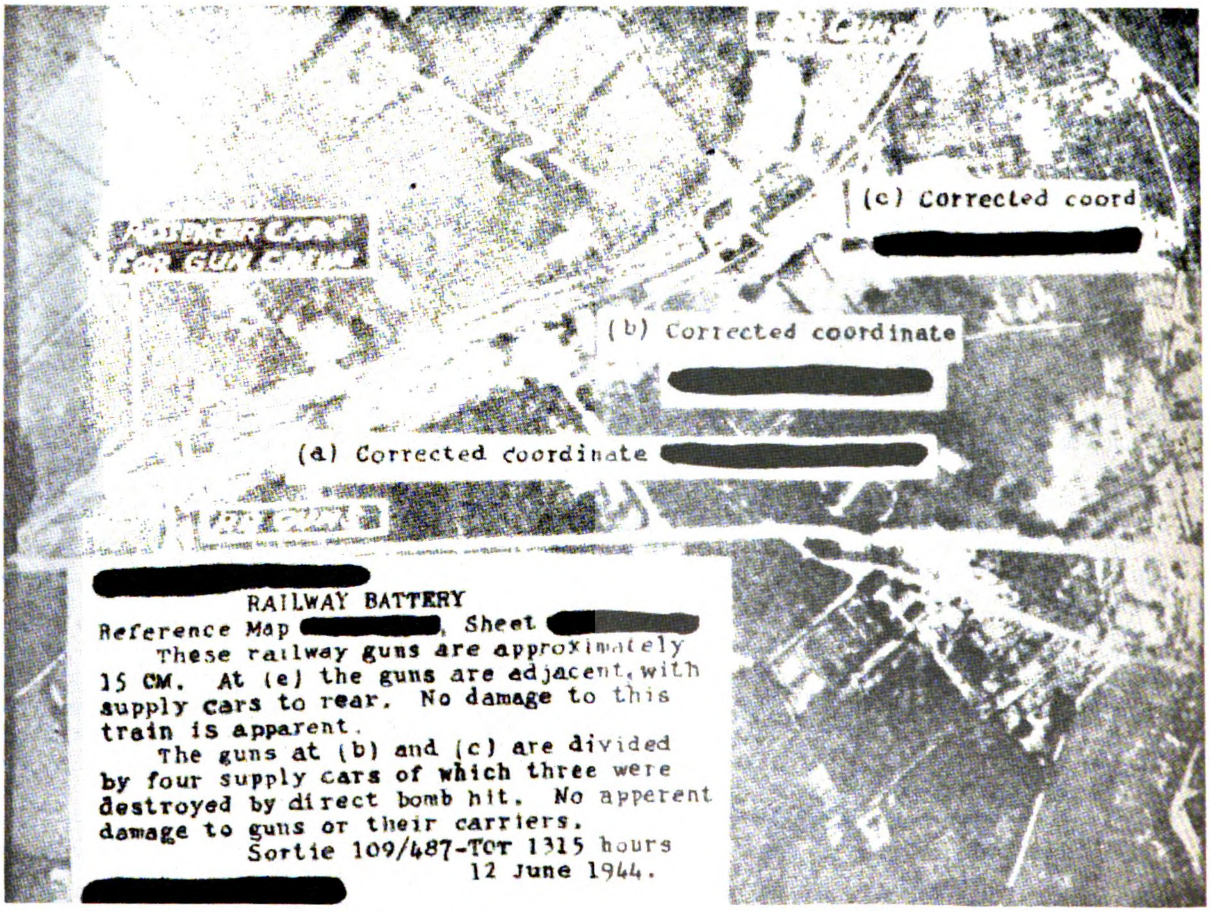
Nomenclature	Dimensions and weight				Power[a]	Tubes	D-c extension operation[b]
	Dimensions in use (inches)	Weight (pounds)	Dimensions in case (inches)	Weight in case (pounds)			
Apparatus, Telegraph; Two-Tone Mark III	18 x 12 x 15¼	70	—	—	24v dc, 3 to 5 amps. (teleprinter and 2-tone unit)	3-6V6 2-6C5	Switched simplex or 2-line simplex with monitoring teleprinter
Teleprinter Switchboard, 15-Line	25½ wide 18 high 21 deep	100	—	—	24v dc, 2 amps. or 80+80 volts, 20 milliamps.	—	Switched simplex with v-f teleg. six channel duplex v-f S+SX No. 2 and 3, S+DX, terminal unit 80+80, local teleprinter
Teleprinter Switchboard, 40-Line	54 high 30 wide 30 deep	300	—	—	24v dc, 2 amps. or 80 + 80 volts, 20 milliamps	—	Same as above

[a] A-c power is 50 cycles.
[b] 2-line simplex similar to American 2-path polar.

Figure 3-83. British

Max. line loss db	*No. channels*	*Major components required per terminal*	*Remarks*
—	—	Main Items are: Apparatus Telegraph Two-tone, Teleprinter 7B (WD), Radio Sender and Receiver Additional Items for Certain Working are: Monitoring Teleprinter, Remote Control Unit "C", Teleprinter Terminal Unit MK III or IV	Portable equipment to provide teleprinter circuit over a radio link; includes sending and receiving features. Two-tone Apparatus when sending modulates carrier wave with one tone (1,560 c.p.s.) for marking and with another tone (840 c.p.s.) for spacing. Receiving side contains two band pass filters (1,560 c.p.s. and 840 c.p.s.) valve amplifier and rectifier. Modulator input circuit impedance is 600 ohms. When working simplex (radio), the radio transmitter (Wireless Set Nos. 12 or 33) may be controlled by *Remote Control Unit C* when two-tone unit and radio transmitter not located together. D-c extension may be to *local* teleprinter or *remote* teleprinter.
—	15 lines	Operator Teleprinter No. 7B (WD), power Supply Units Rectifier No. 7 or storage batteries (24 volts) portable, or Supply Units Rectifier No. 6.	Table mounted type of switchboard with capacity for 15 lines and 7 cord circuits. Simultaneous broadcasting up to six lines is provided for. Interconnects polar circuits operating switched simplex. Space signals used for calling switchboard and for disconnecting; both light line lamps at switchboard. Recall is by *flashing*. Station teleprinters are called by *J Bell* or by *spacing*. Switchboards can be worked together to increase capacity.
—	40 lines	Same as above	Floor mounted type of switchboard with capacity for 40 lines and 15 cord circuits. Other features same as 15 line teleprinter switchboard above.

Army telegraph equipment. (continued).



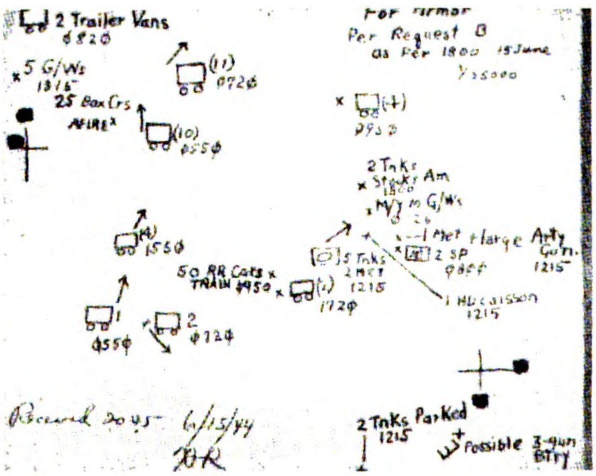


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Figure 4-1. Aerial photograph and map overlay transmitted by facsimile.

CHAPTER 4

FACSIMILE SYSTEMS

Section I. GENERAL DESCRIPTION

401. INTRODUCTION.

a. Facsimile comprises the transmission, by electric signaling, of fixed graphic material including pictures, sketches, text, and handwriting. Pictures (including photographs taken from airplanes), map overlays, and sketches may be valuable means of transmitting military information. Figure 4-1 shows illustrations of a transmitted picture and sketch which are examples of what has actually been used in connection with theater operations. As indicated in this figure, a photograph may be taken from a plane, flown back to the base, developed and then transmitted by wire or radio to an advanced position where it may be used in military operations. Facsimile is also of value for the press.

b. The art is a comparatively new one in electrical communication, and experience has shown that it can be very valuable when put to a use for which it is adapted and when its characteristics and restrictions are clearly understood. Its military usefulness is still in the formative stage, and any specific proposed application requires consideration of what service is desired and what may reasonably be expected to be accomplished. The discussion herein will cover fundamental principles of operation to bring out these possibilities and limitations.

c. Three facsimile machines have been developed by the Signal Corps. These are not interchangeable except as noted. Further information on the physical characteristics of these equipments is given in TM 11–487.

(*1*) *Facsimile Equipment RC–120.* This is a general purpose page machine (fig. 4-2) sending a sheet 7 by 8⅝ inches in about 7½

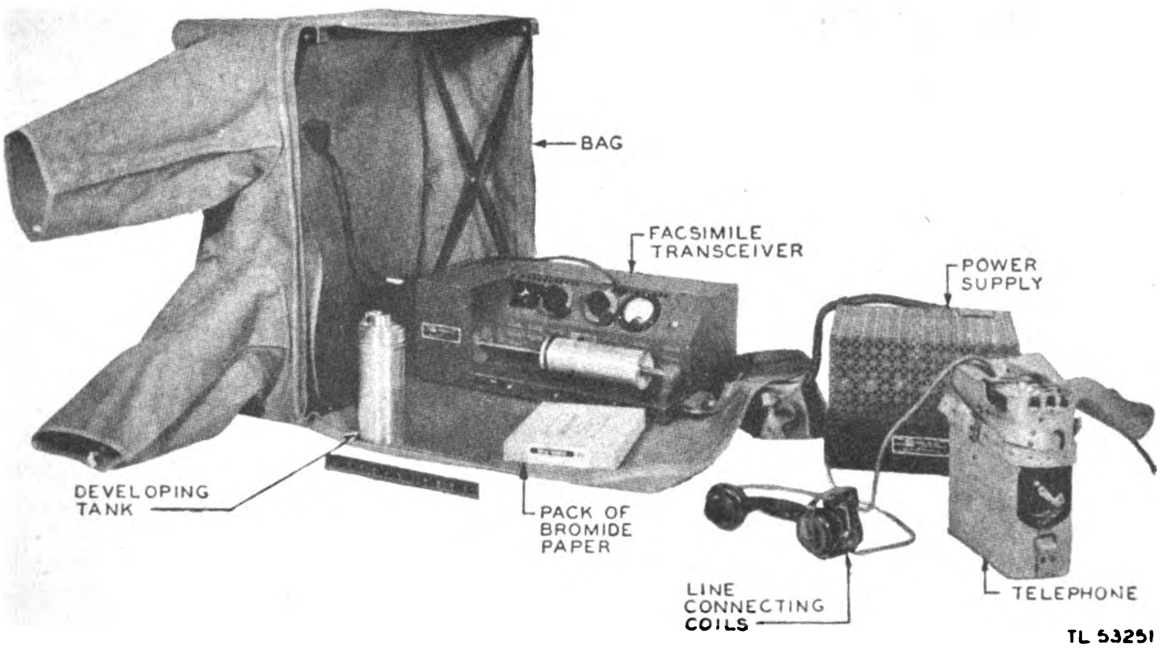

Figure 4-2. Facsimile Equipment RC–120 (page).

minutes. Subject copy of larger size can usually be transmitted with this machine and other page machines by cutting it up into as many separate sheets as are required. It is described in TM 11–375B and TM 11–2252. Facsimile Equipments RC–120–A and RC–120–B include minor improvements in design, but can be used interchangeably with Facsimile Equipment RC–120. Converter CV–2/TX, described in TM 11–2252, may be used with these equipments to change from amplitude to frequency modulation for transmission on radio telephone channels.

(2) *Facsimile Equipment RC–58–B.* This is a machine (fig. 4-3) sending copy in the form of handprinting on tape at 50 inches per minute. It is described in TM 11–374. Transmitting and receiving amplifier equipment is included in a separate box.

(3) *Facsimile Set AN/TXC–1.* In general appearance and technical features, this equipment is similar to Facsimile Equipment RC–120. However, the drum and some associated parts are larger. It is used for sending weather maps and other copy up to 12 by 17½ inches in about 20 minutes and is described in TM 11–375B. Converter CV–2/TX may also be used with this equipment. In view of the difference in picture sizes this equipment can not be used to send to or receive from Facsimile Equipment RC–120.

d. A facsimile network is in operation over a fixed radio system between Washington and the principal foreign theaters. Some notes on this are given in paragraph 402 f.

402. PAGE FACSIMILE.

a. General System. Transmission is carried out by exploring the subject copy, or material

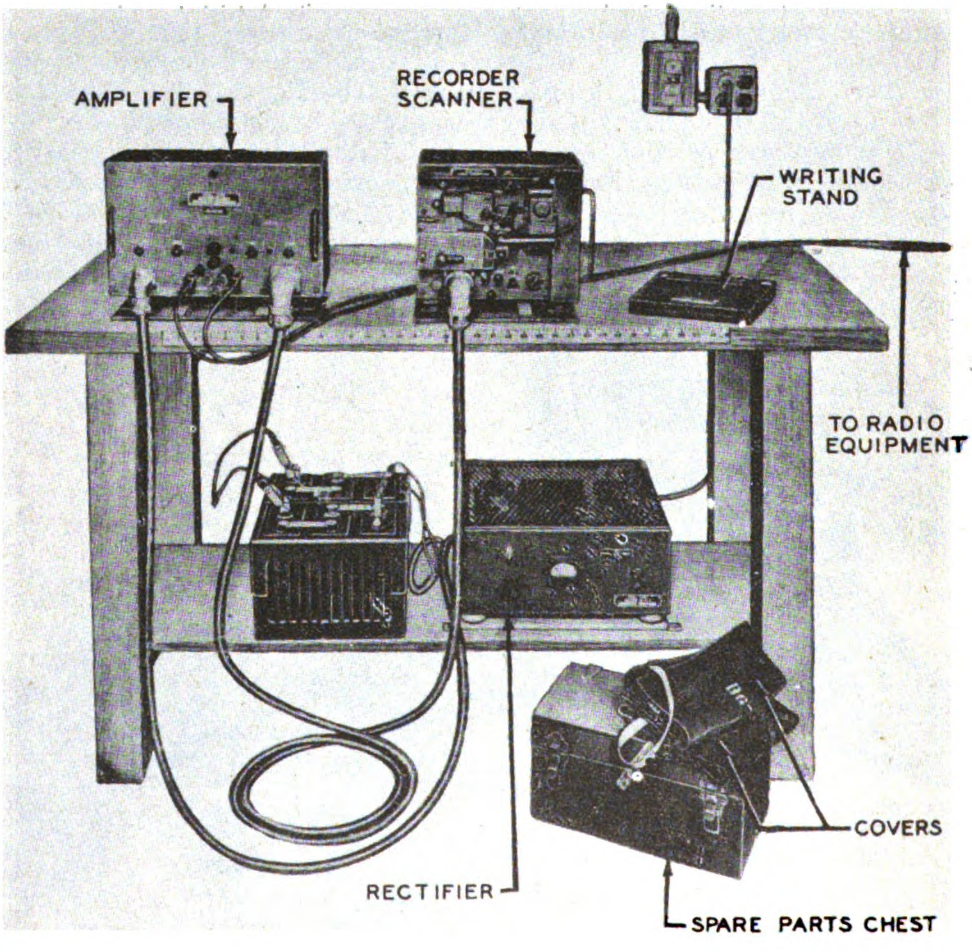

Figure 4-3. Facsimile Equipment RC–58–B (tape).

to be transmitted, with a beam of light along a set of closely spaced parallel lines and translating the blacks and whites of the copy into electrical signals by the use of a photocell. This process is called "scanning". The electrical signal is transmitted to the remote point through a medium, which may be a wire circuit or radio link, in the form of some modulated carrier wave in the voice range that can be conveniently transmitted over an audio channel. At the receiving end the electrical signal is translated into marks on a record sheet which correspond to those on the original subject copy. The marks are placed on the record sheet by a mechanism that traces a parallel line pattern over the sheet corresponding to that at the sending end. In order that the scanning and recording occur at corresponding points in the two sheets, the two motions are synchronized by the use of an accurate local oscillator at each point.

b. Transmitter.

(*1*) The original subject copy is wrapped around a drum which is rotated in front of the scanning head. At the same time the drum moves axially each revolution by an amount equal to the scanning line spacing. A sketch of the arrangement is shown in figure 4-4.

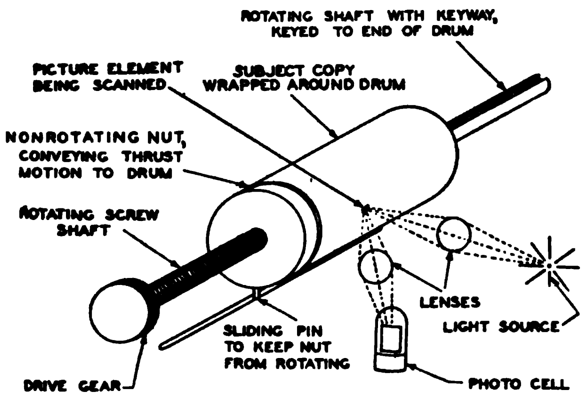

Figure 4-4. Page sending machine.

The light signal input to the exploring photocell has a sustained constant value when a large area of uniform shade of the picture is being explored by the photocell. With a d-c anode supply the photocell output signal would indicate this by a constant value of direct current corresponding to the light input, and markings on the subject copy would be indicated by a modulation of this direct current. Actually, though such a modulated direct current exists in the photocell, it is not used, and the signal is immediately translated into the amplitude modulation of an 1,800-cycle carrier current. The double sideband width is somewhat over 1,250 cycles, extending from about 1,175 to 2,425 cycles. This signal is in a form usuable for transmission over a wire line.

(*2*) Facsimile signals in general tend to use the frequencies in the voice band somewhat inefficiently, as illustrated in a qualitative manner in figure 4-5. Only that part of the

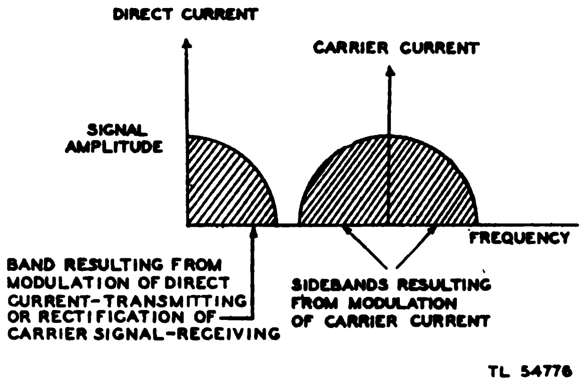

Figure 4-5. Frequency diribution of a-m facsimile signal.

band is used which lies in the upper frequency range. The use of this comparatively narrow band prevents overlap and confusion between the lower sideband of the carrier signal and a band of frequencies one sideband width up from zero frequency. As mentioned in subparagraph (1) above, this latter band of frequencies is generated in the photocell. It is also generated again each time the signal passes through a nonlinear element in the transmission medium.

c. Receiver.

(*1*) The transmitting machine is utilized as a receiver by the use of equipment which is alternative to the scanning head. A choice of several processes is available for translating the received electrical signal into marks on the record sheet.

(*2*) The direct recording process is electrothermal. A stylus is brought to bear on the drum and makes black marks on a specially prepared gray paper (Teledeltos paper) wrapped thereon. At the close of the transmission the copy can be used immediately.

(3) In the photographic process the exposure is made on a film or photographic paper (on the drum) by a modulated light beam from a glow lamp. Recording can be made on film or paper, and the record can be obtained either as a negative or as a positive, according to adjustments made at the sending end. The machine must in this case be operated in a dark room or in a light-proof bag, which can also subsequently permit insertion of the exposed photographic material into a processing tank through the use of armholes. Processing of the photographic material can then be accomplished in the tank in the light outside the light-proof bag.

(4) It is impossible to distinguish detail in the received copy which is finer than the width of the scanning line used in scanning the subject copy at the transmitter. In a general way the markings on the subject copy in an area of the length and width of the spacing between successive lines (*elemental area,* fig. 4-6)

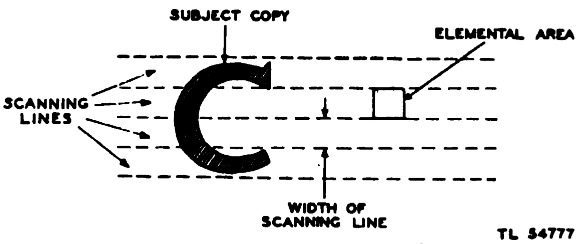

Figure 4-6. Elemental area.

will be averaged together and reproduced at the receiver as an area of more or less uniform density in the record copy. Thus it is impossible to obtain more useful detail out of the received record copy merely by enlarging it.

(5) The choice of recording process to be used at the receiver is a compromise between simplicity of operation and the quality of the result. The photographic process, recording on a film negative from which subsequent positive prints are made, gives the best correspondence in reproduction of detail and in shades of gray from black to white to the original; and this method is needed for high quality work. It is also the only choice which easily permits multiple copies. The direct recording process is the simplest, at the expense of giving the least fidelity. It is probably to be chosen for the majority of the work. The record sheet obtained from one transmission can be used for subject copy for another, but the loss of fidelity in such a retransmission is appreciable. Successive retransmissions degrade the appearance and usefulness of the material rapidly.

d. Synchronization. Extremely accurate tuning-fork-controlled local oscillators are used to control the drum drive motors at the sending and receiving ends. The consequence of a very small speed difference between the receiving and sending drums is quite serious. As an illustration (fig. 4-7), an error in frequency

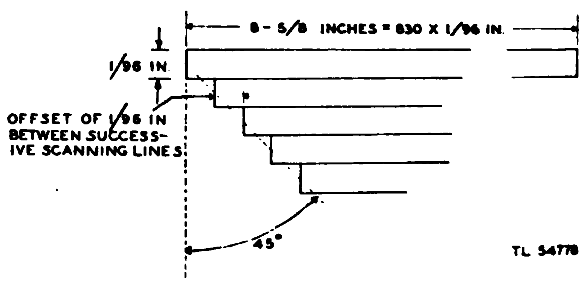

Figure 4-7. Skew caused by synchronization error.

of one part in 830, or 0.12 percent, causes an offset of one line width for every successive scanning line, and consequently a skew of 45° in the record copy. General standards set for commercial facsimile operation call for constancy to 10 parts in a million. It is also necessary to indicate the start of the picture by a suitable signal so that the sending and receiving mechanisms can start simultaneously.

e. Converter. For radio transmission Converter CV–2/TX is available to transform the amplitude-modulated (a-m) signal into a frequency-modulated (f-m) signal. When the system is lined up, a maximum amplitude of the input a-m carrier is translated into an 1,800-cycle output tone. A minimum amplitude of a-m carrier is translated into a 3,000-cycle tone. Intermediate values of a-m carrier are translated into intermediate tones. The output of the converter, therefore, consists of a wave of constant amplitude whose frequency shifts back and forth between 1,800 and 3,000 cycles, according to the input amplitudes and hence according to the lights and shades of the picture being scanned. The total band used, runs from about 1,200 to 3,600 cycles. Figure 4-8 gives a qualitative illustration of this frequency band. This f-m output signal replaces the voice current in a telephone radio link when the link is used for facsimile. Equipment is also provided in the same housing for translating an f-m signal back to an a-m signal for use at the receiving end. Translation in both

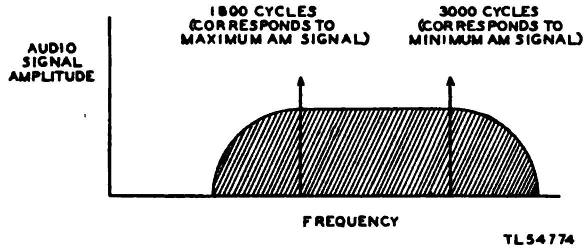

Figure 4-8. Frequency distribution of f-m facsimile signal.

directions simultaneously, however, is not possible. The converter is adapted to operate with both the RC–120 and the AN/TXC–1 machines. The converter is described in TM 11–2252.

f. Fixed Net Equipment. The facsimile equipment in operation between Washington and the principal theaters will send pictures 7 by 8½ inches in 7 minutes, plus one minute for synchronization. The drum is 9.125 inches in circumference, rotates at 100 rpm, and advances 1/100 inch per revolution. The transceiver output is an amplitude modulated 1,800-cycle carrier. Two methods of radio transmission are in use. One employes a converter similar to CV–2/TX, with frequency shift from 1,000 to 2,500 cycles, in the audio signal to be transmitted via wire line and radio link. The other uses the amplitude-modulated signal to shift the frequency of a c-w radiotelegraph transmitter directly, with a white to black frequency swing of 1,500 cycles. In both cases the receiver converts to an f-m signal varying from 1,000 to 2,500 cycles, employing a total band from 300 to 3,200 cycles. This network utilizes equipment manufactured by Acme Newspictures Inc.

403. TAPE FACSIMILE.

a. This machine scans copy in the form of tape. The copy height is ¼ inch and the total width of the tape is ¾ inch. Text is handprinted with pencil by the operator on a writing stand provided with guides and means for holding a roll of blank tape. The copy is threaded through the sending machine which scans it along parallel lines running crosswise of the tape.

b. The sending and receiving machines are mounted in a single housing, and the receiver can be used to monitor outgoing signals if desired. The receiver uses direct electromechanical recording, in which the tape is pressed against an inked printing element to make the marks.

c. The machine handles the tape at the rate of 50 inches per minute and it is expected that about four words can be handprinted every 5 inches. It is impossible, however, to keep up the handprinting on the tape at more than some 15 words per minute. The scanning lines run 72 to the inch and are ⅜-inch high.

d. The amplitude-modulated signals from the photocell pickup are converted to signals which are one of two frequencies: 1,650 cycles for black and 1,150 cycles for white. Either one or the other of these frequencies is transmitted, depending on whether the copy being scanned is black or white. At the receiving station, reception of these two frequencies operates an appropriate mechanical system for producing black and white.

e. Synchronization between sending and receiving ends is effected by a vibrator of approximately constant frequency at each end. The limitation on the speed difference between the two ends is made considerably more lenient than in the case of the page facsimile by printing two lines of received copy on the tape. Imperfect synchronization (fig. 4-9) results in

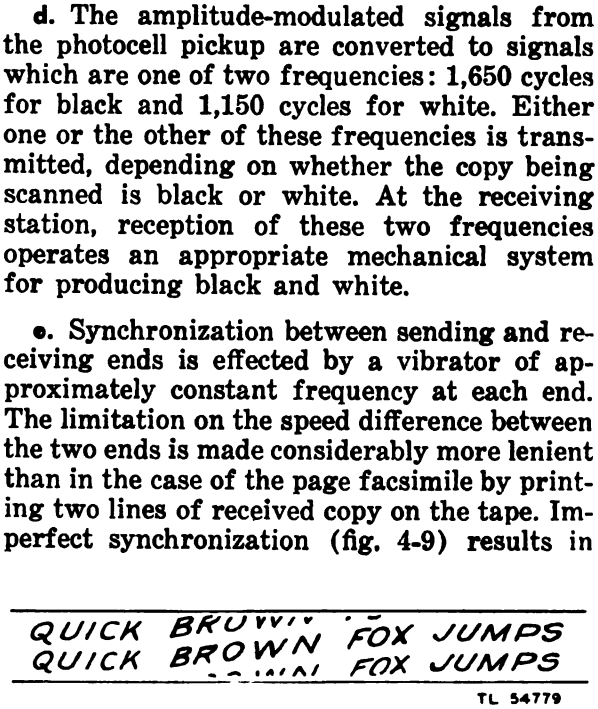

Figure 4-9. Double line reception on tape.

one line approaching an edge of the tape and eventually running off and coming back from the other edge. With two lines of record copy, however, one remains continuous and completely legible.

Section II. TRANSMISSION MEDIUM

404. GENERAL.

Facsimile may be transmitted either by wire or by radio. A wire or radio circuit which is suitable for the transmission of a single voice channel is also suitable for facsimile transmission.

405. WIRE LINES.

a. In normal use, the facsimile system takes over the facilities of a telephone circuit in the transmission medium. The facsimile machine can be coupled to the telephone circuit in three ways, namely: through an attachment placed on the telephone receiver (earpiece of a handset), through a transformer connection, or by direct wire connection to the telephone line.

b. Facsimile is about as susceptible to attenuation-frequency distortion as telephone use of the same channel. Facsimile is, however, more susceptible to *delay distortion*, that is, variations in the transmission time of the various component frequencies of the signal through the band utilized in the transmission medium. Delay distortion is introduced by frequency selective elements in the transmission medium. Examples of sources of delay distortion are: loading in the wire line, filters, repeating coils, and phantom coils. The most common symptom of delay distortion consists of false lines in the received copy paralleling the edges of sharp boundaries between black and white.

c. Other defects to which facsimile transmission is particularly susceptible are interference from other communication channels, echoes, and sudden changes in over-all gain or loss. The susceptibility of the facsimile system to these impairments depends, of course, on the quality of reproduction desired in the received copy. Limiting figures can be given for a high-grade photographic process; the requirements for the other processes will vary with the fidelity required for the character of the material being sent.

d. For general guidance a few limits which have been developed in facsimile experience with wire transmission are listed in figure 4-10. The limits are given for photographic and direct process recording on the equipment described herein, and for general information these are compared with limits for the best grade commercial photographic recording system. The *envelope delay distortion* listed means the difference between maximum and minimum envelope delay in the utilized frequency band. The *envelope delay* is the time of transmission of the envelope of an amplitude-modulated carrier wave, at the frequency of the carrier.

e. Frequency-modulated transmission is expected to be used over wire lines only with the tape facsimile machine. This type of transmission markedly reduces susceptibility to changes in over-all loss (fading), and somewhat reduces the effects of noise. Its influence on effects of delay distortion has not been completely investigated.

f. Facsimile signals may be sent over telephone carrier channels, with the same general limitations as in voice-frequency circuits. However, under some conditions, beat frequencies may arise which lead to bar or moire patterns on the record copy.

	Commercial photographic recording	*Photographic recording*[a]	*Direct process recording*[b]
Sudden changes in over-all loss	0.2 db	0.2 db	1 db
Noise—random (signal-to-noise ratio)	35 db	20 db	17 db
Noise—single frequency (signal-to-noise ratio)	50 db	30 db	20 db
Envelope delay distortion	±0.3 milliseconds	±0.3 milliseconds	±8 milliseconds

[a] RC–120 or AN/TXC–1
[b] RC–120, AN/TXC–1, or RC–58–B

Figure 4-10. Typical limits for facsimile circuit.

406. RADIO CIRCUITS.

a. The principal defects of radio circuits which impair transmission in a facsimile system are:

(*1*) Interference from other radio channels.
(*2*) Static.
(*3*) Fading.
(*4*) Multipath transmission echoes.

b. The limitations on interference from other channels and from static, where the signal is amplitude modulated, are the same as those given under wire circuits. The use of a frequency-modulation signal, from the converter, gives some reduction in susceptibility to this interference.

c. In radio systems, where the sky wave is sufficiently strong to be received, its changing relative phase with the ground wave, or the changing phase between several sky waves, causes fading. The difference in delay between the sky and ground waves, or between several sky waves, causes multiple pictures to be recorded at the receiver. This effect is called *multipath echo,* and facsimile is more susceptible to it than either telegraph or telephone communication just as it is more susceptible to delay distortion. For short circuits these defects are not so likely to be important. For the longer circuits where the sky wave comes in incidentally, or worse, where the sky wave is principally depended upon for the transmission, the defects become serious. The use of a frequency-modulated signal greatly reduces impairments from fading. Its influence in reducing impairments from multipath echo is generally much smaller.

d. The quality of transmission which can be obtained over military radio circuits depends upon a number of adjustments, which are more critical for the picture system than for voice transmission. For example, careful adjustment of the percentage modulation is required to obtain good results. In general, facsimile service over a telephone radio circuit which is subject to fading will be satisfactory a smaller proportion of the time than will telephone service on the same circuit.

407. PRIVACY IN THE TRANSMISSION MEDIUM.

Privacy methods, aside from the use of preenciphered text for subject copy, have been found difficult to use effectively in facsimile transmission. The reason for this difficulty is that the edges of the picture usually show a characteristic discontinuity and that successive scanning lines show close correlation. This periodicity in the signal gives evidence as to the enciphering method used, and critical information for the deciphering of the material. No appreciable privacy can therefore be secured until this characteristic is completely hidden in the signal. Such thorough interspersal is difficult to obtain and rearrange for the legitimate receiver without a fairly substantial amount of apparatus and delicate adjustments.

Section III. FACSIMILE TEXT TRANSMISSION COMPARED TO OTHER FORMS OF COMMUNICATION

408. ELEMENTS OF COMPARISON.

a. General. Facsimile Equipment RC-120 is primarily designed to transmit sketches and diagrams which cannot be done by other forms of communication. However, where it is used to transmit text as such, it competes with these other forms.

b. Word Speeds. The word speed of text transmitted with the Facsimile Equipment RC-120 varies with the size of letters used. With direct recording, typewriter type is about as fine as is practical.[1] Waste space in the form of margins, paragraph indentations and extra space between lines, and the need for arranging messages on a fixed size sheet,

[1] Much higher word speeds than typewriter type permits are theoretically possible if the subject copy is prepared in the form of fine clear printing from type, and photographic reception is used. Solid text of this kind can be transmitted with as much as 40 words per square inch or 300 words per minute. The processing required at both sending and receiving ends, however, makes this procedure generally impractical.

reduce the word speed of the usual subject copy. In the facsimile system time must be allowed to change sheets on the drum at both ends, further reducing the word speed. A practical word speed with these allowances (30 percent for the former and 10 percent additional for the latter) is indicated in figure 4-11 for Facsimile Equipment RC–120. Figures are also given for Tape Facsimile Equipment RC–58–B. These are compared with teletypewriter word speeds.

	Words per minute
Page facsimile with pica typewriter, single spacing, including average waste space, 7 words per square inch	50
Tape facsimile, freely running (transmitting)	40
Tape facsimile, handprinting (to prepare copy for sending)	15
Start-stop teletypewriter, tape sending	60
Start-stop teletypewriter, keyboard sending	30

Figure 4-11. Word speeds.

c. Frequency Band Widths. For effective transmission a facsimile circuit requires substantially a telephone band and displaces the telephone connection. Several telegraph circuits can be accommodated in an equal band width.

d. Noise and Fading on Mediocre Circuits.

(*1*) The frequency band width required for the facsimile system is several times as wide as that needed for a teletypewriter, the factor varying with the arrangement used. The former, therefore, is subjected to some 5 to 10 db more random noise than the latter, under the same noise conditions.

(*2*) Each facsimile character is formed out of a considerably greater number of signal elements than a corresponding teletypewriter character. The failure of a certain proportion of the signal elements to be registered clearly does not, therefore, render the character illegible, whereas it will cause an error in the teletypewriter. Further, the facsimile reception gives a complete record of the signal which permits intelligence to be used in cases of marginal legibility. The teletypewriter interprets the on and off signal in one definite fashion without the use of intelligence in the discrimination.

(*3*) In the teletypewriter, as normally used on wire circuits, the misinterpretation of one pulse can cause errors in a number of successive characters. This can be caused by loss of synchronization or misinterpretation of a carriage-return signal (on a page receiver). However, for use over mediocre circuits, methods are available to overcome these objectionable effects, and with the use of them the teletypewriter suffers no handicap in this regard in comparison with facsimile.

(*4*) In the facsimile system, for freely running text, the loss of transmitted information caused by fadeout (not too prolonged nor too frequent) can be minimized by scanning the text vertically (fig. 4-12). This is because the letters affected do not occur in succession in the same word. In the teletypewriter this cannot be done. The net result of all these considerations is that over a link of marginal quality, facsimile transmission may show an advantage over normal teletypewriter transmission.

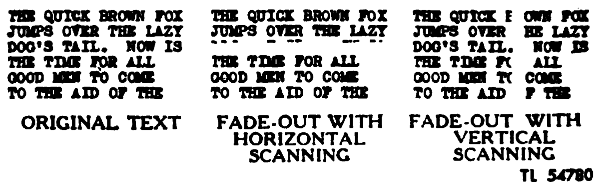

Figure 4-12. Effect of fade-out.

e. Operating Considerations.

(*1*) The received copy obtained from a teletypewriter gives cleaner text than that secured from facsimile. Also the teletypewriter very easily permits the simultaneous making of a number of carbon copies. Where the message has to be relayed, the loss of legibility of facsimile copy in retransmission is a serious handicap. In the teletypewriter system the message can simply be received on a perforated tape which is utilized for automatic sending on the next link. If the message is already clearly typewritten, the facsimile system can use the sheet directly without retyping.

(2) Where the communication, however, is of the question and answer type involving to-and-fro conversation, the teletypewriter is at a considerable advantage because the message can be transmitted and read directly as it is being typed.

(3) In an advanced location where radio is used, the facsimile system has the advantage that the skill necessary for keyboard manipulation at a reasonable speed or for hand telegraph operation is not required. The dial adjustments are of the same general type as those in the radio itself.

(4) The maintenance of the facsimile machine requires some fine mechanical work but much less than a teletypewriter and can presumably be handled by the same force maintaining the radio.

(5) Although no great privacy is obtainable with facsimile, it is superior to straight telephone or manual telegraph, and probably also to unenciphered teletypewriter. Facsimile permits enciphering of text before sending as do the other systems.

409. CONCLUSIONS ON TRANSMISSION OF TEXT

a. Long Wire or Radio Circuit.

(1) *General.* Such a circuit justifies installation of sufficient terminal equipment to maintain a high-grade circuit and to subdivide its frequency band in the most efficient manner. A large volume of traffic is likely to be routed through it.

(2) *Transmission Considerations.* Teletypewriter will be generally chosen for these circuits in preference to facsimile because of the large number of teletypewriter channels which can be accommodated on a telephone circuit as compared to the number of facsimile channels. This is particularly true of long wire circuits.

(3) *Operating Considerations.* These all favor the use of the teletypewriter as against facsimile.

b. Short Wire Circuit. Where traffic is heavy both transmission and operating considerations favor the teletypewriter. Where traffic is light the best arrangement is probably to use d-c manual telegraph or telephone, but lack of manual telegraph operators, the desire for slightly improved privacy, or the desire for a record may occasionally justify facsimile.

c. Short Radio Circuit.

(1) *General.* When it is known in advance that the circuit will be of good quality, the same considerations generally apply as for the short wire circuit. Where this is not known the safe assumption to make for planning in advance is that the circuit will be mediocre. In this case the preferred facilities would be the c-w manual telegraph and telephone, but the desire for slightly improved privacy and a record may occasionally justify facsimile. The following applies to mediocre circuits.

(2) *Transmission Considerations.* Facsimile, telephone, and c-w teletypewriter are roughly equal in their ability to work over a poor v-h-f radio circuit. On poor h-f circuits, fading handicaps both facsimile and teletypewriter.

(3) *Operating Considerations.* These favor the telephone and facsimile systems.

d. Tape Facsimile Equipment RC–58–B. This is generally applicable only to situations where much speed is not necessary, where audible reception, such as with telephone or manual telegraph, is under an unusual handicap, such as in tanks where ambient noise (room noise) is high. Other situations may occur, such as where slightly more privacy is desirable than with teletypewriter, and weight is an important factor. It is thought that the required signal-to-noise ratio is intermediate between that for teletypewriter and that for manual, so that somewhat more transmission range than for teletypewriter can be obtained at relatively slow message speeds, without the necessity for skilled operators.

Section IV. PROCESSES RELATED TO FACSIMILE

410. GENERAL.

Other communication systems may be encountered which are closely related to facsimile. Those most likely to be found are the facsimile printer and the telautograph. These systems have not been used to any great extent, however a description of them is given in this section for general information.

411. FACSIMILE PRINTER.

The facsimile printer, also known as *Hellschreiber* in Europe, makes marks on a receiving tape simulating those which would be obtained if real text had been scanned at the transmitting end. However, the signal is not generated by such scanning but is synthetically produced by a mechanism actuated by keys arranged as on a typewriter keyboard. In this case the same letters will always be formed in the same way and reproduced from the same signal. The transmitter for this equipment is more complicated than that for a regular teletypewriter. Transmission with this system shows generally the same characteristics which are observed with real facsimile except that because of the regularity in forming the signals for the various characters somewhat better economy in the use of frequency bands can be obtained. This type of facsimile equipment is not available through the Signal Corps but may be encountered in Europe.

412. TELAUTOGRAPH.

a. There is a further method of transmitting graphic material, which consists in duplicating at a remote point the motions gone through by a pencil being used for handwriting. Since there are primarily two coordinates involved, at least two communication channels are required. It is necesary in this system to carry out the transmission at the time of actually writing the message or to trace the written message as if writing it anew.

b. Telautograph systems have been developed for use over very short lines (one or two miles or so). Large bold handwriting is needed to obtain legibility. It is not now under procurement and no program has been set up for procuring it.

CHAPTER 5

VOICE-FREQUENCY AND CARRIER TELEPHONY OVER WIRES

Section I. SCOPE

501. INTRODUCTION.

a. This chapter gives engineering information on the types of wire and wire circuits and the types of terminal and intermediate equipment normally associated directly with them in wire telephone systems. Crosstalk considerations and the rehabilitation of captured long distance cable circuits are also discussed.

b. Information on the planning of telephone systems, telephone station equipment, and telephone centrals is given in chapter 2. Other information relative to the engineering, installation, operation, and maintenance of telephone systems is given in chapter 11. Installation and construction of wire lines is covered in chapter 9.

c. Communication requirements near the front differ considerably from those in rear areas. Near the front, speed of installation is essential, and this may result in some sacrifice of service standards even when the work is done by very skilled and careful personnel. In rear areas, it is necessary and practicable to approach the service standards of commercial telephone systems. The requirements of both front and rear areas can be met by use of the wire systems described in this chapter.

d. The wire systems used in front areas are simple and were designed for quick construction. The engineering of these systems is correspondingly simple. Because of the lenient standards tolerable in forward areas, crosstalk and noise difficulties will seldom be of a serious nature; an exception, is the grounded telephone circuit, but this is not standard in the American Army.

e. In more stable areas a better grade of circuit can be provided by more careful engineering, construction, and maintenance. This permits satisfactory communication over long distances (1,000 miles or more) with trunks of low net loss (ch. 2).

Section II. TYPES OF WIRES

502. GENERAL.

The wires used are rubber-covered wires and cable, open wire lines, lead-covered cable, and submarine cable. An aerial construction consisting of two spaced rubber-covered pairs strung like open wire is also used.

503. RUBBER-COVERED WIRES AND CABLES.

a. These include wires with rubber or rubber substitute insulation. Rubber-covered wires can be installed aerially, laid on the ground, or buried, and are comparatively light and flexible. Common types with their weight and 1,000-cycle loss are listed in figure 5-1. More detailed data, including information on other types of wires, are given in section V of this chapter and in chapter 9.

b. Assault wire and field wire are used for loops and short nonrepeatered nonloaded circuits. Wire W-143 is used for voice-frequency circuits where greater range is needed than can be obtained with field wire. The range of Wire W-110-B and Wire W-143 can be extended by means of loading or voice-frequency repeaters.

c. Cable Assembly CC-358-( ) is used primarily for 4-channel carrier operation over intermediate distances (up to 150 miles when placed aerially). This cable is a spiral-four quad (2 pairs) and is supplied in ¼-mile

Nomenclature	Description	Weight[a] (pounds per mile)	1,000-cycle loss[b] (db per mile)		
			Dry	Dry or wet	Wet
Wire W-130-A	Assault wire (nonstabilized)[c]	38	3.5		6.5
Wire W-110-B	Field wire (nonstabilized)	120	1.7		2.8
Wire W-143	Long range tactical wire (stabilized)[c]	240		1.2	
Cable Assembly CC-358-( )	Spiral-four cable (stabilized)	540		0.75	
Cable WC-534 and Cable Assembly CC-345	5-pair cable	600		1.7	
Cable WC-535 and Cable Assembly CC-355-A	10-pair cable	1,200		1.7	

[a] Weight is per mile of product; that is, pair or cable without reels.
[b] Losses are for nonloaded wire, except for Cable Assembly CC-358-( ) which has built-in loading.
[c] See paragraph 503e.

Figure 5-1. Common types of rubber-covered wire and cable.

lengths with connectors at each end. The connectors (fig. 5-2) permit rapid connection of successive ¼-mile reel lengths without splicing. They contain 6 millihenry (mh) loading coils and when joined, a complete system of two loaded pairs capable of transmitting carrier frequencies is provided. If maximum stability is required, it may be obtained by burying the cable to minimize temperature variations. The cable may be used without carrier equipment to provide two voice-frequency circuits. Bridging-Access Plug U–23/G can be used between lengths of Cable Assembly CC–358–( ) to provide a point for testing and access to the circuit. This device consists of a round metal box approximately 4 inches in diameter with three nonloaded cable connectors attached thereto, making the over-all length approximately 7½ inches. The weight is approximately 4½ pounds.

d. The 5- and 10-pair cables are used mainly for short loops where a number of circuits are required. Some of these cables have connectors which can be plugged together for rapid installation. The connectors are not watertight and should be taped or cut off and spliced if exposed to rain or laid in wet places. Cables of this type are also available which are not equipped with connectors.

e. The capacitance, leakage, and loss of the nonstabilized wires (fig. 5-1) increase by large amounts from dry to wet weather. This

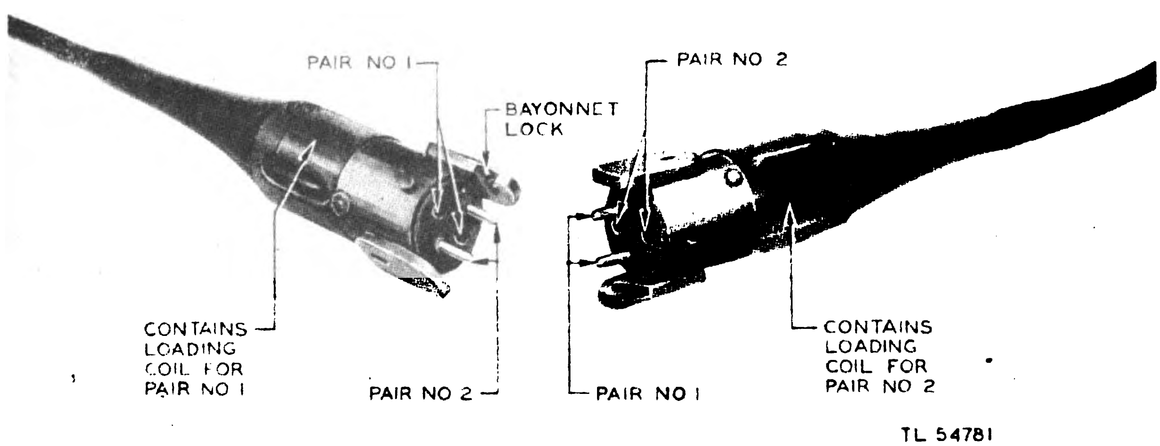

Figure 5-2. Spiral-four cable connectors.

restricts the talking range of these wires, and also limits the improvement in range which can be obtained by use of loading or voice-frequency repeaters. The stabilized wires have a conducting or semiconducting sheath which greatly reduces these changes. The 5- and 10-pair cables are fairly stable when in good condition, provided water does not enter the connectors.

f. Captured enemy rubber-covered wires can be used for voice-frequency circuits if the wire is in good condition. The Germans have single wires, twisted pairs, and spiral-four cable. This latter cable when loaded with the proper loading coils (German) is suitable for carrier-frequency transmission. The principal Japanese wires are single conductors. A description of enemy wires is in TB SIG E 15.

504. SPACED AERIAL PAIRS.

An aerial construction consisting of two *spaced pairs* of rubber-covered wires is useful under some circumstances. The two wires of one pair are connected together to form one side of the circuit and the two wires of the other pair form the other side. The two pairs are spaced about 8 inches apart and are strung like open wire on poles or trees, using insulators when practicable. This gives a large reduction in attenuation as compared with a single pair, except on lines through very heavy foliage. Contacts with foliage, trees, etc. can introduce large leakage losses in the spaced-pair circuit, even though the conductors are insulated. Another use for this form of construction is as an insert in open wire lines in sections where it is not feasible to keep the line clear of tree contacts, etc. The leakage losses introduced by tree contacts will be less for the insulated wire than for bare wire.

505. OPEN WIRE LINES.

a. Open wire lines have relatively low losses at voice and carrier frequencies and can be used to provide circuits with satisfactory transmission for substantially any length within a theater of operations. Open wire circuits are never loaded.

b. A type of open wire construction has been worked out for Army use which combines the features of economy in shipping space and weight of material, simple construction, and transmission characteristics permitting carrier operation up to 32,000 cycles on all pairs. Such lines have transpositions designed for a maximum of two crossarms with four pairs per crossarm. (For a discussion of 4-crossarm lines and use of 10-pin crossarms see paragraphs 557 and 558 respectively.)

c. The wires usually will be 080 or 104 copper-steel for new construction and repair, except where copper is readily available. The copper-steel wires are very strong, take minimum shipping space, and give satisfactory transmission. All-steel wires are not satisfactory for carrier.

d. The British Army has a form of open wire construction known as *multi-airline* (MAL). This provides an extremely light line which can be installed much more rapidly than other types. The line usually has two pairs, one above the other, on short crossarms. British practice is to use one pair for carrier operation and the other as a voice-frequency order wire for use in maintenance of the line.

e. Other types of open wire construction may be found in place or may be rehabilitated for Army use. These lines may have various wire spacings, gauges, and transposition arrangements. Transpositions on some pairs may be good for voice-frequency circuits and on others for both voice and carrier frequencies. The transposition systems may be designed for phantomed or nonphantomed operation of voice-frequency circuits. Suggestions for using existing lines are given in secton VI of this chapter.

f. The construction of open wire lines is discussed in more detail in chapter 9.

506. LEAD-COVERED LAND CABLES.

a. When the situation is stable enough to permit their use, lead-covered cables are used to obtain comparatively large numbers of voice-frequency circuits, usually on a loaded basis with repeaters. By burying the cables, a stable transmission medium is afforded. Short lengths of lead-covered cable are also used as incidental cables in open wire lines; that is, as an entrance cable between the end of the open wire line and the office equipment, or as an intermediate cable between the two sections of an open wire line.

b. Lead-covered cables have paper-insulated conductors twisted as pairs or quads. The cables are manufactured in many sizes from 7 quads (14 pairs) to 150 quads or more. The quads may be of two types: multiple-twin and spiral-four (also called *star-quad*). The *multiple-twin quad* consists of two twisted pairs twisted together to form a quad. The *spiral-four quad* consists of four wires laid together and twisted as a group, the diagonally opposite wires being used as a pair. Lead-covered quadded cables of American manufacture are always multiple-twin but foreign cables may be of either type. The wires in long distance cables of American manufacture are usually 19- or 16-gauge solid copper.

c. When lead-covered cables are terminated at a frame in an office, a short length (at least 5 feet) of *tip* cable must be used between the main cable and the frame. The tip cable is lead covered and has textile insulation which absorbs moisture much less rapidly than paper insulation would if exposed to the air. Tip cables should have quadded conductors if the main cable is quadded.

507. SUBMARINE CABLES.

a. Wire-armored lead-covered paper-insulated submarine cables are used as inserts in communication lines, both open wire and cable. Double-paper-insulated submarine cables of standard design are suitable for depths of water up to 250 feet without danger of sheath collapse or of excessive water penetration along the cable in case of sheath failure. Such cables may function satisfactorily for months or years in greater depths, but there is danger of a gradual sheath collapse or flattening because of the excessive pressure, which may force the wires through the insulation and cause gradual failure. Submarine cables with extra-dense or firm cores and thicker sheaths have been designed for greater depths, up to about 1,000 feet in special cases. For greater depths special cables of different construction are required.

b. Rubber-covered wires and cables can be used as submarine cables provided they are not likely to be subject to excessive abrasion or other mechanical damage; all connections and splices must be made watertight. Installation practices for this purpose are discussed in chapter 9.

Section III. TYPES OF EQUIPMENT

508. TACTICAL AND FIXED PLANT.

a. The types of available equipment may be divided broadly between tactical and fixed plant. This division is descriptive only and does not imply particular limits on the field of use of either type of equipment. The tactical equipment may be used in fixed plant communications systems, or vice versa, when it will give the service desired.

b. Tactical equipment can be moved rapidly from place to place, set up quickly and easily, and used with minimum protection from weather. The equipment includes built-in testing means and has controls and adjustments which are simple and easy to operate. Tactical equipment is normally used with rubber-covered wires and cables, or open wire lines.

c. In rear areas, the fixed plant circuits are apt to be longer and more permanent in nature, a higher grade of service is expected, and operation with a minimum of attention is highly desirable. These requirements make it desirable to use equipment more nearly resembling commercial types. For this purpose, a line of *packaged* equipment is available for voice-frequency and carrier telephone systems and for d-c and voice-frequency carrier telegraph systems. It is similar to commercial equipment but is assembled in units in a manner to require a minimum of engineering and installation effort. It is larger and heavier and requires more power than tactical equipment and must be protected from the weather when set up for operation. High-grade transmission over long distances is possible with packaged equipment, the wires normally used being open wire lines and lead-covered cables.

d. Joint Army-Navy nomenclature was assigned to packaged equipment just before this manual was printed. The packaged telephone equipment referred to in this chapter by its commercial designation, and its equivalent Army-Navy nomenclature is as follows:

Commercial designation	*Army-Navy nomenclature*
H carrier	
Terminal X-66217A ..	Carrier Terminal OA-13/FC
Repeater X-66217B ..	Carrier Repeater OA-10/FC
Line panel X-66217C.	Carrier Filter F-36/FC

Commercial designation	*Army-Navy nomenclature*
C carrier	
East Terminal X-61819P	Carrier Terminal OA-11/FC
West terminal X-61819R	Carrier Terminal OA-12/FC
Repeater X-61819S	Carrier Repeater OA-9/FC
Transfer panel X-61823B	Carrier Filter F-37/FC
V-f telephone repeater	
(single) X-61821J	Telephone Repeater OA-7/FC
(triple) X-61821K	Telephone Repeater OA-8/FC
Line terminating panel	
Simplex X-61823H	Line-simplex Terminal OA–15/FC
Composite X-61823C	Line-composite Terminal OA-14/FC
V-f ringer	
X-61820A	Ringer TA-38/FC
X-61820B	Ringer TA-39/FC

Commerical designation	*Army-Navy nomenclature*
C carrier testing package X-61819T	Test Set AN/FCM-1
V-f telephone testing package X-61821L	Test Set AN/FCM-2
5A (SPL) attenuator	Attenuator TS-402/U
13A (SPL) transmission measuring set	Decibel Meter TS-399/U
19C (SPL) oscillator	Audio Oscillator TS-379/U
32A (SPL) transmission measuring set	Decibel Meter TS-400/U
51A (SPL) oscillator	Oscillator TS-401/U
67B (SPL) test set	Test Set TS-190/U
Volt-ohm milliammeter per D-166852	Multimeter TS-380/U

Section IV. TYPES OF CIRCUITS

509. GENERAL.

This section discusses the characteristics and limitations of the various types of circuits and gives information on such matters as coordination of frequencies and levels of carrier systems, treatment of incidental cables inserted in carrier pairs of open wire lines, and other matters of interest in connection with the choice and use of wire circuits.

510. BALANCED AND GROUNDED CIRCUITS.

All of the telephone systems described in this chapter are balanced (metallic) transmission systems. Ground-return telephone circuits are inherently unbalanced, and are therefore noisier, more subject to crosstalk, and messages over them are more easily intercepted. Ground-return circuits have somewhat lower attenuation at voice frequencies except when installed through heavy foliage where the leakage losses may be much higher than for a balanced circuit. A ground-return circuit requires only one wire thereby providing a considerable reduction in weight, however the circuit is more likely to fail completely because of wire damage. Whenever ground-return circuits are used it is important to have a good ground connection. Methods of making such connections are outlined in chapter 10.

511. PHANTOM CIRCUITS.

If two pairs of wires of the proper type are available, a third transmission path may be derived from them by using one pair of wires for one side of the third circuit and the second pair for the other side. The usual method of doing this is by means of repeating coils as indicated in figure 5-3. This derived circuit is known as a *phantom circuit.* For satisfactory phantom operation on open wire lines it is necessary that the two wires of a pair have approximately equal resistances and that the lines be suitably transposed to prevent objectionable crosstalk among the three constituent circuits of each phantom group and between nearby phantom groups. In cable circuits, crosstalk considerations require the use of quadded conductors (par. 506b.) suitably spliced at appropriate intervals to minimize side-to-side and phantom-to-side crosstalk. Also, the phantom-deriving repeating coils must be well balanced. Phantom circuits tend to be more noisy than their side circuits, or nonphantomed circuits, particularly if the lines or equipment are not maintained in good electrical balance. As a general rule, phantoms are not used on rubber-covered wire, copper-

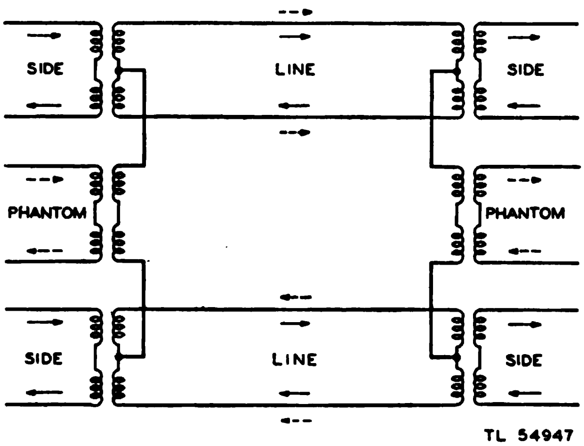

Figure 5-3. Phantom circuit.

steel wires, open wire lines not transposed for phantom operation, spiral-four quads in lead-covered cables, and multiple-twin quads in lead-covered cables having 27 quads or less.

512. NONLOADED AND LOADED CIRCUITS.

a. Open wire circuits are always used nonloaded. Rubber-covered wires or cables and lead-covered paper-insulated cables may be used nonloaded or loaded. Loading is the addition of series inductance at regular intervals along a line. This raises the impedance of the circuit thereby decreasing the series losses due to conductor resistance. Loading increases any shunt losses caused by leakage and also causes the line to have a *cut-off frequency* above which the loss becomes very high. The loss is actually increased by loading at frequencies above about 90 percent of the cut-off frequency. The approximate cut-off frequency and the nominal impedance of a loaded line are given by the following expressions:

$$f_c = \frac{1}{\pi\sqrt{LC}}$$

$$Z = \sqrt{\frac{L}{C}}$$

where f_c = cut-off frequency in cycles
Z = nominal impedance (resistance) in ohms
L = inductance of a loading coil in henries
C = capacitance of a loading section in farads

b. The usual method of designating loading systems is by first indicating the spacing of the loading coils in feet, then the inductance of the side circuit in millihenries (mh), and last the inductance of the phantom circuit, if there is one, in millihenries (mh). For example, 6000-88-50 represents a loading system in which the loading coils are spaced 6,000 feet apart, the inductance of the side-circuit loading coils is 88 mh, and the phantom-circuit loading coils is 50 mh. Similarly 6000-88 represents a nonphantomed loaded circuit with 88 mh loading coils spaced 6,000 feet apart.

c. The loading used by the Army will normally consist of 88-millihenry coils spaced at 1-mile intervals on Wire W–110–B, 5/8-mile (or 1¼-mile) intervals on Wire W–143, and 6,000-foot intervals on lead-covered cable pairs. The cut-off frequency of these loadings is high enough for satisfactory speech channels but they cannot be used for carrier transmission. The carrier loading on spiral-four cable has a high cut-off frequency because the spacing is only ¼ mile, comparatively low capacitance cable is used (0.12 mf per mile compared to 0.19 mf per mile for other field wires) and the inductance per loading coil is only 6 millihenries.

d. On Wire W–110–B where the leakage tends to be high, the reduction in attenuation (transmission loss) brought about by loading is not as great as on Wire W–143 where the leakage losses are at a minimum. In any loaded wire, however, if the insulation between wires or to ground is poorly maintained, for example, by allowing the splices to become leaky, the leakage losses will be high and talking ranges will be decreased to perhaps less than the range of nonloaded wires.

e. When 2-wire loaded circuits are to be repeatered, it is important to have the loading coils spaced at regular intervals in order to maintain a smooth impedance characteristic which can be balanced by the networks in the 2-wire repeaters. In the case of nonstabilized wire, such as Wire W–110–B, both the impedance and cut-off frequency will vary with weather conditions so that only moderate 2-wire repeater gains can be used.

f. In addition to the 88-millihenry loading referred to in subparagraph c above, there are many other types of commercial voice-frequency and carrier-frequency loadings which are available or may be encountered in foreign countries. These include loading systems for phantomed and nonphantomed, 2-wire and 4-wire voice-frequency circuits. Loading for phantomed quads is by means of phantom loading units which consist of three loading coils, two for the side circuits and one for the phantom. These coils have special adjustments to reduce crosstalk between the side and phantom circuits. Data on common American loading systems are given in figure 5-40 and on foreign and American systems in TM 11–487.

513. NONREPEATERED VOICE-FREQUENCY CIRCUITS.

a. These circuits consist simply of a pair of wires terminating in telephones or switchboards. Repeating coils may be provided at the ends for noise reduction, to derive a simplex telegraph connection, or to provide a phantom tap. The pairs may be equipped with composite sets at each end to derive two d-c grounded telegraph circuits. When repeating coils are required, use may be made of Coil C–161, or the repeating coil provided on the line terminating and simplex panel X–61823H or the line terminating and composite panel X–61823C. The latter two units include protectors. The line terminating and composite panel also includes a composite set.

b. Figure 5-4 gives the maximum talking ranges for nonrepeatered circuits on common types of facilities. More detailed transmission information is in figure 5-44 and in chapter 2.

Type of circuit	*Description*	*Miles*	
		Nonloaded	*Loaded*
	Rubber-covered wire and cable assemblies		
W-130-A	Assault wire	4.5	—
W-110-B	Field wire	11	19[a]
W-143	Long range tactical wire	25	94[b]
CC-358-( )	Spiral-four cable	—	40
CC-345	5-pair cable	18	—
CC-355-A	10-pair cable	18	—
	Open wire		
080 C-S, 40%	8-inch spaced pairs	120	—
104 C-S, 40%	8-inch spaced pairs	165	—
104 Copper	8-inch spaced pairs	360	—

[a] 5280-88 loading; that is, 88-millihenry coils spaced 5,280 feet apart.

[b] 3300-88 loading.

Figure 5-4. Maximum talking ranges of representative nonrepeatered point-to-point circuits (30 db in wet weather).

514. REPEATERED VOICE-FREQUENCY CIRCUITS.

a. **General.** The range of voice-frequency circuits can be extended by the use of repeaters. These are of three general types: the 21-type, the 22-type, and the 4-wire repeater.

b. **21-type Repeaters.** A 21-type repeater (fig. 5-5) has a circuit arrangement which requires no balancing networks, and stability

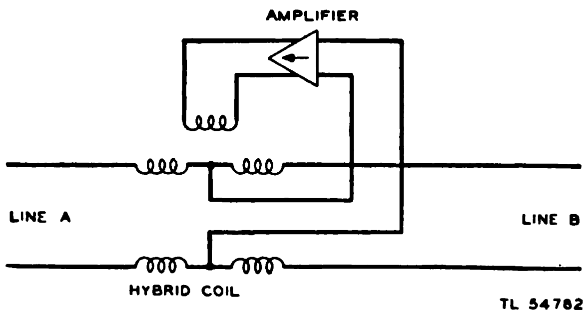

Figure 5-5. 21-type repeater.

(freedom from singing) is realized by the balance between the lines on the two sides of the repeater. As stability depends upon the impedance on the two sides of the repeater being alike, 21-type repeaters are not suitable for use on circuits made up of more than one kind of facility. The best location for a 21-type repeater is at the midpoint of a circuit. With similar wires on the two sides of the repeater, changes of impedance with weather tend to be the same, thus helping to maintain stability. This is of advantage where repeaters are required on nonstabilized wires. It is possible to use a 21-type repeater on a loaded circuit but the usable gain is subject to wide variations and in some cases may be very small. These repeaters can be worked in tandem if the loss between repeaters considerably exceeds the repeater gain but in general there is little transmission advantage in this usage.

c. 22-type Repeaters. A 22-type repeater (fig. 5-6) has a circuit arrangement with two balancing networks. Stability is obtained by

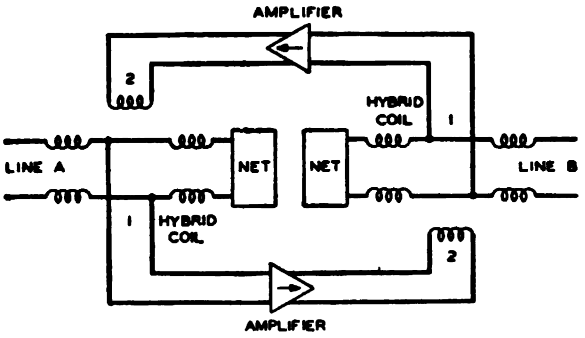

Figure 5-6. 22-type repeater.

the balance between the impedance of each network and its associated line. This type of repeater may be used at a circuit terminal or at intermediate points and will operate satisfactorily in tandem with other 22-type repeaters. These repeaters can be used on any type of stabilized wire for which suitable balancing networks are avilable. They may be used also on nonstabilized wire but at considerably reduced gain. The usable gain of a 22-type repeater is limited to a value giving adequate margin against singing or near-singing. In some cases, crosstalk or echoes, rather than singing, may limit the usable gain.

d. Balance. The principles of balance underlying the operation of 21-type and 22-type repeaters are discussed in chapter 12.

e. Four-wire Repeaters. A 4-wire repeater (fig. 5-7) consists of two one-way amplifiers

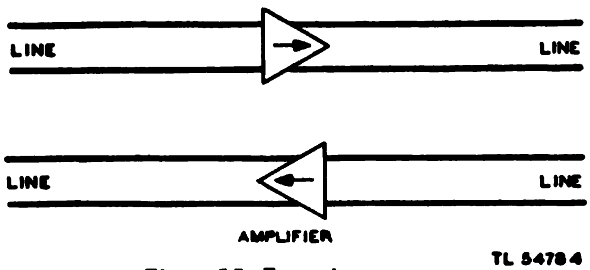

Figure 5-7. Four-wire repeater.

which are pointed in opposite directions for insertion in the two pairs of a 4-wire circuit. Four-wire repeaters can be used at circuit terminals or at intermediate points and can be used in tandem with other 4-wire repeaters. A 4-wire repeater is inherently stable and can therefore be used to give substantial gains on lines of irregular impedance. The usable gains will generally be limited by crosstalk, noise, or transmission variations.

515. TWO-WIRE VERSUS 4-WIRE CIRCUITS.

a. A 2-wire circuit transmits speech currents in both directions over a single pair of wires whereas a 4-wire circuit uses separate pairs for the two directions of transmission. At the terminals of the 4-wire circuit the two one-way paths are combined by means of hybrid coils to provide a 2-wire termination at the telephone or switchboard.

b. Most repeatered Army voice-frequency circuits are on a 2-wire basis because only one pair of wires is required per circuit compared with two pairs for 4-wire circuits. This saves shipping space and reduces line maintenance effort. Four-wire voice-frequency circuits are advantageous over wires having such irregular impedance that operation of 2-wire repeaters is not practicable with reasonable gains. When loading coils are missing or damaged, or where there are other line irregularities, balances may be so low that singing or near-singing will occur with 2-wire repeaters. Four-wire circuits, however, may be obtained over pairs with large irregularities and considerable amounts of gain may be inserted at each repeater point without danger of singing or excessive echoes.

c. Four-wire circuits are also used as trunk circuits in lead-covered cables in rear areas when it is not practicable to obtain the regularity of impedance necessary to permit 2-wire operation.

d. On circuits of nonstabilized wire, such as Wire W–110–B, the variation of net loss (ch. 12) from wet to dry weather is so great that over-all singing tends to be a limitation regardless of whether 2-wire or 4-wire repeaters are used. The result is that on such wire the maximum length obtainable with repeatered 4-wire circuits is little greater than with 2-wire circuits. However, higher gains can be used and fewer repeaters are required with 4-wire operation, and the maximum circuit length can be extended with manual regulation with less difficulty than on a 2-wire basis.

516. PORTABLE REPEATERS.

a. Telephone Repeater EE–89–A. This is a small portable 21-type repeater for use prin-

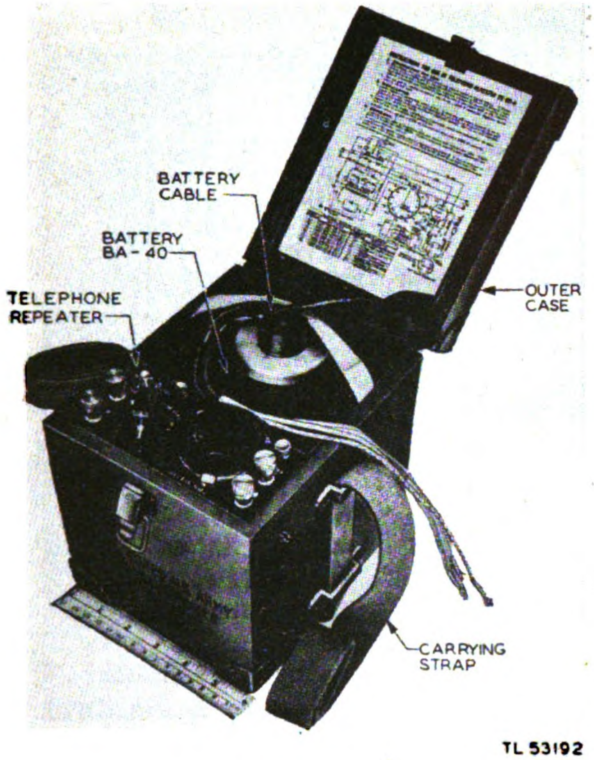

Figure 5-8. Telephone Repeater EE-89-A.

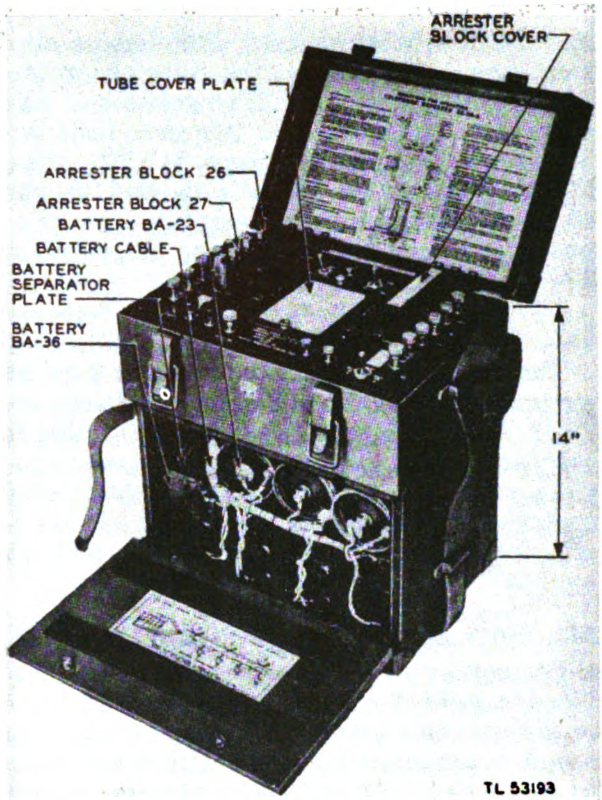

Figure 5-9. Telephone Repeater EE-99-A.

cipally on nonloaded field wires (fig. 5-8). It will pass 20 cycle or 1,000-20 cycle ringing. The simplex circuit is carried through the repeater and is not brought out to terminals. TM 11–2006 covers the description and operation of this repeater.

b. Telephone Repeater EE–99–A. Telephone Repeater EE–99–A (part of Telephone Repeater Set TC–29–A (Voice-frequency)) is a small portable 4-wire repeater, now rated as *Limited Standard,* which may be available in some theaters (fig. 5-9). It is designed for use on field wires. The repeater will pass voice-frequency (such as 500-20 or 1,000-20 cycle) signaling. When 20-cycle signaling is used, the 20-cycle signal is passed over the phantom circuit (par. 511) derived from the two pairs of conductors. D-c telegraph can be operated over the simplex circuits except where 20-cycle ringing is required. Arrangements are included for providing a 2-wire termination on one side of the repeater, for use when the repeater is at a circuit terminal. TM 11–348 covers the description and operation of this repeater.

c. Telephone Repeater TP–14–( ). This is a portable 22-type repeater (fig. 5-10) which became available in 1945. The repeater has built-in adjustable balancing networks and equalizers which are designed to permit operation on most types of Army wire lines. The repeater will pass voice-frequency signaling. Provision is made for bypassing 20 cycles around the repeater so that 20-cycle signaling

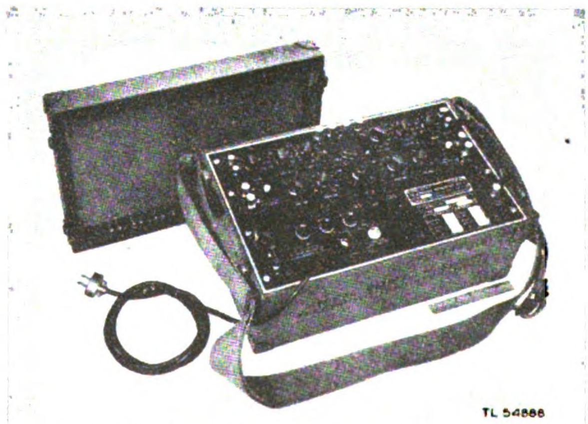

Figure 5-10. Telephone Repeater TP–14–( ).

may be used when desired. Phantom or simplex circuits can be carried through or terminated at the repeater. Composite sets and composite balancing sets are not included. The repeater operates from 115-230 volts, 50-60 cycles ac, or 12 volts dc and weighs 46 pounds, including the carrying case. Telephone Repeater TP–14–( ) is described in TM 11–2007.

517. TELEPHONE TP–9.

The range of nonrepeatered point-to-point circuits can be increased by use of Telephone TP–9. This telephone has fixed transmitting gain and adjustable receiving gain, and provides reversible one-way transmission under control of the push-to-talk switch on the handset. Information on this telephone and its application is in chapter 2.

518. PACKAGED VOICE-FREQUENCY REPEATER.

Packaged voice-frequency repeaters are provided in units of either one repeater (fig. 5-11) or three repeaters (fig. 5-12). Each repeater in a unit is arranged for use as either a 22-type or a 4-wire repeater. The repeaters include built-in composite sets, adjustable equalization for 2-wire and 4-wire circuits, and adjustable networks for balancing almost any type of 2-wire line. Each unit includes a power pack for a-c operation, and a bridging circuit to permit talking from a repeater to any other

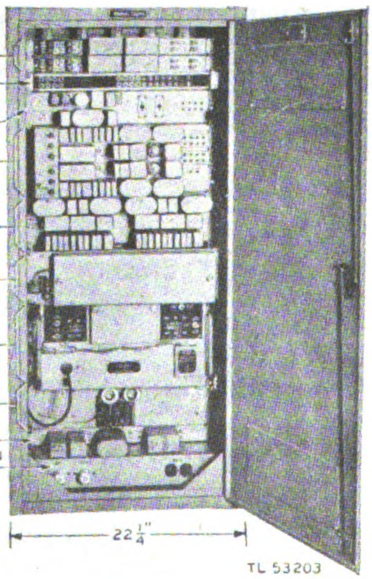

Figure 5-11. Packaged voice-frequency telephone repeater X–61821J.

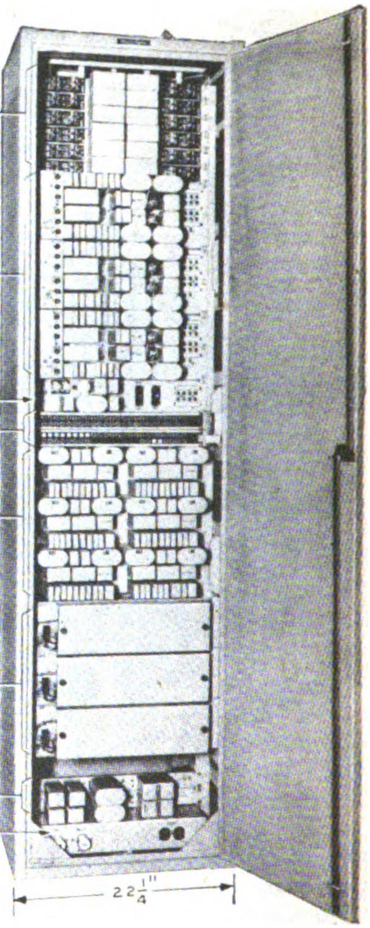

Figure 5-12. Packaged voice-frequency telephone repeater X–61821K.

repeater or to the circuit terminals. Two 1,000-20 cycle ringers are included in the cabinet with the single repeater unit. They may be used with any circuit in the office which requires a ringer. The 3-repeater unit does not include ringers. The packaged repeaters are designed for fixed plant service, the principal use being on open wire lines and lead-covered cables on a 2-wire basis, and on lead-covered cables on a 4-wire basis. The equipment and installation procedures are covered in TM 11–2028 and TM 11–2027.

519. COMPARISON OF REPEATERED AND NONREPEATERED CIRCUIT LENGTHS.

A comparison of the allowable circuit lengths for repeatered and nonrepeatered circuits is given for typical cases in figure 5-13. A single repeater in the middle of the circuit is assumed. Where trunk circuits with several repeater sections in tandem are involved, the repeater sections will generally be shorter (par. 542). Repeater spacings for other types of facilities are discussed in paragraph 541.

Type of circut	Circuit length (miles)	
	Non-repeatered	With 2-wire repeater
Point-to-point circuits [a], *30-db net loss*		
Wire W-110-B	11	15 [b]
Wire W-143	25	37 [b]
080 C-S open wire pair	120	180
Trunk circuits [a], *6-db net loss*		
16 ga., lead-covered cable	8	35
16 ga., loaded [c], lead-covered cable	32	110
19 ga., lead-covered cable	5.5	24
19 ga., loaded [c], lead-covered cable	17	58
080 C-S open wire pair	24	85
104 C-S open wire pair	33	115
104 Copper open wire pair	72	255

[a] Circuits are nonloaded except as indicated.

[b] These figures are for Repeater EE–89–A (21-type); all other figures are for a 22-type repeater with a 15-db gain for open wire and loaded cable circuits and 20-db gain for non-loaded cable circuits.

[c] Loading 6000-88; that is, 88 millihenries at 6,000-foot intervals.

Figure 5-13. Comparison of maximum circuit lengths of non-repeatered circuits and circuits with a single repeater.

520. CARRIER SYSTEMS, GENERAL.

a. A carrier system makes it possible to obtain a number of independent telephone circuits over the same transmission path. This is accomplished by shifting the usual 200- to 2,800-cycle telephone band to another frequency range such as 3,200 to 5,800 cycles. This is similar to transmission over radio circuits except that radio circuits usually work on a double side band basis taking twice as much frequency space as the original voice band, whereas the wire carrier systems eliminate one side band and the carrier current, thus saving frequency space on the line and more effectively using amplifier power. The process of shifting the telephone bands and stacking them one above the other in the frequency range is carried out in the carrier terminal equipment which is always required for a carrier system. The operating length of carrier systems can be increased by the use of carrier repeaters at intermediate points. Army types of carrier systems are used on open wire and suitably designed rubber-covered wires, but ordinarily are not used on lead-covered cables.

b. Carrier operation is desirable because it permits maximum use of existing facilities, reduces the amount of open wire construction, and saves in shipping space and weight of materials. The carrier equipment can be transferred readily from one location or area to another as requirements change. The time required to establish a given number of carrier circuits on existing wire is much less than is required for stringing new wire.

c. Carrier systems are of three kinds which differ in the way the two directions of transmission required for telephony are handled. These three kinds are physical 4-wire, balanced 2-wire, and equivalent 4-wire. The particular type used has important reactions on the application and layout of carrier systems. All three kinds are used with tactical equipment. Fixed plant carrier systems using packaged equipment work only on the equivalent 4-wire principle.

d. Physical 4-wire systems use separate pairs and the same band of frequencies for each direction of transmission. The system uses two independent one-way paths like an ordinary 4-wire telephone circuit except that the frequency band extends beyond the voice range. Physical 4-wire systems are used for carrier on cables because this results in the lowest practicable top frequency and attenuation for a given number of circuits. When used on open wire lines, physical 4-wire systems are subject to high crosstalk between high-level outgoing currents of one system and low-level incoming currents of the same frequency on another system, unless repeater spacings are suitably reduced.

e. Balanced 2-wire systems use only one pair of wires and the same frequency band for each direction of transmission. Hybrid coils and balancing networks are used at terminals and repeaters to separate the two directions of transmission. The transmission path between terminals is like an ordinary 2-wire telephone circuit except for the higher frequencies used. Freedom from instability and singing is obtained by the balance between the lines and networks and by use of short repeater sections with only moderate gains. Balanced 2-wire operation is of use

Carrier system	No. of circuits	No. of pairs	Type of line	Type of operation	Approx. frequency range (kilocycles)	
					A to B	B to A
Spiral-four	4	2	CC-358-( ) or open wire	Physical 4-wire	0.2-11.6	0.2-11.6
Carrier hybrid	4	1	Open wire	Balanced 2-wire	0.2-11.6	0.2-11.6
Open wire converter	4	1	Open wire	Equivalent 4-wire	20.8-32.2	0.2-11.6

Figure 5-14. Tactical carrier systems.

principally on open wire lines but can be applied also to other types of wires for short distances. The number of balanced 2-wire carrier systems that can be worked on an open wire line without danger of high crosstalk between different systems will depend on the repeater spacing, type of line, etc. (par. 523e).

f. Equivalent 4-wire systems use only one pair of wires but the frequency bands for the two directions of transmission are different, one band being above the other in frequency. Separation of the two directions at repeaters and terminals is done by means of filters. This avoids the disadvantages of 2-wire balanced operation while requiring only one pair of wires and retaining all of the transmission advantages of a 4-wire circuit. However, these advantages are gained at the expense of more than doubling the top frequency of the system. For this reason, equivalent 4-wire carrier operation is normally used only on open wire lines. As a given frequency band always transmits in the same direction for any system on the line, crosstalk is of the far-end type. Therefore, repeaters of higher gain can be used and a large number of systems can be worked on a line with suitably designed transpositions.

521. TACTICAL CARRIER SYSTEMS.

a. The types of tactical carrier telephone systems and the lines on which they are normally used are listed in figure 5-14. The spiral-four system using Telephone Terminal CF–1–( ) and Telephone Repeater CF–3–( ) is designed for use on Cable Assemblies CC–358–( ) but may be used also on open wire. The carrier hybrid system uses the spiral-four equipment plus Carrier Hybrid CF–7, which makes possible carrier operation on open wire on a pair per system basis. The open wire converter system using Telephone Terminal CF–1–( ), Converter CF–4–( ), and Repeater CF–5–( ) is the most suitable tactical system for open wire, where commercial standards are to be approached.

b. Voice-frequency carrier telegraph systems can be operated over the telephone channels of these systems as discussed in chapter 3.

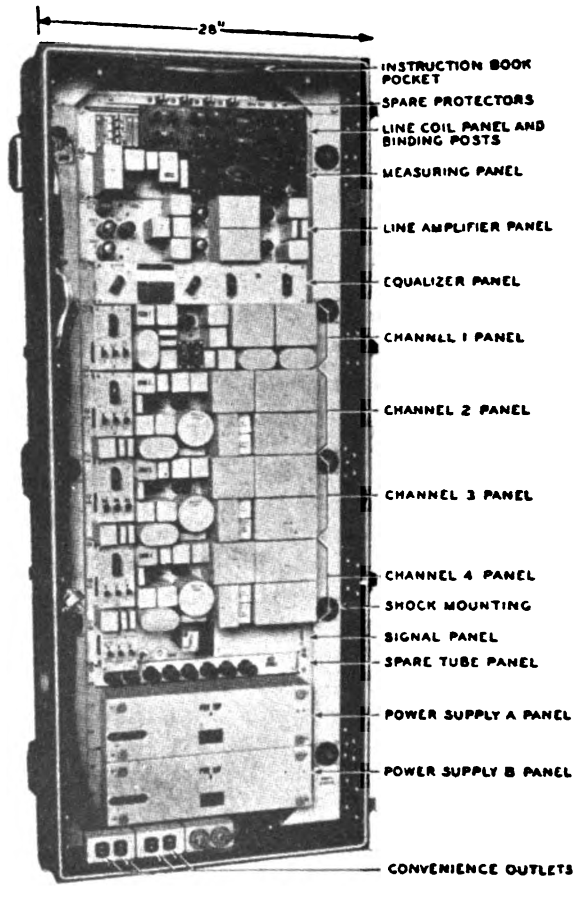

Figure 5-15. Telephone Terminal CF–1–A.

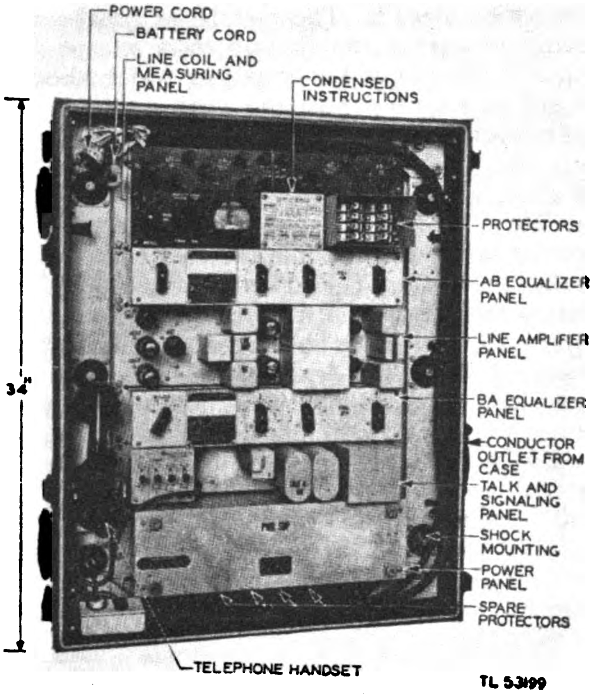

Figure 5-16. Repeater CF-3-A.

522. SPIRAL-FOUR CARRIER SYSTEM.

a. General.

(*1*) The basic equipment units of the spiral-four carrier system are Telephone Terminal CF–1–( ) (Carrier), part of Telephone Terminal Set TC–21 (Carrier) and Repeater CF–3–( ) (Carrier), part of Repeater Set TC–23 (Carrier).

(*2*) Telephone Terminal CF–1–( ) and Repeater CF–3–A are shown in figures 5-15 and 5-16 respectively. The equipment is described in TM 11–341. Information on a complete 100-mile spiral-four system, Carrier System AN/TCC–2, is given in TM 11–2001.

b. On Cable Assembly CC–358–( ).

(*1*) The spiral-four carrier equipment is designed basically for use as a physical 4-wire system on Cable Assembly CC–358–( ). Figure 5-17 shows schematically the arrangements for nonrepeatered and repeatered circuits.

(*2*) Each system provides one voice-frequency and three carrier telephone circuits in the frequency range 0.2 to 11.6 kc. Transmission characteristics permit 6-db repeatered circuits about 150 miles long when the cable is aerial or on the ground, or about 400 miles long when it is buried. Transmission factors limiting the length, are loss variations caused by temperature changes, and noise. In practice, buried cable lengths have been considerably less than 400 miles. Normal repeater spacings are about 25 miles; these are limited by noise and available repeater gain. When noise is low, somewhat longer spacings can be used with some complications in maintenance.

(*3*) When no intermediate repeaters are used, as in figure 5-17-A, circuit lengths up to 35 miles or more may be used by increasing the transmitting output at the terminals. Means for increasing the output are included in Telephone Terminals CF–1–A having serial

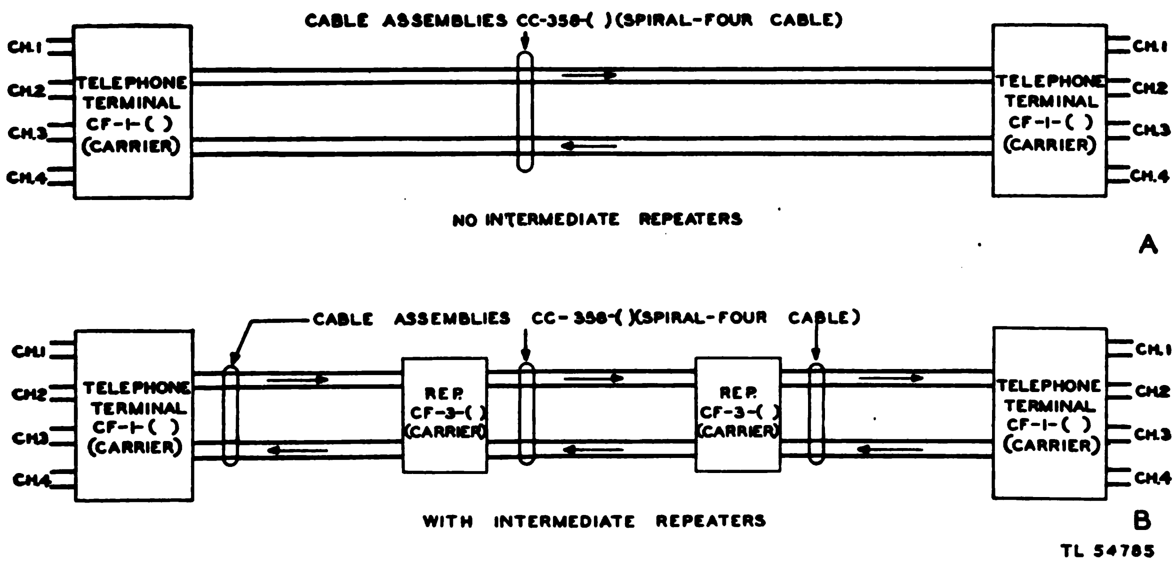

Figure 5-17. Spiral-four cable carrier system.

numbers greater than 516. Under favorable noise and crosstalk conditions, single section systems can be operated for lengths of 55 miles at 6-db net loss or 80 miles at 30-db net loss. The gain of the terminal is sufficient for this purpose. At or near these extreme conditions, singing may occur in cases of unusually poor near-end side-to-side crosstalk in the spiral-four cable.[1]

(4) Two d-c channels are provided over the two simplexes of the cable. Normally, one of these is used as a signaling channel to call in the intermediate repeater attendants. The other can be used for a telegraph circuit of one or two repeater sections.

c. On Wire W–143. The spiral-four system can be used on an emergency basis over two pairs of nonloaded Wire W–143 with repeater sections about 14 miles in length. There are some restrictions on the use of Wire W–143 for this purpose, as some characteristics, such as capacitance unbalance, may give noisy operation in certain areas having high static noise levels. A special equalizer is required if one or more intermediate repeaters are involved. This equalizer consists of an 11-millihenry (mh) inductor in series with an 80-ohm resistor, shunted across the input of each repeater and terminal. It can be made up in the field, the inductor being obtained by the parallel connection of the four half windings of two 88-millihenry (mh) loading coils. Figure 5-18 shows the equalizer and the method of connecting the Coils C–114–A for this purpose. Satisfactory circuits of 6-db net loss can be obtained in this way for lengths up to about 100 miles under favorable conditions.

d. On Open Wire.

(1) The spiral-four system can be used as a physical 4-wire system on two open wire pairs. The method of setting up such a system is the same as for the spiral-four cable system, except that the instructions with the equipment do not give typical equalizer settings for open wire circuits. These settings can be determined during the line-up tests except for the MILES dial of the equalizer which should be set on step 0 for copper wire and step 30 for copper-steel wire.

(2) The lines used may be combinations of open wire, Cable Assembly CC–358–( ), or Wire W–143 without serious effects on transmission except some increased loss. This makes the system useful in front areas where well-constructed open wire lines may not exist. Single systems may be operated on a nonrepeatered basis for lengths of 100 miles or more of open wire, giving four circuits on two pairs of wires. Circuit lengths can be increased by the use of repeaters. Two or more systems on the same line lead to crosstalk difficulties and require much shorter section lengths and repeater spacings for high-grade crosstalk performance. More detailed data on the allowable circuit lengths are given in paragraph 543b and figure 5-45.

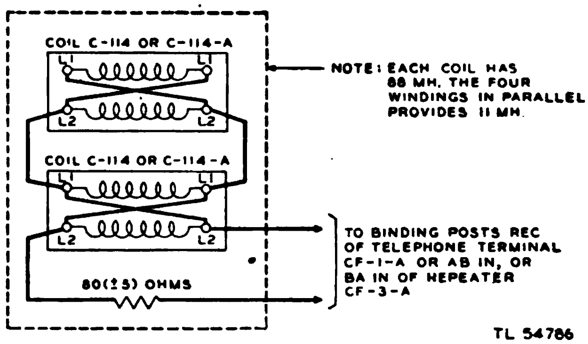

Figure 5-18. Locally made equalizer for Wire W–143.

(3) If this system is operated on a physical 4-wire basis on an open wire lead carrying the open wire converter, type C (par. 528), type H (par. 527) or other equivalent 4-wire systems, high near-end crosstalk is likely to result, particularly if the spiral-four system is on a pair adjacent to that occupied by one of the other systems. Selection of pairs to reduce crosstalk is discussed in paragraph 530b.

e. On Loaded Paper-insulated Conductors. The spiral-four system can be operated in lead-covered cables on paper-insulated conductors equipped with loading of sufficiently high cut-off frequency. The cut-off frequency of the loading should be about 25 percent greater than the highest frequency to be transmitted over the spiral-four system. Some European loading systems are designed for music cir-

[1] This condition can be remedied, when necessary, by keeping reels with poor crosstalk (crosstalk loss per reel less than 12 db greater than the gain of the terminal) at least 3 miles away from either end of the repeater section. Methods of measuring the crosstalk are described in paragraph 564. The least crosstalk loss at 11 kc for a cable reel meeting specification limits is about 43 db (1,650 mmf capacitance unbalance); the crosstalk loss at 11 kc corresponding to the rms capacitance unbalance in a reel is about 67 db. The crosstalk with such a long repeater section may also affect carrier telegraph operation, as discussed in chapter 3.

cuits and carrier systems, and have cut-off frequencies in the range 7,500 to 17,000 cycles on the sides or phantoms. These would permit using two to four channels of the spiral-four system, depending on the cut-off frequency. This use on underground cables, will provide circuits of stable net loss with a minimum of interruptions in service.

523. CARRIER HYBRID SYSTEM.

a. Carrier Hybrid CF–7 in combination with spiral-four equipment is used for balanced 2-wire carrier operation, using the same frequency band for each direction of transmission over open wire lines. This saves one pair as compared with physical 4-wire operation, but with restrictions on the length of the repeater sections and the required regularity of line construction.

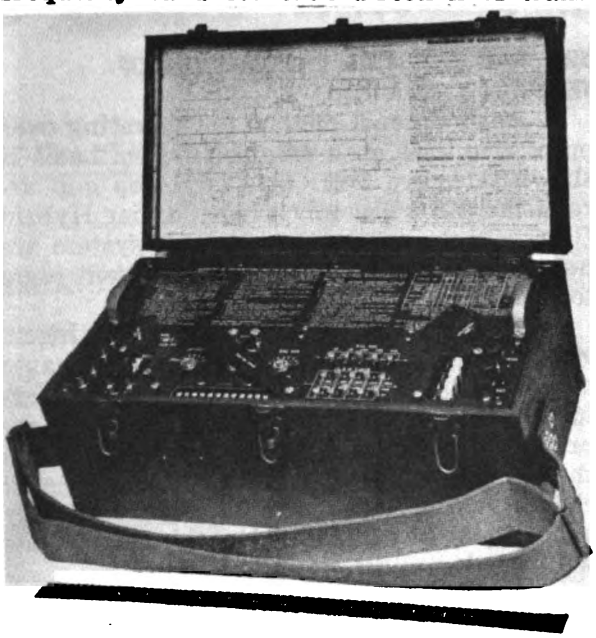

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Figure 5-19. Carrier Hybrid CF-7.

b. Carrier Hybrid CF–7 (fig. 5-19) includes a repeating coil hybrid, a balancing network, protectors, and a composite set for deriving two d-c telegraph channels. A description of this equipment is given in TM 11–2003.

c. Figure 5-20 shows schematically the layout of a carrier hybrid system.

d. Repeater section lengths must be kept short in this system to avoid singing difficulties. On well constructed lines with small irregularities, nonrepeatered circuits can be worked for 65 miles at 6-db net loss and 135 miles at 30-db net loss, on 80-mil copper-steel pairs. Longer lengths can be operated with repeater spacings of about 50 miles on this wire. If the lines are damaged or poorly constructed, and have changes in wire spacing or gauge, or have short lengths of inserted cable, the usable gain will be decreased. Such irregularities may reduce the maximum length of nonrepeatered circuits to not more than 45 miles at 6-db net loss and 115 miles at 30-db net loss. Irregularities in line construction are likely to be more common in front areas and this characteristic of the carrier hybrid system should be allowed for in laying out systems in such areas. Detailed data on circuit lengths and repeater spacings are given in paragraph 543c and figure 5-46.

e. If more than one carrier hybrid system is operated on a line, near-end crosstalk will occur between oppositely directed paths. On new carrier transposed lines of Army construction, it will generally be possible to operate two carrier hybrid systems per crossarm with good crosstalk performance (par. 549c), or four per crossarm with crosstalk acceptable for forward areas. Existing lines may have poor crosstalk characteristics and operation of a number of systems will generally involve accepting higher crosstalk, increased circuit net losses, or reduced repeater spacings.

f. The carrier hybrid system can be used on Wire W–143 or Cable Assembly CC–358–( ) for moderate distances, as given in figure 5-46. If both pairs of the spiral-four cable are used for these distances, crosstalk between the two systems will approach the maximum

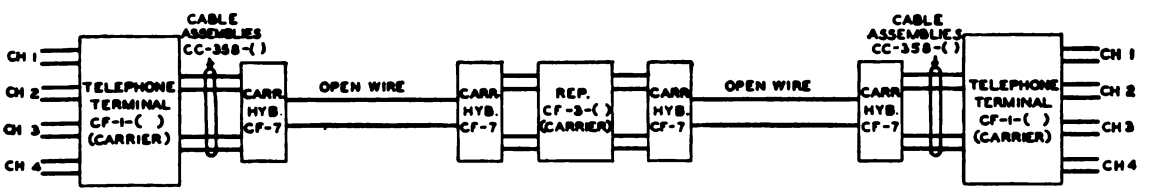

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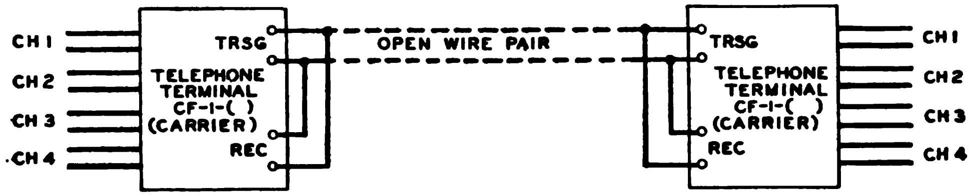
Figure 5-20. Balanced 2-wire carrier hybrid system.



DIAL AND KEY SETTING AT EACH TERMINAL

MILES DIAL	DIAL 1	DIAL 4	DIAL 2	GAIN DIALS	OUTPUT KEY	REC. LEV KEY
0	0[a]	0	4	20 (CH. 1 TO 3) 22 (CH. 4)	+10 db[a]	NORMAL

[a] IF OUTPUT KEY IS NOT PROVIDED ON THE TERMINAL, SET DIAL 1 ON 10 INSTEAD OF 0.

TL 54788

Figure 5-21. Pair-per-system operation of Telephone Terminals CF-1-( ).

tolerable for forward areas. If one pair of Cable Assembly CC-358-( ) becomes damaged in a spiral-four system, operation on a balanced 2-wire basis in the faulty section can be used as an emergency method.

g. The carrier hybrid system can be converted to a physical 4-wire system or vice versa very easily, especially in the case of nonrepeatered systems. This allows considerable flexibility in the use of the two systems. Where sufficient pairs are available, physical 4-wire operation provides a more stable and less vulnerable system with wide latitude in the makeup of the line wires. The carrier hybrid system is for use where pairs are at a premium and the distance to be spanned is within the capabilities of the system as limited by line irregularities. Use of the system on very irregular lines in front areas is possible on a single section basis provided no attempt is made to insert large amounts of gain; that is, the system may be used to yield more circuits on a pair of wires but not to increase the range any large amount in such cases.

h. The carrier terminal and its associated hybrid can be separated and connections between the two made on a 4-wire basis. This is illustrated in figure 5-20, where Cable Assembly CC-358-( ) is shown connecting the terminals to the hybrids. This separation of the two units of equipment may be found desirable to avoid long cable lengths between the hybrid and the open wire line; for example, it may be desired to place the terminal in a less exposed location where it can be camouflaged. Separation of the two units in this manner should be avoided whenever possible as it makes it awkward to adjust the balancing network in the carrier hybrid.

524. PAIR-PER-SYSTEM OPERATION OF TELEPHONE TERMINALS CF-1-( ).

a. An emergency method for operating over open wire lines on a pair per system basis is shown in figure 5-21. This is a stop gap arrangement for use only when Carrier Hybrid CF-7 and the open wire converter system are not available, and there are not sufficient pairs to allow physical 4-wire operation.

b. It is not possible in this system to insert gain at either terminal, as this would cause circuit instability and singing. For satisfactory operation, the dial settings should be approximately as indicated in figure 5-21. With these settings the over-all net loss of each channel would exceed the line attenuation by about 9 db. If properly adjusted, the circuits will not sing under any line conditions.

c. The circuit lengths with this system are limited to about 25 miles on 080 copper-steel wire for circuits having 18-db net loss, and about 60 miles for point-to-point circuits with 30-db net loss. Distances about three times as long can be spanned on 104 copper wire, as indicated in figure 5-47. Any inserted cable would reduce these lengths by the insertion loss of the cable.

d. Except for the connections shown in figure 5-21, the procedures for setting up this system are the same as for ordinary spiral-four systems. However, a line-up of the system by means of testing current is not required and is not desirable. The various dials at each terminal should be set as indicated in the figure without regard to any over-all measurements. Small readjustments of the GAIN dials of the individual channels may be made as required to prevent the circuits from sounding *tinny* or to improve the volume. The signaling channel over the simplex is set up in the normal manner. The second simplex tap provided in the terminal equipment is not used, and no connections should be made to it.

525. OPEN WIRE CONVERTER SYSTEM.

a. The open wire converter system is an equivalent 4-wire system, designed for operation over open wire pairs without the limitations of the physical 4-wire and carrier hybrid systems. This system uses Telephone Terminal CF–1–( ) (Carrier); Converter CF–4 (Carrier) 2-wire to 4-wire, part of Converter Set TC–33; and Repeater CF–5 (Carrier) 2-wire, part of Repeater Set TC–37. Figure 5-22 shows the converter and figure 5-23 the repeater equipment. The equipment is described in TM 11–2008.

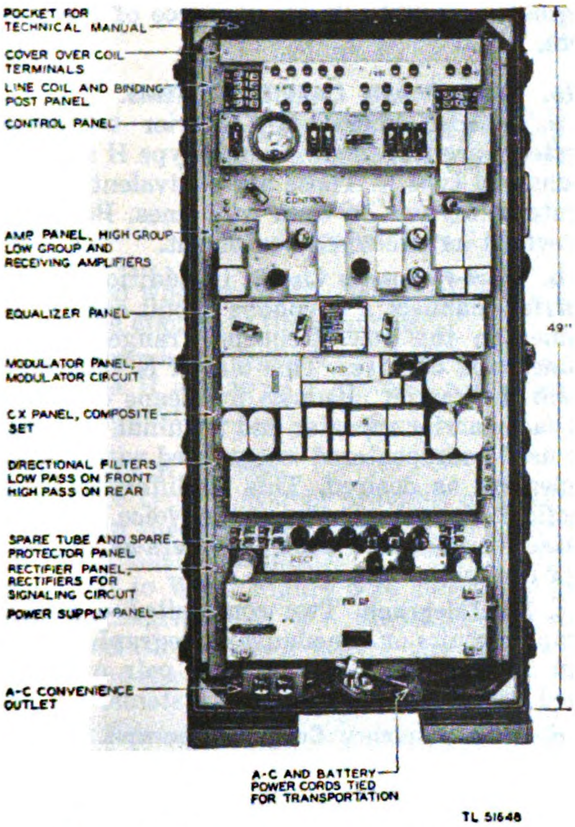


Figure 5-22. Converter CF–4 (2-wire to 4-wire).

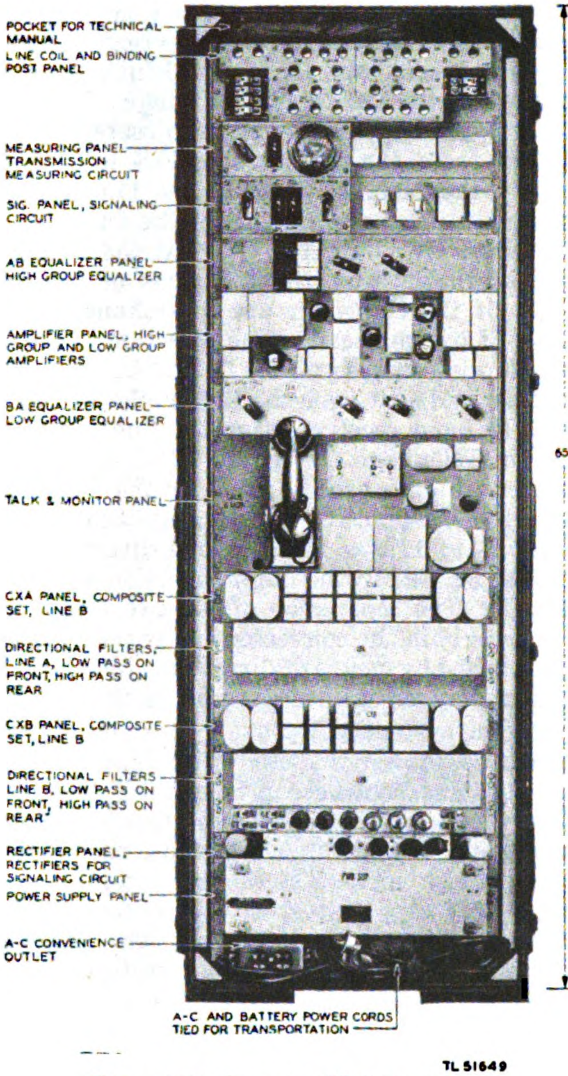


Figure 5-23. Repeater CF–5 (2-wire).

b. Figure 5-24 shows a schematic layout of a repeatered open wire converter carrier system. The transmission over the open wire line in one direction is 0.2 to 11.6 kilocycles (kc) and in the other is 20.8 to 32.2 kilocycles (kc).

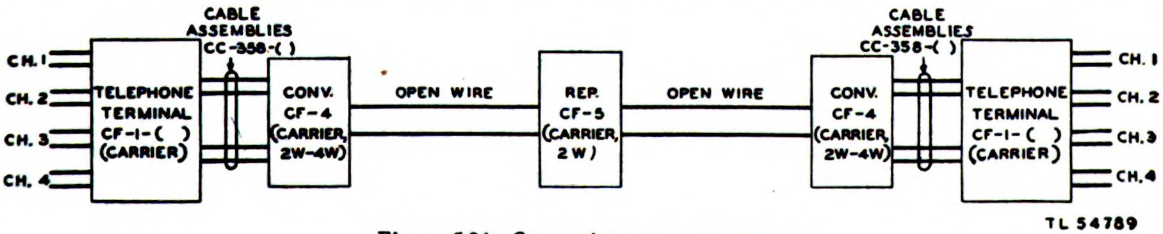


Figure 5-24. Open wire converter system.

c. Telephone Terminal CF–1–( ) is connected over two pairs of wire to Converter CF–4 and thence to the open wire line. At Converter CF–4 at one end of the system, the band of frequencies for one direction of transmission is sent over the line without frequency change in the 0.2 to 11.6 kc range. The band of frequencies for the other direction is received from the line in the 20.8 to 32.2 kc range, then converted to 0.2 to 11.6 kc, and passed to the receiving side of the CF–1–( ) terminal. At Converter CF–4 at the opposite end of the system, the functions of the two sides of the converter are interchanged: the band of frequencies for one direction of transmission is raised from 0.2 to 11.6 kc to 20.8 to 32.2 kc and sent over the line while the 0.2 to 11.6 kc band received from the line is passed on to Telephone Terminal CF–1–( ). Repeater CF–5 is used to increase the allowable length of system. It provides amplification for the 0.2- to 11.6-kc band in one direction and 20.8 to 32.2 kc in the other direction of transmission. The separation of the two frequency bands in both the converter and repeater is accomplished by means of directional filters (low- and high-pass) which are part of these units.

d. The system will provide four circuits per pair, and the circuit can be operated at 6-db net loss for distances up to about 1,000 miles (with some relaxation of crosstalk standards if systems are operated for such long distance on adjacent pairs). The normal repeater spacing on 080 copper-steel wire is 80 to 90 miles. Noise and available gain limit the repeater spacings. When used as a single-section system without repeaters, distances up to 135 and 200 miles can be spanned on 080 copper-steel wire, for circuit net losses of 6 db and 30 db, respectively. Additional data on repeater spacings are in paragraph 543e.

e. On 4-pair and 8-pair open wire lines transposed as outlined in TM 11–368 or TM 11–2253, each pair may be used for an open wire converter system. These will provide a maximum of 32 telephone channels on 8 pairs of wires. The system may be used on the same pole line with fixed plant packaged carrier systems and most foreign systems.

f. Combinations of the open wire converter system on open wire in tandem with the spiral-four system on Cable Assembly CC–358–( ) can be operated without bringing the channels down to voice frequencies at the junction point. Converter CF–4 and Repeater CF–3–( ) are used at the junction in these cases. Converter CF–4 may also be used alone at the junction of the open wire and an entrance cable up to about a mile in length. This may be useful for camouflaging the approach to the carrier terminal and it avoids the transmission penalties of having the cable in the open wire line. A source of power is required for the converter.

g. Two composited d-c telegraph channels are provided, one of which is normally used for signaling purposes in maintenance of the system.

526. FIXED PLANT CARRIER SYSTEMS.

a. General. Fixed plant carrier telephone systems are the single channel type H and the 3-channel type C. These are equivalent 4-wire systems for use on open wire lines. Both are provided as *packaged* equipment.

b. Voice-frequency Circuit. In addition to the carrier channels, a telephone circuit can be obtained in the voice-frequency range on the same pairs of wires. This circuit is separated from the carrier channels by means of filters at each carrier repeater and terminal, and can be used nonrepeatered or equipped with 2-wire repeaters as desired. This is different from tactical equipment where the voice channel passes through the same amplifiers as the carrier channels.

c. D-c Telegraph. Two composited d-c telegraph circuits or one simplex telegraph circuit can be obtained over the same pair of wires used for the type H or type C systems.

d. Voice-frequency Carrier Telegraph. Voice-frequency carrier telegraph can be transmitted over the carrier telephone channels. The telegraph system may consist of the 6- and 12-channel packaged equipment or the CF–2–A, CF–2–B, and CF–6 equipment.

e. Equipment Features. The packaged type H and type C systems are patterned after commercial systems but include special features desirable for Signal Corps use. The equipment is designed for a-c operation with built-in power packs. Each packaged unit has optional arrangements to permit its use under a wide variety of conditions. Provision is made for terminating the channels at voice frequencies on either a 2-wire or 4-wire basis. The 4-wire termination is used where a circuit consists of type C, type H, or 4-wire voice-frequency sections permanently connected in tandem. It is

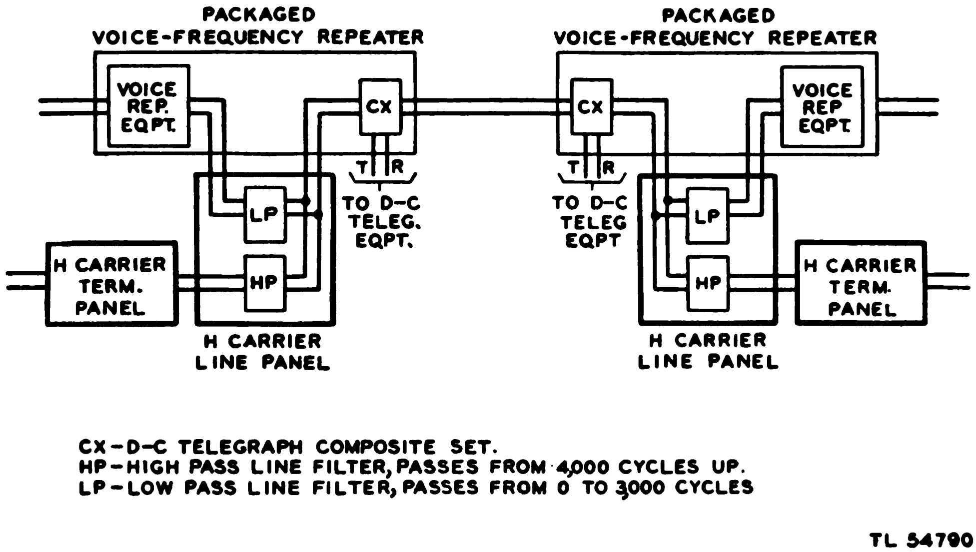


Figure 5-25. Type H system and voice-frequency circuit on open wire.

also used when voice-frequency telegraph systems are applied to the channels.

f. Transmission Data. Transmission data for the type H and type C systems are given in paragraph 543e.

527. TYPE H SYSTEM.

a. The type H system provides one carrier circuit in the frequency range 4.0 to 6.9 kc for West to East transmission and 7.4 to 10.3 kc for East to West. Figure 5-25 shows the general arrangement of a nonrepeatered system in association with a 2-wire voice-frequency telephone circuit.

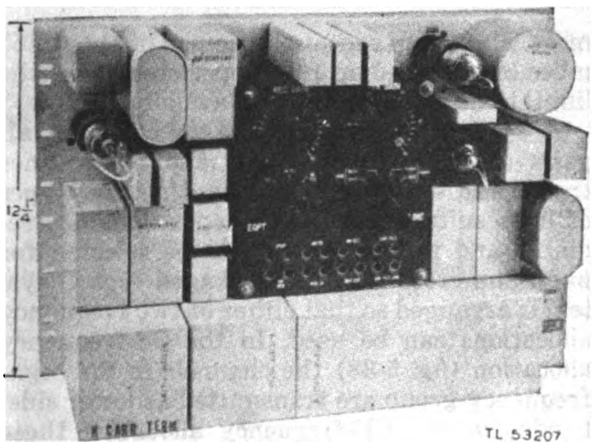


Figure 5-26. Type H carrier terminal panel X-66217A.

b. The type H systems are normally used as single section systems. Circuits having 6-db net loss can be obtained for lengths up to 145 miles on 104 copper-steel wire. The circuit lengths can be increased by use of a type H carrier repeater. Corrections for transmission variations with temperature and weather are made manually, when necessary.

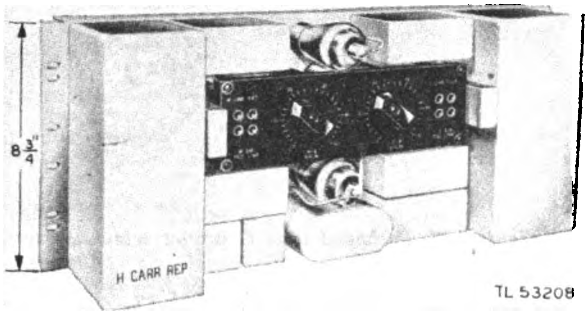


Figure 5-27. Type H carrier repeater panel X-66217B.

c. The major components of the packaged type H system are shown in figures 5-26 and 5-27. The terminal is universal; that is, it can be arranged as an East or a West terminal by throwing a switch. The terminal is also arranged so that two terminals can be associated to provide a 3-channel system (voice plus 2 carrier) for physical 4-wire operation over suitable wire or radio systems. The packaged type H equipment does not include protectors or composite sets. Protectors can be provided from the line terminating and simplex panel described in TM 11-2020. Protectors and composite sets can be provided by associating the type H equipment with the packaged voice-frequency repeater or the line terminating and

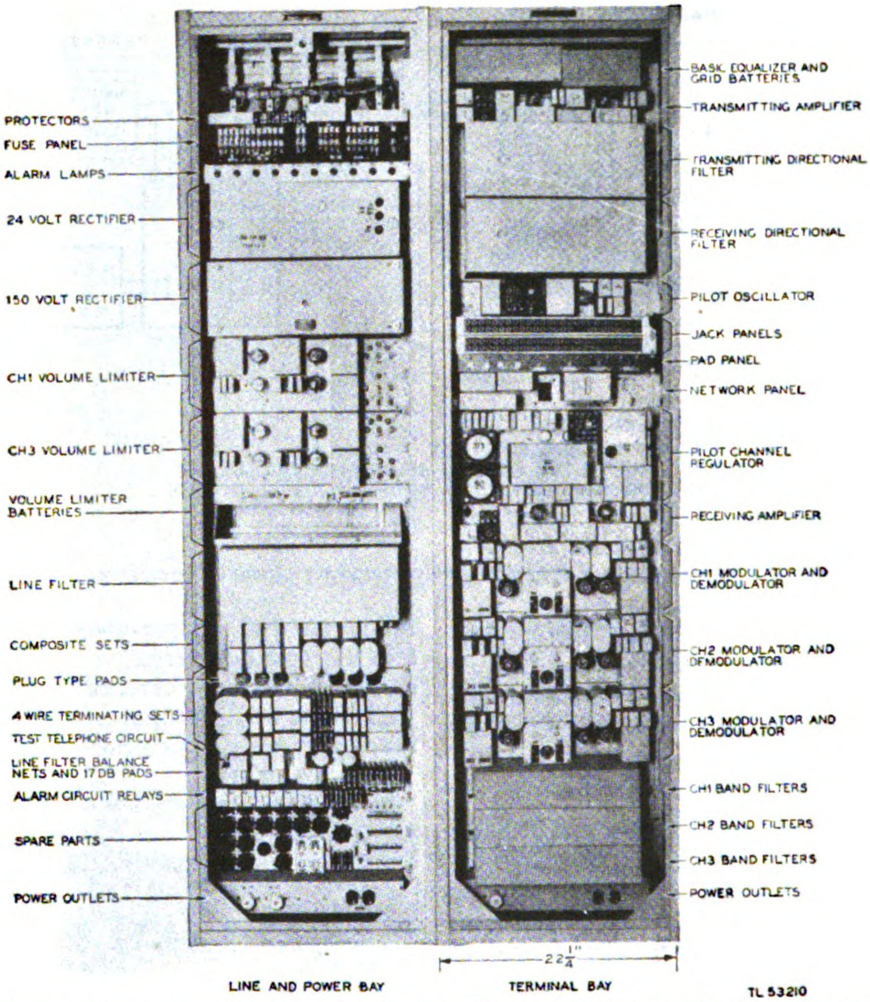


Figure 5-28. Packaged type C carrier telephone terminal (East terminal X–61819P; West terminal X–61819R).

composite panel described in TM 11–2031. The type H system and its installation are covered in TM 11–2025 and TM 11–2038.

528. TYPE C SYSTEMS.

a. Type C systems provide three high-grade carrier channels in the frequency range 6.5 to 15.7 kc for the East to West transmission and 18 to 28.2 for West to East. The type C packaged terminal and repeater are shown in figures 5-28 and 5-29 respectively. A schematic of a repeatered type C system with a voice-frequency telephone circuit on the same pair of wires is shown in figure 5-30.

b. Type C systems have automatic regulation to take care of transmission variations and can provide circuits having 6-db net loss for practically any length up to 1,000 miles or more. Maximum repeater spacings of about 155 miles can be used on 104 copper-steel wire, the limitations being noise and available gain.

c. Type C systems can be operated on all pairs of U. S. Army 4-pair and 8-pair lines transposed for 30-kc operation. On other types of lines suitable carrier transpositions are required and pairs may need to be selected for minimum crosstalk. The packaged type C system is arranged so that either of two frequency allocations can be used. In the CS-frequency allocation (fig. 5-33) the channels in the high-frequency group are transmitted as lower sidebands; in the CU-frequency allocation these channels are transmitted as upper sidebands. This feature is provided to reduce crosstalk effects as crosstalk between upper sidebands on one system and lower sidebands on another system will not be intelligible.

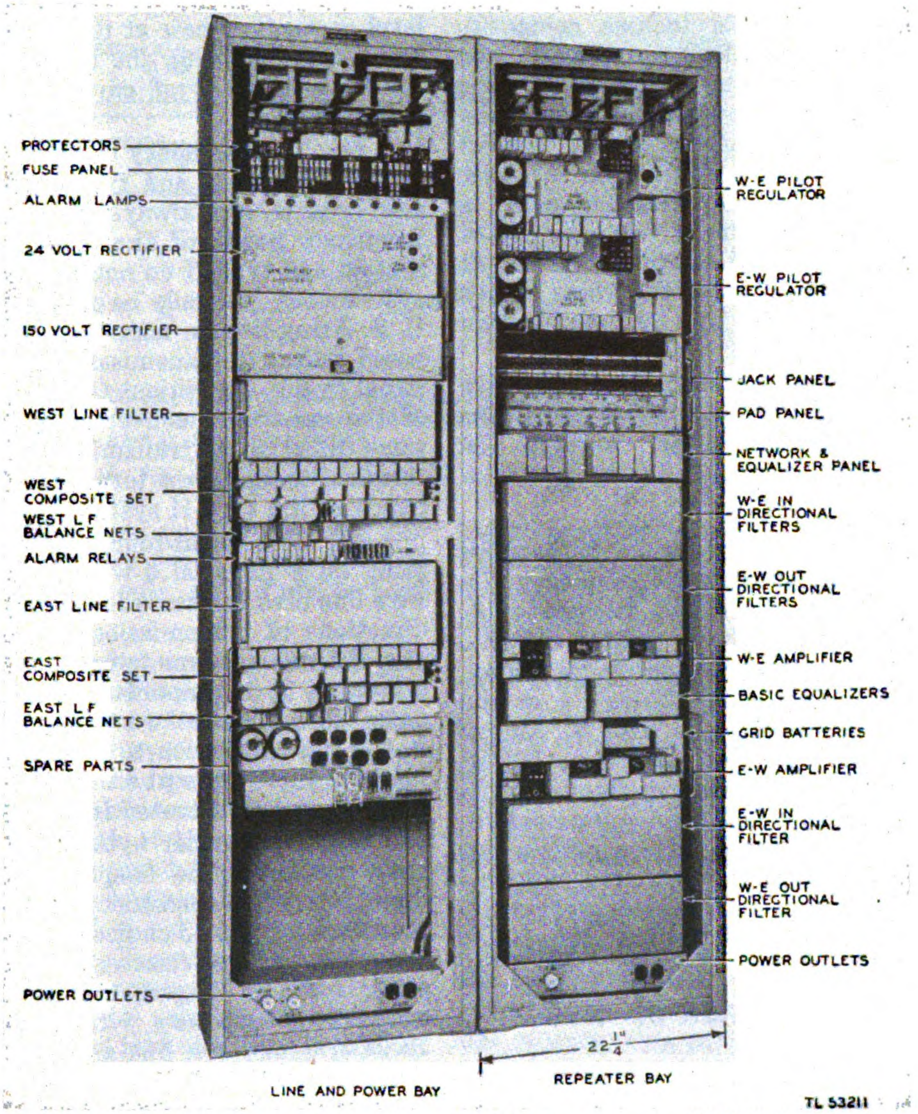


Figure 5-29. Packaged type C carrier telephone repeater X-61819S.

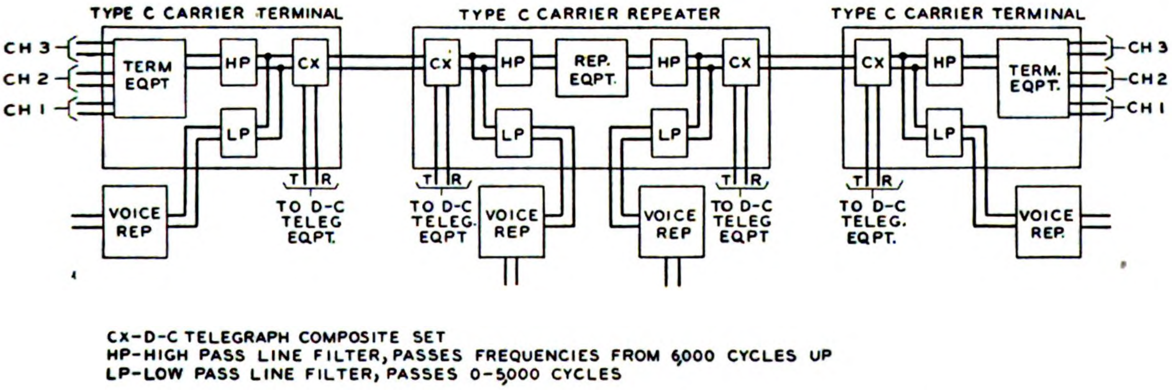


Figure 5-30. Type C system and voice-frequency circuit on open wire.

d. The packaged units include composite sets for deriving d-c telegraph circuits, line filters for separating the carrier from the voice circuit, and volume limiters for the telephone channels when a voice-frequency carrier telegraph system is operated over another channel. A type C carrier transfer panel is available as a separate unit. This consists of line filters and associated equipment to permit separating the type C from the voice circuit at an intermediate point in a repeater section (par. 532).

e. The type C system and its installation are described in TM 11–2026 and TM 11–2023. The carrier transfer panel is covered in TM 11–2031.

529. SIGNALING.

Voice-frequency signaling must be used on all carrier circuits, on all voice-frequency circuits equipped with packaged 22-type or 4-wire repeaters, and on all composited circuits. The 1,000-20 cycle ringers used by the Signal Corps are normally the EE–101–( ) or the packaged ringers X–61820A and B. Ringer TA–3/FT provides either 1,000-20 or 500-20 cycle ringing, the latter being used when operating with British or European equipment requiring this type of ringing. Twenty-cycle signaling can be used on nonrepeatered, noncomposited circuits, and on voice-frequency circuits equipped with Repeaters EE–89–A, EE–99–A, or TP–14–( ).

530. SYSTEM COORDINATION ON OPEN WIRE LINES.

a. Repeater Locations. When different kinds of telephone and telegraph systems are used on an open wire line, there are certain features of system layouts which should be coordinated. It is desirable to locate all telegraph, voice, and carrier repeaters at the same points. This centralizes maintenance and is desirable from a transmission standpoint as it reduces the possibility of excessive level differences between systems, which would produce crosstalk.

b. Frequency Coordination.

(*1*) It is desirable that transmission within any carrier-frequency band be in the same direction on all carrier systems on a line. When this is arranged the frequencies are said to be coordinated. Frequency coordination tends to prevent the high near-end crosstalk which would occur if currents of the same frequency were at high level on one pair and at a low level on another pair at the same point on the line. Charts showing the frequency allocations for various types of carrier systems are in paragraph 534.

(*2*) The frequency bands of the open wire converter system and type C, and of type C and type H, can always be coordinated. The frequency bands of the open wire converter system and type H do not coordinate but both systems can generally be operated on the same U. S. Army line on nonadjacent carrier transposed pairs, if transmission from the B terminal to the A terminal (0.2- to 11.6-kc band) of the open wire converter system is in the same direction as transmission from the East terminal to the West terminal (7.4- to 10.3-kc band) of the type H system.

(*3*) The spiral-four carrier system operating on a physical 4-wire basis on an open wire line uses the same frequency band in both directions of transmission. Where more than one of these systems is operated on the same crossarm, it is important that the adjacent pairs used in the two systems be operated in the same direction to keep level differences between these pairs at a minimum. Such an arrangement is illustrated in figure 5-31-A.

(*4*) The carrier hybrid systems on open wire use the same frequency band in both directions of transmission on one pair and therefore permit no choice in how the systems should be pointed relative to each other or to other systems. Expedients used for keeping crosstalk satisfactory with more than one of these systems on a line are: reduced repeater gains and spacings, and selection of pairs, usually based on obtaining the maximum physical separation between pairs carrying the same frequency bands in opposite directions. Such arrangements are illustrated in figures 5-31-B and -C, which apply when two systems are to be operated per crossarm. As many as four systems per crossarm may be usable where the crosstalk standards for forward areas (par. 549b) apply.

(*5*) The methods of assigning pairs for spiral-four or carrier hybrid systems per crossarm shown in figure 5-31 are for lines having American types of carrier transpositions. Some other method of assignment may be found desirable on other types of lines. On lines with barrelled squares, crosstalk between pairs in horizontally or vertically adjacent squares is worse than for combinations with more sepa-

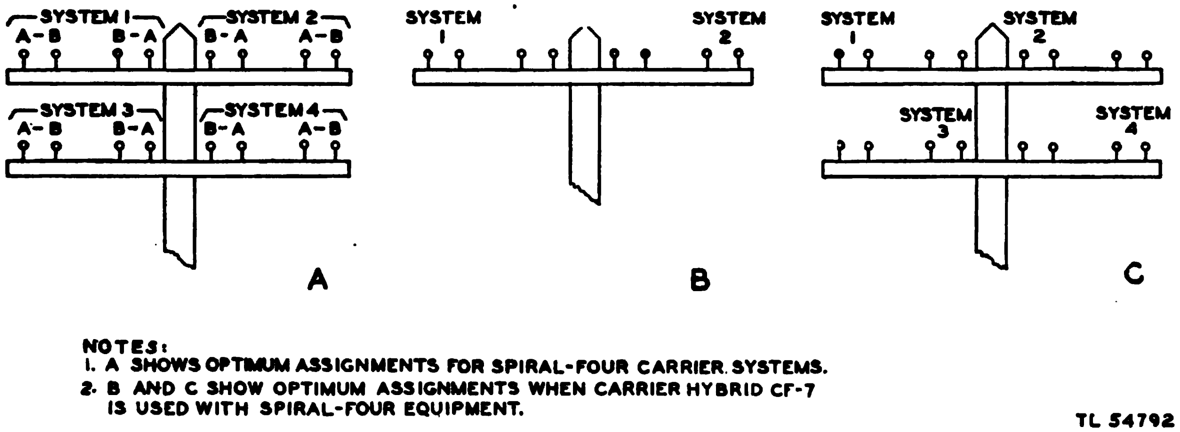


Figure 5-31. Pair assignments for spiral-four and carrier hybrid systems on open wire.

ration. When 10-pin crossarms are used the pair formed by the two wires adjacent to the pole, that is, the *pole pair,* should not be used for carrier.

(*6*) As another example of system pair assignments, assume that a type C system is operating on one pair of a line and it is desired to add one spiral-four system working physical 4-wire on two other pairs. A large level difference will exist between the low-frequency group (East to West) of the type C and the spiral-four frequency band transmitting West to East, since the frequency bands are practically the same and the directions of transmission are opposite. Therefore, the pair used for West to East transmission on the spiral-four system should be selected to have the greater crosstalk loss into the type C pair. In the absence of measurements or other data on transpositions, it is a fair supposition that pairs far apart will have the least crosstalk.

(*7*) Where the repeater section lengths are much shorter than the maximum allowable, the need for using the segregation arrangements shown in figure 5-31 is decreased, because the level difference is reduced by the amount of reduction in line loss as compared to the maximum.

c. Level Coordination. When different types of systems are operated on the same line, the output levels should be made about the same on all systems for a given frequency range on the line. This usually gives optimum results from a crosstalk standpoint. If a branch line joins a main line at an intermediate point in the main line repeater section, or if a repeater or carrier terminal is used at an intermediate point, readjustment of system levels may be required to equalize the levels at the intermediate point. Means for making such adjustments are included in the carrier equipment.

531. CABLES IN OPEN WIRE LINES.

a. Incidental cables in open wire lines will require consideration in planning and construction in order to avoid undesirable transmission reactions. Nonloaded cable in particular has a much lower impedance than an open wire pair and when used in the line can be an important source of increased transmission loss and crosstalk. Incidental cables also cause irregularities in the line impedance which limit the usable repeater gains on 2-wire circuits.

b. Incidental cable should be avoided by the use of open wire construction to the greatest extent practicable. Long span open wire construction can be used for road and river crossings. The aerial spaced pair construction described in paragraph 504 is desirable where use of insulated wire is necessary, such as through foliage which cannot be kept clear of the line. The impedance of this construction approximates open wire line impedance and thus minimizes reflection effects.

c. When cables are used, the transmission effects will depend on the type of system. With spiral-four equipment operated physical 4-wire, the principal effect will be an increase in the transmission loss of the line. For carrier hybrid operation, cables will reduce the balance obtainable between the line and network, and in general will allow use of only moderate gains. In the open wire converter, type C, and type H systems the important effects are increased crosstalk and transmission loss.

d. Allowable lengths of incidental cables for various types of systems are discussed in paragraph 545. When cables are used nonloaded, the lengths tend to be short, especially for carrier operation. By use of loading, the impedance can be increased and much longer lengths are usable. Suggestions for loading incidental cables in tactical systems and reference to carrier loadings for fixed plant systems are given in paragraph 545.

e. In using pairs on an existing open wire line, a check should be made to see whether all loaded cables included will transmit the desired frequency band. Carrier operation is not possible over cable pairs with voice-frequency loading because of the cut-off effect referred to in paragraph 512a. The cut-off frequency of Cable Assembly CC–358–( ) is not high enough to pass the frequencies required for the open wire converter and type C carrier systems.

532. DROPPING CIRCUITS ON CARRIER PAIRS.

a. In laying out circuits to meet particular traffic demands, it may be advantageous to use some of the channels of a carrier system for circuits of less than the complete system length. For example, the system may run from A to C, and a circuit from A to B, as well as one from B to C, may be needed. This can be obtained by dropping circuits in the ways described below.

b. One or more channels can always be dropped at an intermediate point on a carrier route by installing terminals back-to-back; that is, by terminating a carrier system at voice frequency in both directions at the intermediate point.

c. Arrangements are provided for bridging at repeater points on the No. 1 channel of the open wire converter system. A similar bridge can be made on the voice-frequency channel of spiral-four systems by means of a simple modification of the equipment described in Change 1 to TM 11–341 dated 15 February 1944. A short voice-frequency extension can be used from the repeater point. This provides a comparatively high net loss circuit (20 db or more) from the bridge to either terminal or to a bridge at another repeater. As the voice-frequency or No. 1 channel is normally used in routine maintenance of these systems, coordination of use of the circuit for maintenance and message purposes will be necessary.

d. On pairs with type H or type C carrier systems, the voice-frequency circuit is separate at the carrier repeater points and may be bridged or terminated as desired. By the use of carrier transfer panels and line terminating and composite panels (or line terminating and simplex panels), the voice-frequency circuit can also be separated and terminated at an intermediate point in the carrier repeater section.

e. A voice-frequency bridge with short extension can be made on any line at points between repeaters by means of Telephone Unit EE–105. The loss between the bridge and the circuit terminal will be high in most cases (20 db or more depending on the location of the set) and in the case of the tactical carrier systems, will require coordination in use of the circuit for maintenance and message purposes.

533. CIRCUITS IN TANDEM

a. It will be necessary on occasion to connect telephone circuits permanently in tandem in order to build up longer circuits. The connections between circuits can be made with the individual circuits terminated at voice frequencies on either a 2-wire or a 4-wire basis. It is preferable to connect the circuits together on a 4-wire basis because this will permit lower net losses and give better overall transmission.

b. Telephone Terminal CF–1–A is arranged only for 2-wire termination but the modifications described in TM 11–2001 can be made when it is necessary to provide 4-wire terminations of the channels. Future manufacture of this equipment, starting early in 1945, will include key arrangements to simplify the setting up of either 2-wire or 4-wire terminations. Voice-frequency repeatered circuits or type C and type H carrier systems, set up by means of packaged equipment, can be terminated either 2-wire or 4-wire.

c. When two circuits are connected together on a 4-wire basis, adjustment of the gains and losses at the junction point will be necessary. The method of making these adjustments varies with the type of equipment and is described in the manuals on the equipment. The principles involved are illustrated in figure 5-32 where circuits Nos. 1 and 2 may be any types of circuit, wire or radio, terminated on a 4-wire basis at their junction. Assume first that circuits Nos. 1 and 2 are terminated on a 2-wire basis and lined up for operation as separate circuits, with normal gains and levels for each circuit. Then when the two circuits are connected in tandem on a 4-wire basis as shown, gains or losses represented by P and P′ need to be inserted at the junction point. The gain or loss of P should be such that the transmission level at the input of C will be the same as when circuit No. 2 is terminated on a 2-wire basis for operation alone. Likewise, the gain or loss of P′ should make the transmission level at the input of C′ the same as when circuit No. 1 is terminated on a 2-wire basis for operation alone. The gain or loss represented by P and P′ is obtained by adjustment of pads (provided in some types of equip-

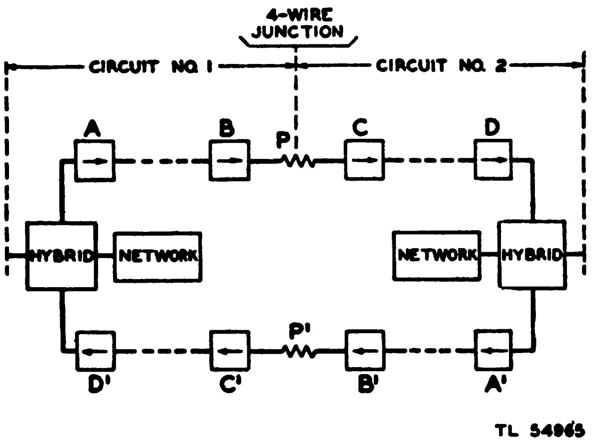


Figure 5-32. Four-wire circuits connected in tandem.

ment), and by changing the gain of C and C′. The combination circuit should be made to have the same net loss in the two directions of transmission by changing the gains at D and D′, as required. This general method of setting up 4-wire connections is applicable where circuits Nos. 1 and 2 are capable of operating separately at net losses of 6 to 9 db each. If the circuits involved cannot operate at net losses as low as this, or if the net losses of the two circuits are widely different, it may be necessary to change the gains at C and C′ or even at A and A′, to avoid singing difficulties on the built-up circuit. Special cases of this kind may be met if one of the circuits is a 2-wire voice-frequency or type H carrier circuit.

d. When circuits are connected together permanently on a 2-wire basis, a modification of the normal adjustment of circuit net losses is desirable to reduce the loss of the over-all connection. Designating the two points to be connected as A and B, the channel receiving gains at the intermediate point should be increased so that the transmission losses from A and B to the intermediate point are 0 db and the losses from the intermediate point to A and B are 6 db. This will give an over-all net loss of 6 db in each direction as compared with a value of 12 db which would be obtained if the two circuits were adjusted in the normal manner. If three circuits are permanently connected in tandem, the end circuits in the connection would be adjusted in the manner described, and the middle circuit set up to have 0-db loss in each direction. This will give a 6-db over-all loss instead of 18 db. The foregoing assumes that the individual circuits are each capable of working at 6-db net loss when operated alone, and that the wiring between the circuit terminals at a junction point is short.

e. It is important to coordinate the type of ringing equipment used at the terminals of a built-up circuit. The ringing equipment at the two ends does not have to be of the same nomenclature but it must be designed to receive and transmit the same kind of signals over the circuit. Voice-frequency signaling over U. S. Army lines is normally 1,000-20 cycles. The British use 500-20 cycles and sometimes unmodulated 500 cycles. European circuits may also use 500-20 cycle ringing. If the ringers at the two ends are of the same type, it is not necessary to provide any ringing equipment at intermediate junctions in the built-up circuit. If ringers of the same type are not available at the two ends, coordination may be effected by providing suitable ringers connected back-to-back at an intermediate point. Thus, a circuit might be equipped with 500-20 cycle ringers at each end and connected to another circuit equipped with 1,000-20 cycle ringers. A 2-wire termination of each circuit at the junction is necessary in this case.

534. FREQUENCY ALLOCATIONS OF CARRIER SYSTEMS.

a. The frequency allocations of various American, British, and French carrier systems are shown in figures 5-33 to 5-35 inclusive. These also show the normal output levels on the line. The information in these figures will be useful in coordinating the directions of transmission and output levels of different systems as discussed in paragraph 530.

b. The frequency allocations of Japanese and German civilian systems are shown in figures 5-36 and 5-37. These are based on available information in technical magazines and there may be some other types of carrier systems (including coaxial cable systems).

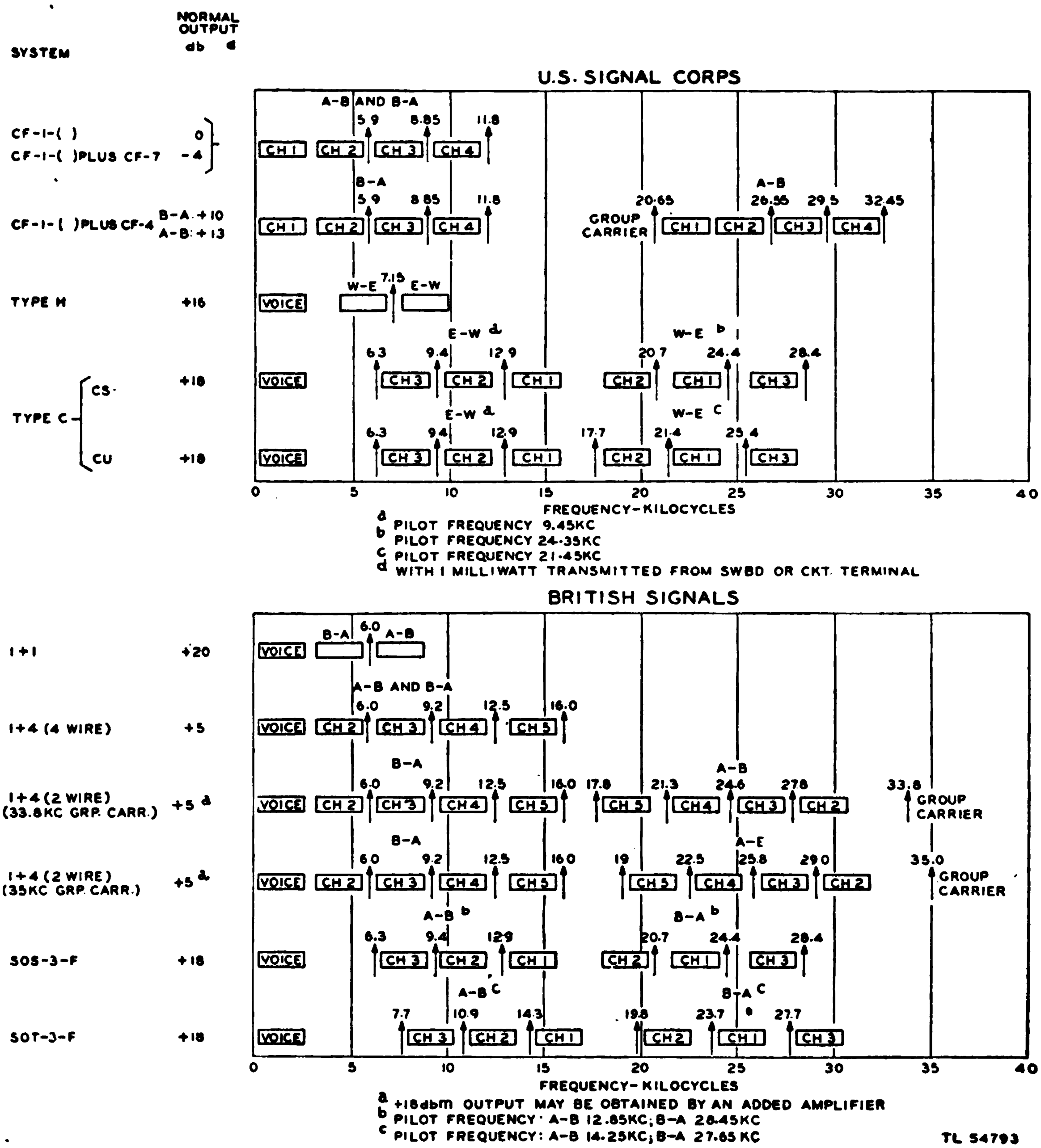


Figure 5-33. Frequency allocations of U. S. Army and British Army carrier telephone systems.

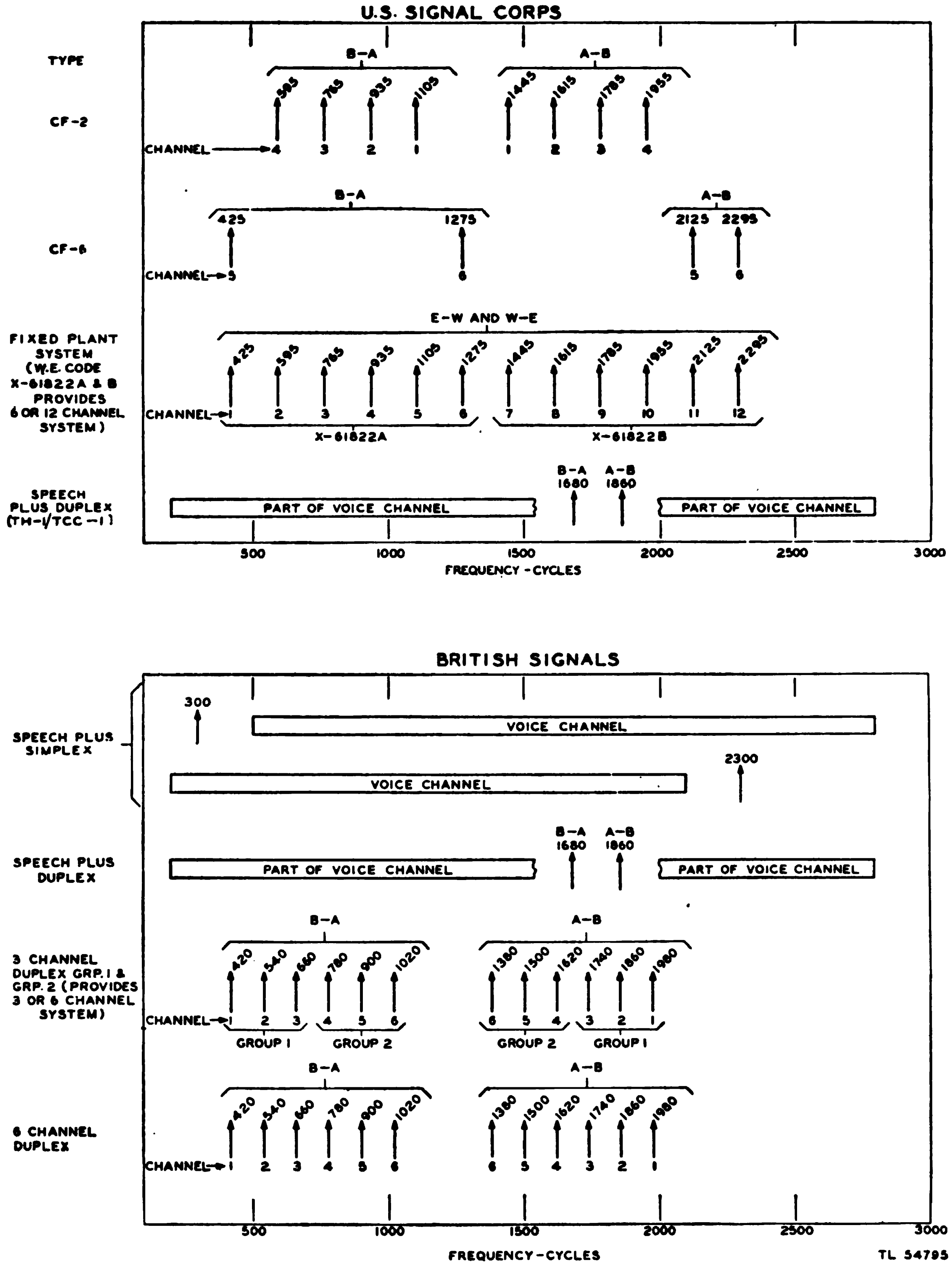


Figure 5-34. Frequency allocations of U. S. Army and British Army voice-frequency telegraph systems.

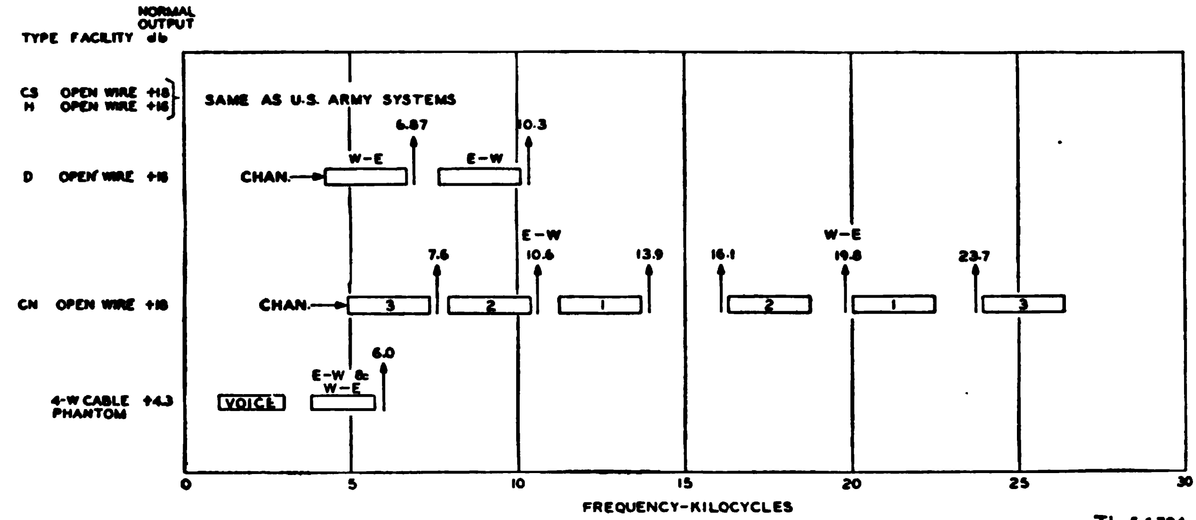


Figure 5-35. Frequency allocations of French carrier telephone systems.

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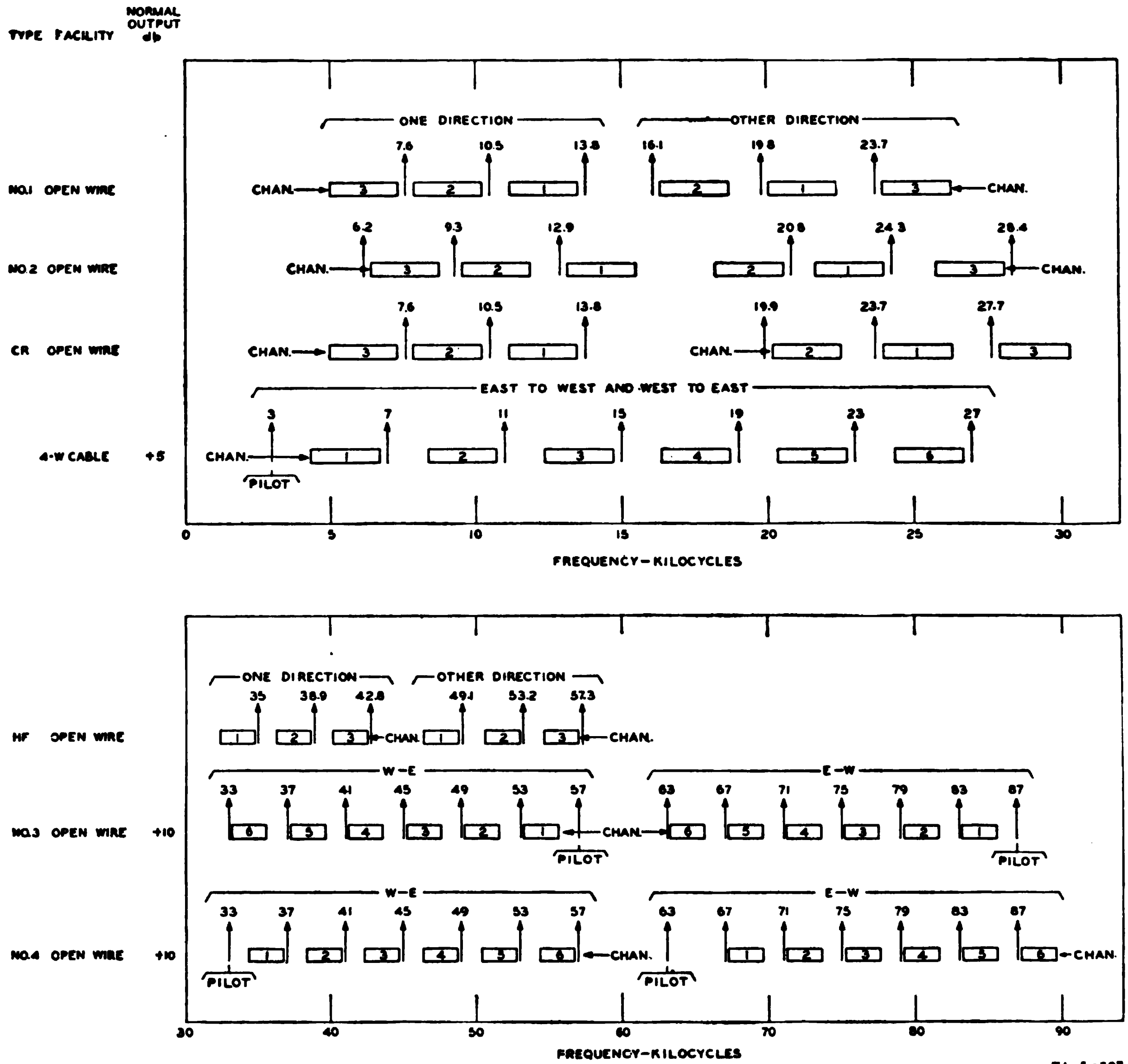

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Figure 5-36. Frequency allocations of Japanese carrier telephone systems.

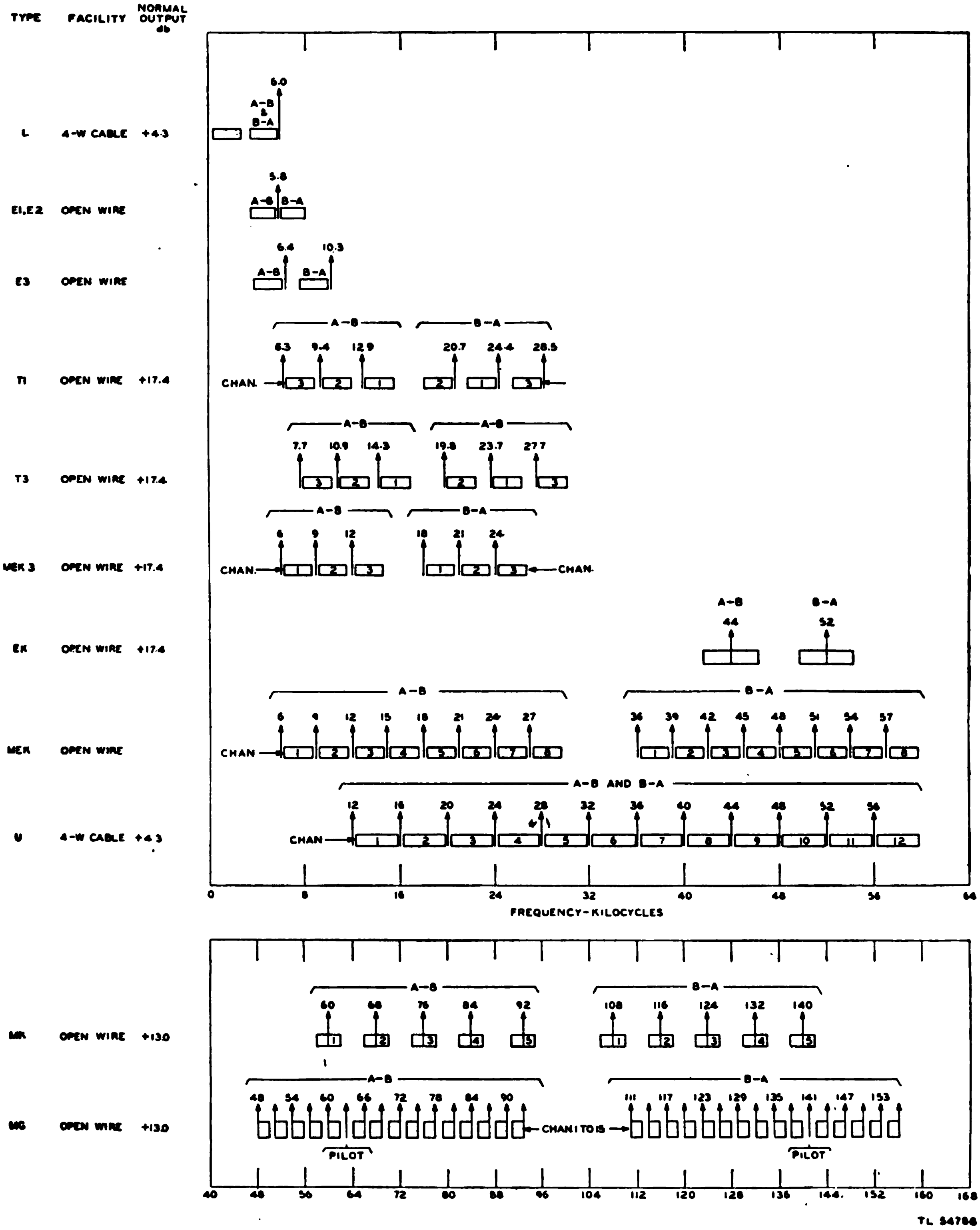


Figure 5-37. Frequency allocations of German carrier telephone systems.

Section V. TRANSMISSION DATA

535. GENERAL.

This section gives data for use in estimating the transmission results obtainable with various combinations of wire and equipment. Transmission guides in the form of talking ranges, repeater spacings, etc., are given to indicate the types of circuit layouts which should give satisfactory transmission results under representative conditions. The data are given in tabular form in figures 5-38 to 5-48 inclusive which are collected under paragraph 544.

536. ATTENUATION AND IMPEDANCE.

a. The attenuation at various frequencies and the 1,000-cycle impedance of various types of lines are given in figures 5-38 to 5-40, inclusive.

b. The losses in figure 5-38 are for open wire lines of the type referred to in paragraph 505b, and described in detail in TM 11–368 and TM 11–2253. Lines with different wire spacings will have somewhat different attenuations and impedances but these differences will be unimportant for most purposes. The figures assume lines in good condition without much leakage and do not allow for the presence of ice, hoar frost, or wet snow on the line wires. If tree branches, vines, or other foreign materials are allowed to touch the wires, the losses may be much greater, the circuits may be quite noisy, and d-c telegraph circuits may be unusable. When ice or snow covers the wires the losses also will be much greater, particularly at carrier frequencies.

c. Some foreign lines will have conductor sizes different from those listed in figure 5-38. The attenuation of such lines can be estimated approximately by interpolation between the figures given. The attenuation of a phantom circuit is about 0.8 of that of the corresponding side circuit. Chapter 9 gives the relation between the diameters of American and foreign conductors.

d. Nonstabilized rubber-covered wires are greatly affected by moisture on the wires, largely because this increases the capacitance between wires. However, if the insulation of wires is not maintained the leakage losses will be greatly increased. In addition, series resistance may develop, particularly at splices where the wires tend to oxidize to form a high-resistance contact; large additional losses and excessive noise may be introduced in this way. The losses of field wires used as pairs are not much affected by occasional contacts with tree branches and other material.

e. The transmission data in figure 5-40 are for common types of American civilian loading systems which may be used in some military installations. Similar data on foreign loading systems are in TM 11–487.

537. BRIDGING LOSSES.

a. It will sometimes be necessary to add a bridged connection to a voice-frequency circuit. The losses caused by such connections are given in figure 5-41. The loss to through transmission is the loss added to the through circuit by the bridged connection. The loss from the line to the bridged circuit is the loss in power received at the bridged line as compared with the power that would be received if the through line did not extend beyond the bridging point.

b. If there are several bridges, the total added loss in the through circuit will be the sum of the separate bridging losses. The loss will be somewhat less if the bridges are close together. The losses of figure 5-41 apply when the bridged line is long, that is, with a loss of at least 6 db. Short bridged lines terminated in Telephone EE–8–( ) will cause bridging losses intermediate between the values shown for the facility and Telephone EE–8–( ).

c. Bridging losses will vary considerably with frequency. A Telephone EE–8–( ) bridged across an open wire pair may cause a loss to through transmission of 10 to 15 db at 500 cycles (ch. 2). This will be particularly important if 500-20 cycles signaling is used on a pair.

538. LOSS OF CABLES INSERTED IN OPEN WIRE LINES.

The loss added by nonloaded cables inserted in open wire lines consists of the attenuation of the cable plus reflection losses. At carrier frequencies, the reflection losses are large because the impedance of nonloaded cable is much lower than the open wire pair impedance. The exact computation of the added loss is complicated but an approximate method, accurate for most purposes, is given in figure 5-42. As an example of the use of figure 5-42, the loss added by inserting 2,400 feet of 19 gauge nonloaded cable in an open wire pair would be $24 \times 0.22 = 5.3$ db at 27 kc. The loss added by 3,200 feet would be $4.0 + \frac{3{,}200}{5{,}280} \times 3.0 = 5.8$ db. The value 3.0 db per mile of 19 gauge cable at 27 kc is derived, by interpolation, from figure 5-39. The reflection losses and multiplying factors for frequencies other than those given in figure 5-42 can be estimated readily by interpolation.

539. EQUIPMENT LOSSES.

Equipment at terminals or intermediate points may introduce appreciable losses which must be allowed for. Switchboard losses may also be important in the case of switched circuits. Typical equipment losses are given in figure 5-43.

540. TRANSMISSION RANGES FOR NONREPEATERED VOICE-FREQUENCY CIRCUITS.

Figure 5-44 shows maximum talking ranges for various kinds of nonrepeatered voice-frequency circuits. These are shown for 6-, 18- and 30-db circuits, which are suitable respectively, for via trunks, terminal trunks, and point-to-point circuits. For pairs whose losses vary from dry to wet, the wet condition is assumed. The lengths given assume wire in good condition, without excessive leakage or high-resistance joints. Any incidental losses, discussed in paragraphs 537 to 539 inclusive, will reduce the talking range.

541. TRANSMISSION RANGES FOR REPEATERED VOICE-FREQUENCY CIRCUITS.

a. General. Talking ranges for repeatered voice-frequency circuits are given in figure 5-44. The following subparagraphs discuss the factors involved in the use of the data.

b. Telephone Repeater EE–89–A. The principal usage of this repeater is expected to be on nonloaded rubber-covered wires. The repeater can be used on open wire pairs if the line impedances are sufficiently uniform and the low power output of the repeater is not a limitation. The circuit lengths applying for this repeater in figure 5-44 assume that the repeater has 12– to 15–db gain and is located at the center of the circuit. In cases where the repeater cannot be located near the center point, the range should be reduced so that twice the dry weather loss on the short side of the repeater exceeds the one way repeater gain by at least 6 db. This consideration will be important only on low net loss circuits. In a specific circuit, the gain actually realizable may differ somewhat from the assumed value and may be higher if the line impedances on each side of the repeater are closely the same.

c. Telephone Repeater TP–14–( ). The repeatered talking ranges given in figure 5-44 apply for this repeater except on certain types of lines where the range may be reduced because of limitations of available gain (18 db at 1,000 cycles) or balances obtainable with the networks provided in the repeater. These exceptions are covered by the notes of figure 5-44. Except for these, the application of the repeater is governed by the same transmission considerations as for the packaged voice-frequency repeater, discussed in subparagraph d below.

d. Packaged Voice-frequency Telephone Repeater.

(*1*) The data given in figure 5-44 apply for a packaged voice-frequency repeater operated as a 22-type repeater at the center of a circuit. Singing and crosstalk are the principal limitations on the usable gain of such a repeater. Figure 5-44 is based on gains of 20 db for nonloaded paper-insulated cable or nonloaded stabilized wire and 15 db for open wire lines, which are assumed of moderately uniform construction and impedance. Gains of 20 db could be used on the high-grade fixed plant open wire lines described in TM 11–2253. This would permit longer repeater spacings as discussed in detail in TM 11–2022. Usable gains would be lower than are assumed in figure 5-44 if the lines have large impedance irregularities or excessive crosstalk.

(*2*) Although figure 5-44 is for a repeater in the center of the circuit, approximately the same range could be obtained with a terminal repeater at each end of the circuit.

(*3*) If the desired length of circuit is greater than shown in figure 5-44, more repeaters may be added. The following shows approximately the amount of total gain usable in various numbers of repeaters: one repeater, gain G; two repeaters, 1.9G; three repeaters, 2.6G; and four repeaters, 3.3G. This assumes that the distance from the end repeaters of the circuit to the circuit terminal is equal to one half the normal spacing between repeaters. From these factors and from the differences between repeatered and nonrepeatered ranges in figure 5-44, the allowable lengths of circuits with various numbers of repeaters may be estimated on stabilized wire. For example, for nonloaded Wire W–143 the nonrepeatered range for a 6-db net loss circuit is 5 miles, and the similar range for one central repeater is 22 miles or a difference of $22 - 5 \doteq 17$ miles. The allowable length for two intermediate repeaters is, therefore, $5 + 1.9(17) = 37$ miles and for three intermediate repeaters is about $5 + 2.6(17) = 49$ miles. General rules for assigning gains to the various repeaters in a circuit are given in paragraph 546.

(*4*) On nonstabilized wire, the same method may be used but with the further restriction that the net loss in dry weather should not become less than 3 db at any time. This will limit the range of nonstabilized wires. Also, for some of the longer lengths of repeatered open wire circuits, some manual regulation would be necessary under extreme weather conditions in the case of nominal 6-db net loss circuits.

(*5*) The margin against singing would be appreciably degraded by operating circuits at net losses lower than 6 db. No repeatered 2-wire line should be operated at a net loss lower than 3 db under the extreme attenuation variations likely to occur with weather and temperature changes.

(*6*) The data given in figure 5-44 for lead-covered cable pairs are for circuits in forward areas where crosstalk standards may be relaxed. Repeater spacings for trunk circuits in rear areas are discussed in paragraph 542.

542. VOICE-FREQUENCY LEAD-COVERED CABLES.

a. Small Cables.

(*1*) Lead-covered cables installed by the Army are expected to be of the 7-, 12-, or 27-quad size in most cases. These cables are used principally for 2-wire and 4-wire voice-frequency repeatered circuits in rear areas, but some use for them may be found in forward areas when conditions are reasonably stable. If both directions of the 4-wire circuits are to be operated in the same cable, 4-wire segregation arrangements similar to figure 5-85-B should be used. With such segregation, average repeater spacings up to about 40 miles for 19 gauge, 6000-88 loaded circuits, or about 70 miles for 16 gauge, 6000-88 loaded circuits may be used for 2-wire and 4-wire circuits in American type cables of the 7- to 27-quad sizes. By using two small cables with oppositely bound 4-wire paths in different cables, higher repeater gains can be used with good crosstalk performance. This assumes that there are no 2-wire circuits in the cables. Under these conditions the above repeater spacings may be doubled, provided repeaters of sufficiently high gain are available and unusual noise conditions are not encountered, such as noisy open wire pairs tapping into the cable near repeater inputs.

(*2*) If the phantom is not used, capacitance unbalance corrective work during installation will not be necessary. To obtain high-grade crosstalk performance between pairs, splicing should be such as to equalize the exposure between the pairs. By this is meant that any two pairs through the spliced cable should, in so far as practicable, appear a minimum number of times as pairs of the same quad, pairs in adjacent quads, etc. The 2-wire repeater balances obtainable tend to be low, because of large capacitance deviations from pair to pair. These deviations can be improved by cutting long reel lengths at 750 or 1,500 foot intervals, and resplicing so as to equalize the pair capacitances. Splicing at these shorter intervals would also improve the crosstalk performance. Such splicing may not be practicable, however, in many Signal Corps installations.

(*3*) Assuming that a cable of the 7- to 27-quad size is used for 2-wire and 4-wire circuits, with the repeater spacings and methods of segregation and splicing referred to in subparagraphs (1) and (2) above, crosstalk considerations make it desirable to restrict the 2-wire circuits to lengths of one repeater section and 8-db net loss, or two repeater sections and 11-db net loss. The 4-wire circuits can be operated at net losses of 6 to 8 db (depending on the cable size, etc.) for lengths of about 500 miles. If segregation of the oppositely bound 4-wire paths is not used, the net loss of 4-wire circuits would need to be increased about 6 db to obtain crosstalk performance equivalent to that with segregation. If the average repeater spacings are in excess of those in subparagraph (1) above, the circuit net losses would need to be increased 1 db for each increase of 1 db in the repeater section loss, in order not to degrade crosstalk performance.

b. Large Cables. Large lead-covered cables (up to 300 pairs or more) may be taken over from the enemy or installed in stable areas where large numbers of circuits are needed. Special techniques and tools are required to install and maintain these cables. Special engineering is also required and this should be done well in advance of the time the cables will be used. The repeater stations will be located at fairly regular intervals which may be 35 to 100 miles, depending upon the wire gauge, loading, and transmission requirements. When existing cables are used to provide Army circuits, the best transmission results will be obtained if the Army circuits are laid out with the same repeater gains, etc. as the civilian circuits previously in operation. Information on rehabilitation of damaged long distance cables is covered in section VII.

543. CARRIER REPEATER SECTION LENGTHS.

a. General.

(*1*) Figures 5-45 to 5-48, inclusive, give circuit lengths and repeater spacings for carrier systems. The tables cover both single section and repeatered systems for circuit net losses of 6 db and 30 db. Lengths for other net losses, or net losses for other lengths, can be estimated by straight line interpolation between the figures. In some cases, the net loss of 30 db applies to the top channel of a system and lower net losses may be obtainable on other channels. Also, in some cases the net loss could be reduced at the expense of increased noise. The figures are based on the crosstalk and noise standards for rear areas, discussed in section VI and in chapter 12, and consideration of the available gain in the equipment.

(*2*) If the length of a nonrepeatered system approaches that given for 30-db net loss circuits, and if a teletypewriter is used on voice-frequency carrier telegraph channels, considerable telegraph errors due to atmospheric static may occur in the season when thunderstorms prevail. With the spiral-four carrier system, telegraph transmission may be improved under this condition by the use of telephone channel 2 instead of channel 3 because of the lower line loss of channel 2. Other expedients are repeated transmission of the message, or the use of manual telegraph during periods of high static.

b. Spiral-four Systems. Figure 5-45 applies to the physical 4-wire operation described in paragraph 522. In the case of the open wire system, figures for two systems on a line are governed by crosstalk. Line construction described in TM 11-368 or TM 11-2253, and crosstalk standards per paragraph 549c, are assumed. Where crosstalk standards can be relaxed, longer section lengths are possible for 2-system operation on such lines. However, where existing open wire lines of other types are used, crosstalk may be inherently high and it may be necessary to adhere to the lengths given for 2-system operation and also accept poorer crosstalk.

c. Carrier Hybrid Systems.

(*1*) Figure 5-46 applies to the carrier hybrid system described in paragraph 523. In this case, no particular distinction has been made in the table between one- and 2-system operation on the line. The lengths indicated will allow 2-system operation on outside pairs of lines of the type described in TM 11-368. On adjacent pairs, the lengths should not exceed the values for 2-system operation in figure 5-45 and even at these lengths the crosstalk performance is likely to be poorer than indicated in paragraph 549c.

(*2*) Figure 5-46 gives section lengths for two values of repeater balance: 25 db and 15 db. The 25-db balance would apply to a well constructed line, without changes in wire gauge and spacing, and with inserted cables limited to the lengths and types discussed in paragraph 545. The 15-db balance is for a line of moderately poor construction with inserted lengths of cable, etc. It does not represent the worst condition that may be encountered.

d. Pair-per-system Operation of Terminals CF-1-( ). Figure 5-47 applies to the arrangements described in paragraph 524. The maximum circuit lengths for open wire assume that there are no incidental losses due to inserted cables, etc. Allowance should be made for such losses in laying out these systems.

e. Equivalent 4-wire Systems. Figure 5-48 gives data for the open wire converter, type H, and type C systems described in paragraphs 525, 527, and 528 respectively. The lengths are based on noise limitations and available gain and should be considered as maximum values. If the lines include any long lengths of cable or other sources of loss besides the open wire pair, the spacings should be shortened in proportion to the excess loss. The type C automatic regulation will be inoperative at the lengths given for nonrepeatered systems and 30-db net loss.

544. TABULAR DATA.

Figures 5-38 to 5-48, inclusive, give data covering the transmission characteristics of wires and wire-line circuits. Information covering the physical characteristics of these wires together with construction data are given in chapter 9. Further information is given in TM 11-487.

Description[a]	*D-c resistance (ohms per loop mile)*	*1,000-cycle impedance (ohms)*	*Condition of wire*	*Approximate attenuation*[b] *(db per mile)*				
				1 kc	*3 kc*	*11 kc*	*20 kc*	*30 kc*
080 Copper	17.5	680-j235	Dry	0.11	0.13	0.14	0.16	0.19
			Wet	0.13	0.15	0.17	0.20	0.24
104 Copper	10.3	614-j145	Dry	0.074	0.089	0.099	0.13	0.15
			Wet	0.083	0.11	0.12	0.16	0.19
128 Copper	6.8	580-j97	Dry	0.052	0.071	0.080	0.11	0.13
			Wet	0.061	0.088	0.100	0.14	0.16
165 Copper	4.1	545-j60	Dry	0.034	0.056	0.064	0.084	0.10
			Wet	0.042	0.072	0.083	0.11	0.13
080 40% C-S	42.8	791-j481	Dry	0.23	0.31	0.32	0.33	0.33
			Wet	0.25	0.34	0.35	0.36	0.37
104 40% C-S	25.3	686-j335	Dry	0.16	0.20	0.20	0.21	0.21
			Wet	0.18	0.22	0.23	0.24	0.24
128 40% C-S	16.7	613-j227	Dry	0.12	0.14	0.14	0.14	0.15
			Wet	0.13	0.16	0.16	0.17	0.18
104 30% C-S	33.8	740-j418	Dry	0.21	0.28	0.28	0.29	0.29
			Wet	0.22	0.30	0.31	0.32	0.33
128 30% C-S	22.3	649-j291	Dry	0.15	0.19	0.20	0.20	0.20
			Wet	0.17	0.22	0.22	0.23	0.24
083 GI	130	1,380-j830	Dry	0.36	1.2	1.4	2.1	2.5
			Wet	0.37	1.2	1.4	2.1	2.5
109 GS	75	1,230-j630	Dry	0.30	1.1	1.3	1.7	2.0
			Wet	0.31	1.1	1.3	1.7	2.0

[a] C-S denotes copper-steel. Percentage is conductivity relative to copper. GS denotes galvanized steel, GI denotes galvanized iron.

[b] Attenuations are for side circuits at 70°F and assume use of Insulators IN-15 and IN-128 in good condition, that trees, brush, etc., do not touch wires, and that recommended construction practices are followed. Pole spacing is assumed 200 feet except for 080 copper and twin pairs for which 150 feet is assumed. Pin spacing in all cases is assumed to be 8 inches.

Figure 5-38. Transmission data on open wire lines
(continued on opposite page).

Description	*D-c resistance (ohms per loop mile)*	*1,000-cycle impedance (ohms)*	*Condition of wire*	*Approximate attenuation[a] (db per mile)*				
				1 kc	*8 kc*	*11 kc*	*20 kc*	*30 kc*
			Twin pairs[b] (rubber-covered wires)					
W-110-B open wire	93		Dry	0.43	0.66	0.68	0.70	0.73
			Wet	0.46	0.68	0.71	0.75	0.79
W-110-B tree	93		Dry	0.44	0.68	0.70	0.75	0.80
			Wet	1.1	1.6	1.7	2.1	2.6
W-143 open wire	17.5		Dry	0.13	0.14	0.14	0.16	0.17
			Wet	0.14	0.16	0.17	0.20	0.23

[a] Attenuations are for side circuits at 70°F and assume use of Insulators IN-15 and IN-128 in good condition, that trees, brush, etc., do not touch wires, and that recommended construction practices are followed. Pole spacing is assumed 200 feet except for 080 copper and twin pairs for which 150 feet is assumed. Pin spacing in all cases is assumed to be 8 inches.

[b] Two wires of one pair used in parallel form one side of the circuit and two wires of another pair form the other side, also known as spaced aerial pairs (par. 504). The *open wire* twin pair is assumed to be strung like open wire on insulators and poles with 8-inch spacing. The *tree* twin pair is made of two Wire W-110-B pairs tied to trees, the spacing varying from 8 to 24 inches. Attenuations apply when there are few contacts with foliage, etc.

Figure 5-38. Transmission data on open wire lines (continued).

Type	*Loading[a]*	*D-c resistance[b] (ohms per loop mile)*	*Capacitance (mf per mile)*	*1,000-cycle impedance[c] (ohms)*	*Approximate attenuation[b] (db per mile)*				
					1 kc	*8 kc*	*11 kc*	*20 kc*	*30 kc*
				Lead-covered paper-insulated cable					
16 ga. side[d]	nonloaded	42	0.062	255-j214	0.73	1.36	1.43	1.63	1.87
19 ga. side[d]	nonloaded	86	0.062	345-j317	1.08	2.37	2.55	2.84	3.07
19 ga. pair	nonloaded	86	0.084	295-j273	1.26	—	—	—	—
22 ga. pair	nonloaded	171	0.082	416-j399	1.79	—	—	—	—
24 ga. pair	nonloaded	274	0.072	558-j542	2.14	—	—	—	—
24 ga. pair	nonloaded	274	0.084	517-j503	2.31	—	—	—	—
26 ga. pair	nonloaded	440	0.069	718-j706	2.67	—	—	—	—
16 ga. side[d]	6000-88	50	0.062	1,120-j53	0.19	—	—	—	—
19 ga. side[d]	6000-88	94	0.062	1,125-j103	0.36	—	—	—	—

[a] The type of loading is shown by a number representing the wire distance between loading coils expressed in feet followed by a number representing the inductance of the loading coil expressed in millihenries.

[b] The data in this table apply at a temperature of 70° F.

[c] For loaded circuits, the 1,000-cycle impedance is for the midsection point of a loading section, that is, a point midway between two adjacent loading coils.

[d] These are quadded cables; all others are nonquadded.

Figure 5-39. Transmission data on wires and cables (continued on following page).

Type	Loading[a]	D-c resistance[b] (ohms per loop mile)	Capacitance (mf per mile)	1,000-cycle impedance[c] (ohms)	Approximate attenuation[b] (db per mile)				
					1 kc	8 kc	11 kc	20 kc	30 kc
Rubber-covered wire and cable									
W-130-A wet	nonloaded	590	0.28	432-j372	6.5	14.5	16.5	19.0	22.0
W-130-A dry	nonloaded	590	0.09	775-j697	3.5	8.0	9.0	10.5	12.5
W-130-C wet	nonloaded	590	0.15	560-j540	4.5	11.0	12.0	14.0	16.0
W-130-C dry	nonloaded	590	0.06	900-j860	2.9	7.0	8.0	9.0	10.5
W-130 wet	nonloaded	590	0.19	505-j475	5.0	12.5	13.5	16.0	18.5
W-130 dry	nonloaded	590	0.07	890-j850	3.0	7.0	8.0	9.0	10.5
WD-3/TT	nonloaded	590	Characteristics approximately the same as Wire W-130						
W-110-B wet	nonloaded	186	0.18	300-j270	2.8	6.4	7.2	8.9	11.2
W-110-B dry	nonloaded	186	0.07	485-j440	1.7	3.7	4.0	4.6	5.2
W-110-B wet	5280-88	195	0.18	775-j105	1.6	—	—	—	—
W-110-B dry	5280-88	195	0.07	1,175-j180	0.8	—	—	—	—
W-50 wet	nonloaded	26	0.24	112-j81	1.0	1.9	2.1	3.0	4.2
W-50 dry	nonloaded	26	0.07	215-j147	0.55	0.85	0.9	1.05	1.25
W-108 wet	nonloaded	180	0.24	253-j238	3.2	7.9	8.9	10.9	12.3
W-108 dry	nonloaded	180	0.13	337-j319	2.3	5.7	6.3	7.2	7.6
W-108-A wet	nonloaded	230	0.24	285-j268	3.6	9.3	10.5	13.1	15.0
W-108-A dry	nonloaded	230	0.13	380-j364	2.7	6.7	7.5	8.8	9.5
W-143	nonloaded	35	0.21	130-j105	1.2	2.1	2.2	2.5	2.9
W-143	3300-88	48	0.21	870-j20	0.32	—	—	—	—
WC-548 side	nonloaded	71	0.12	235-j200	1.3	2.5	2.7	3.0	3.4
CC-358-( )side	1320-6	77	0.12	475-j105	0.75	0.85	0.95	—	—
CC-358-( )phantom	nonloaded	39	0.27	130-j85	1.3	2.5	2.7	3.5	4.4
CC-345	nonloaded	90	0.14	240-j220	1.7	3.7	4.0	4.6	5.0
CC-355-A	nonloaded	90	0.14	240-j220	1.7	3.7	4.0	4.6	5.0

[a] The type of loading is shown by a number representing the wire distance between loading coils expressed in feet followed by a number representing the inductance of the loading coil expressed in millihenries.

[b] The data in this table apply at a temperature of 70° F. Data are approximate as the electrical characteristics of these wires are subject to variations because of material substitutions and difficulties in controlling manufacturing processes.

[c] For loaded circuits, the 1,000-cycle impedance is for the midsection point of a loading section, that is, a point midway between two adjacent loading coils.

Figure 5-39. Transmission data on wires and cables (continued).

QUADDED CABLES[a]

Loading[b]	Nominal[c] impedance (ohms)	Cut-off frequency (cycles)	Attenuation, 1,000-cycle, 55° F (db per mile)	
			19 ga.	16 ga.
B-88-50-S	1,550	5,600	0.28	0.16
B-88-50-P	930	5,900	0.23	0.14
H-174-106-S	1,550	2,900	0.28	0.16
H-174-106-P	950	2,900	0.22	0.13
H-172-63-S	1,550	2,900	0.27	0.16
H-172-63-P	750	3,700	0.28	0.16
H-88-50-S	1,100	4,000	0.35	0.19
H-88-50-P	650	4,200	0.30	0.16
H-44-25-S	800	5,600	0.47	0.25
H-44-25-P	500	5,900	0.39	0.21
B-22-N	800	11,000	0.45	0.24
H-44-N	800	5,600	0.47	0.25
H-88-N	1,100	4,000	0.35	0.19

[a] Capacitance of quadded cables: 0.062 mf per mile (side) 0.102 mf per mile (phantom).

[b] The first letter indicates the coil spacing (H = 6,000 ft. and B = 3,000 ft.): the first and second numbers indicate the inductances (millihenries) of the side and phantom loading coils, respectively; and the last letter indicates whether it is a side circuit (S), a phantom circuit (P), or a nonphantomed pair (N).

NONQUADDED CABLES[d]

Gauge cable (B&S)	Loading	Nominal[c] impedance (ohms)	Cut-off frequency (cycles)	Attenuation, 1,000-cycle, 68° F (db per mile)
26	H-88	1,050	3,800	1.68
24	H-44	750	5,300	1.46
	H-88	1,050	3,700	1.13
	B-88	1,450	5,300	0.86
22	H-44	700	5,000	1.04
	H-88	1,000	3,500	0.79
	B-88	1,400	5,000	0.60
	B-135	1,700	4,000	0.48
19	H-44	700	5,000	0.56
	H-88	950	3,500	0.42
	B-88	1,350	4,900	0.34
	B-135	1,700	3,900	0.26

[c] For loaded cable $Z = \sqrt{\frac{L}{C}}$, where L is loading coil inductance in henries and C is loading section capacitance in farads. For nonloaded cable $Z = \sqrt{\frac{R}{2\pi fC}}$; where R and C are the resistance and capacitance per unit length and f is the frequency (1,000 cycles assumed).

[d] Transmission data apply to nonquadded cables having the following capacitance:

26 ga. = 0.069 mf per mile
24 ga. = 0.072 mf per mile
22 ga. = 0.082 mf per mile
19 ga. = 0.084 mf per mile

Figure 5-40. American civil loading systems.

Through line	Bridging line	Transmission loss due to bridging (db)[a]	
		Loss to through transmission	Loss from through line to bridge
Open wire pair	Open wire pair	3.5	3.5
Open wire pair	W-143 nonloaded	10.0	1.5
Open wire pair	W-143 3300-88	3.0	3.5
Open wire pair	CC-358-( )	5.0	3.0
Open wire pair	W-110-B nonloaded[b]	5.5	2.5
Open wire pair	W-110-B 5280-88[b]	4.0	4.0
Open wire pair	Telephone EE-8-( )[c]	1.0[d]	4.0[d]
Open wire pair	Telephone Unit EE-105, low impedance	2.0	5.0[e]
Open wire pair	Telephone Unit EE-105, medium impedance	1.0	13.5[e]
Open wire pair	Telephone Unit EE-105, high impedance	0.5	19.0[e]
W-143 nonloaded	W-143 nonloaded	3.5	3.5
W-143 nonloaded	W-143 3300-88	0.5	5.5
W-143 nonloaded	W-110-B nonloaded[b]	1.5	4.5
W-143 nonloaded	Telephone EE-8-( )[c]	0.5[d]	6.0[d]
W-143 3300-88	W-143 nonloaded	11.0	1.0
W-143 3300-88	W-143 3300-88	3.5	3.5
W-143 3300-88	W-110-B nonloaded[b]	6.0	2.5
W-143 3300-88	Telephone EE-8-( )[c]	2.5[d]	3.5[d]
W-110-B nonloaded[b]	W-110-B nonloaded[b]	3.5	3.5
W-110-B nonloaded[b]	Telephone EE-8-( )[c]	0.5[d]	4.5[d]

[a] Based on impedance of open wire pairs using 104 mil copper-steel wire, conductivity 40%. For open wire pairs of other sizes, the losses will not be substantially different.

[b] Wire W-110-B assumed to be wet.

[c] The bridging loss of Telephone EE-8-( ) will be substantially different at 500 cycles from the values shown. When bridged on an open wire line the bridging loss may be as much as 10 to 15 db at 500 cycles.

[d] Losses are for the listening condition. When talking, losses will not be materially different.

[e] Includes losses of series resistance and filter in Telephone Unit EE-105.

Figure 5-41. Bridging losses at 1,000 cycles.

Type of nonloaded wire or cable	*Up to maximum lengths shown: insertion loss in db = factor x length in hundred feet*[a]		*For greater lengths: insertion loss in db = reflection loss plus attenuation*	*Type of nonloaded wire or cable*	*Up to maximum lengths shown: insertion loss in db = factor x length in hundred feet*[a]		*For greater lengths: insertion loss in db = reflection loss plus attenuation*
	Max. length (ft.)	*Factor*	*Reflection loss, two functions (db)*		*Max. length (ft.)*	*Factor*	*Reflection loss, two functions (db)*
Frequency: 1 kc				*Frequency: 11 kc*			
16 ga.	55,000	0.016	1.3	16 ga.	6,100	0.09	3.9
19 ga.	90,000	0.021	0.4	19 ga.	7,400	0.09	3.2
WC-548	35,000	0.030	1.6	WC-548	3,900	0.17	4.7
W-143	18,000	0.044	4.1	W-143	2,700	0.30	7.1
W-110-B (wet)	24,000	0.055	0.7	W-110-B (wet)	2,800	0.27	3.9
W-50 (wet)	16,000	0.055	5.7	W-50 (wet)	2,700	0.33	7.7
Frequency: 8 kc				*Frequency: 27 kc*			
16 ga.	8,200	0.07	3.7	16 ga.	2,200	0.22	4.2
19 ga.	9,900	0.07	2.6	19 ga.	2,400	0.22	4.0
WC-548	5,800	0.13	4.3	WC-548	1,500	0.41	5.2
W-143	3,400	0.24	7.0	W-143	1,100	0.74	7.3
W-110-B (wet)	3,500	0.22	3.4	W-110-B (wet)	1,100	0.67	5.0
W-50 (wet)	3,400	0.26	7.6	W-50 (wet)	1,100	0.81	7.7

[a] See paragraph 538 for example of use.

Figure 5-42. Loss of cables inserted in open wire lines.

Equipment	*Frequency (kc)*	*Loss (db)*
Repeating coil.	1	0.8
Composite set.	1	0 1
Low pass section, type C line filter.	1	0.5
Low pass section, type H line filter.	1	0.1
High pass section, type C line filter.	27	0.4
High pass section, type H line filter.	8	0.2
Switchboards.	1	[a]

[a] Losses for various type of switchboards are given in TM 11-487.

Figure 5-43. Transmission losses in telephone equipment.

Type	1,000 cycle attenuation wet weather (db/mi)	Nonrepeatered talking range (miles)[a]			Repeatered talking ranges (miles)[a] One central 2-wire repeater[b, c]		
		6-db net loss	18-db net loss	30-db net loss	6-db net loss	18-db net loss	30-db net loss
			Open wire[d]				
080 C-S 40%	0.25	24	72	120	85	130	180
104 C-S 40%	0.18	33	100	165	115	185	250
128 C-S 40%[e]	0.13	46	140	230	160	255	345
080 Copper[e]	0.13	46	140	230	160	255	345
104 Copper	0.083	72	215	360	255	395	540
128 Copper	0.061	100	300	500	345	540	740
165 Copper	0.042	145	435	725	500	785	1,070
083 GI[e]	0.37	16	48	80	57	90	120
109 GS	0.31	19	57	95	68	105	145
W-110-B open wire twin pair[f]	0.46	13	39	65	—	—	—
W-110-B tree twin pair[f]	1.1	5	16	27	—	—	—
W-143 open wire twin pair[f]	0.14	43	130	215	—	—	—
			Lead-covered cable				
16 ga. nonloaded[e]	0.73	8	25	41	35	50	65
16 ga. 6000-88	0.19	32	95	155	110	175	235
19 ga. nonloaded[e]	1.08	5.5	16.5	28	24	35	45
19 ga. 6000-88	0.36	17	50	85	58	90	125

[a] Talking ranges are based on wet weather attenuations. They assume local or common battery telephones. The ranges for circuits with 30-db net loss and sound-powered telephones will be approximately 0.5 of the indicated distance for nonrepeatered circuits and 0.7 of the indicated distance for repeatered circuits.

[b] The talking ranges are for one central or two terminal 22-type repeaters (par. 541). The figures apply to the 22-type packaged voice-frequency 2-wire repeater, and also to Telephone Repeater TP-14- ( ) except as indicated in notes *e* and *f*.

[c] The 21-type Telephone Repeater EE-89-A is not used for 6-db net loss circuits. It can be used at the range indicated for 18-db and 30-db net loss circuits on Wire W-110-B and on open wire lines if the lines are reasonably free from impedance irregularities. Loaded circuits are not satisfactory. On Wire W-143 and nonloaded pairs in lead-covered cables the ranges will be about 5 miles less than those shown.

[d] Open wire lines are assumed to be constructed per TM 11-368 or TM 11-2253 and to be well maintained. Shorter spacings will be required on lines with irregularities or materially different weather conditions.

[e] For this facility no specific settings of the balancing network in TP-14- ( ) are available, but approximate settings may be obtained experimentally. The talking range will be reduced if adequate balance is not obtained. For nonloaded pairs in lead-covered cables the distances with Telephone Repeater TP-14- ( ) are about 3 miles less than those shown.

[f] Twin pair construction is described in figure 5-38 (note). The talking ranges apply where there are few contacts with foliage and trees, except at supports.

Figure 5-44. Talking ranges of voice-frequency circuits
(continued on opposite page).

Type	1,000 cycle attenuation wet weather (db/mi)	Nonrepeatered talking range (miles)[a]			Repeatered talking ranges (miles)[a] One central 2-wire repeater[b], [c]		
		6-db net loss	18-db net loss	30-db net loss	6-db net loss	18-db net loss	30-db net loss
Rubber-covered wire and cable							
W-143[d]	1.20	5	15	25	22	32	42
W-143 3300-88[e]	0.32	19	56	94	65	103	140
CC-358-( )	0.75	8	24	40	28	44	60
W-110-B nonloaded	2.80	2	6	11	4	9	15
W-110-B 5280-88	1.60	4	11	19	8	14	25
W-130-A	6.5	0.9	3	4.5	—	—	—
W-130-C	4.5	1.3	4	7	—	—	—
CC-345	1.70	3.5	11	18	—	—	—
CC-355-A	1.70	3.5	11	18	—	—	—

[a] Talking ranges are based on wet weather attenuations. They assume local or common battery telephones. The ranges for circuits with 30-db net loss and sound-powered telephones will be approximately 0.5 of the indicated distance for nonrepeatered circuits and 0.7 of the indicated distance for repeatered circuits.

[b] The talking ranges are for one central or two terminal 22-type repeaters (par. 541). The figures apply to the 22-type packaged voice-frequency 2-wire repeater, and also to Telephone Repeater TP-14- ( ) except as indicated in notes *e* and *f*.

[c] The 21-type Telephone Repeater EE-89-A is not used for 6-db net loss circuits. It can be used at the range indicated for 18-db and 30-db net loss circuits on Wire W-110-B and on open wire lines if the lines are reasonably free from impedance irregularities. Loaded circuits are not satisfactory. On Wire W-143 and nonloaded pairs in lead-covered cables the ranges will be about 5 miles less than those shown.

[d] For Wire W-143 the distances with Telephone Repeater TP-14- ( ) are about 2 miles less than those shown, as limited by available gain.

[e] For this facility no specific settings of the balancing network in TP-14- ( ) are available, but approximate settings may be obtained experimentally. The talking range will be reduced if adequate balance is not obtained. For nonloaded pairs in lead-covered cables the distances with Telephone Repeater TP-14- ( ) are about 3 miles less than those shown.

Figure 5-44. Talking ranges of voice-frequency circuits (continued).

Type of circuit	*Circuit length (miles)* [a] *(without repeaters)*				*Repeater spacing (miles)* [a] *(with repeaters)*	
	1 system per line		*2 systems per line* [b]		*1 system per line with 6-db net loss*	*2 systems per line* [b] *with 6-db net loss*
	6-db net loss	*30-db net loss*	*6-db net loss*	*30-db net loss*		
Rubber-covered cable and wire						
CC-358-( )	45	70	—	—	25	—
W-143 nonloaded	17	28	—	—	14	—
Open wire						
080 C-S 40%	110	185	50	115	70	30
104 C-S 40%	170	275	70	175	95	40
128 C-S 40%	230	380	95	240	170	55
080 Copper	220	365	90	230	180	55
104 Copper	300	510	130	335	245	80
128 Copper	350	600	145	390	285	85
165 Copper	425	730	180	475	345	100

[a] Figures assume that +10 db output level is used for all except repeatered systems on Cable Assembly CC-358-( ) where 0 db output level is assumed.

[b] Figures for two systems on an open wire line assume crosstalk conditions applying to the construction described in TM 11-368 or TM 11-2253, systems assigned as shown in figure 5-31, and crosstalk standards given in paragraph 549 c.

Figure 5-45. Spiral-four carrier on cable and open wire, circuit lengths and repeater spacings for physical 4-wire systems.

Type of circuit	*Circuit length (miles) (without repeaters)*				*Repeater spacing (miles) (with repeaters)*	
	25-db balance [a]		*15-db balance* [a]		*25-db balance* [a] *with 6-db net loss*	*15-db balance* [a] *with 6-db net loss*
	6-db net loss	*30-db net loss*	*6-db net loss*	*30-db net loss*		
Rubber-covered cable and wire						
CC-358-( )	—	—	16	42	—	7
W-143 nonloaded	12	23	7	18	8	3

[a] Balances of 25 db and 15 db mean that the line and network impedances can be matched within 11% and 36% respectively, at all transmitted frequencies. Figures for 25-db balances are for well constructed lines; 15-db balances are for lines with moderately irregular construction, with intermediate cables, etc.

Figure 5-46. Carrier hybrid system, circuit lengths and repeater spacings *(continued on opposite page).*

Type of circuit	*Circuit length (miles) (without repeaters)*				*Repeater spacing (miles) (with repeaters)*	
	25-db balance[a]		*15-db balance*[a]		*25-db balance*[a] *with 6-db net loss*	*15-db balance*[a] *with 6-db net loss*
	6-db net loss	*30-db net loss*	*6-db net loss*	*30-db net loss*		
Open wire[b]						
080 C-S 40%	65	135	45	115	50	20
104 C-S 40%	95	200	70	175	70	30
128 C-S 40%	135	285	100	250	95	45
080 Copper	130	270	95	235	95	40
104 Copper	185	380	135	335	135	60
128 Copper	210	450	160	400	150	70
165 Copper	245	535	195	480	175	85

[a] Balances of 25 db and 15 db mean that the line and network impedances can be matched within 11% and 36% respectively, at all transmitted frequencies. Figures for 25-db balances are for well constructed lines; 15-db balances are for lines with moderately irregular construction, with intermediate cables, etc.

[b] More than one carrier hybrid system can be worked on lines constructed as outlined in TM 11-368 or TM 11-2253, as discussed in paragraph 545.

Figure 5-46. Carrier hybrid system, circuit lengths and repeater spacings (continued).

Type of circuit	*Circuit length (miles)*[a]	
	18-db net loss	*30-db net loss*
080 C-S 40%	25	60
104 C-S 40%	40	90
128 C-S 40%	55	130
080 Copper	53	125
104 Copper	75	175
128 Copper	90	210
165 Copper	110	255
CC-358-( )	9.5	22

[a] The lengths for open wire circuits assume lines without inserted cable. Cable may be used in the line but the circuit lengths will be reduced substantially by the added loss.

Figure 5-47. Pair-per-system operation of Telephone Terminals CF-1-( ), circuit lengths.

Type of circuit	Circuit lengths (miles) (without repeaters) [a]						Repeater spacings (miles) (with repeaters) [b]		
	Open wire converter		Type C		Type H		Open wire converter	Type C	Type H
	6-db net loss	30-db net loss	6-db net loss	30-db net loss	6-db net loss	30-db net loss	6-db net loss	6-db net loss	6-db net loss
080 C-S 40%	135	200	110	190	95	165	90	100	80
104 C-S 40%	195	295	165	290	145	255	120	155	125
128 C-S 40%	255	390	235	375	200	350	170	210	175
080 Copper	185	280	185	290	215	375	140	160	180
104 Copper	245	380	240	375	290	510	190	205	245
128 Copper	285	440	285	440	360	635	215	245	305
165 Copper	340	535	335	520	440	780	255	295	375

[a] Circuit lengths given for systems with no repeaters will require unequal levels at the output of the receiving terminal amplifier in some cases, but the net loss can be adjusted in the individual channels. Transmitting levels for open wire converter systems without repeaters are assumed 5 db higher than for systems with repeaters.

[b] Spacings assume line sections are entirely open wire and constructed in accordance with TM 11-368 or TM 11-2253. If there are entrance or intermediate cables, the line sections should be shortened enough to offset the loss in the cables, including the reflection losses at the junctions of the cable and open wire.

Figure 5-48. Open wire converter, type C, and type H systems, circuit lengths and repeater spacings.

545. LENGTHS OF ENTRANCE AND INTERMEDIATE CABLES.

a. General. Nonloaded rubber-insulated cables or wire, or nonloaded lead-covered paper-insulated cables inserted in open wire lines may degrade transmission in three different ways, namely: added loss; increased crosstalk, particularly at carrier frequencies; and reduced repeater balance.

b. With Spiral-four System. With physical 4-wire operation of spiral-four equipment on open wire, the principal effect of nonloaded cable is to increase the transmission loss. A method of calculating the loss of a piece of nonloaded cable or wire inserted in an open wire line is described in paragraph 538. Where the inserts are long enough to cause excessive loss, Cable Assemblies CC-358-( ) should be used. A somewhat better impedance match will be obtained if a half-section termination is used at the open wire junctions; that is, with 660 feet of cable between the open wire and the end loading coils. The two sides of a spiral-four quad should be used for the same system.

c. With Carrier Hybrid Systems.

(*1*) Cables in carrier hybrid systems have the effect of impairing the balance between the line and network, in addition to the added loss. Impairment of repeater balance reduces the allowable repeater gain, which has the effect of increasing the loss still further. To reduce this penalty, Carrier Hybrid CF-7 includes means for balancing nonloaded entrance cables for lengths up to about 60 percent of the values given in figure 5-49 for entrance cables on 2-wire voice-frequency circuits. Longer entrance cables would require capacitances beyond the values available in the balancing capacitor of the network. Intermediate cables located near a hybrid, but not adjacent, cannot be balanced accurately and should normally be limited to 20 percent of the lengths given in figure 5-49 for intermediate cables on voice-frequency circuits, in cases where repeater gains and spacings are based on 25-db balances. Longer nonloaded lengths can be used if the systems are set up on the basis of 15-db balances, but it will generally be desirable to use loading to obtain better performance.

(*2*) A method for loading cables in carrier hybrid systems is illustrated in figure 5-50-A. Cable Assembly CC-358-( ) is used and the cable is cut so that there is 420 feet of

Type of wire of cable	Feet per length[a]							
	Entrance or intermediate cable						Repeatered voice-frequency circuits	
	Type C carrier system			Type H carrier system			Entrance cable[b]	Intermediate cable[b]
	1 length per section	2 lengths per section	3 lengths per section	1 length per section	2 lengths per section	3 lengths per section		
16 or 19 ga.[c]	240	170	140	720	510	420	6,000	1,100
W-143	80	55	45	240	165	135	2,000	350
WC-548[d]	125	90	70	375	270	210	3,000	600
W-110-B	80	55	45	240	165	135	200	200
W-50	65	45	40	200	140	110	150	150

[a] The lengths given in this table are for high-grade transmission performance.

[b] For intermediate cables in voice-frequency circuits, longer lengths than those indicated can be used when cables are separated from the nearest repeater by more than 3-db line loss. At the center of a section the allowable length is about the same as for entrance cable.

[c] Lengths are for lead-covered paper-insulated pairs or quads of 0.062 mf per mile capacitance. It is desirable to use one pair per quad in quads which are not adjacent in lead-covered quadded cables, for carrier operation.

[d] Both side circuits of Cable WC-548 generally can be used, if these lengths are not exceeded. WC-548 is the spiral-four cable used in Cable Assembly CC-358-( ).

Figure 5-49. Maximum lengths for nonloaded cables and rubber-covered wires in open wire carrier and voice-frequency circuits, fixed plant systems.

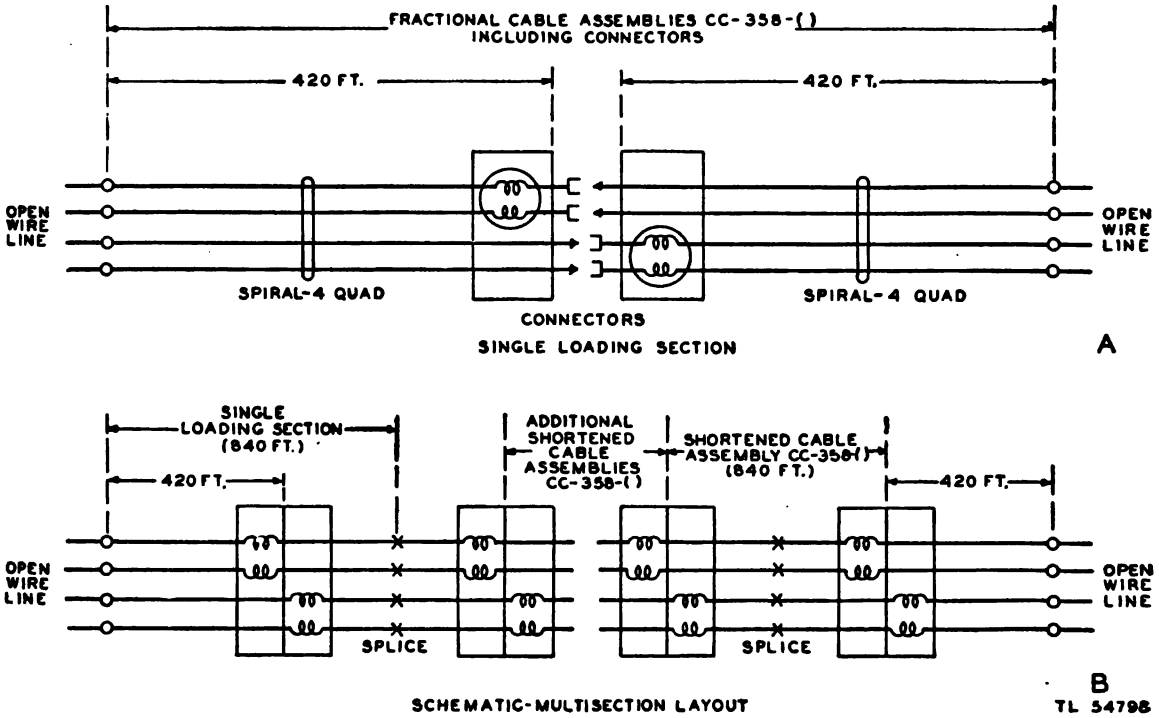


Figure 5-50. Improvised loaded cable, 12-kc band, for inserting in open wire.

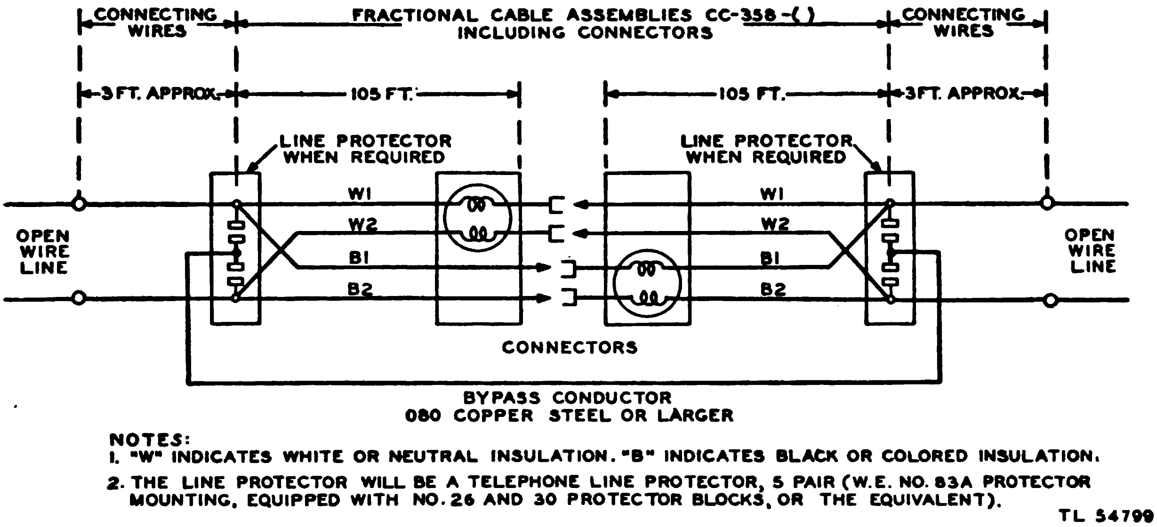


Figure 5-51. Improvised loaded cable, 32-kc band, for inserting in open wire.

cable adjacent to each connector. This provides a cable loading section consisting of a 6-millihenry coil at the center of 840 feet of cable. It is suitable for transmission of frequencies up to 12 kc and has an impedance which closely matches the open wire impedance. If the distance to be spanned is shorter than 840 feet, the complete section should be used and the excess cable coiled up. For distances greater than 840 feet, loading sections can be connected in tandem, as illustrated in figure 5-50-B. This provides a loaded cable with end sections of about 420 feet and distance between loading coils of 840 feet. Protectors should be provided at the junction of the cable and open wire if required in accordance with the information in chapter 10. Special care should be taken to make good splices with low series resistance and low leakage, in order to avoid excessive noise and crosstalk.

(*3*) An alternative to the loading arrangement described in subparagraph (2) above is the use of Cable Assembly CC–358–( ), terminated at half section at each end. This alternative loading arrangement has the advantage that it can be installed more rapidly, but the impedance matching performance is not as good and the useable repeater gains will be somewhat lower.

d. With Open Wire Converter Systems.

(*1*) Nonloaded cable in an open wire converter system (CF–4) should be limited to the values given in figure 5-49 for type C systems when high-grade crosstalk results are desired. Considerably longer lengths (up to two times or even more) may be used in forward areas. It is desirable, however, to load cables exceeding the limiting lengths given, as discussed below.

(*2*) For lengths of 210 feet or under, the layout shown in figure 5-51 can be used for loading. This arrangement is satisfactory for transmission of frequencies up to about 30 kc. It can be obtained by using the two connectors of Cable Assembly CC–358–( ), with 105 feet of cable adjacent to each connector. The two pairs of the quad should be connected in parallel and then connected between the open wire pairs as shown, including short connecting wires at each end. An entire spiral-four quad is required for each open wire pair. If the distance is shorter than 210 feet, the excess wire should be coiled up and hung on the open wire pole. Protection should be provided in accordance with information in chapter 10. Figure 5-51 shows protection for buried cable. The bypass conductor should be carried in close proximity to the cable. It is not necessary to provide a special ground connection.

(*3*) For longer distances several sections may be connected in tandem. The additional sections may be made from Cable Assemblies CC–358–( ) by cutting out a part of the cable and splicing the conductors together to form 210-foot lengths with connectors at each end. Special care should be taken to make good

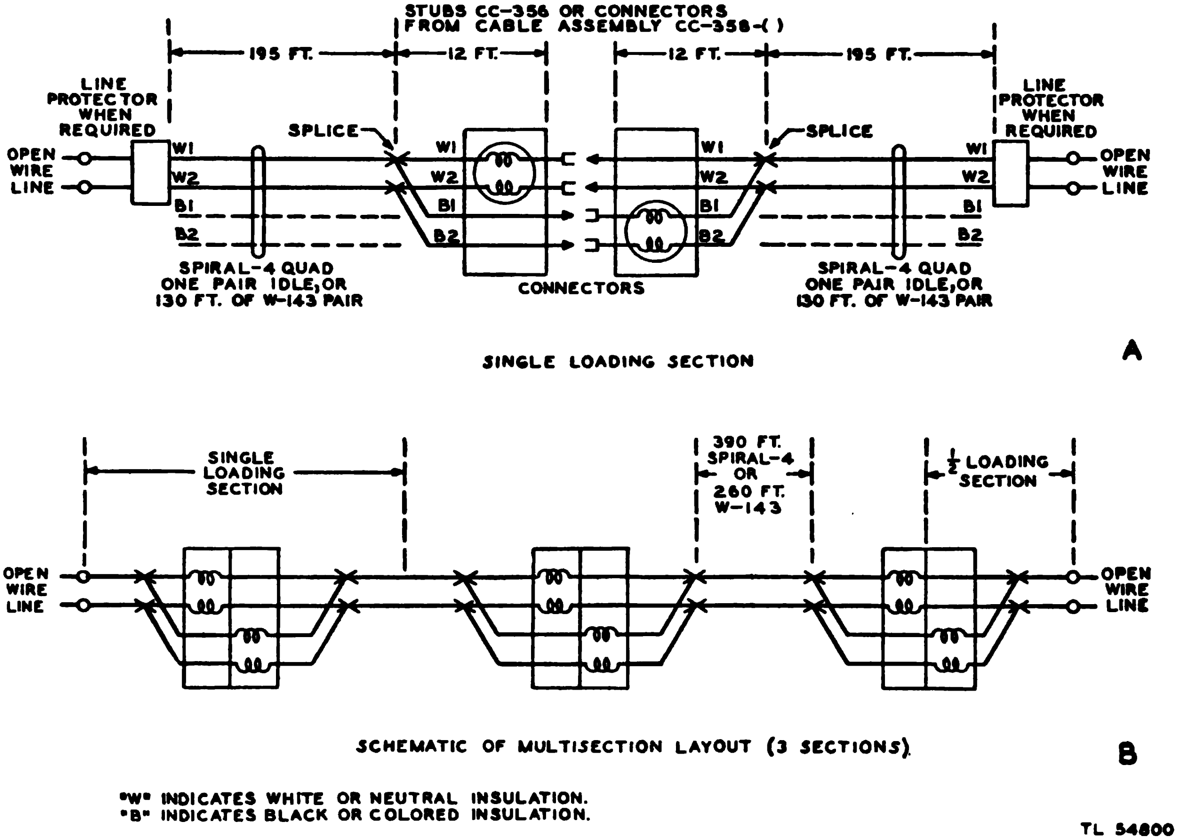


Figure 5-52. Improvised loaded rubber-insulated wire or cable, 32-kc band, for inserting in open wire.

splices, with low series resistance and low leakage, in order to avoid excessive noise and crosstalk. The additional section should be inserted between the connectors shown in figure 5-51. If protection is required in accordance with chapter 10, the bypass conductor should be extended the entire length of the cable or, as an alternative, protector grounds may be established at each end and the bypass conductor omitted. Two loading sections will cover a distance up to about 420 feet and three sections up to 630 feet. Modulation effects are likely to be serious if large numbers of sections are used in tandem, or if the loss of the repeater section exceeds about 30 db. It will be necessary to operate d-c telegraph on a simplex basis over the loaded pairs to avoid modulation effects, which would be excessive with composited operation.

(*4*) An alternative construction is possible which takes somewhat longer to install but which permits greater lengths of cable between the loading coils. This is illustrated in figure 5-52-A. The 3-millihenry inductance is obtained by parallel connection of the loading coils in Cable Stubs CC–356. One pair of a 195-foot length of spiral-four quad is connected on each side of the loading coil, providing a total geographical length of 414 feet. A number of sections can be used in tandem as shown in figure 5-52-B. If desired, a 130-foot length of Wire W–143 can be used instead of the 195-foot length of spiral-four. Here also, special care should be taken to make good splices.

e. With Fixed Plant Systems.

(*1*) Limits for nonloaded cable lengths for fixed plant systems are given in figure 5-49. These lengths assume the necessity for high-grade transmission and crosstalk performance; if longer lengths are unavoidable, carrier loaded paper-insulated lead-covered cable should be used. Suitable types of commercial carrier loading are listed in TM 11–487. The standard commercial loading arrangements for 32-kc band transmission such as the Bell System C–4.1 loading, require the installation of the coils at intervals shorter than the theoretical spacing, and involve capacitance measurements and capacitance building-out adjustments of the individual carrier loading sections so that the capacitance of each loading section closely approximates the theoretical ideal value. Adjustable capacitors are used for building out cable capacitance. They correct for manufacturing deviations in cable capacitance and for geographical spacing irregularities, and ensure cable impedance characteristics close to the theoretical design values.

(*2*) In most situations where loaded incidental cables are warranted in 32-kc band fixed plant carrier systems, the impedance matching requirements can be satisfied with a simplified form of the C–4.1 loading, without making capacitance measurements. This simplified loading makes use of the loading apparatus designed for the C–4.1 system, installed at a geographical spacing of 930 feet of cable having a capacitance of 0.062 mf per mile. The primary objective in the layout of the loading is to have the average loading section capacitance approximate the theoretical design value. The usual manufacturing deviations in cable capacitance are tolerated, and building-out adjustments are made only to correct for objectionable departures from the desired loading section length. These adjustments can be made in terms of distance measurements, and of the unit length or nominal capacitance values of the building-out devices. The simplest of the various available building-out procedures is to use cables. For example, when the distance between loading points is less than full section (930 ft. 0.062 mf/mi. cable), a full-section length (930 ft.) may be used, with the excess length coiled up, or looped back and forth. The simplified loading layout and adjustment procedure may result in appreciable reflection crosstalk between different carrier systems on the same line. The magnitude of this crosstalk, however, should generally be satisfactory on Army lines that have been designed to have low near-end crosstalk. Detailed information regarding the loading apparatus, and the layout and installation procedures can be obtained through Army Communications Service.

(*3*) Suitable commercial autotransformers can be used at junctions of open wire and cable for impedance matching purposes. They restrict the use of grounded d-c telegraph to one circuit per pair (on account of coupling between such telegraph circuits in the autotransformer) and result in low return losses at voice frequencies, so their use is in general limited to cases where these factors are not controlling, and to cases where loading is difficult to apply, for example, submarine cables that would require the use of submarine loading coil cases. Such autotransformers are not stocked by the Signal Corps.

(*4*) Special allocation of pairs may be needed in lead-covered cables, especially small size cables, to provide low enough coupling to permit high-grade crosstalk performance. The cable should contain enough pairs so that the carrier pairs can be separated by other pairs, as described in paragraph 562.

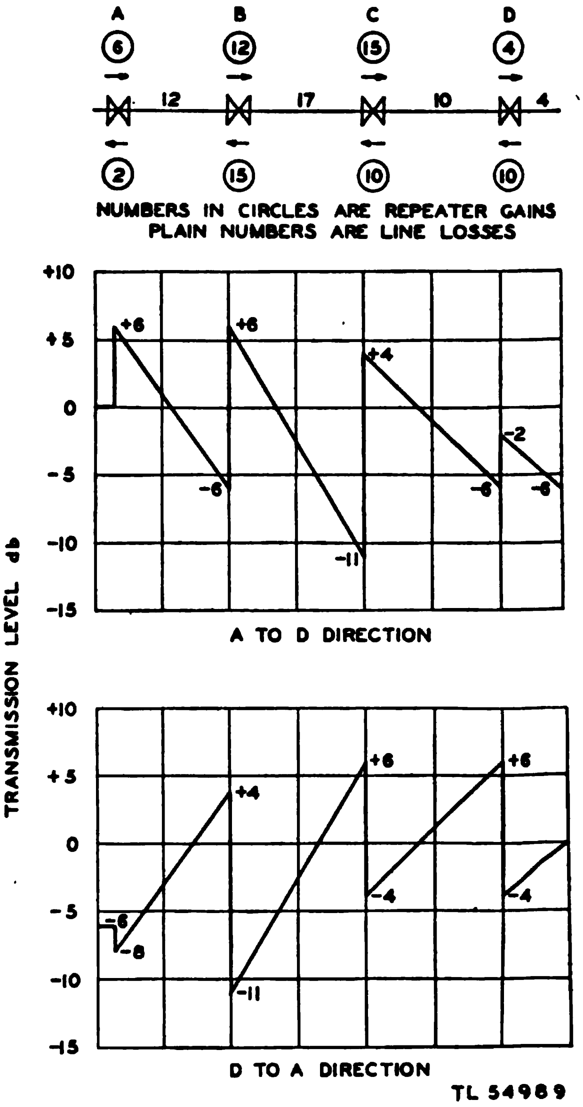


Figure 5-53. Transmission level diagram.

546. REPEATER GAINS ON VOICE-FREQUENCY CIRCUITS.

a. The repeater gains in a voice-frequency circuit must be adjusted so that singing will not occur and there will not be excessive overloading, noise, or crosstalk. Within these limitations, the overall circuit net loss should be adjusted as nearly as possible to the desired value and should be the same in both directions of transmission. Since repeaters will be located near towns or other convenient points, the distance between repeaters may not be uniform and the gains will therefore be different at different repeaters. For the same reason, the gains at any one repeater may be different in the two directions of transmission. General rules for assigning repeater gains on either 2-wire or 4-wire circuits are as follows.

(*1*) The transmitting gain (in the direction transmitting away from the switchboard) of the first repeater in a circuit should provide a transmission level (ch. 12) at the repeater output of +6 db for 2-wire circuits and +10 db for 4-wire circuits.

(*2*) The gain of an intermediate repeater in a given direction of transmission should not exceed the loss of the preceding line section. It may be made equal to the line section loss either on 4-wire circuits, or on 2-wire circuits if singing conditions permit. This will make the transmission level at the output of any of the intermediate repeaters not greater than +6 db on 2-wire circuits and +10 db on 4-wire circuits.

(*3*) The receiving gain (in the direction receiving from the line) of the last repeater in a circuit should be adjusted to give the desired over-all circuit loss, assuming that singing is not a limitation. The over-all loss should be the same for the two directions of transmission.

(*4*) The gains used in a 2-wire repeater should not exceed the values allowable from a singing standpoint as discussed in paragraph 541d.

b. If repeater gains are assigned in accordance with the general rules stated in subparagraph a above, it may be possible to obtain an improvement in singing margins on 2-wire circuits by gain readjustments after the circuits are set up and tested. Such readjustments will depend on the particular layout and the balances realized and will be necessary only if satisfactory performance cannot be obtained with the normal gain assignments.

c. An example of the application of these rules to the assignment of repeater gains in 2-wire circuits is shown in figure 5-53. Singing considerations are assumed to limit the gain to a maximum of 15 db in each direction of transmission in this example. The repeaters at A and D have transmitting gains of 6 db and 10 db, respectively, which give transmission levels of plus 6 db at the outputs of the repeaters on the line side. The receiving gains of these repeaters at A and D are adjusted to give a circuit net loss of 6 db. The intermediate repeaters have gains equal to the loss of the preceding line section or 15 db, whichever is lower, in accordance with subparagraphs a (2) and (4) above.

d. Preparation of circuit layout cards recording the assigned gains and gain control adjustments of packaged voice-frequency repeaters is described in chapter 11.

Section VI. CROSSTALK

547. INTRODUCTION.

a. Conditions Close to the Front.

(*1*) Near the front, speed of installation is essential. While this does not justify careless construction methods, the required speed may result in degradation of the crosstalk standards practicable for construction in rear areas. The most lenient crosstalk criterion which can be tolerated is that the crosstalk be only faint enough so that a listener will not confuse it with the desired speech. This lenient criterion can be met with rubber-covered wires in good condition even if they are bunched together. For open wire voice-frequency circuits on U. S. Army or on other lines, and for U. S. Army carrier circuits on the U. S. Army open wire lines, it can be met on pairs which pass the ordinary tests for wire troubles.

(*2*) On any existing open wire line it should be practicable to operate one CF–1 carrier system (assuming of course that there are no cable inserts with voice-frequency loading). Possible difficulties on lines not transposed for carrier are singing and absorption peaks. An *absorption peak* is an excessive transmission loss caused by crosstalk into the surrounding wires and back again in a phase which opposes the original transmission. This same phenomenon can cause crosstalk from the output of a high-gain repeater into its input and hence cause singing. On repeatered circuits, singing is apt to be the controlling limitation unless the repeater gain is quite low. The practical remedy for either trouble, in the areas in question, is to move the carrier system to other wires, if available. Pairs on which the transposition interval is not over about a quarter mile should not be subject to these troubles when the CF–1 carrier system is used.

(*3*) When more than one carrier system is operated on French or Italian open wire lines (par. 561c), it is desirable from the crosstalk standpoint to assign only one carrier system to any one group, or square, of four adjacent wires. On other types of open wire line, if more than one CF–1 carrier system is used, the pair assignments should preferably be made so that transmission is in the same direction on adjacent pairs which carry different carrier systems, as shown in figure 5-31. It is desirable to observe the open wire repeater spacings given in paragraphs 543b and c. Increased repeater spacing results in increased amplification of crosstalk between CF–1 carrier systems or between CF–7 carrier systems. Since the crosstalk performance of lines in forward areas may be considerably poorer than in rear areas, increased amplification of the crosstalk might result in violating even the very lenient crosstalk criterion mentioned above. Where spiral-four cable is inserted in tandem with open wire, avoid the use of the same spiral-four cable for opposite directional channels of different CF–1 systems.

b. Other Conditions. The rest of this section applies primarily to areas, particularly those having open wire lines, where crosstalk performance better than that described above is needed. Information is given on methods of transposing open wire lines and controlling crosstalk in entrance and intermediate cables. Transpositions for new U. S. Army open wire lines per TM 11–368 and TM 11–2253 are discussed. Some information on transposing short lines with 10-pin crossarms is included, and available information on lines existing in certain foreign countries is given. The problem of adding wire to captured plant may arise or it may be necessary to connect different types of lines in tandem. As an aid in such special problems, a discussion of crosstalk standards and principles of crosstalk control is included.

548. TERMINOLOGY.

a. If a listener on one circuit hears the speech of a talker on another circuit, the listener is said to hear *crosstalk*. The listener's circuit and the talker's circuit are called the disturbed circuit and the disturbing circuit, respectively.

b. As indicated in figure 5-54, if crosstalk is heard on the disturbed circuit at the same end of the line at which the talker energizes

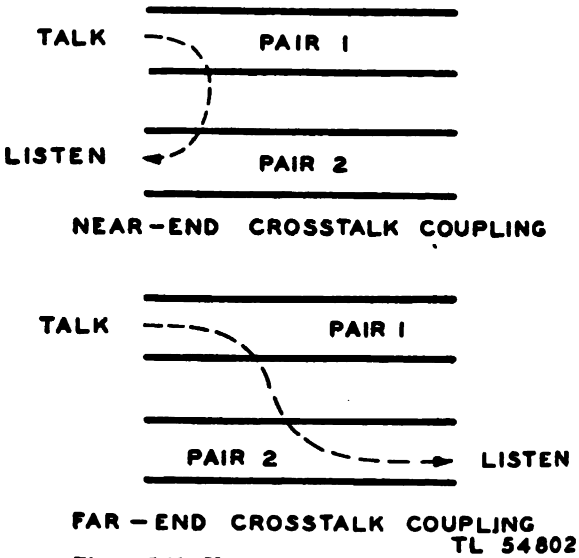


Figure 5-54. Near-end and far-end crosstalk.

the disturbing circuit, the crosstalk is called *near-end crosstalk.* If crosstalk from the same talker were heard at the opposite end of the disturbed circuit, we would call it *far-end crosstalk,* and the British would call it *distant-end crosstalk.* If the same band of frequencies is transmitted in both directions over both disturbing and disturbed circuits, as is the case with voice-frequency and certain carrier systems, both types of crosstalk may occur. With many carrier systems, the same frequency band is not sent in both directions on the circuits, thus preventing a listener from hearing near-end crosstalk, but permitting him to hear far-end crosstalk. Crosstalk of the near-end type may be a problem on the latter systems, however, as covered in paragraph 551.

c. The crosstalk volume heard by a listener depends upon a number of factors, one of the controlling factors being the coupling between the disturbing and disturbed circuits. Since crosstalk coupling may be thought of as a transmission path of high loss between two circuits, crosstalk coupling may be called *cross-talk loss,* and as such expressed in db. Crosstalk coupling may also be expressed in *crosstalk units* which are one million times the square root of the ratio of power received from the disturbed circuit to the power delivered to the disturbing circuit. For example, the power ratio for a loss of 60 db would be one-millionth. The square root of this power ratio is one-thousandth, which multiplied by 1,000,000 would be 1,000. By definition therefore, the magnitude of this coupling may be expressed as equal to 1,000 crosstalk units, or 60-db crosstalk loss.

d. Other terms, with which one studying crosstalk problems should become familar, are crosstalk amplification, equal level crosstalk, reflection crosstalk, interaction crosstalk, signal-to-crosstalk ratio, etc. These terms are explained at appropriate points in the text that follows.

549. CROSSTALK STANDARDS.

a. Experiments have shown that a listener has difficulty in distinguishing between the main talker and a crosstalker unless the speech volume he receives from the main talker is at least 13 db higher than that from the crosstalker. This ratio of received speech volume, that is, main talker to crosstalker, is called the *signal-to-crosstalk ratio.*

b. The following discussion shows that the crosstalk loss should not be less than about 40 db in order to provide a signal-to-crosstalk ratio of at least 13 db. If the main talker talks at a volume of —5 vu over a circuit of 30 db loss (fig. 5-55), his received speech volume is —35 vu. If the crosstalker talks at a volume —5 vu his received speech volume through the indicated crosstalk loss of 43 db is —48 vu, or the signal-to-crosstalk ratio is 13 db. With circuit losses greater than 30 db (ch. 2), crosstalk losses greater than 43 db are required to maintain a 13-db signal-to-crosstalk ratio. With circuit losses less than 30 db, crosstalk losses less than 43 db would maintain the ratio, assuming the main talker and the crosstalker deliver equal volumes. Since the volume of the crosstalker may be considerably greater than that of the main talker, allowance must be made for volume difference. Hence the crosstalk loss from the input of one circuit to the output of another circuit, called *input-to-output crosstalk loss,* should not be less than about 40 db, even for circuits close to the front; and 50 db is a more desirable objective. With a 40-db crosstalk loss, an 18-db *terminal* circuit (ch. 2), and no volume difference, the signal-to-crosstalk ratio would be 40 — 18 = 22 db. This is a margin of 9 db over the minimum value of 13 db, thus permitting a 9-db volume difference. A 6-db terminal circuit would, on this basis, permit a 21-db volume difference. However, a 6-db end link in a built-up connection would permit only about the same volume difference as an 18-db terminal circuit, because of the losses preceding the end link.

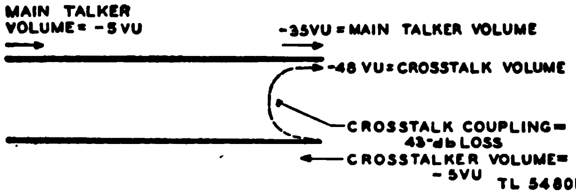


Figure 5-55. Crosstalk volume.

c. On high-grade circuits in rear areas, speech should be easily distinguishable from crosstalk, and the chance of overhearing intelligible crosstalk should be kept small. A good objective for the latter purpose is an input-to-output crosstalk loss of at least 60 db. This applies to terminal circuits or to via circuits of at least 6-db net loss.

d. A 6-db smaller crosstalk loss is permissible between carrier systems such as the CS and CU, which have frequency allocations differing enough to make crosstalk between them unintelligible, even though the crosstalk is just as loud as that between like carrier systems.

550. CROSSTALK AMPLIFICATION.

a. **General.** Suppose two paralleling circuits extend from A to D as shown on figure 5-56 and that there is a lumped crosstalk loss of 40 db between the two circuits at point A. The transmission path between the two circuits at point A will, of course, be a 40-db loss. Now suppose that the crosstalk loss is located at point B and that the loss of each circuit between A and B is 5 db. The transmission path between the two circuits at point A is then 50 db., that is, the sum of three losses, namely: a 5-db loss in the disturbing circuit between A and the crosstalk coupling at B; a crosstalk loss of 40 db; and a transmission loss of 5 db from B to A on the disturbed circuit. Now, suppose that the crosstalk loss is located at point C and that there is an amplifier of 9-db gain in each circuit between B and C. Each circuit now has a 4-db gain between points A and C. The transmission path between the two circuits

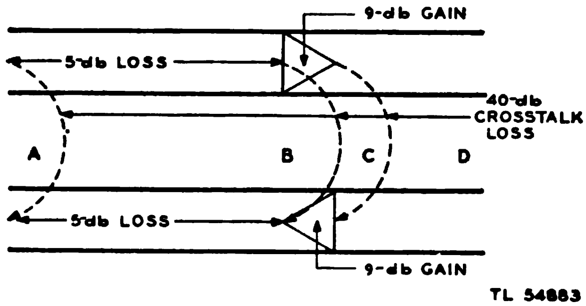


Figure 5-56. Loss or gain in crosstalk path.

at point A will then be a 32-db loss, that is, the sum of two 4-db gains and a 40-db crosstalk loss. The sum of the two 4-db gains, that is, the gain from the sending terminal of the disturbing circuit to the point where the crosstalk loss is given, plus the gain from this point on the disturbed circuit to its receiving terminal, is called the *crosstalk amplification.* This amplification may, in particular cases, turn out to be a loss rather than a gain. If there is a known crosstalk loss between two circuits in a particular section of line or piece of apparatus, it is necessary to know the crosstalk amplification in order to determine the crosstalk loss from the sending terminal of the disturbing circuit to the receiving terminal of the disturbed circuit. It is this latter crosstalk loss which is of interest in judging the crosstalk performance of the circuits. Crosstalk losses between parts of two repeatered circuits at various points in their length can be brought to a common base by subtracting from each the proper crosstalk amplification Crosstalk losses, thus reduced to a common base, may be combined (par. 563) to obtain the total crosstalk loss. Crosstalk amplification values may be readily deduced from transmission level diagrams as discussed in the following subparagraphs.

b. Near-end Case. Figure 5-57 indicates two paralleling 2-way circuits, equipped with terminal and intermediate repeaters, extending between points A and C. Level diagrams are shown for the disturbing circuit in the A to C direction and for the disturbed circuit in the C to A direction. In level diagrams, losses are taken as negative quantities and gains as positive quantities (ch. 12). Assume a crosstalk loss of 40 db between the two circuits at point B as indicated. This crosstalk loss might be lumped or it might be the loss between the two circuits at point B due to crosstalk couplings distributed along the length B to C. From the level diagram the loss in the disturbing circuit from the input at A to the amplifier output at B is –4 db. On the disturbed circuit there is a gain of $21 - 6 = 15$ db from the point of coupling at B to the output at A, since the level at A is higher than the level at B. The sum of the gains and losses in the transmission path between the two circuits at point A is as follows:

$$-4-40+(21-6) = -40+11 = -29 \text{ db}$$

Since the crosstalk coupling of 40 db at point B appears as a crosstalk coupling of 29 db at A the crosstalk amplification is 11 db. The above expression may be written as follows: $L_1 - X + (-L_2 + N_2) = -X + L_1 - L_2 + N_2$ where L_1 indicates the level at point B on the disturbing circuit, L_2 the level at B on the disturbed circuit, N_2 the net loss of the disturbed

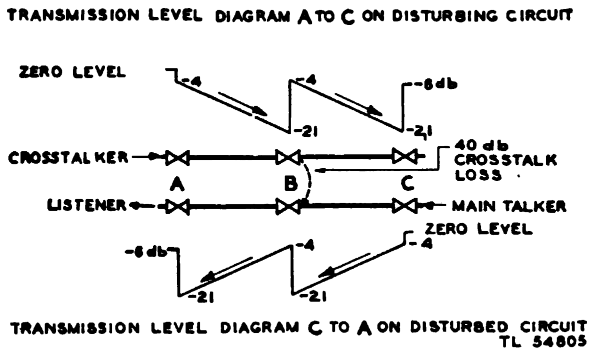


Figure 5-57. Near-end crosstalk amplification.

circuit, and X the crosstalk loss at point B. It is evident from the above that the crosstalk amplification equals $L_1 - L_2 + N_2$. If the net loss of the disturbed circuit were zero, the crosstalk amplification would be simply $L_1 - L_2$. The crosstalk loss plus $L_1 - L_2$ is called the *equal level crosstalk loss,* that is, the crosstalk loss between circuit terminals when the levels of the two circuits at this point are alike. Couplings at various points may be reduced to a common base by computing the equal level crosstalk loss corresponding to each one. This merely involves noting the level difference on the level diagrams for each point of coupling and adding it to the corresponding crosstalk loss. The equal level crosstalk between circuit terminals plus the net loss of the disturbed circuit gives the crosstalk coupling between circuit terminals for any assumed or chosen net loss.

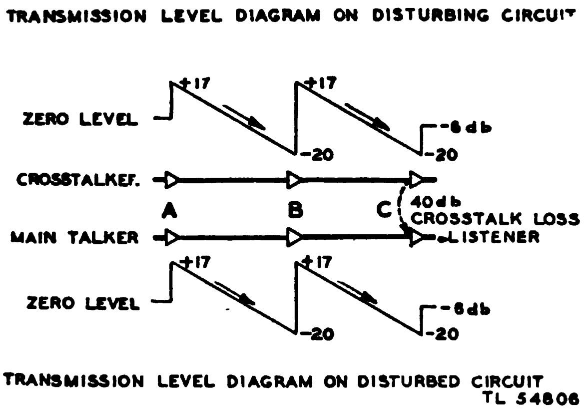


Figure 5-58. Far-end crosstalk amplification.

c. Far-end Case. Figure 5-58 indicates two paralleling circuits between points A and C transmitting in the same direction. These circuits are assumed to be alike and have the same level diagram. It is assumed that there is a crosstalk loss of 40 db at point C. Since this loss occurs at points of equal level the equal level crosstalk is 40 db and the crosstalk between circuit terminals at point C is 40 db plus the net loss of the disturbed circuit, that is, 46 db. The crosstalk loss indicated at point C might be due to a lumped coupling or might be the loss, measured at C, due to distributed couplings along the length B to C. A common method of measuring such coupling involves energizing the disturbing circuit at B and comparing the powers received at C on the disturbed and disturbing circuits. The latter is called *output-to-output* or *unamplified far-end crosstalk loss.* Data in this form are often more convenient to obtain and analyze than input-to-output far-end crosstalk losses. In a more general case, the levels of the two circuits at point C would be different and the equal level crosstalk loss would not be equal to the unamplified far-end crosstalk loss.

d. Repeater Spacing. In figures 5-57 and 5-58 circuit net losses of −6 db and unamplified crosstalk losses of 40 db are assumed in both cases. The line section losses and repeater gains for the far-end case (fig. 5-58) and for the near-end case (fig. 5-57) are 37 db and 17 db, respectively. The repeater gains for the near-end case are thus 20 db smaller than those for the far-end case. With the same crosstalk loss and 20 db smaller repeater gains the input-to-output near-end crosstalk, however, is 17 db poorer than the input-to-output far-end crosstalk. It is evident from this that the gain introduced by repeaters tends to increase the seriousness of near-end crosstalk. Hence near-end crosstalk is a factor tending to limit repeater section lengths on voice-frequency circuits, and on carrier circuits transmitting the same frequencies in both directions, such as the carrier hybrid system. With systems like the type C carrier system, which use different frequency bands in opposite directions, far-end crosstalk is normally the predominating type. An exception, as explained later, is interaction crosstalk around the repeaters. Since the transmission levels on disturbing and disturbed circuits involved in far-end crosstalk coupling are equal for like types of circuits, these repeater gains do not increase the seriousness of far-end crosstalk and such gains are limited mainly by noise considerations.

e. Avoidance of Unusual Level Differences. With repeatered circuits transmitting the same frequency in both directions, crosstalk amplification due to level differences is inevitable. The rules for repeater spacing given in section V of this chapter are intended to suitably limit crosstalk amplification. With carrier systems such as type C, which transmit a given carrier frequency in only one direction, it is usually possible to avoid level differences, and it is important to do so. If one of two such systems has a relatively higher transmitting level, an unusual level difference is created, and the equal level crosstalk loss from the high-level to the low-level circuit will be less than if both circuits had the same transmitting levels. If a branch line joins a main line at an intermediate point in the main line repeater section, a level difference may be created and readjustment of the repeater output levels may be necessary to avoid it. If two circuits are repeatered at different points, differences in level will occur which will increase the amplified crosstalk from the higher-level to the lower-level circuit, and level adjustments to decrease these differences may be desirable. Where two circuits have the same repeater points but are of different loss per unit length, the best crosstalk results are obtained if the levels are so adjusted that they will be the same at the middle of the repeater section.

551. TRANSPOSITION THEORY.

a. If there were on a pole line, only a single pair of similar wires arranged in a horizontal plane and distant from sources of electrical disturbances, there would be little need for transpositions. Such sources would induce substantially equal voltages in the two wires and cause equal currents returning through the earth, and but little differential interfering current in the circuit composed of the two wires. Most of this differential current would be due to chance differences between the wires, that is , differences in sag, in diameter, in the quality of the joints, etc. Such chance irregularities in construction would not be systematic and, therefore, the interfering current would not ordinarily be reduced by transpositions.

b. When there are several telephone pairs on a pole line, the two wires of a pair can not be equally distant from all other wires on the line. Transpositions are necessary, therefore, to equalize the voltages induced in the two wires of a pair from transmission of speech, telegraph, or noise currents over various combinations of other wires on the line or over these wires with ground return.

c. To equalize the distance between two wires of a pair and a third paralleling wire it would only be necessary to transpose the pair once at the center of a long length. This would not be satisfactory from the crosstalk and noise standpoints because of the attenuation in magnitude and change in phase of the transmission currents as they proceed along the line. In figure 5-59 two near-end crosstalk paths are indicated by dotted lines, one for each half of the circuit. The transposition reverses the direction of the crosstalk current due to the second half of the line and the two crosstalk currents tend to annul. The two crosstalk currents will be out of phase by twice the phase change in the distance from the crosstalker to the transposition. If the frequency were 30 kc and the distance out to the transposition were 1½ miles the phase change out and back would be about 180°, and the two crosstalk currents would tend to add rather than to subtract. Because the phase change per unit length increases about directly with frequency, the maximum permissible distance between transpositions depends upon the top frequency to be transmitted.

d. Since the far-end crosstalk paths indicated by dash lines in figure 5-59 are alike in attenuation and phase change, it might be thought that far-end crosstalk would be neutralized by a single transposition in a long length. Near-end crosstalk occurs, however, from the first pair to some other circuit and from this third circuit back to the second pair. If there are only two pairs on a line the important tertiary (third) circuit is the phantom of the two pairs. In order to minimize near-end crosstalk to all tertiary circuits and thus minimize the resulting far-end crosstalk component, each pair must be transposed frequently. Crosstalk involving coupling via tertiary circuits is called *interaction crosstalk.*

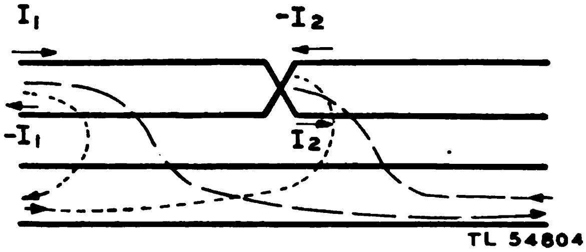


Figure 5-59. Crosstalk with a single transposition.

e. Interaction crosstalk is particularly important at carrier repeater points, since the crosstalk path is from high-level repeater outputs to the tertiary and from the tertiary to low-level repeater inputs. The crosstalk in this path is thus amplified by the gain of the repeater. A similar path at the middle of the repeater section would be at a point of approximately zero level difference. Interaction crosstalk may occur from a repeater output to its own input and cause singing if the gain is large.

f. Various devices (TM 11–368) are used to suppress interaction crosstalk. To prevent repeater singing at frequencies above the operating range and consequent overloading of the repeater, Repeater CF–5 (carrier) is provided with a *roof filter*. Singing or crosstalk within the operating frequency range may require suppression measures. These measures are not needed when carrier systems restricted to a top frequency of about 12 kc are used on U. S.

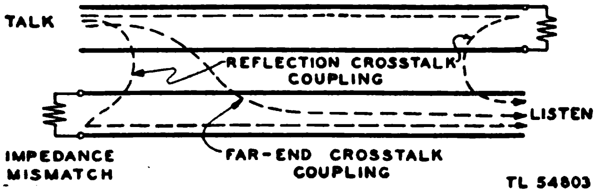


Figure 5-60. Reflection crosstalk.

Army lines (TM 11–368 and TM 11–2253) or on other lines designed for a top frequency of about 30 kc. When carrier systems with top frequencies of about 30 kc are used on U. S. Army lines some of the following suppression measures may be necessary: insertion of *suppression coils* in the other pairs and simplex legs; reduction of ground resistance at repeater points; and limitation of repeater section lengths.

g. When a particular frequency band is sent in only one direction on a line, far-end crosstalk is the controlling type. However, as indicated in figure 5-60, unless the pairs have terminating impedances which give a reasonably good match with the impedances of the open wire line, near-end crosstalk may be reflected and appear as an important component of the far-end crosstalk. For this reason it is important to avoid impedance mismatches either at repeater points or at points where cable or rubber-covered wire is inserted in open wire lines (par. 545).

552. TRANSPOSITION TYPES.

a. The American, and to a considerable extent the British, system of transposing involves having all wires on a pole line normally parallel and transposing one or more of the pairs at suitable intervals. The transposition patterns used are called *fundamental types* and are shown in figure 5-61.

b. The letter designations are the conventional shorthand method for describing the transpositions in a pair of wires. This may be useful in obtaining information from headquarters regarding additional pairs which it may be planned to string on an existing line. In such cases the transpositions in the existing pairs may be described by the letters. For example, the set of transpositions for pair 1-2 of the U. S. Army line is type A, because this

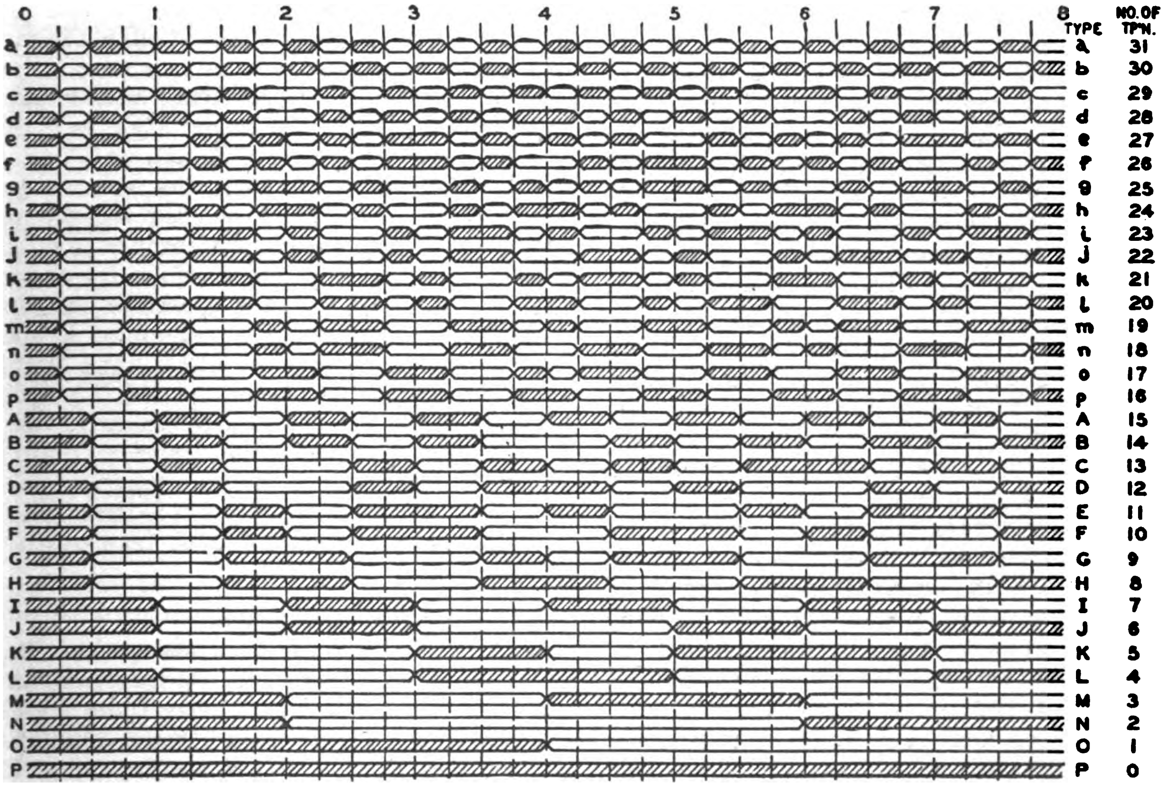


Figure 5-6. Fundamental types in 32 transposition intervals.

pair has 15 transpositions in 32 intervals (fig. 5-61). Similarly, the type for pair 3-4 is I, since in this pair there are seven transpositions in the 32 intervals. The transposition at the end of the last interval is not counted here, but is reckoned as an S-pole transposition (subpar. d). Since capital letters and small letters denote materially different types of transpositions, great care must be used in transmitting the information by means of these letters. To properly use the shorthand method it is necessary to specify the transposition types on the various pairs and the number of pole spans involved or the length of line and average pole spacing. The types with relatively few transpositions can exist in shorter lengths of line than the types with more transpositions. For example, type M could exist in four transposition intervals, or a minimum of eight spans with rolling transpositions, which require two spans per transposition. Type A requires 32 transposition intervals or 64 pole spans.

c. Other patterns may be obtained by using more transposition poles. The usual method of designating patterns with more than 32 intervals is to indicate additional transposition poles by subscripts; for example, a_1 means that there are 32 additional transpositions at the mid-points of the 32 transposition intervals in figure 5-61, giving a total of 63 transpositions for a_1. The subscript 2 indicates two additional transpositions at the first and third quarter points of the transposition intervals in figure 5-61. Subscript 3 means transpositions at all three quarter points.

d. It is convenient to divide a line into *transposition sections*. Within a transposition section each pair is transposed using one of the fundamental types on one pair, a different fundamental type on a second pair, etc. The end of a section is sometimes called a *balance point* and is a suitable point for branching circuits or for junctions of lines with different transposition arrangements. The pole at the end of a transposition section is traditionally called the S pole. Transpositions in some of the pairs are often specified at S poles, since if the line consists of a succession of similar transposition sections the crosstalk coupling may be improved in this manner.

e. The crosstalk between two transposed pairs depends considerably upon the *relative type*, that is, the fundamental type on one pair relative to that on the other. To obtain the relative type, count the number of points within a transposition section where there are transpositions in one pair or the other but not in both. For example, consider pairs 1-2 and 13-14 of the U. S. Army line (figs. 5-63 and 5-64). Within the full transposition section there are 12 points where pair 1-2 is transposed and pair 13-14 is not, and 16 points where pair 13-14 is transposed and pair 1-2 is not. Hence there are 28 relative transpositions; these correspond to type d (fig. 5-61). The relative P means that all transpositions in both pairs are alike, which is undesirable. To a lesser degree it is undesirable to use a regular succession of the same relative types such as O, M, I, A, a, a_1, a_3. Of these relative types, O is least desirable; the desirability increasing in the order named.

f. The maximum transposition pole spacing to properly control crosstalk is a function of the top frequency. For a 2-crossarm line the following rough rules may be used:

Voice frequency........	1 mile
12 kilocycles........	1,300 feet
30 kilocycles..........	600 feet

g. It may be desired to add wire to lines with French or Italian transpositions. If the special hardware required is not available it may be necessary to transpose the new wire as per instructions for the U. S. Army line. In adding wire transposed American style to a line whose transposition plan is not well understood, it is best to transpose the new wire at points different from those used for the old wire, in order to avoid considerable parallels between old and new pairs which by chance are so transposed that the crosstalk coupling tends to accumulate. For example, French long distance lines (par. 561) have points four pole-spans (200 meters or 656 ft.) apart where the pairs may be rotated a quarter turn. If pairs are added under the American plan, it would be best to have the transposition poles three pole-spans apart, unless it is practical to make a careful study of both transposition plans.

553. NEW OPEN WIRE LINES.

a. A simple transposition scheme has been devised for use with U. S. Army open wire lines. The lines and the transpositions are described in TM 11–368 and TM 11–2253; the transpositions are described herein and in TB Sig 73. They are suitable for carrier operation up to 30 kc on all pairs on two standard 4-

pair 88-inch crossarms, thus permitting 32 telephone channels on a single pole line. Pair 7-8 of these lines is suitable for operation up to about 150 kc. Short 2-pair crossarms for light traffic routes can be obtained by sawing 88-inch crossarms in half.

b. The expected crosstalk performance is that given in paragraph 549c for circuits up to 1,000 miles on the eight pairs, provided carrier systems like the CS and CU (par. 528c) are used. Equally good performance on 4,000 to 5,000 mile circuits is possible on selected pairs or channels. If equally good performance on all pairs of very long lines having two or more crossarms is required, information on suitable transpositions may be obtained through Army Communications Service.

c. The transpositions are made by tying the two wires of a pair into two grooves in Insulator IN–128, which is a special transposition insulator sometimes called TW. The two wires are tied on the same side of the insulator. This is known as a rolling type of transposition. Figure 5-62 shows a rolling type transposition using Insulator IN–128. It also shows a rolling type transposition on a drop bracket and a point type transposition. The point type transposition is completed over a few inches, while the rolling type requires two spans for completion. Point type transpositions using special hardware are worth while on long commercial multiarm carrier lines. The design of the U. S. Army line is such that the systematic effect of rolling type transpositions on crosstalk is greatly reduced. For this reason use of Insulator IN–128 at transposition points on Army lines will result in crosstalk performance only slightly poorer than that with point type transpositions. If drop bracket transpositions were used, the crosstalk for the worst pair combination would be about 6 db poorer than with Insulator IN–128, and the crosstalk, on the average, about 3 db poorer. While the use of drop brackets might be expedient for some of these lines, their use should obviously be avoided on long lines on which good crosstalk performance is required.

d. Figure 5-62 also indicates an improvised *tandem* transposition using two Insulators IN–128. There has been concern about wire hits resulting from transposing on a single Insulator IN–128 when it is desired to use pole spacing around 200 feet, and when the available personnel cannot be expected to properly equalize the sags of the two wires of a pair. The tandem transposition may be of interest in such situations as an alternative to the drop bracket transposition. The hardware required with the former is simpler, and the crosstalk characteristics are about like those for transpositions made with a single Insulator IN–128. Suitable spacings between the two Insulators IN–128 are 12 inches on straightaway line sections and 8½ inches on corners up to 30 degrees away from the straightaway. For transpositions at corners with greater angles, it would be necessary to use two pole spans to make the turn. For the hardware, a break iron with four holes might be improvised and short shank steel pins with wooden cobs similar to those used

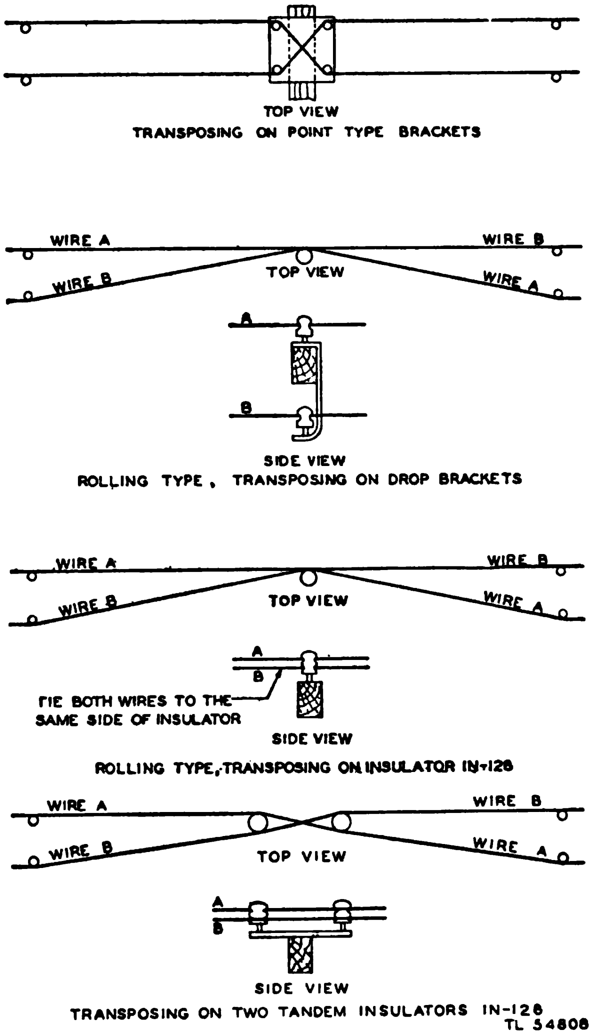
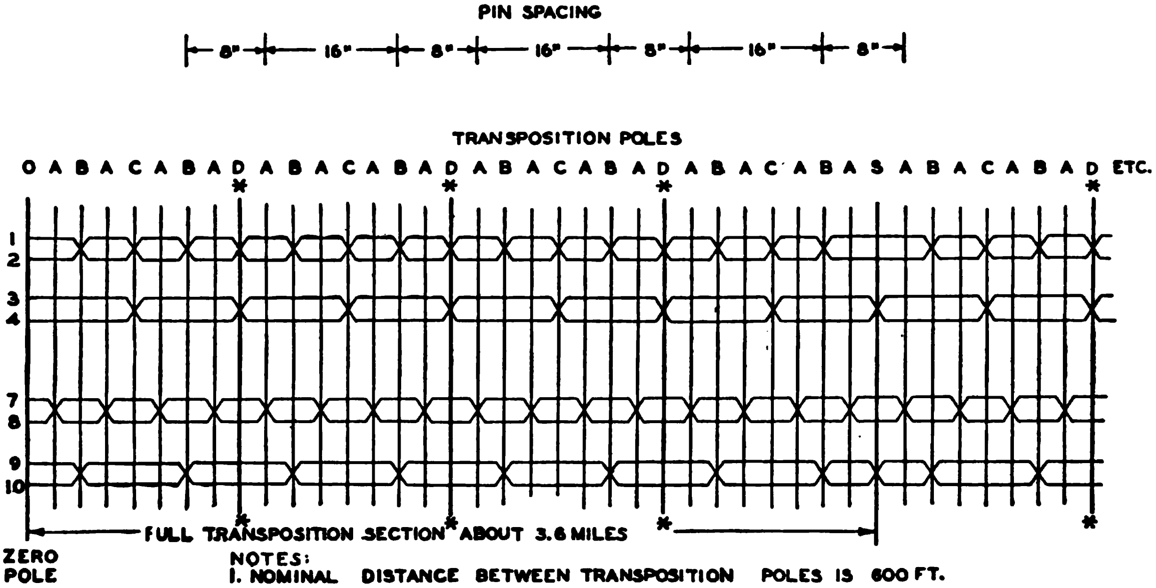


Figure 5-62. Methods of transposing a pair of wires.

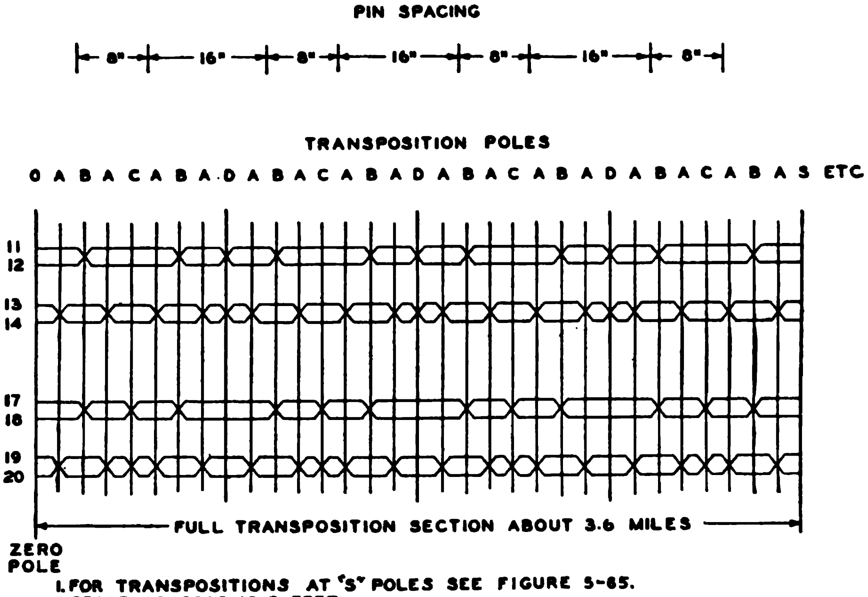
with drop brackets could be used. The tandem transposition could also be made by mounting wooden pins on a wooden support such as a section of crossarm. The horizontal spacing between the two wires of a pair at one of the Insulators IN–128 is about 2½ inches. Tie wires at the two insulators are not necessary. The line wires may be easily sprung into the grooves of the two insulators. However, this reduces the sag in the two adjacent spans by 2 to 3 inches for spans between 200 and 150 feet in length. In stringing wires the tensions should be adjusted as far as practicable to obtain normal sag after transposing.



NOTES:
1. NOMINAL DISTANCE BETWEEN TRANSPOSITION POLES IS 600 FT.
2. TIE WIRES TO SIDES OF INSULATORS AWAY FROM THE POLE.
* IN TACTICAL CONSTRUCTION, THESE POLES ARE DESIGNATED "C" POLES ON ONE-CROSSARM LINES.

TL 54809

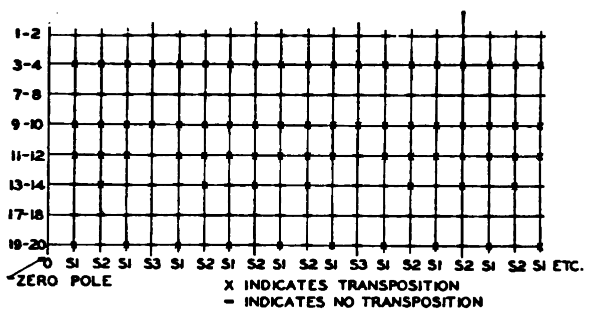
Figure 5-63. U. S. Army line, transpositions for first 4-pair crossarm.



1. FOR TRANSPOSITIONS AT "S" POLES SEE FIGURE 5-65.
2. SPACE CROSSARMS 3 FEET.
3. FOR TRANSPOSITIONS IN PAIRS 1-2 TO 9-10 SEE FIGURE 5-63.
NOMINAL DISTANCE BETWEEN TRANSPOSITION POLES IS 600 FEET

TL 54810

Figure 5-64. U. S. Army line, transpositions for second 4-pair crossarm.



TL 54811

Figure 5-65. U. S. Army line, transpositions at S poles.

554. U. S. ARMY LINE, NORMAL TRANSPOSITION SECTIONS.

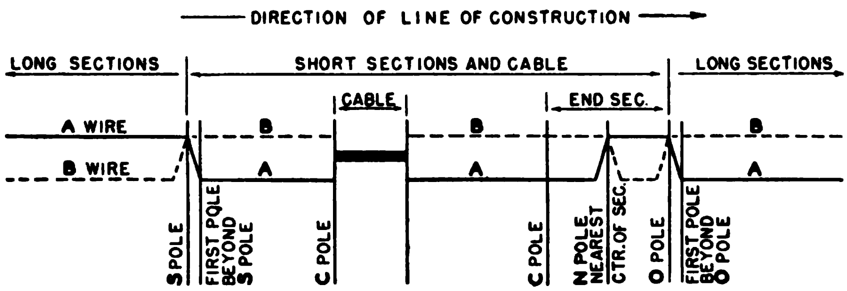
The transposition arrangements are shown on figures 5-63 to 5-65 inclusive. Figures 5-63 and 5-64 indicate a succession of similar transposition sections each about 3.6 miles in length and ending in an S pole. Transpositions at S poles for pairs on both the first and second crossarms are shown on figure 5-65. For the first crossarm the transpositions are alike at all S poles. The drawings also show the spacing of the wires and of the transposition poles.

555. U. S. ARMY LINE, SHORT SECTIONS.

a. General. In addition to the nominal 3.6-mile transposition sections indicated on the above figures, it may be necessary to use short transposition sections because of unavoidable discontinuities in a uniform succession of long sections. On a line where crosstalk standards are relaxed, a short section may consist of any part of a long section. Special short sections for better grade lines are described in subparagraphs b and c below. On the best lines, the number of discontinuities requiring short sections is reduced to a practical minimum. The short sections discussed in TM 11–368 (tactical lines) are usually parts of long sections. The short sections of TM 11–2253 (fixed plant lines) have, in most cases, different transposition arrangements than a part of a long section with the same number of transposition poles. The planning for the short sections specified for tactical lines is simpler but the short sections specified for fixed plant lines give better crosstalk results. In any short section of a line, the transpositions in all the pairs should follow the same short section scheme.

b. Short Sections for Tactical Lines.

(*1*) A suitable short section consists of any whole number of eighths of a full transposition section, but short sections of lesser length may be created. A normal one-eighth section is 2,400-feet long, but a length having not less than eight spans of wire may be used



NOTES:

1. AT S POLES TRANSPOSE PER FIG5-65(EXCEPT SEE NOTE 4). O POLE BEGINS A LONG SECTION.

2. WIRE A ON THE FIRST POLE BEYOND THE O POLE SHOULD BE ON THE SAME PIN AS IT IS ON THE FIRST POLE BEYOND THE PRECEDING S POLE.

3. SHORT SECTIONS CONSIST OF ONE OR MORE 1/8 THS OF FULL SECTION. ON TWO CROSSARM LINE THE TRANSPOSITION POLES ARE SPACED 450' OR LESS. ANY 1/8TH MAY BE SHORTENED TO AS FEW AS 8 SPANS. IN 3 TO 7 SPANS USE **END** SECTION. ONE OR TWO SPAN **END** SECTIONS ARE LEFT UNTRANSPOSED.

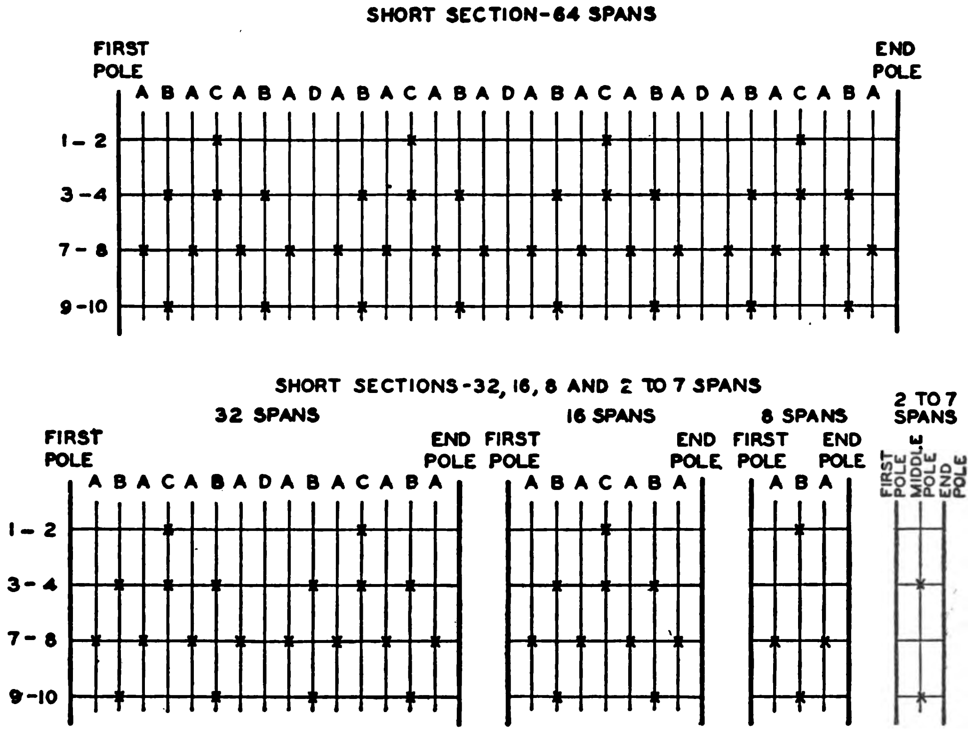
4. IN **END** SECTIONS TRANSPOSE PAIRS 3–4, 9–10, 11–12, 17–18. FOR A PAIR TRANSPOSED WITHIN A 3-SPAN **END** SECTION, IF DRAWINGS CALL FOR TRANSPOSITIONS AT BOTH **C** (OR **S**) AND **O** POLES, OMIT BOTH; FOR A TRANSPOSITION AT **O** POLE AND NONE AT **C** (OR **S**), LOCATE THE TRANSPOSITION WITHIN **END** SECTION TWO SPANS BEFORE THE **O** POLE.

TL 54812

Figure 5-66. U. S. Army line, transpositions at junctions between long and short transposition sections.

as an eighth section. This eighth section limitation is desirable to minimize the number of spans on a one-arm line in which the two wires of a pair are abnormally spaced because they are pulled together at Insulator IN–128. In the case of a 2-arm line the limitation is necessary in order to avoid transpositions on adjacent poles in some pairs on the second arm.

(2) On one-arm lines, if seven spans or less are to be treated, the length is regarded as an END section. An END section consisting of one or two spans is left untransposed. In an END section of three to seven spans, certain of the pairs are transposed at approximately the middle as indicated by note 4 of figure 5-66. This figure is an illustration of the use of short sections. It shows but a single pair of wires which requires a transposition as per figure 5-65 at an S pole completing a long section, and at which a short section or series of short sections starts. While the transpositions as per figures 5-63 to 5-65 are not shown on figure 5-66, except for the transposition at the S pole, such transpositions should be installed at all transposition poles except in the special case covered by note 4 of figure 5-66. In a 3-span END section, it is not possible to transpose a pair within the section and at both terminal poles of the END section, because the transpositions require two spans for completion. For this reason certain transpositions which would normally be placed at the terminal poles of END sections as per figures 5-63 to 5-65, must be omitted with 3-span



NOTES:

1. SHORT SECTIONS SHOULD BE COMBINED AS SHOWN IN FIGURE 5-69.

2. WHEN SHORT SECTIONS ARE COMBINED THE END POLE OF ONE SECTION SERVES AS THE FIRST POLE OF THE ADJACENT SECTION.

3. AT THE END OF A SHORT SECTION WHEN NO OTHER SHORT SECTION FOLLOWS, OR AT THE END OF A COMBINATION OF SHORT SECTIONS, TRANSPOSE AT THE END POLE SO THAT THE WIRES ON THIS POLE OCCUPY THE SAME PIN POSITIONS AS THEY HAD UPON LEAVING THE S POLE AT THE END OF THE LAST FULL TRANSPOSITION SECTION. THIS WILL RESULT IN THE WIRES ENTERING THE NEXT FULL SECTION IN THE SAME PIN POSITIONS THEY WOULD HAVE OCCUPIED IF THE SHORT SECTION OR SECTIONS DID NOT EXIST.

4. NOMINAL DISTANCE BETWEEN TRANSPOSITION POLES IN SHORT SECTIONS IS 300 FEET (2 SPANS), EXCEPT IN 2 TO 7 SPANS WHERE THE DISTANCE WILL BE FROM 1 TO 4 SPANS.

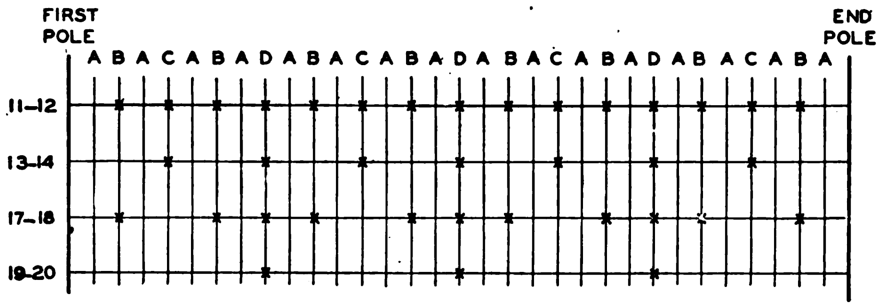
TL 54813

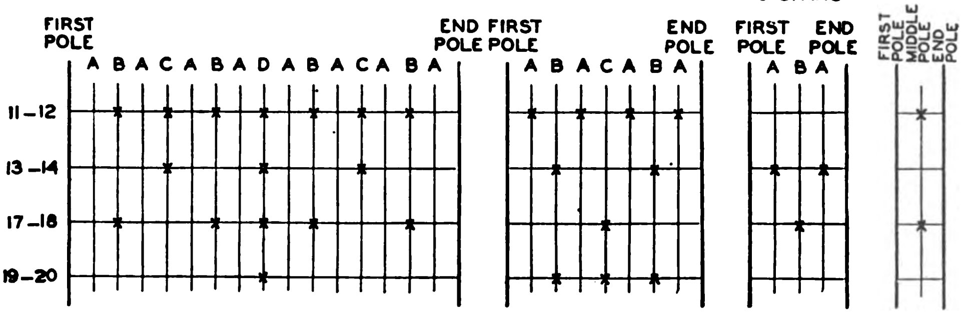
Figure 5-67. Transpositions for first crossarm, U. S. Army fixed plant short sections.

END sections. The standard S-pole transpositions are placed at the S pole preceding a short transposition section or succession of short sections. The transpositions at the last pole of such a short section arrangement are so made that each wire has the same pin position just beyond this pole as it has just beyond the preceding S pole which terminated a long section. Thus, the full transposition sections will have the wires of each pair connected together in the same way as if the short transposition sections and any associated insulated wire or cable inserts did not exist.

(*3*) Short transposition sections for a 2-crossarm line are handled in a similar fashion except that the transposition interval should be reduced from 600 feet to not more than 450 feet in an eighth section. Any whole number of eighth sections or shortened eighth sections may be used to transpose a special length. The END section is handled in the same way as with a one-crossarm line. One transposition is placed in each of pairs 3-4, 9-10, 11-12, and 17-18.

c. Short Sections for Fixed Plant Lines. Figures 5-67 and 5-68 (taken from TM 11–2253) show the transposition arrangements. Short sections for 8, 16, 32, and 64 spans are shown, the transposition pole spacing being two spans (nominally 300 feet). The 2-7 span section is the same as the END section discussed above except that TM 11–2253 (unlike TM 11–368) specifies transpositions on Insulator IN–128 at the midpoint of a 2-span END section.





NOTES:

1. SHORT SECTIONS SHOULD BE COMBINED AS SHOWN IN FIGURE 5-69.

2. WHEN SHORT SECTIONS ARE COMBINED, THE END POLE OF ONE SECTION SERVES AS THE FIRST POLE OF THE ADJACENT SECTION. AT THIS POLE TRANSPOSE PAIR 19-20.

3. AT THE END OF A SHORT SECTION WHEN NO OTHER SHORT SECTION FOLLOWS, OR AT THE END OF A COMBINATION OF SHORT SECTIONS, TRANSPOSE AT THE END POLE SO THAT THE WIRES ON THIS POLE OCCUPY THE SAME PIN POSITIONS AS THEY HAD UPON LEAVING THE S POLE AT THE END OF THE LAST FULL TRANSPOSITION SECTION. THIS WILL RESULT IN THE WIRES ENTERING THE NEXT FULL SECTION IN THE SAME PIN POSITIONS THEY WOULD HAVE OCCUPIED IF THE SHORT SECTION OR SECTIONS DID NOT EXIST.

4. NOMINAL DISTANCE BETWEEN TRANSPOSITION POLES IN SHORT SECTIONS IS 300 FEET (2 SPANS), EXCEPT IN 2 TO 7 SPANS WHERE THE DISTANCE WILL BE FROM 1 TO 4 SPANS.

TL 54814

Figure 5-68. Transpositions for second crossarm, U. S. Army fixed plant short sections.

No. of spans	Use short sections	No. of spans	Use short sections
2–7	2 to 7	66–71	64 and 2 to 7
8–9*	8	72–73*	64 and 8
10–15	8 and 2 to 7	74–79	64 and 8 and 2 to 7
16–17*	16	80–81*	64 and 16
18–23	16 and 2 to 7	82–87	64 and 16 and 2 to 7
24–25*	16 and 8	88–89*	64 and 16 and 8
26–31	16 and 8 and 2 to 7	90–95	64 and 16 and 8 and 2 to 7
32–33*	32	96–97*	64 and 32
34–39	32 and 2 to 7	98–103	64 and 32 and 2 to 7
40–41*	32 and 8	104–105*	64 and 32 and 8
42–47	32 and 8 and 2 to 7	106–111	64 and 32 and 8 and 2 to 7
48–49*	32 and 16	112–113*	64 and 32 and 16
50–55	32 and 16 and 2 to 7	114–119	64 and 32 and 16 and 2 to 7
56–57*	32 and 16 and 8	120–121*	64 and 32 and 16 and 8
58–63	32 and 16 and 8 and 2 to 7	123–127*	64 and 32 and 16 and 8 and 2 to 7
64–65*	64		

* No transpositions made in last span.

Figure 5-69. Combinations of U. S. Army fixed plant short transposition sections.

Figure 5-69 (from TM 11–2253) shows how to lay out short sections for lengths from 2 to 127 spans. Note 3 of figures 5-67 and 5-68 gives instructions similar to those of note 2 of figure 5-66. These instructions require transpositions in some cases at one or both of the S and O poles which are at the ends of a short section or series of short sections. While TM 11–2253 does not specifically cover this point, it should be noted that when a 2- or 3-span END section terminates at an O pole (start of long section), or has an S pole (end of long section) on one end and O pole on the other, the rules of TM 11–2253 may call for transpositions in certain pairs on adjacent poles. Since this is impossible with rolling type transpositions, proceed in the following manner. If the drawings call for transpositions in a pair at both ends of and within a 2- or 3-span END section omit the transpositions at the ends. If the drawings call for transpositions in a pair at one end of and within a 2-span END section omit both transpositions. For the same situation with a 3-span END section, space the two transpositions two poles apart. It should be noted that the transposition arrangements at A, B, C, or D poles in short sections may not be the same as those used on similarly designated poles in full sections. Confusion may be avoided by associating some modifying symbol with the pole letters for short sections. For example, small letters or a circle around the capital letters might be used.

556. U. S. ARMY LINE, TRANSPOSITION POLE AND WIRE SPACING DEVIATIONS.

a. The following standards regarding deviations apply to rear area plant. For construction close to the front and relaxed crosstalk standards, small pole and wire spacing deviations are not important.

b. The actual spacing between any two successive transposition poles minus the intended average transposition pole spacing (600 ft., etc.) is called the deviation. The following are suitable standards: the maximum deviation should not exceed 100 feet; only a very small percentage of the deviations should approach 100 feet; the sum of all deviations (regardless of signs) divided by the total number of deviations should not exceed about 33 feet. A more precise rule, which permits a few very large deviations when necessary, is as follows: the sum of the squares of the deviations (in feet) in a given length of line (not longer than a repeater section nor shorter than a transposition section) should not exceed three times the given length of line (feet). However, any single deviation greater than about 400 feet should be avoided. In order to take care of local conditions when necessary, the intended average spacing may be changed at an S pole, but should not be changed between S poles.

c. The distance between the highest and lowest wires on a given crossarm, as measured at the lowest point in a span, is called the *sag difference*. For a one-crossarm line a maximum sag difference of 5 inches is permissible. For a 2-crossarm line the maximum sag difference should not exceed 3½ inches and only a very small percentage of the differences should approach 3½ inches. The average sag of the first crossarm wires in a given span should be as nearly as practicable the same as the average sag of the second crossarm wires in the same span.

557. U. S. ARMY LINE, ARRANGEMENTS FOR JOINT ENTRANCE OF TWO LINES.

a. Situations may arise where it is impracticable to avoid joining two U. S. Army lines for a short distance; for example, it might be necessary to bring two 2-arm lines into a station over a 4-arm line. Where 3-arm or 4-arm joint line sections are unavoidable they should be constructed to give the necessary physical clearance and strength, and certain precautions are necessary to obtain suitable carrier frequency crosstalk performance (par. 549c). The joint sections should not ordinarily be more than 3.6 miles long (one full transposition section); the pole where the two lines join should be at or within about two spans of an S pole or the terminal pole of a fixed plant or tactical short section; and transposition arrangements, pair assignments, and avoidance of transmission level differences, as discussed in the following subparagraphs, are required. It is assumed that standard 88-inch crossarms spaced 3 feet apart are used; if the spacing is 2 instead of 3 feet, the coupling loss will be 3 to 6 db less. The combining of two lines more than once is undesirable for crosstalk reasons.

b. To avoid the complication of additional transposition patterns, it is recommended that pairs on the third arm be transposed like those on the first arm and pairs on the fourth arm be transposed like those on the second arm. This results in transposing pairs alike on alternate arms. To obtain the maximum separation and crosstalk loss between such like-transposed pairs, it is recommended that pair 29-30 be transposed like pair 1-2, 27-28 like pair 3-4, 39-40 like pair 11-12, etc. The order of the transposition patterns on the third and fourth crossarms is reversed with respect to the order on the first two arms; that is, the patterns are allocated from right to left instead of from left to right. The crosstalk improvement resulting from this reversal is about 6 db at 30 kc and as much as 15 db at 11 kc.

c. The minimum output-to-output far-end crosstalk loss would be about 60 db at 30 kc. The far-end crosstalk loss between circuit terminals is greater than this by an amount equal to the net loss of the disturbed circuit and less by any level difference existing at the office end of the joint line. Unless there is an unusual level difference, the far-end crosstalk loss between circuit terminals should be above 60 db, the allowable value for fixed plant construction. Since a coupling loss as little as 60 db may exist in one joint section, several such sections in a telephone line are obviously undesirable.

d. As noted in TM 11–2022, a serious crosstalk problem occurs if it is attempted to operate carrier systems of maximum frequency of about 30 kc in opposite directions over the same pole line in entering an office. Such operation should be avoided except under extraordinary circumstances, since the repeater spacings given in paragraph 543 involve near-end crosstalk amplification of from about 25 to 40 db and it is difficult to find two pairs on the same line which would give satisfactory crosstalk loss between circuit terminals. For example, 80-db unamplified crosstalk loss would result in only 45-db loss after 35-db crosstalk amplification. However, with a 3- or 4- crossarm line it might be practical to operate two opposite directional carrier systems for about 2 miles or less, provided these systems utilized pairs on opposite sides of the poles with at least one intervening crossarm and provided the pairs had at least three relative transpositions per mile (such as pairs 7-8 and 21-22 of the U. S. Army line). The crosstalk coupling before amplification might be expected to lie between 85 and 90 db. Under such circumstances the use of dissimilar systems such as CS and CU is desirable since these involve only unintelligible crosstalk, for which a 6 db smaller crosstalk loss is permissible. Omitting the proviso for an intervening crossarm would probably decrease the crosstalk coupling loss by about 6 db, with a 4-, 3-, or 2-arm joint line section.

e. If CF–1 or CF–7 carrier systems are to be routed over a joint line section, fixed plant transpositions should be used within the joint section on all pairs. Suitable pair assignments for CF–1 and CF–7 systems on a 2-arm line are given in figure 5-31; the same assignments are recommended for the third and fourth crossarms of a joint line section. For example, CF–7 systems could suitably go on pairs 1-2, 7-8, 13-14, and 19-20; and on pairs 21-22, 27-28, 33-34, and 39-40. With these assignments, the unamplified near-end crosstalk loss at 11 kc (approximate midband frequency for top channel) is not likely to be less than about 75 db. The crosstalk amplification, for the repeater spacings given in paragraph 543, amounts to around 12 to 17 db; hence the crosstalk loss after amplification is expected to be not poorer than about 60 db.

f. If the above pair assignments are not adhered to and if the joint line is transposed to fixed plant short sections, the 11 kc near-end crosstalk between vertically adjacent pairs on the second and third arms may be 3 to 10 db poorer than the crosstalk with the above pair assignments. If the joint line is transposed to a 3.6-mile transposition section, the 11 kc near-end crosstalk between pairs 11-12 and 21-22 and between pairs 13-14 and 23-24 will be about 20 db poorer than the crosstalk with the above pair assignments. This is about as bad as the crosstalk in a repeater section between horizontally adjacent pairs.

g. If for some reason it becomes necessary to use joint lines for several 3.6-mile sections, the S-pole transpositions shown in figure 5-70 are recommended. The purpose of S-pole transpositions is to adjust the relative phases of the crosstalk contributions from several 3.6-mile sections so that they will tend to cancel at the repeater input. S-pole transpositions do not reduce crosstalk resulting from irregularities in construction, but are effective in reducing crosstalk controlled by transposition types when the line consists of a succession of full transposition sections uninterrupted by intermediate short sections, lengths of inserted cable, or other discontinuities. When the line is well constructed and free from discontinuities, and the S-pole transpositions of figure 5-70 are used, it is estimated that on the worst pair combinations the crosstalk in one repeater section will be little poorer than in a single 3.6-mile joint line; under other circumstances the crosstalk in a repeater section or a line several transposition sections long may be considerably poorer than in 3.6 miles.

Pair	*S-pole transpositions*[a]							
21–22	—	—	—	X	—	—	—	X
23–24	X	—	X	X	X	—	X	X
27–28	—	X	—	X	—	X	—	—
29–30	X	—	X	—	X	—	X	X
31–32	—	X	—	X	—	X	—	X
33–34	—	X	—	—	—	X	—	—
37–38	—	—	—	—	—	—	—	X
39–40	—	—	—	X	—	—	—	—
S pole	S1	S2	S1	S3	S1	S2	S1	S4

[a] X = transposition
— = no transposition
[b] Transpositions within 3.6-mile sections on third and fourth crossarms have patterns reversed from those on first two arms; that is, pair 21–22 is transposed like pair 9–10, etc. After eight S poles, repeat the S-pole transpositions shown above.

Figure 5-70. S-pole transpositions for third and fourth crossarms on poles carrying two U. S. Army lines.

558. USE OF 10-FOOT CROSSARM.

a. A 10-foot, 10-pin crossarm often used in the Bell System is known as the type A. Stocks of such crossarms may be available abroad. The pin spacing of the type A crossarm, in inches, is as follows: 12, 12, 12, 12, 16, 12, 12, 12, 12. A one- or 2-crossarm line using type A crossarms and drop brackets, and U. S. Army line transpositions and crossarm spacing, would have crosstalk about 9 db worse than that of the standard U. S. Army line. Of this increase, about 6 db is chargeable to the pin spacing and about 3 db to the drop brackets. A further increase of about 3 db would be brought about by 2-foot spacing between crossarms instead of 3-foot spacing.

b. The alternatives listed in subparagraphs (1) to (4) below are available for improving the crosstalk with the type A crossarm.

(*1*) Convert the type A arm to a 4-pair, 88-inch arm by boring four new holes and cutting off the excess length on each end.

(*2*) Convert the type A arm to a 4-pair, 10-foot arm by boring four new holes to give the following pin spacing, in inches: 8, 28, 8, 24, 8, 28, 8.

(*3*) Convert the type A arm to a 4-pair, 10-foot arm by using all the existing pins except Nos. 3 and 8, to give the following pin spacing, in inches: 12, 24, 12, 16, 12, 24, 12.

(*4*) Convert the type A arm to a 5-pair, 10-foot arm with 8-inch spacing between wires of each nonpole pair by boring four new holes and thus obtaining the following pin spacing in inches: 8, 16, 8, 16, 16, 16, 8, 16, 8. Type CW (wood pins) and type CS (steel pins) 10-foot arms are already bored in this manner.

(*5*) These alternatives rank in the following order of merit: (2), (4), (1), (3), as regards the improvement in crosstalk between nonpole pairs. Use of standard Bell System transposition types instead of the U. S. Army types would not give enough crosstalk improvement on a one- or 2-crossarm line to warrant the additional complexity and increased number of transpositions required. If 10-foot crossarms are used, the type of construction must be made sturdy enough to withstand the increased stresses as compared to those with 88-inch crossarms.

c. If for some reason pole pairs must be used on the type A crossarm, the transposition types given in figure 5-71 are suggested for pole pairs when the U. S. Army transpositions are used on the nonpole pairs; the pole pairs should be used for voice-frequency operation only. The information for pole pairs on the third and fourth crossarms assumes that the nonpole pairs on the third and fourth arms have reversed transposition patterns as compared to those on the first and second arms (par. 557). The crosstalk between nonpole pairs with type A crossarms and such usage will, of course, be substantially poorer than that stated for 88-inch crossarms in paragraph 557.

Pair	*Transposition types*[a]						
	Full section	*Fixed plant short sections*					*8-pole transpositions*
		64 spans	*32 spans*	*16 spans*	*8 spans*	*2–7 spans*	
5–6	K	J	M	O	P	P	—
15–16	G	K	N	M	P	P	—
25–26	M	L	M	O	O	O	X
35–36	L	M	N	M	P	P	—

[a] Types of transpositions are shown in figure 5–61.

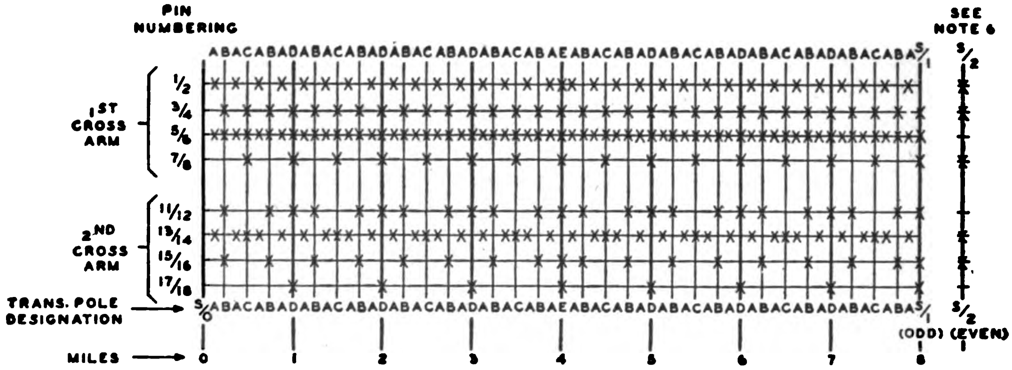
Figure 5-71. Transpositions for pole pairs for short voice-frequency circuits.

d. When the type A crossarm is used in commercial circuits, carrier-frequency crosstalk can be reduced by the use of four different frequency allocations for type C carrier, instead of the two allocations (CS and CU) available with packaged type C systems, or the single allocation used with tactical carrier systems.

559. BRITISH ARMY LINES.

a. Two 4-way or 8-way Arms. The British Army has a transposition system and short crossarm very similar to those used in the U. S. Army line. (*Four-way* in this connection means four conductors per crossarm.) This system is indicated in figure 5-72. The transpositions are arranged somewhat differently in the British and the American systems. The wire numbering is different and the British system does not contemplate the use of carrier systems on the two outside pairs of the second arm. Pair 5-6 of the British system is suitable for operation of carrier frequencies up to about 150 kilocycles.

b. Multi-airline (MAL). In some theaters, the British have used a light and rapid tactical construction known as multi-airline (par. 505d).

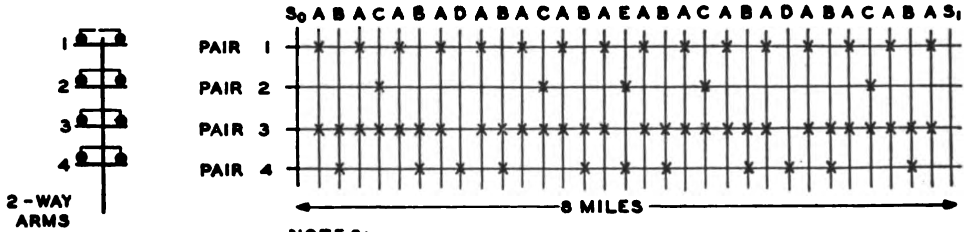


NOTES:

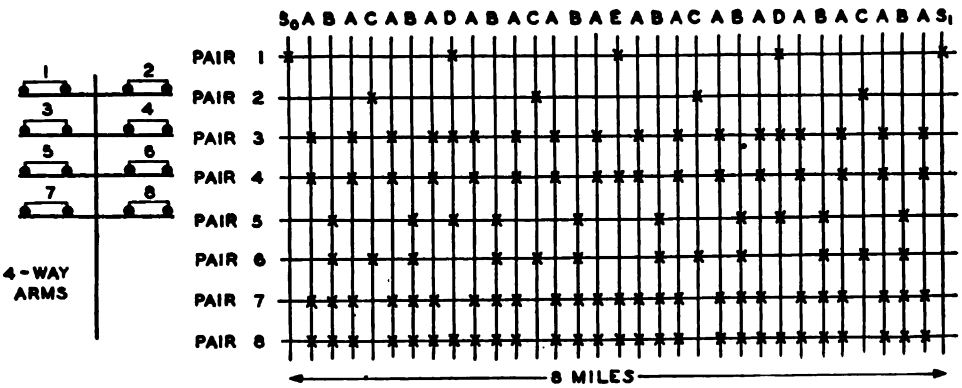
1. THESE TRANSPOSITIONS ARE SUITABLE FOR APPLICATION TO ROUTES HAVING CROSS SECTIONS SHOWN THAT IS FOR TWO 4-WAY OR TWO 8-WAY ARMS.
2. THE DESIGN IS INTENDED FOR APPLICATION TO SECTIONS APPROXIMATELY 8 MILES BUT NOT EXCEEDING 8 1/4 MILES IN LENGTH.
3. WHERE NECESSARY THE SECTION MAY BE TERMINATED AT ANY NOMINAL 1 MILE POINT THAT IS ANY D, E, OR S POLE.
4. RESIDUAL SECTIONS LESS THAN ONE MILE IN LENGTH SHOULD BE DEALT WITH BY USING ONE-EIGHTH OF THE SECTION (S/O TO D) THE POLE SPACING BEING ADJUSTED IF NECESSARY TO SECURE EIGHT SUBSTANTIALLY EQUAL INTERVALS.
5. TRANSPOSITION POLES SHOULD BE SO LOCATED THAT THE LENGTH OF ANY TRANSPOSITION INTERVAL (NORMALLY 220 YARDS) DOES NOT DIFFER BY MORE THAN 25 YARDS FROM THE AVERAGE INTERVAL FOR THE TRANSPOSITION SECTION OF WHICH IT FORMS A PART. THE AVERAGE DEVIATION FOR ALL INTERVALS COMPRISING SECTION SHOULD NOT EXCEED 10 YARDS.
6. USE S/ODD OR S/EVEN TRANSPOSITIONS AT END OF ALTERNATE TRANSPOSITION SECTIONS.
7. IT WILL BE NOTED THAT IF ONLY ONE 8-WAY ARM IS USED, THE TRANSPOSITIONS ON THE "C" AND "D" POLES ARE IDENTICAL, BUT THE POLES SHOULD STILL BE LETTERED "C" AND "D" CORRECTLY, IN ORDER TO CATER FOR THE LATER APPEARANCE OF A SECOND ARM.
8. IF THE ROUTE HAS TO CHANGE FROM 4-WAY TO 8-WAY OR VICE VERSA FOR A FEW POLES FOR CONSTRUCTIONAL REASONS, THE CROSSING OF THE WIRES SHOULD CARRY ON AS IF NO CHANGE HAD BEEN MADE.
9. PIN SPACING:-O 8" O 16" O 8" O 18" O 8" O 16" O 8" O TWO FEET BETWEEN CROSSARMS.

TL 54816

Figure 5-72. British Army line transpositions (rearrangement of British Signals drawing).



NOTES:
1. TRANSPOSITION SECTION IS 8 MILES LONG.
2. INTERVAL BETWEEN TRANSPOSITION POLES IS 1/4 MILE.



NOTES:
1. TRANSPOSITION SECTION IS 8 MILES LONG.
2. INTERVAL BETWEEN TRANSPOSITION POLES IS 1/4 MILE.
3. THIS SYSTEM USEFUL FOR MAL ROUTES.

TL 54817

Figure 5-73. British flat transposition system (rearrangement of British Signals drawing).

The most common arrangement involves two 12-inch spaced pairs on two crossarms 12 inches apart. The two pairs are usually not transposed. The far-end crosstalk is apt to be unimportant except when wire sag differences are very marked. The near-end crosstalk makes it difficult to use both pairs simultaneously for voice-frequency circuits or for carrier systems using the same carrier frequencies for both directions of transmission. Less difficulty would be expected with carrier systems such as type C which uses different carrier frequencies in the two directions. This assumes, however, that large impedance mismatches do not exist at the terminals or at intermediate points since such mismatches would cause serious reflections of near-end crosstalk. Sometimes 4-pin crossarms are used on the multi-airlines. Horizontally adjacent wires are used as pairs. Point-type transpositions are used. Suitable transpositions for voice-frequency operation are given in figure 5-73 which is a rearrangement of a British Signals drawing.

c. Line with Rotating Pairs. The British have also used a more substantial line construction involving two short crossarms one foot apart. Each crossarm has a 12-inch spaced pair on each side of the pole and therefore there are four wires arranged on the corners of a square on each side of the pole. Diagonally opposite wires in a square are used for the two wires of a pair. Each square is rotated a quarter of a revolution in one span at specified intervals. For example, one square might be rotated at intervals of 5 spans and the second square might be similarly treated except that every fourth rotation would be omitted in order to reduce crosstalk between pairs in different squares. While experience has shown that the crosstalk with such an arrangement is rather poor, it might be expedient to use this construction for moderate distances (about 100 miles) for voice or even for carrier operation. An advantage is that no special hardware or insulators are required. A disadvantage is that wires with only one 1-foot vertical separation cross at the center of each span, with consequent chances of wire hits.

560. DIFFERENT LINES IN TANDEM.

It may be necessary to use sections of line in tandem, some of which are transposed to the American system and others to a British system. If the type of transposition system changes between repeaters, a full transposition section of one type of transposition system should be completed (with the aid of intervening short sections, if necessary) before starting in with a full section of the other type of system.

561. EXISTING LINES.

a. Existing lines will be found which are not transposed according to TM 11–368 or TM 11–2253. They may be transposed by the British method (par. 559) or by the French and Italian methods shown in figures 5-74 to 5-79, inclusive. If it is desired to use such lines

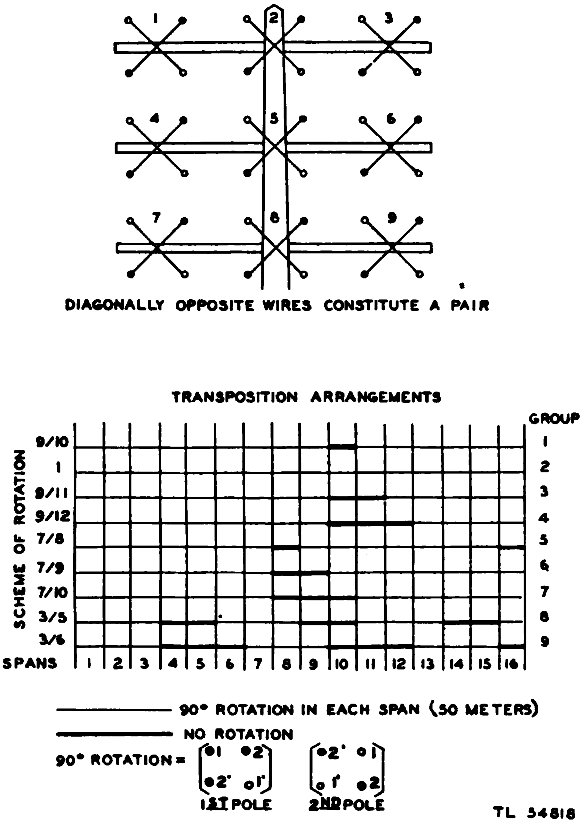


Figure 5-74. S.E.T. Italian 9-group telephone line.

or fragments of them and to add wire to them, and the special hardware required for the foreign type of construction is not available, it may be desired to fill in gaps with American construction. In such a case the best way is to terminate the American construction in an S pole of a long section or in a complete short section and to terminate the foreign line at a balance point. Filling in gaps in existing lines may involve connecting together pairs of different conductivity or gauge. Reflections occur at such junctions but these are not apt to affect

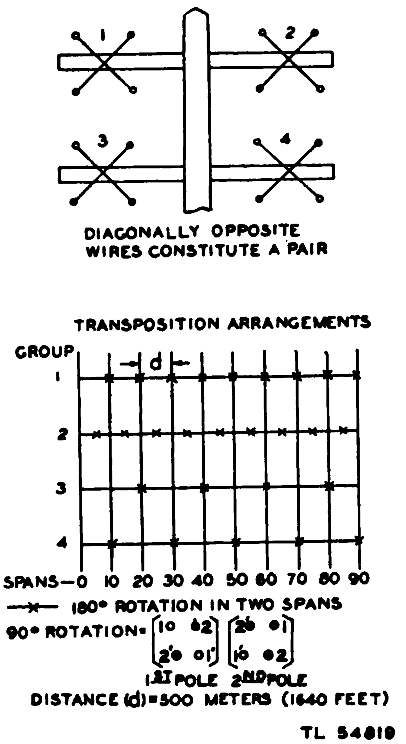


Figure 5-75. CIRCOLO Italian State 4-group telephone line.

crosstalk seriously. They may have a noticeable effect on the balance at a 22-type repeater point. The poorest return loss due to such a junction would be about 23 to 26 db. If it is desired to add wire with the American type of construction to such lines the most practical procedure is given in paragraph 552g.

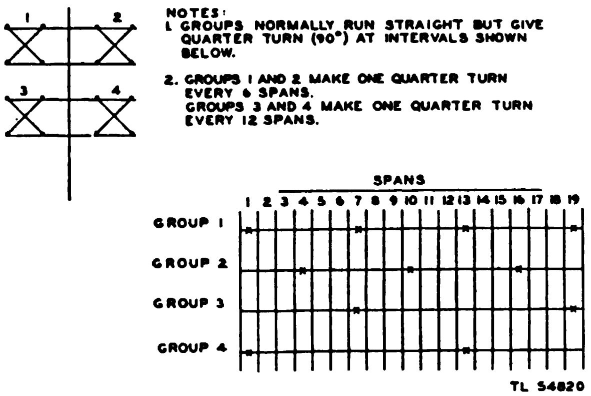


Figure 5-76. TIMO Italian 4-group telephone line (rearrangement of British Signals drawing).

b. With both French and Italian construction the four wires of a group are arranged on the corners of a square. Diagonally opposite wires in a square are used for a pair. With the Italian 9-group line construction (fig. 5-74), the squares are rotated rather continuously, there being a 90° twist in each span. There are certain omissions of these twists, presumably to reduce crosstalk between different squares. The Italian 4-group line of figure 5-75 has 180° rotations in two spans at intervals of 500 meters (1,640 feet) or more. The 4-group line of figure 5-76 has 90° twists in one span at intervals of 6 or 12 spans. With the French plan of figures 5-77 and 5-78, there is usually a 90° twist in two spans at each fifth pole. This requires special hardware at the center of the two spans. There is sometimes a 180° twist in four spans as indicated on figure 5-78. The French plan of figure 5-79 uses a 90° twist in two spans at intervals of 0.25 to 1 kilometer as indicated by arrangements A to D. When there are more than four groups on a line 180° twists in four spans are superposed at 4-kilo-

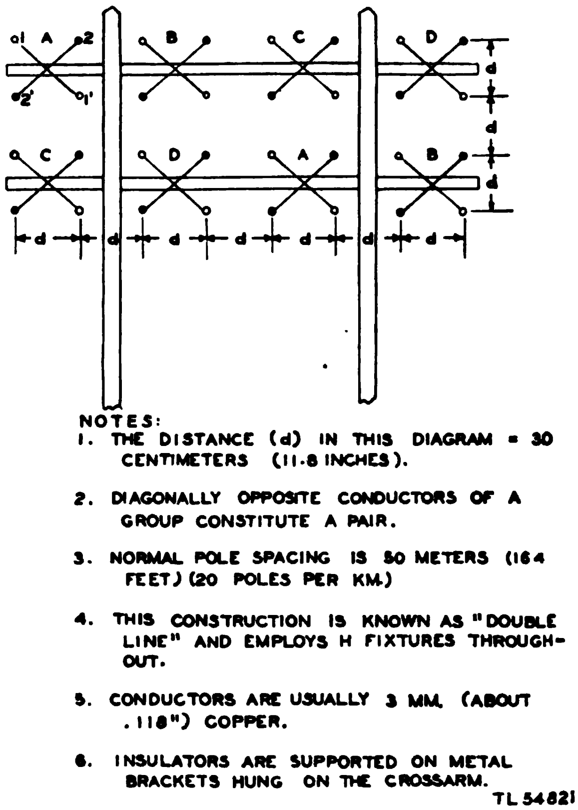


Figure 5-77. French telephone lines in North Africa; pole, crossarm, and wire arrangements.

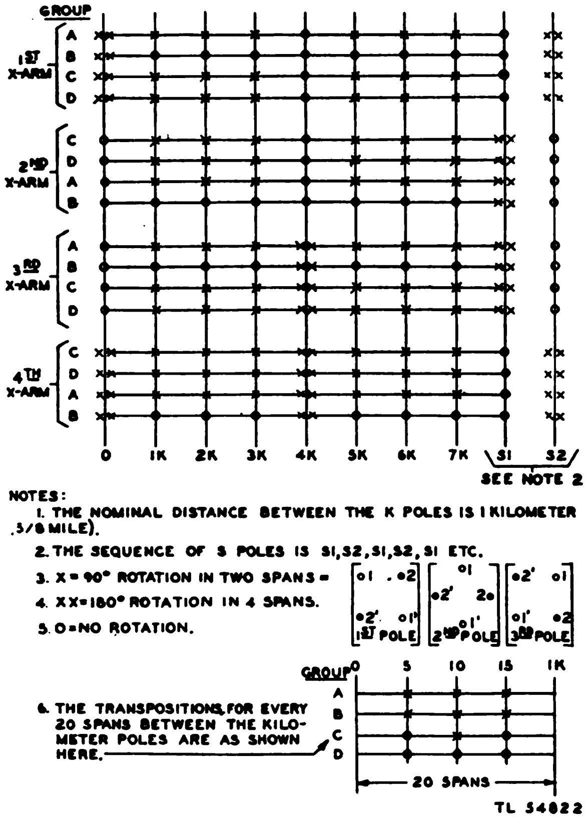


Figure 5-78. French telephone lines in North Africa, transposition arrangements.

meter (2.35-mile) intervals to improve crosstalk between groups designated by the same letters A to D. If a line has more than four crossarms or if a crossarm has more than four groups, then the fifth, sixth, etc., are treated like the first, second, etc. Carrier systems may be worked on selected pairs according to some reports. The two pairs in a square are in planes at right angles and tend to be noninductive to each other. Measurements in the United States have indicated that this tendency may be offset to a considerable extent by irregularities in wire or pole spacing. Not all the pairs in different squares are, in principle, noninductive to each other and therefore not all the squares are rotated alike.

c. Figure 5-80-A gives a rough method of estimating the far-end crosstalk loss of the French and Italian lines for like carrier channels of 6-db net loss. The data in this figure were obtained from measurements made on a short length of line in the United States on which the wires had been arranged in squares with 90° rotations in each span, and from a field trial of the U. S. Army line. The table indicates that the crosstalk loss between pairs in the same square is especially low and that the crosstalk loss between pairs in adjacent squares may be higher, although not so high

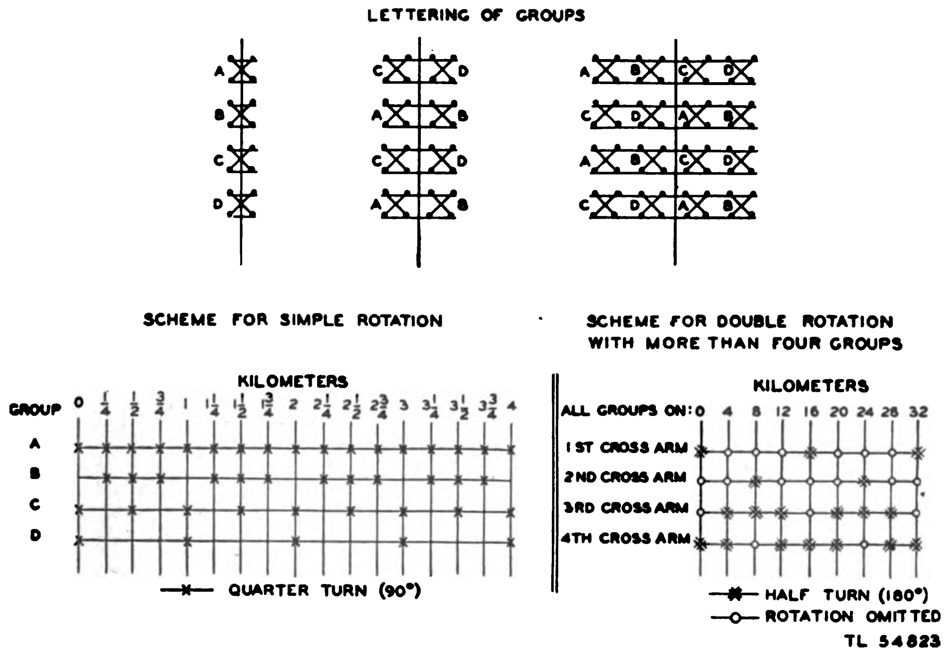


Figure 5-79. French rotation transposition system (rearrangement of British Signals drawing).

MINIMUM FAR-END CROSSTALK LOSS BETWEEN CIRCUITS OF 6-DB NET LOSS[a]

Type of line		*Crosstalk loss for 100 miles (db)*[b]		*Miles for minimum crosstalk loss*			
				60 db		*50 db*	
		12 kc	*30 kc*	*12 kc*	*30 kc*	*12 kc*	*30 kc*
U. S. Army, one crossarm	Adjacent pairs	74	66	2,500	400		
	Other combinations	78	70	6,300	1,000		
Foreign	Pairs in same squares	57	49	50	10	500	100
	Pairs in adjacent squares	66	58	400	63	4,000	630

A

MINIMUM NEAR-END *UNAMPLIFIED* CROSSTALK LOSS IN 100 MILES[a]

Type of line		*Crosstalk loss for 100 miles (db)*	
		12 kc	*30 kc*
U. S. Army, one crossarm	Adjacent pairs	65	56
	Other combinations	70	70
Foreign	Pairs in same squares	48	37
	Pairs in adjacent squares	56	50

B

[a] The crosstalk loss figures assume that any systematic coupling between pairs in different squares is sufficiently reduced by rotations. This assumption is dubious at carrier frequencies particularly above 12 kc when the rotations are more than about 500 meters (1,640 feet) apart.

[b] For double the length subtract 3 db and for half the length add 3 db etc., that is subtract 10 log (L ÷ 100).

Figure 5-80. Crosstalk estimates, U. S. Army versus French or Italian lines.

as for the American system. As noted in the table, the estimates assume that systematic coupling between pairs in different squares is made negligible by rotations. In cases where the transposition intervals are large compared with those recommended in paragraph 552f, or where transposition pole spacing irregularities are large, the coupling between such pairs may be poorer than shown in the table. Experience with rehabilitated lines in one theater was, that because of difficulty in establishing sufficiently exact transposition intervals the crosstalk between pairs in adjacent squares was poorer than between pairs in the same square. Where the crosstalk standards of paragraph 549c are to be met, it is advisable to avoid using the same or adjacent squares for two carrier systems of the 2-wire or equivalent 4-wire types and to place such systems as far apart on the line as feasible. If carrier systems are to be placed on adjacent pairs on the U. S. Army line or on pairs in the same square or adjacent squares in a rotated square line, it is desirable to use unlike carrier systems such as the CS and CU (par. 528c). The crosstalk between such systems is unintelligible and the tolerable crosstalk loss is about 6 db less than that for like carrier systems. Figure 5-80-B gives some coupling figures for unamplified near-end crosstalk. The tabular values may be translated to crosstalk loss between circuit terminals as per paragraph 550. Voice-frequency coupling losses will be about 10 db more than those listed for 12 kilocycles in figure 5-80. Since the performance at carrier frequencies on these foreign lines is dubious, crosstalk

Type of paper-insulated cable[a]	*Pair-to-pair combination*	*Rms capacitance unbalance (mmf per 0.1 mile)*	*Minimum crosstalk loss in 1 mile of cable (db)*	
			Nonloaded 30 kc	*Loaded 30 kc*
Multiple-twin	Side-to-own-side	20	70	54
Spiral-four	Side-to-own-side	40	64	48
Multiple-twin	Adjacent quads	15	73	57
Spiral-four	Adjacent quads	2	90	74
Multiple-twin	3-quad to 9-quad layer	7	79	63
Multiple-twin	9-quad to 15-quad layer	5	82	66

[a] Definitions of multiple-twin and spiral-four are given in paragraph 506b.

Formulas for 1 mile of cable or less:

Nonloaded cable; minimum crosstalk loss

$$db = 120 - 20 \log [CF\sqrt{10L}\ (1 - 0.028\ FL)]$$

Loaded cable; minimum crosstalk loss

$$db = 120 - 20 \log (CF\sqrt{10\ L})$$

C = root mean square (rms) capacitance unbalance (mmf per 0.1 mile)
F = frequency (kc)
L = length (miles)

Values and formulas apply particularly to equal level far-end crosstalk but are sufficiently accurate to estimate unamplified near-end crosstalk.

Figure 5-81. Minimum crosstalk loss due to capacitance unbalance.

measurements may be necessary to obtain suitable pairs. Improvised methods of measuring crosstalk are described in paragraph 564.

562. CROSSTALK IN ENTRANCE AND INTERMEDIATE CABLES.

a. Low crosstalk loss between paper-insulated cable pairs used in open wire carrier circuits must be avoided. For this reason it is generally necessary to avoid using both sides of the same cable quad, two pairs in adjacent multiple-twin quads, or pairs in adjacent layers containing fewer than about 15 multiple-twin quads.

b. Figure 5-81 gives estimates of the minimum crosstalk losses (equal level far-end crosstalk) for such pairs in one mile of cable. The formulas in figure 5-81 may be used where estimates of crosstalk losses are needed for other frequencies, shorter lengths, or other capacitance unbalances. The estimates and formulas also apply with fair accuracy to unamplified near-end crosstalk in one-mile or shorter cables since attenuation may be neglected in such short lengths. It is assumed that the cable pairs are directly connected to the open wire or to terminal apparatus having an impedance of about 600 ohms, because impedance matching devices will probably not be used at such junctions. If loaded cables are used, their cut-off frequency must be sufficiently high to permit satisfactory transmission of the top frequency of the carrier system.

c. To determine the crosstalk loss between circuit terminals corresponding to the figure 5-81 values, follow the methods in paragraph 550. This loss may then be compared with the estimated crosstalk loss (between circuit terminals) in the open wire to determine whether the over-all performance will be materially degraded by use of the cable. If there are several cables in a carrier repeater section, the total crosstalk loss for all cables should be computed as per paragraph 563.

563. COMBINATION OF CROSSTALK LOSSES.

Figure 5-82 indicates a method of combining two crosstalk losses (between circuit terminals or on some other comparable basis) to determine the total loss when the crosstalk currents are expected to combine at random. The difference between two losses is used to determine a value in db to be subtracted from the smaller of the two to get the total effect. The chart may be used for combining any number of crosstalk losses taking two at a time.

A		B	A		B	A		B
From	To		From	To		From	To	
0	0.1	3.0	2.2	2.5	2.0	6.1	6.7	0.9
0.1	0.3	2.9	2.5	2.7	1.9	6.7	7.2	0.8
0.3	0.5	2.8	2.7	3.0	1.8	7.2	7.9	0.7
0.5	0.8	2.7	3.0	3.4	1.7	7.9	8.7	0.6
0.8	1.0	2.6	3.4	3.7	1.6	8.7	9.6	0.5
1.0	1.2	2.5	3.7	4.0	1.5	9.6	10.8	0.4
1.2	1.4	2.4	4.0	4.4	1.4	10.8	12.3	0.3
1.4	1.7	2.3	4.4	4.8	1.3	12.3	14.5	0.2
1.7	1.9	2.2	4.8	5.2	1.2	14.5	19.4	0.1
1.9	2.2	2.1	5.2	5.6	1.1	19.4	Inf.	Zero
			5.6	6.1	1.0			

A = arithmetic difference in db
B = number of db to subtract from smaller loss

Figure 5-82. Method of combining two crosstalk losses.

564. IMPROVISED METHODS OF MEASURING CROSSTALK.

a. General. Since apparatus specifically designed for measuring crosstalk is usually not available in the Army, improvised measuring methods with apparatus more generally available are described below. Figure 5-83 gives several arrangements for measuring near-end and far-end crosstalk coupling, in terms of db crosstalk loss, using apparatus of the types listed in figure 5-84. In these arrangements the wiring should be carefully laid out to avoid crosstalk in the test apparatus, by preserving pairing and by separating high-level from low-level circuits. The arrangement should be tested with 600-ohm resistors replacing the telephone lines shown in the figure, to determine whether the crosstalk in the test apparatus is insignificant. The circuit arrangements for near-end crosstalk are devised to measure the insertion loss between 600-ohm resistances, that is, the loss caused by connecting the input of the disturbing circuit to a 600-ohm transmitting circuit and the output of the disturbed circuit to a 600-ohm receiving circuit instead of connecting the transmitting circuit directly to the receiving circuit. Far-end crosstalk as usually measured (including the arrangements shown in figure 5-83) is the crosstalk loss between the far ends of the disturbing and disturbed circuits (here assumed to be co-terminous); that is, *measured far-end crosstalk.* The loss measured is the input-to-output insertion loss between 600-ohm resistances less the insertion loss of the disturbing circuit between 600-ohm resistances. Corrections to measured far-end or near-end crosstalk, to express them in terms of equal level crosstalk, can be made in accordance with the principles in paragraph 550. In measuring crosstalk on carrier or repeatered circuits, the output of the testing oscillator must be limited so as not to overload the repeaters or terminal equipment. An input of zero dbm (1 milliwatt) at zero transmission level is safe.

b. Types of Apparatus and Methods. Figure 5-84 lists some portable apparatus which can be used in the testing arrangements given in figure 5-83. The oscillators, detectors, and attenuator listed in figure 5-84 are designed for a 600-ohm impedance. They may be used directly on lines of approximately this impedance, as indicated in figure 5-83. For measurements of crosstalk on other circuits, these testing arrangements should preferably be modified by using impedance matching arrangements to match the lines to the measuring apparatus, and the lines should be properly terminated in approximately their characteristic impedances. In measuring far-end crosstalk, if the oscillator-end termination of the disturbed circuit, or the detector-end termination of the disturbing circuit, badly mismatches the line, there will be a reflected near-end-crosstalk component in the far-end crosstalk measurement. Crosstalk measurements with the apparatus shown in figure 5-84 should be made at several frequencies, except for far-end crosstalk on voice-frequency circuits, where a 1,000-cycle measurement is sufficient. Otherwise, on voice-frequency systems and at voice frequencies on channels of carrier systems, measurements should be made at 500, 1,000, and 2,000 cycles; and on carrier systems, at carrier frequencies corresponding to 500, 1,000, and 2,000 cycles in the voice channels of the disturbing circuit; and the rms (root mean square) value taken. This is obtained by averaging the power ratios (less than unity) corresponding to the db of crosstalk loss measured (ch. 12) and taking the db value corresponding to this average ratio.

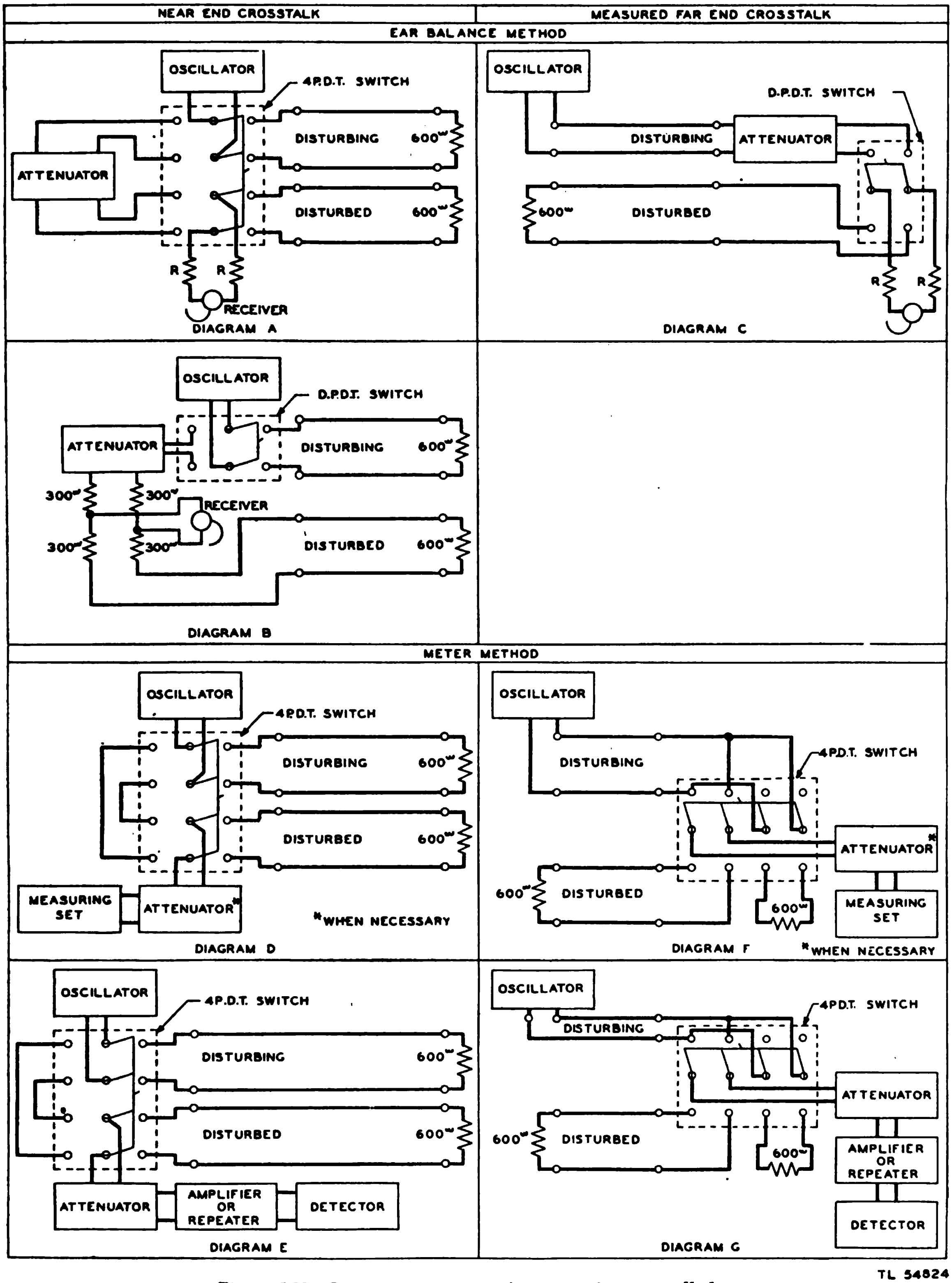


Figure 5-83. Circuit arrangements for measuring crosstalk loss.

c. Ear Balance and Meter Methods. Figure 5-83 gives two types of set-ups for measuring crosstalk: an ear balance method (diagrams A to C) and arrangements using meter indicating measuring sets (diagrams D to G). The ear balance arrangements are necessarily confined to measurements on voice-frequency circuits or at voice frequencies on channels of carrier systems. The meter method may be used for measuring crosstalk at voice or carrier frequencies, the limitations depending on the frequency and sensitivity range of the particular apparatus used.

d. Ear Balance Methods. Diagrams A, B, and C show three testing arrangements for measuring crosstalk using the ear balance method. This method consists of listening to the testing tone on the disturbed circuit via the crosstalk path, then switching to the oscillator circuit and adjusting the attenuator until the tone is of equal intensity. The number of db inserted in the attenuator may then be read as the crosstalk loss. Resistors R should be chosen so that the resistive component of the impedance of the receiver plus 2R is about 600 ohms at 1,000 cycles. The two resistors should be as nearly alike as practicable, preferably within 2 percent and a difference of more than 10 percent should be avoided. Suitable approximate values of R are given below for various receivers available in the Army.

Receiver	*Approx. 1,000-cycle receiver impedance*	*R*	*Total*
R-22 (single receiver part of Head and Chest Set HS-19)	150 + j260	200	550 + j260
HS-30-( ) (double, insert type receivers)	130 + j150	250	630 + j150

Diagrams A and B are for near-end crosstalk measurements. Diagram A, the simplest arrangement may be used satisfactorily in the absence of high circuit noise. Diagram B uses an arrangement which allows noise, present on the disturbed circuit, to be heard in both positions of the oscillator. This arrangement permits a more accurate balance to be made in the presence of high noise than is possible with the arrangement in diagram A. The 300-ohm resistors prevent error in measuring the crosstalk insertion loss when the impedance of the disturbed circuit is quite different from a 600-ohm resistance. For example, without the resistors and for a line impedance of 1,200 ohms resistance, the measured crosstalk loss would be 2.5 db too great. Evidently the resistors can be considerably below 300 ohms without causing large errors. The two resistors in different wires and on the same side of the receiver should be alike, however, and preferably within 2 percent. No padding resistors in series with the receiver are necessary. In diagram C (the arrangement for far-end tests) at least 10 db should be left in the attenuator so that the disturbing line may be properly terminated when listening is done on the disturbed circuit.

e. Meter Methods.

(*1*) Diagrams D, E, F, and G give crosstalk testing arrangements using meter indicating detectors. The measuring method for diagrams D and F consists of obtaining a measurement of the oscillator output power on the measuring set, then switching and measuring the power of the test frequency on the disturbed circuit. The difference in the two readings in db is a measure of the crosstalk loss. The method for diagrams E and G is to adjust the attenuator, with the switch in the oscillator position, until a meter deflection is obtained on the detector. Then switch to the disturbed circuit and again adjust the attenuator until the same meter deflection is obtained. The difference in the attenuator settings will be a measure of the crosstalk loss in db. A precaution must be taken to be certain that the detector or measuring set on the disturbed circuit is measuring the testing frequency and not noise. This should be checked by switching the oscillator on and off. If the received power with the oscillator off is at least 9 db less than that with the oscillator on, the error introduced by the noise is less than 0.5 db. By applying a correction, crosstalk may be measured in the presence of somewhat higher noise. Measure on the disturbed circuit with the oscillator on, and again with it turned off. Compute the apparent crosstalk loss with the oscillator on; make a similar computation using the disturbed circuit reading with the oscillator off and the same oscillator power reading. Find the db difference between these apparent crosstalk losses, and use it in the table below to obtain a db correction. Add the correction to the apparent crosstalk loss with the oscillator turned on, to obtain the real crosstalk loss.

Apparatus[a]	*Frequency range (cycles)*	*Range (db)*	*Input or output impedance (ohms)*
13A transmission measuring set	30- 20,000	+10 to −45 dbm[b]	600
32A transmission measuring set	150-150,000	+35 to −35 dbm	135 or 600
2B noise measuring set (Stock No. 3F4265)	60- 12,000	+25 to −99 dbm at 1,000 cps	600
17B oscillator (Stock No. 3F3570-3)	50-150,000	+18 to 0 dbm	135 or 600
19C oscillator	30- 15,000	up to +6 dbm	600
51A oscillator	2,000- 79,000	+16 to −75 dbm	135[c]
5A attenuator	0-100,000	1 to 81 db loss	600
Telephone Repeater EE-99-A	Voice	35 db gain for each of two amplifiers, at 1,000 cycles	300[d]
Telephone Repeater TP-14-( )	Voice	18 db gain at 1,000 cycles	600

[a] All except last two items are Western Electric Company designations.

[b] Dbm = db referred to 1 milliwatt.

[c] Use 135:600 ohm coil in 32A transmission measuring set to obtain 600-ohm output.

[d] At least 6 db should be left in the attenuator when placed at the input of this repeater, to avoid errors due to mismatching.

Figure 5-84. Apparatus usable in improvised crosstalk measurements.

For example, if the apparent crosstalk loss determined with the oscillator on is 50 db and with the oscillator off is 52 db, the difference is 2 db. From the table below, the correction to be applied to the 50 db reading is 4 db giving a true crosstalk loss of 50 + 4 or 54 db.

Difference in db:	6 to 9	4 to 5	3	2	1.5	1
Correction in db:	1	2	3	4	5	7

(*2*) Diagrams D and F are crosstalk measuring arrangements for use where a Western Electric Company 2B noise measuring set is available; or for measuring small crosstalk losses with a Western Electric Company 13A or 32A transmission measuring set at frequencies indicated in figure 5-84. For an oscillator output of 0 dbm (1 milliwatt) a maximum coupling loss of 45 or 35 db may be measured using the 13A or 32A set respectively. The Western Electric Company 2B noise measuring set may be used for measuring considerably greater values of crosstalk loss at frequencies up to around 12,000 cycles. For measurements on pairs without repeaters or terminal apparatus, larger values of crosstalk loss may be measured by using higher oscillator outputs.

(*3*) Diagrams E and G give crosstalk measuring arrangements to permit measurement of higher values of crosstalk loss. A repeater or amplifier, such as Telephone Repeaters EE-99-A or TP-14-( ) for voice frequencies, is used ahead of the detector to increase its sensitivity. In using Telephone Repeater EE-99-A in this measuring set-up, at least 6 db must always remain in the attenuator ahead of it to avoid inaccuracies due to the mismatch between its 300-ohm input and the rest of the measuring circuit. The equalizer networks in the repeater may be switched in, when necessary, to provide low- and high-frequency noise reduction.

f. Use of Telephone Terminal CF-1-( ).

(*1*) Telephone Terminal CF-1-( ) can also be used to measure crosstalk at the frequencies which are obtained when the 1,000-cycle test tone is sent on one or more of the four telephone channels. For measuring near-end crosstalk, the transmitting portion of the terminal is connected to the disturbing circuit, and the receiving portion to the disturbed circuit; the crosstalk is amplified by the receiving portion of the terminal and read on the db meter associated with the terminal;

and the nominal gain in the terminal is allowed for in converting the measurement into crosstalk loss.

(2) The procedure is as follows. Send normal testing power into the channel chosen for test. Set the OUTPUT key, where provided, in the NORMAL position. In the case of Carrier Terminal CF–1–B, set the channel 2 WIRE-4 WIRE key to the 2 WIRE position. Set REC LEV key in the operated position. Set MILES dial on step 0, dial 1 on step 30, dial 2 on step 4, dial 4 on step 14. Set the switch on the MEAS panel to measure the 2-wire output of the channel under test. Adjust the GAIN dial so as to obtain a deflection on the db meter. Add the setting of the GAIN dial, the reading of the db meter (upper scale, neglecting the minus sign), and the appropriate constant from the following table, to obtain the approximate crosstalk loss in db.

Channel	*Test frequency at output of carrier terminal (kc)*	*Constant to be added*
1	1.0	7
2	4.9	11
3	7.85	15
4	10.8	21

For example, if channel 4 is used, and the GAIN dial is on 30, and the meter reads –20, the crosstalk loss is 30+20+21=71 db. If the GAIN dial is set on its top step (step 45), the gain may vary by about ±3 db from its nominal value on account of the small amount of feedback in the receiving amplifier with this setting; and there will be a corresponding uncertainty in the crosstalk measurement.

(3) When this method is used to measure the side-to-side crosstalk in a single Cable Assembly CC–358–( ), the cable assembly should normally be connected to Telephone Terminal CF–1–( ) through a Cable Stub CC–356 which has low crosstalk, as determined by a separate test. If the far end of the cable assembly or cable stub is left unterminated for simplicity in testing, and the crosstalk is due to capacitance unbalance, the meter reading will be approximately 12 db higher in the test condition than with the cable in service and therefore terminated, and 12 db should be added to the crosstalk loss as determined in subparagraph (2) above. Also, when the disturbing pair is unterminated, the normal meter reading will not be obtained at the output of the transmitting amplifier; this is unimportant since the proper oscillator output adjustment is not determined by this meter reading. The connectors should be dry and clean, when making the measurement and when in service.

(4) The nominal impedance of Telephone Terminal CF–1–( ) is about 470 ohms, but fairly sizable departures from this value occur, particularly at the higher frequencies; hence there will be some unwanted reflection effects, producing minor errors in the measured crosstalk, if the terminal is used to test other than spiral-four cable.

(5) Two Telephone Terminals CF–1–( ) could be used in a generally similar fashion to test far-end crosstalk, sending from one end at a time.

(6) In terminals provided with an OUTPUT key, by using + 10 db instead of NORMAL output where this is permissible, 10 db greater crosstalk loss can be measured. Crosstalk at other frequencies can be obtained by using an oscillator other than the test oscillator in the carrier terminal, and allowing for its sending level, set low enough not to overload the terminal; the transmitting portion of a v-f carrier telegraph channel might be used. If other test frequencies are used, the additive constant in the table in subparagraph (3) above should be adjusted, by interpolation, for the test frequency used.

Section VII. REHABILITATION OF CAPTURED LONG DISTANCE CABLE CIRCUITS

565. GENERAL.

a. Long distance cables in captured territory provide a means of establishing large numbers of long haul circuits with a minimum expenditure of material. Some sections of these cables and a substantial part of the loading apparatus may be damaged by the enemy and will need to be rehabilitated or replaced to make the circuits usable.

b. It is important that the cable sections rehabilitated initially be made capable of a good grade of transmission because with the passage of time the circuits will have to be extended in length and will ultimately become part of the rear area communication network. This will require careful planning and engineering and personnel skilled in all phases of the work. *It is essential to have cable splicers and testers trained in the technique of splicing and testing quadded cables.* Rehabilitation done without skilled personnel and without sufficient regard to transmission performance is likely to prove unsatisfactory in the long run. Of course temporary expedients can be employed to establish circuits needed during the initial phase of rehabilitaton.

c. If need for rehabilitating a cable can be foreseen in advance it will be desirable to take steps to have the proper kind of cable, sleeves, loading apparatus, cable terminals, and miscellaneous material on hand for replacement purposes. This will greatly simplify rehabilitation and will give the best transmission results. The offices frequently will be destroyed by the enemy, so it is important to provide means for terminating the cable pairs in new offices. Sealed cable terminals are best for this purpose; for example, cable terminal having stock No. 5C2502 is suitable for terminating a 102 pair cable. Distributing frames, such as the one having stock No. 4E2523G, may be used also. If these are used, a short length of silk and cotton covered tip cable (par. 506) should be provided between the frame and the lead-covered cable. In many cases it will not be possible to duplicate apparatus or to anticipate requirements, especially as to the extent of damage. A search for material available locally will be necessary under these conditions. Replacement cable lengths may be found locally as it is the practice in some countries to store such cable in a safe place near the repeater stations. As a substitute for sleeves, lead sheet may be procurable and cut and formed to size.

d. Complete information on the cable and loading apparatus involved is essential. Some of this information can be obtained in advance, some may be obtained on the spot from local records or local inhabitants, and some can be determined by physical inspection and tests on the job. Important items are: the number of wires and wire sizes; whether the cable is paired, or has multiple-twin or spiral-four quads; cable lay-up and method of segregating 4-wire circuits; capacitance of the cable; and inductance of the various types of loading coils and physical characteristics of loading apparatus. The extent of damage must also be known, including the length and locations of cable sections to be replaced, the number and locations of loading points requiring new loading apparatus, and the number and types of loading units required.

e. Care must be taken at all splices to keep the pairs and quads intact, since a split pair or phantom would probably be so susceptible to noise and crosstalk as to make the circuits useless. It is desirable also to restore the original continuity of each wire through a loading section in order to minimize the degradation in crosstalk (par. 568). It is not necessary to restore the original continuity of conductors at loading coil splices but it is important that a given pair or quad have the same loading throughout a repeater section (par. 569). As a preliminary to splicing it is necessary to know the code identification of the insulation. The paper may be colored or it may be plain and marked with printed numerals or symbols. The quads may have identifying thread binders. It is preferable to secure information in advance as to these codes from manufacturers records or from the local telephone administration. When this is not possible, the cable should be examined in the vicinity of a cable terminal and the cable coding determined by test. A spare or partially damaged cable terminal with some cable attached may serve the same purpose. If necessary, the sheath can be removed from the cable and very careful examination made of the cable layer by layer and quad by quad. To avoid displacing the wires during examination, the core should be bound at both ends of the exposed section, layer by layer, as they are uncovered and the quads released and bent back only as each is identified.

f. In Europe, cables with spiral-four construction (star quads) will be found, as well as multiple-twin quadded construction commonly used in the United States. The type of construction should be determined before splicing. In spiral-four cables the four wires are twisted together as a group so that each wire occupies a corner of the square thus formed. The wires in diagonally opposite corners of the square form a pair. It is difficult to distinguish between multiple-twin and spiral-four construction if the exposed wires have been disturbed. When there is doubt as to the type of construction and records are not available, a length of sheath should be removed and careful inspection made of the construction used.

g. Other outside plant considerations, such as special tools and equipment required, are covered in chapter 9.

h. A suggested organization of personnel for cable rehabilitation consists of a supervisor, two cable testers, and 8 to 10 splicing teams each consisting of a splicer and helper. Separate transportation for each tester and each splicing team is desirable.

i. Selection of suitable buildings for housing repeaters and other equipment is important for operation of the communication system. Factors to be considered in this connection are: adequacy of protection from weather, floor space in relation to future requirements, floor strength, living quarters for personnel, etc. (ch. 11).

566. FOUR-WIRE OPERATION.

a. It is advisable to plan on the operation of any repeatered circuits on a 4-wire basis. Two-wire repeatered circuits are much more subject to trouble from impedance irregularities caused by misplaced or damaged loading coils, etc. Irregularities of this nature merely increase the loss and introduce irregularities in the transmission-frequency characteristics of 4-wire circuits, whereas on 2-wire circuits they are likely to cause singing and require greatly reduced repeater gains. Nonrepeatered 2-wire circuits can, of course, be used for short lengths, as limited by their loss. If damage to the cable is small, and the damaged loading coils can be replaced by coils having the same inductance, it may be feasible to operate 2-wire circuits on a repeatered basis.

b. The packaged voice-frequency repeaters (par. 518) are suitable for use on cable circuits. When these repeaters are not available, Repeater EE–99–A may be used. Repeater TP–14–( ) is a 2-wire repeater but two of them can be used if necessary to make a 4-wire repeater. In this case, the gain controls of the unused amplifier of each of the two repeaters should be turned to the step which gives no transmission.

567. SEGREGATION FOR 4-WIRE OPERATION.

a. In 4-wire circuit operation, pairs in the cable normally are divided into two groups, one for each direction of transmission. This is done to obtain a 10- to 20-db increase in the near-end crosstalk loss between opposite directional circuits; this is desirable because of the large crosstalk amplification involved (par. 550). Examples of American practice in segregating the 4-wire groups in multiple-twin cables are shown in figures 5-85-A, -B, and -C. These methods may be used also in some foreign cable installations.

b. Figure 5-85-A illustrates concentric segregation, in which inner layers are used for one direction of transmission and outer layers for the other direction. Quads for 2-wire circuits are used to separate oppositely bound 4-wire groups in the same layer. The 2-wire group may utilize a complete layer and may include quads in the center of the cable. Where oppositely bound 4-wire quads are in touching layers, dependence is placed on the opposite direction of stranding lay for these layers, and on splicing planned (in commercial installations) to minimize crosstalk coupling between groups.

c. Figure 5-85-B illustrates split-layer segregation, in which the oppositely bound 4-wire groups are diametrically opposite in each layer and separated by one or more quads of the 2-wire group. The 2-wire group may include the center quads. Figure 5-85-C is a special case of split-layer segregation, in which two diametrically opposite quads in each layer are used as separators; these separator quads are used for 2-wire circuits. Since figures 5-85-B and -C are idealized, the cross section of the cable will agree with the sketches at only a few points, because the stranding lay is clockwise for one layer and counterclockwise for the adjacent layer. However, considering each layer separately, the oppositely bound groups are diametrically opposite and separated by diametrically opposite quads of the 2-wire group.

d. Figure 5-85-D shows the 4-wire groups separated by a diametric shield. Figure 5-85-E shows them separated by a concentric shield (layer shield). Such shields may be found in some foreign cables.

e. In reconditioning a cable for 4-wire operation, it will be desirable to maintain the segregation between the 4-wire groups. Segregation is necessary because, unlike 2-wire circuits in the same group, there may be a

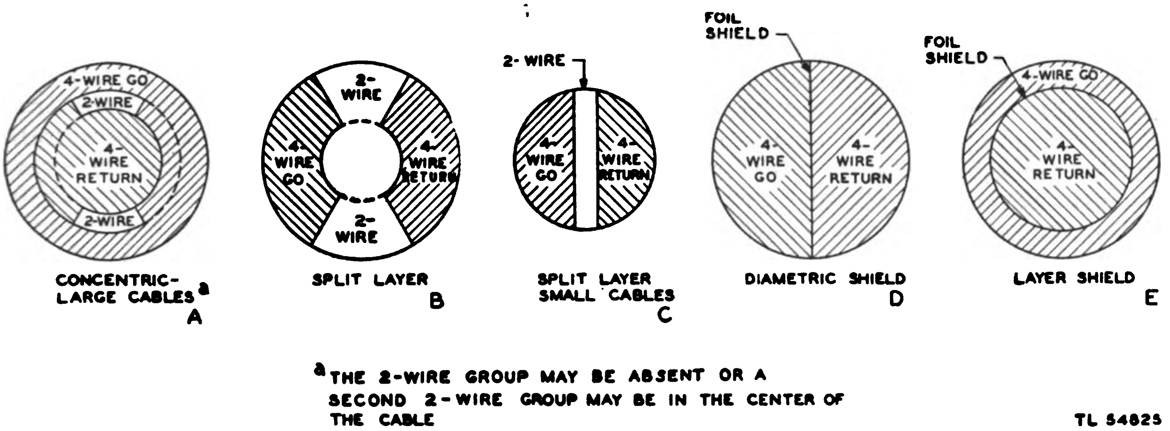


Figure 5-85. Typical segregation methods for long distance cables.

large number of repeater sections in tandem, all contributing to the crosstalk. Two repeater sections are 3 db worse than one, 4 sections 6 db worse, 8 sections 9 db worse, etc. Also the near-end crosstalk amplification for 4-wire circuits is usually much greater than that for 2-wire circuits. If segregation in a cable cannot be restored, the crosstalk degradation will depend on the number and location of the nonsegregated sections, and will approach 10 to 20 db in extreme cases of damage. The greatest benefit from segregation is obtained in cable sections close to the ends of the repeater sections because it is at these points that the greatest differences in level occur between oppositely bound pairs. Near the middle of the repeater section segregation is not so essential because the level differences are small.

f. To maintain segregation through undamaged lengths and replacing lengths, the two 4-wire groups must be identified. This may be a difficult problem. If a length extending out from a repeater station is undamaged and the 4-wire groups can be identified at the repeater station, the cable segregation can be determined by buzzer or other suitable identification tests from the office to the end of the undamaged portion. If the cable cannot be identified in this way either of the following methods can be tried: consult local records regarding color codes of quads, quad count, size of conductors, type of 4-wire circuit loading, etc.; or inspect one or two undamaged splices within a loading section or an undamaged loading splice, since the groups may be indicated in splices. If identification is not possible, segregation through undamaged lengths can be maintained by a quad-for-quad substitution provided at least one wire of each quad is continuous. Such substitution requires identification of the same quad at both ends of the damaged length, disconnection of this quad, and splicing a quad in the new length in its place.

g. If more than one cable is available on a route, opposite directional circuits can be placed in separate cables. Circuits employing different loading systems may be used in opposite directions provided both loading systems are satisfactory for the circuit length required.

h. If quads in a 2-wire group must be used to establish 4-wire circuits, there will be no segregation between opposite directional 4-wire quads. If the 4-wire repeaters are placed at the same location as the original 2-wire repeaters, and if the circuit lengths are restricted to the lengths normally used for 2-wire operation, crosstalk results should be satisfactory.

i. Segregation in replacement lengths can be accomplished by using one of the segregation methods illustrated in figures 5-85-A, -B, or -C or by using a separate cáble for each direction.

568. CAPACITANCE UNBALANCE.

a. Side-to-side and phantom-to-side capacitance unbalances in cable quads are important sources of side-to-side and phantom-to-side crosstalk, respectively. The capacitances involved are those between each wire of one side circuit and the two wires of the other side circuit, in the same quad, and also the capacitances between each wire of the quad and all other conductors in the cable as well as the sheath. If certain conditions of equality are met in the values of these capacitances, the capacitance unbalances, and hence the within-quad crosstalk will be a minimum. In normal civilian cable installations, the capacitance unbalances are reduced as much as possible in order that crosstalk will not be excessive. This is usually done by measuring unbalances at one or more splices in the loading sections, selecting quads with approximately equal unbalances, and splicing these selected quads, with or without transpositions, as required to obtain minimum over-all loading section unbalances. On a few residual quads, the unbalances may not match satisfactorily and small condensers are connected between appropriate wires of the quad for further unbalance reduction. Another method, used on some cables installed by the Germans, involves splicing the cable without regard to capacitance unbalance, and applying capacitors at one point in a loading section on all quads having excess capacitance unbalances.

b. Restoration of a cable to its original crosstalk performance, requires capacitance unbalance tests and correction in each loading section affected. Since this requires special testing apparatus and techniques, and considerable time, it may not be practicable in most military situations. An alternative is to recondition the cable without capacitance unbalance testing, but to maintain the original continuity of the conductors to the greatest extent practicable. The resulting degradation in phantom-to-side crosstalk would be zero with no replacements and reach a maximum of about 20 db if the capacitance unbalance correction were upset in every loading section. If high crosstalk should develop as the 4-wire circuits are extended to longer lengths, it would be feasible to improve the crosstalk by use of within-quad balancing capacitors at the ends of reconditioned 4-wire repeater sections. This requires special techniques and equipment but by the time such a procedure is required it should be possible to make arrangements for these and plan the work so as to cause minimum circuit interruption. Methods of making such localized capacitance unbalance corrections, and measuring crosstalk coupling, are described in Section G72.225 and Section E36.105, issue 2 of Bell System Practices. A large reduction in side-to-side crosstalk (15 to 20 db) may be obtained in this way. The reduction in phantom-to-side crosstalk is limited to 6 to 8 db by the differences in attenuation and velocity of propagation of the side and phantom circuits.

c. Loading section capacitance unbalances after rehabilitation depend upon the number of replaced sections, their lengths, their locations relative to loading coils or capacitance unbalance corrective splices, and whether or not the original continuity of the conductors has been restored. If the original continuity of the conductors has not been restored, the capacitance unbalance may be much greater than that of the replacement cables alone.

d. Approximate rms values of capacitance unbalances (mmf) of lead-covered multiple-twin quadded cables are given in the following table. A comparison of the capacitance unbalance figures indicates the advantage of making test splices, when practicable, in which capacitance unbalance corrections are made.

Length	*Capacitance unbalance (mmf)*	
	Phantom-to-side	*Side-to-side*
1,500-foot reel	75	30
6,000 feet (1,500-foot reels) with no test splices	150	60
6,000 feet with three test splices	15	15
6,000 feet with one test splice	40	30

The minimum crosstalk loss due to capacitance unbalances may be estimated from the following formulas:

Minimum crosstalk loss (db) (equal level far-end at 1,000 cycles),

$$\text{Phantom-to-side} = 180-20 \log (4C\sqrt{N}\sqrt{|Z_s|\,|Z_p|})$$
$$\text{Side-to-side} = 180-20 \log (2C\sqrt{N}\,|Z_s|)$$

Where C = appropriate rms capacitance unbalance (mmf) for a loading section.

N = number of loading sections.

$|Z_s|$ = magnitude of nominal impedance of side circuit (par. 571)

$|Z_p|$ = magnitude of nominal impedance of phantom circuit (par. 571)

Substitution in these formulas shows that the estimated minimum crosstalk losses are about 69-db phantom-to-side and 73-db side-to-side for a 50-mile section (N=44) having 3 test splices per loading section and using the 6000-88-50 loading system (par. 571). The rms crosstalk losses may be estimated by adding 8 db to the minimum losses. Because of crosstalk in loading units, these minimum crosstalk losses might be reduced about 3 db. An additional reduction in the phantom-to-side minimum crosstalk loss will be caused by crosstalk coupling resulting from differences in the resistances of the two wires of the side circuit. Unless the wire joints at splices are properly soldered the latter reduction may be large and the crosstalk loss may be extremely variable.

e. Phantoms are not generally used on spiral-four quads because of the high crosstalk between side and phantom circuits in the same quad.

569. LOADING CONSIDERATIONS, 4-WIRE CIRCUITS.

a. When it is impossible to duplicate the loading apparatus which must be replaced, it will be necessary to use the nearest available equivalent as substitutes. Paragraph 571 discusses the loading systems likely to be encountered and lists a number of American loading units and loading coils whch can be used for replacement work. When the phantom will be used, it will generally be necessary to use phantom loading units which consist of two loading coils for the side circuits and one loading coil for the phantom. When phantoms are not involved, 88-mh loading coils from Signal Corps stocks may be used. These units or coils may be used singly, or two in series or in parallel to obtain close to the desired inductance.

b. Parallel or series connection of phantom loading units or coils increases the crosstalk contributed by the loading coils because of the increased number of coils on the circuit. In addition, phantom loading units of American manufacture are adjusted in the factory for minimum crosstalk in circuits having the impedance for which the loading is designed. Because of the change in circuit impedance when series or parallel connection is used, the side-to-phantom crosstalk will be increased and to a lesser extent the side-to-side crosstalk. With loading units in parallel or in series, the phantom-to-side crosstalk per loading section may be as important as an rms capacitance unbalance of 30 to 50 mmf. The relation between mmf and crosstalk loss is discussed in paragraph 568d. Phantom loading units have a fixed ratio of side-to-phantom inductance, which may not be the same as that of the units which they replace, so it will not always be possible to duplicate both the side and phantom inductance.

c. When the inductance of a replacement coil is not the same as that of the coil replaced, an increase in attenuation generally results. If a number of such replacements must be made the penalty will be less if the replacements can be located at consecutive loading points so as to make a homogeneous section of circuit. If a number of the existing loading coil cases are removed for repair, it may be possible to relocate them so that the new cases can be grouped consecutively.

d. The introduction of loading coils of the wrong inductance at scattered points in a loaded circuit causes irregularities in the transmission-frequency characteristic of the circuit as well as excess loss. These effects increase with the amount of the inductance departure from normal, the number of such loading points in a repeater section, and the number of repeater sections affected. Irregularities in the transmission-frequency characteristics make it difficult to equalize the circuit and are undesirable from the standpoint of voice-frequency telegraph transmission and operation of telephone circuits at low net loss.

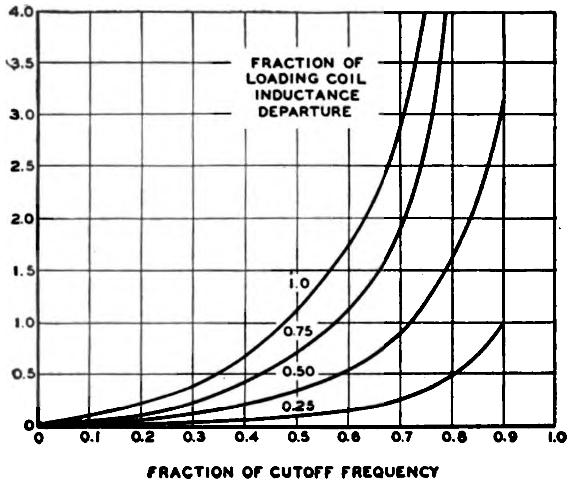


Figure 5-86. Loss caused by a departure from average inductance at a single loading point.

e. Figure 5-86 gives data for estimating the approximate increase in line loss which will occur when a loading coil with an inductance excess or deficiency is inserted at a single loading point. For example, if an 88-mh coil is used in place of a 177-mh coil at one loading point of a circuit having 177-mh loading at 6,000 feet spacing, the increased loss would be 0.9 db at 2,000 cycles. This is obtained by reading the curve for a loading departure of $\frac{177-88}{177} = 0.5$ and for a fraction of the cut-off frequency of $\frac{2,000}{2,900} = 0.7$. The value of 2,900 cycles, for the cut-off frequency of 6000-177 loading, is obtained from figure 5-89. A similar use of figure 5-86 gives an excess loss of 0.2 db at 1,000 cycles, for this example.

f. Loading coils with equal inductance departures at two or more widely separated points will cause an increase in loss roughly proportional to the number of coils. Continuing the example of subparagraph e above, the effect of substituting 88 mh for 177-mh coils at five well separated points in a circuit would be in the order of 5 db at 2,000 cycles and 1 db at 1,000 cycles. This represents a considerable narrowing of the useful frequency band. If similar irregularities occurred at 10 loading points the effect would be twice as great as for 5 points, provided the 10 points were scattered over two or more repeater sections. If scattered over only one repeater section, the excess loss probably would not be as large as that estimated by this method because a considerable separation between the loading irregularities is necessary for figure 5-86 to apply. However, the transmission-frequency characteristic would tend to have large irregularities in this case, as discussed in subparagraph d above.

g. When coils having the wrong inductance are used at consecutive loading points instead of being widely scattered, the loss increase will be at a slower rate than the increase in number of coils; if the number of such points is large, the transmission loss of the complete section approaches the sum of the attenuations of the original and repaired sections plus a small (usually negligible) reflection loss at the junctions. When this condition is reached, if the replacement coils have a lower inductance than the original, the loss of the complete section will have increased; if they have a higher inductance, the loss at low and medium frequencies will have decreased but the cut-off frequency will have been lowered. This is illustrated by the results of computations made by exact methods which show that if half of a normal repeater section were 6000-88 loaded and the other half 6000-177 loaded, the repeater section loss at 1,000 cycles would be about 1.5 db more than if the whole repeater section were 6000-177 loaded. The cut-off frequency would be that of the 6000-177 loading. A similar type of computation indicates that the substitution of 88-mh for 177-mh coils at five consecutive loading points in a 6000-177 loaded circuit would increase the loss 1.1 db at 2,000 cycles. This, of course, is much less than the effect of substitution at five widely separated points, as estimated in subparagraph f above.

h. Incorrect loading section capacitance is also a cause of impedance irregularity. This may result from replacing portions of the cable with cables having different pair capacitance per mile from that of the original. Military stocks of lead-covered cable have a nominal pair capacitance of 0.062 mf and phantom capacitance of 0.102 mf per mile. The nominal capacitances per mile of commercial long distance multiple-twin quad cables are expected to lie in the range from about 0.054 to 0.62 mf for side circuits and 0.087 to 0.102 mf for phantoms. Lead-covered cable with spiral-four quads usually have a capacitance of 0.062 mf per mile for the side circuits and about three times as high for the phantom. The effect of a capacitance excess or deficiency, expressed as a fraction of normal loading section capacitance, is approximately the same as for an equal fractional excess or deficiency in loading coil inductance. This can be estimated from figure 5-86.

i. The end section of a loaded cable is the distance from the office to the first loading point in the repeater section, expressed as a fraction of the normal distance between loading points. Loaded cables are usually terminated at about 0.5 end section. Some loading systems are designed for *midcoil termination*, in which case there is a coil of half the normal inductance at the office and a full section of cable between the office loading coil and the next loading point. If the cable has to be rerouted, or the office relocated, it may not be feasible to restore the original end section or termination of the cable. This will not be serious in the case of four-wire operation as the principal effect will be to make it somewhat more difficult to equalize long circuits. The effect of end sections on 2-wire circuits is discussed in paragraph 570b(6).

j. Foreign cables of the *Krarup* type have conductors which are continuously loaded by means of iron wire wrapped spirally around each conductor. If sections of this type of cable must be replaced, probably the only practicable expedient will be to use ordinary non-loaded lead-covered cable. This will increase the loss and introduce impedance irregularities but the effects should be tolerable for 4-wire circuit operation if the replacement lengths do not total more than about a mile per repeater section. More extensive repair would require special engineering, including consideration of applying coil loading to any long lengths of the replacement cable.

570. TWO-WIRE CIRCUITS.

a. Capacitance Unbalance. Near-end crosstalk is amplified by repeaters on either 4-wire or 2-wire circuits. On 4-wire circuits suitable near-end crosstalk performance is obtained by segregation (par. 567). On 2-wire circuits suitable near-end crosstalk performance for circuits in the same quad cannot be obtained even though the repeater gains are less and the circuits are shorter, unless the capacitance unbalances are low. Therefore, capacitance unbalances within quads carrying 2-wire circuits, if near a repeater, are very much more serious than they are in 4-wire circuits. Unbalances near the middle of a 2-wire repeater section are not so important because of the smaller level differences at such points.

b. Loading Considerations.

(*1*) In rehabilitating 2-wire cable circuits the loading considerations discussed in paragraph 569 apply. It is highly desirable to duplicate the original loading units or else select units having the right inductance. Selections may be made from the American loading units discussed in paragraph 571.

(*2*) Any deviation from uniformity in loading coil inductance or loading section capacitance will cause impedance irregularities in a loaded circuit. These irregularities will affect the balance of 2-wire repeaters used on the circuit. The effects on balance may be estimated by using figure 5-87. This figure shows the approximate return loss caused by inserting a loading coil of incorrect inductance at one loading point. If the loading point is at a distance from the repeater, the actual return loss at the repeater will be approximately (R + 2A) db where R is the return loss obtained from figure 5-87, and A is the loss between the repeater and the loading irregularity. Hence, an irregularity will have the least effect on balance if it is located at the center of a repeater section. If there is more than one loading irregularity in the repeater section, the return loss at the repeater will be the combined return loss of each irregularity computed separately. The separate return losses should be converted to power ratios, added, and reconverted to db, to secure the combined return loss. The method of converting db to power ratio and vice versa is described in chapter 12. Return losses in db are considered to be negative when using chapter 12. Return loss computations should be made using the frequency at which the repeater is most likely to sing. This frequency will depend on the type of filter used in the repeater, but, in the absence of other information, a frequency of 2,500 cycles per second may be used.

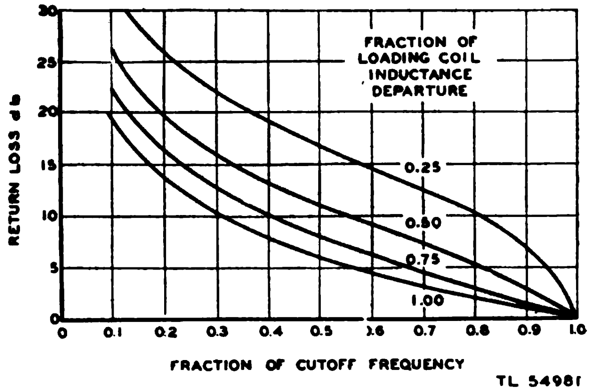


Figure 5-87. Return loss caused by a departure from average inductance at a single loading point.

(*3*) The procedure described in subparagraph (2) above, is illustrated in the following example. Assume that a repeatered, 2-wire, 19-gauge circuit with 6000-177 loading has an 88-mh loading coil substituted for a 177-mh coil at one loading point. Let this loading point be so located that there is a loss of 3.5 db between it and the 2-wire repeater. The loading coil inductance departure is $\frac{177-88}{177} = 0.5$ and the fraction of the cut-off frequency is $\frac{2,500}{2,900} =$ 0.86. Figure 5-87 indicates that the return loss of this irregularity will be 4 db at the loading point. The return loss at the repeater will be 4 + (2 × 3.5) = 11 db. If there were another similar loading irregularity located 6.5 db away from the repeater, the return loss of this second irregularity would be $4 + (2 \times 6.5) = 17$ db at the repeater. The power ratios corresponding to 11 db and 17 db are 0.08 and 0.02, respectively. The sum is 0.10 which corresponds to about 10 db. This is the combined return loss of the loading irregularities at the repeater. A return loss of 10 db would be too low in the usual case, as it would permit the repeater to have only about 5-db gain. Under conditions of smaller inductance departures located further away from the repeater, computations of this sort might indicate that satisfactory repeater gains could be used.

(*4*) Although figure 5-87 is drawn in terms of loading coil inductance departure, it may be used to determine the effect of capacitance deviations, as described in subparagraph 569h. Such deviations will most often occur when a loading section is too long or too short. For example, if the normal loading coil spacing is 6,000 feet, a section only 4,500 feet long would have a deficiency of $\frac{6{,}000-4{,}500}{6{,}000} = 0.25$. The curve marked 0.25 in figure 5-87 would apply in this case. The geographical location of an irregularity due to a capacitance deviation may be assumed as being located at the midpoint of the affected loading section.

(*5*) The foregoing discussion indicates that 2-wire operation with repeaters is likely to be unsatisfactory unless the cable can be restored practically to its original condition. However, if the cable is practically intact and the replacement loading units can be grouped, 2-wire operation may be feasible with reduced repeater gains even if the inductance differs somewhat from the desired value. Figure 5-88 gives the approximate junction return losses between two electrically long sections of cable loaded at the same spacing with coils of somewhat different inductances. To get the effect on repeater balance, twice the loss between the repeater and the junction should be added.

Ratio of loading inductances	*Junction return loss (db)*		
	0.3fc[a]	*0.5fc*[a]	*0.75fc*[a]
0.9	31.5	29.5	24.5
0.8	25	23	19
0.7	21	19	15.5
0.6	18	16	13
0.5	15.5	13.5	11

[a] f_c is the cut-off frequency of the section using the higher loading inductance. The reflection loss at the junction will seldom exceed 0.1 db at 1,000 cycles.

Figure 5-88. Junction return losses between two loaded circuits having different loading inductances.

(*6*) It will be necessary to readjust the building-out capacitors in the balancing networks of the repeaters to compensate for any change from the normal length of end-section (par. 569i). Some networks are designed to balance any end section above about 0.2 if the building-out capacitors are properly adjusted. Other types of networks may be designed for a particular end section. When the loading points cannot be located to give the desired loading section or end-section capacitance, it may be possible to arrange the loading so that there will be a capacitance deficiency in the sections involved. Then the equivalent of normal capacitance can be obtained by building-out the capacitance with the proper length of building-out cable which may be connected in series or as a bridge on the main cable. Use of building-out cables for this purpose is covered in Bell System Practice, Section AB23.195.

571. LOADING SYSTEMS AND APPARATUS

a. Foreign Loading Systems. Figure 5-89 gives the loading systems which have been approved by the International Consulting Committee, Telephony (CCIF) for international circuits. These and others listed in TM 11-487 may be encountered. TM 11-487 gives a method for estimating the 1,000-cycle loss per mile with these loadings and the usual sizes of wire.

b. Loading Units. Some of the American types of loading units which can be used for repairing CCIF standard loading systems are given in figure 5-90. These units are designed for loading the two sides and the phantom of a phantom group. Except for the MF11 loading unit, they are not stocked by the Signal Corps. The units not carried in stock may be obtained on special order through Army Communications Service, specifying the number of units per loading point and the number of loading points. If necessary, two of these units may be connected in series or parallel to obtain approximately the correct loading in-

Loading system[a]	*Nominal impedance (ohms)*		*Cut-off frequency (cycles)*	
	Side	*Phantom*	*Side*	*Phantom*
5577-30-12	700	350	7,470	9,300
6000-44-18	800	400	5,800	7,000
6000-44-25	800	500	5,800	6,000
6562-50-20	850	450	5,430	6,830
6000-88-36	1,150	550	4,100	5,000
3000-88-36	1,600	800	5,800	7,000
6000-88-50	1,150	650	4,100	4,300
3000-88-50	1,600	950	5,800	6,000
5577-140-56	1,550	800	3,500	4,400
6000-177-63	1,600	700	2,900	3,600
6000-177-107	1,600	1,000	2,900	2,900
6562-190-70	1,600	750	2,710	3,465
6562-200-70	1,700	800	2,710	3,660
10730-65	700		3,500	

[a] In the loading systems, the first number is the coil spacing in feet, the second is the inductance of the side circuit loading coil in millihenries, and the third, when present, is the inductance of the phantom loading coil in millihenries. TM 11-487 lists the cable capacitance normally involved with the given loading systems.

Figure 5-89. Loading systems approved by the CCIF for international circuits.

Western Electric Company type	*Inductance (mh)*		*Resistance (ohms)*			
			Side circuit		*Phantom*	
	Side circuit	*Phantom*	*Dc*	*1,000 cycle*	*Dc*	*1,000 cycle*
MF1	172	63	13.8	16.4	6.9	7.6
MF11	88	50	6.3	7.2	3.1	3.6
MF2	44	25	3.6	4.0	1.8	2.0
MF4	31	18	3.1	3.4	1.5	1.7

Figure 5-90. American loading units.

ductance. The increased phantom-to-side crosstalk, is discussed in paragraph 569b.

c. Nonphantom Loading Coils. It may sometimes be expedient to use nonphantom type coils (88 mh) from Signal Corps stocks in the theater to restore a nonphantom circuit to operating condition. Two coils may be connected in tandem to obtain 176 mh or two coils may be connected in parallel to obtain 44 mh. Loading Coil C-114-A (88 mh) should not be used for loading of paper-insulated cables except as a very temporary expedient because of the difficulty of making the installation moistureproof.

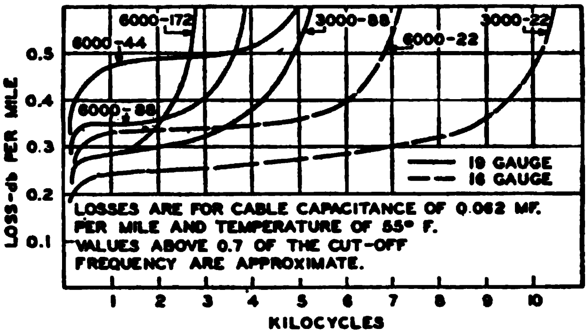
572. IDENTIFYING LOADED CIRCUITS.

a. General. In cable restoration work it is necessary to know the cable lay-up; 4-wire segregation method; side and phantom circuit capacitance per unit length of the cable; loading coil inductance, spacing, and pair assignments; and the identification of the loading coils in any loading coil cases which need to be inserted, either in new cases, cases severed from the cable as the result of sabotage, or cases disconnected for repair. If local records are not available giving the desired data, it will be necessary to resort to other means for acquiring this knowledge. The cable lay-up and 4-wire segregation methods may be found by inspection as discussed in paragraph 567. The loading coil spacing may be determined by linear measurement after locating two adjacent loading points. The capacitance per unit length can usually be measured. Where this is impossible, it will be necessary to assume values, such as 0.062 mf and 0.102 mf per mile, for side circuit and phantom, respectively, (par. 569h). The loading coil inductance and loading spacing identifies the loading system. However, on a given circuit group, the capacitance per loading section must be known if it is necessary to resort to transmission measurements in order to determine the loading coil inductance. The capacitance C per loading section equals the spacing times the capacitance per unit length.

b. Determination of Loading Coil Inductance.

(*1*) Several methods of determining the inductance of loading coils are given in the following paragraphs. These methods depend on the relation between the capacitance per loading section, assumed to be known, and other factors which may be determined by transmission or impedance measurements. The choice of method to use depends upon the available testing apparatus and the length of undamaged cable section.

(*2*) The loading coil inductance may be calculated from the capacitance per loading section and the cut-off frequency. When the



COIL SPACING-FEET	6000	6000	6000	3000	6000	3000
COIL INDUCTANCE-MH.	172	88	44	88	22	22
CUT-OFF FREQUENCY-KC.	2.9	4.0	5.6	5.6	7.9	11.0
NOMINAL IMPEDANCE-OHMS	1550	1100	800	1550	550	800

TL 54966

Figure 5-91. Transmission loss of loaded cables.

undamaged section of cable is several loading sections long, the cut-off frequency may be determined approximately by measuring the loss at a number of frequencies and then assuming the cut-off frequency to be about 15 percent higher than the frequency at which the loss is 1.5 times the loss at 1,000 cycles. Figure 5-91, illustrates the shapes of typical attenuation-frequency characteristics for circuits with several loading inductances and spacings. The inductance of the loading coil can be calculated by substituting known values in the formula

$$L = \frac{1}{\pi^2 f_c^2 C}$$

Where f_c = cut-off frequency in cycles
L = loading coil inductance in henries
C = loading section capacitance in farads

(*3*) If the section is too long to be within the range of the transmission measuring set, the inductance may be calculated from the loading section capacitance and the nominal impedance. The nominal impedance, Z, may be estimated roughly by measuring the loss caused at 1,000 cycles by bridging the circuit terminal across the output of an oscillator sending into a transmission measuring set, both of known impedances. The bridged or nominal impedance Z can be calculated from the formula

$$Z = \frac{Z_o}{2(r-1)}$$

where Z_o is the oscillator or the measuring set impedance, (the two are here assumed to be equal) and r is the current ratio corresponding to the measured loss in db (ch. 12). The inductance can then be calculated by substituting known values in the formula.

$$L = Z^2 C$$

Where L = loading coil inductance in henries
C = loading section capacitance in farads

(*4*) If an impedance bridge is available the loading coil inductance, L, can be determined from measured values of short-circuit impedance, Z_s, and open-circuit impedance, Z_o. The impedance of the circuit is measured with the far end of the line short-circuited and is repeated with the far end open, using the same frequency setting of the oscillator for both measurements. The frequency should be approximately 1,000 cycles. Best results will be obtained when the distance from each end of the section under test to the nearest loading coil is 0.5 of a loading section. Under this condition, the inductance of the loading coil in henries is equal to the product of the absolute magnitudes of the short-circuit impedance and the open-circuit impedance divided by the capacitance of the loading section in farads. This may be expressed by the formula

$$L = \frac{Z_s Z_o}{C} \text{ henries}$$

If the cable does not terminate with 0.5 loading section at each end, the multiplier $(1+\frac{x}{n})$ should be added to the formula, where n is the number of loading coils and x is the algebraic sum of the departures from 0.5 end section at the two ends of the cable. In this case the formula becomes

$$L = \frac{Z_s Z_o}{C}\left(1+\frac{x}{n}\right) \text{ henries}$$

The actual loading coil inductance will be slightly lower than the value estimated from this formula because the estimated value includes the inductance of a loading section length of the cable. This may be estimated by assuming the inductance of the cable to be about one millihenry per mile.

(5) If an impedance bridge is not available and the section of cable is too short to identify the cut-off frequency, the loading coil inductance may be determined by disconnecting a loading coil case and measuring the coil inductances. A record of how coils were connected to the cable pairs should be kept so that, by tracing the circuits through the section of cable, the inductance measurements of the coils in a single loading coil case can be used to determine the loading system used on the various pairs of the cable. The inductance of a loading coil can be measured by connecting the coil and a series capacitor as a shunt across the output of a variable-frequency oscillator sending into a transmission measuring set. The oscillator frequency is varied to determine the resonant frequency which is the frequency at which maximum loss occurs. The inductance of the coil can be calculated from the known values of the resonant frequency and the capacitance of the auxiliary capacitor. For phantom group units, the side and phantom inductances can be measured separately. Resonant frequencies for typical loading units are given in figure 5-92.

Loading unit	*Auxiliary capacitor (mf)*	*Approximate resonant frequency (cycles)*	
		Side	*Phantom*
172-63	0.25	770	1,270
140-56	0.25	850	1,345
88-50	0.25	1,075	1,420
44-25	0.5	1,075	1,420

Figure 5-92. Loading coil identification, resonant frequencies.

(6) To identify the loading coils in an isolated loading coil case, the coil inductances may be measured by means of an impedance bridge if a suitable one is available. Otherwise the method given in subparagraph (5) above, may be used.

573. TELEGRAPH OPERATION.

a. D-c telegraph circuits can be established over the simplex circuits of the cable pairs of rehabilitated cable. It is not desirable to operate U. S. Army telegraph equipment on a composited basis over cable pairs because the telegraph distortion and the telegraph thump in the telephone circuits would be excessive. Composited operation on cables will be possible if civilian equipment designed for this purpose is found intact.

b. It is possible that some foreign installations will have repeating coils permanently inserted in each pair at the splice where the cable enters the building. If these coils do not have simplex taps brought out, it will be necessary to remove the coils and provide other repeating coils with simplex taps. It is desirable to have the junction point of the cable pairs and office equipment accessible so that d-c tests can be made to locate troubles on the pairs.

c. Voice-frequency carrier telegraph systems can be applied to the telephone circuits in the cable. The number of usable telegraph channels will depend on the band width of the telephone circuits and whether the circuits are 2-wire or 4-wire, as discussed in chapter 3.

CHAPTER 6

RADIO SYSTEMS

Section I. GENERAL FACTORS

601. SCOPE.

a. This chapter covers primarily the transmission aspects of radio circuits. General background considerations are in section I. V-h-f transmission is covered in section II, which contains methods for estimating communication performance over various types of terrain and over sea water, a summary of the principles of proper v-h-f antenna siting, and information on radio relay systems. V-h-f antenna types are described in section III. H-f transmission information, including estimates of ground-wave and sky-wave communication ranges, is given in section IV. H-f antenna types and general transmission line data are covered in section V. Types of mutual interference are described and methods for estimating the likelihood of mutual interference between different radio sets in the same vicinity are discussed in section VI. Information on remote control units, which are used when the talker or the signal center is at some distance from the radio set, is found in section VII. A brief summary of the characteristics of the chief Signal Corps radio sets used for ground communication and of a number of U. S. Navy and British radio sets is in section VIII.

b. A general discussion of the fields of use of miltary radio and wire circuits is in chapter 1. While the radio propagation data given in this chapter apply both to telephone and telegraph, the information on radio telegraph systems from the telegraph point of view is covered in chapter 3, which includes, in particular, radio teletypewriter systems. Data on c-w telegraph communication ranges, however, are in section IV. Information relating to radio traffic, radio plant layout, and radio maintenance is given in chapter 11. More detailed information on Signal Corps ground radio equipment is in TM 11-487.

c. This manual does not cover v-h-f fighter control, radio direction finding, or radar. It gives only incidental information on aircraft radio transmission, and on radio sets used in service between ground and aircraft which are also useful for ground radio communication.

602. GENERAL.

a. Selection of Equipment. Radio equipment for use by the Army is available in a wide variety of types covering nearly any situation apt to be encountered. The solution of theater radio problems involves the evaluation of a number of factors relating to radio transmission under the particular conditions involved and the selection of proper equipment through knowledge of the types and capabilities of facilities at hand or available by procurement.

b. Service Requirements and Physical Conditions. The major factors to be considered before selection of equipment can be undertaken are:

(*1*) Maximum distance over which communication is required.

(*2*) Amount of traffic to be handled.

(*3*) Availability of frequency assignments.

(*4*) Degree of reliability desired.

(*5*) Degree of security desired.

(*6*) Degree of portability desired.

(*7*) Time available for installation.

(*8*) Type of intervening terrain, that is, whether the radio path is over sea or land; whether the land is flat or mountainous, jungle or relatively open.

(*9*) Type of facilities required, that is, telephone, teletypewriter, facsimile, or hand telegraph. This is influenced by other requirements, such as security and traffic load.

(*10*) Type of service, such as fixed ground communication to mobile stations, ground to aircraft, etc. Also, whether point-to-point only, or switchable facilities are required.

(*11*) Type of power supply available, for example, engine generators, commercial power, or batteries.

c. Electrical Requirements. With the above factors known, reference to sections II to VIII of this chapter, supplemented by additional information on radio sets and associated equipment given in TM 11–487, permits the determination of the following equipment requirements:

(*1*) General type of facility required. Fixed plant or tactical, single-channel or multichannel equipment are available.

(*2*) Frequency range of set to be used. Radio sets available now or in the near future cover frequencies from about 10 kilocycles to at least 300 megacycles.

(*3*) Radiated power required. Radio sets for tactical use have outputs ranging from a fraction of a watt to several hundred watts. Transmitters rated from 300 watts to 40 kilowatts are available for fixed point-to-point communication.

(*4*) Type of antenna required. Antennas range from the small whips used on *handy-talkies* to large rhombic and diversity antenna systems used on the powerful fixed station installations. The type is influenced by the transmission requirements and space available for proper siting.

(*5*) Power supply requirement. Power supplies range from dry batteries for small portable sets to gasoline or diesel engine-driven alternators or commercial power supply for the larger installations.

(*6*) Remote control requirements. These are influenced by antenna siting arrangements and service requirements.

603. GENERAL TYPES OF FACILITIES.

a. General types of radio facilities which are available for use include the tactical sets issued as standard equipment to the various field units, which incorporate features making them desirable for portable and mobile use; and the fixed plant installations which are made available through the Army Communications Service.[1] The type best suited to the particular needs in a given situation depends largely upon the time available for installation. This may involve the use of tactical equipment as a stop-gap solution for a problem which ultimately should utilize equipment in the fixed plant category. On the other hand, when the need for circuits can be foreseen and planned for in advance, time may permit a better solution, involving procurement of suitable fixed plant apparatus, if needed, and the technical assistance of the Army Communications Service. Such procedure is essential in meeting theater requirements for the more permanent long distance circuits, because tactical sets of sufficient power and operating in the proper frequency bands are not available or suitable for many such purposes. For example, long-distance circuits involving the use of frequencies as low as 100 kilocycles or powers as high as 40 kilowatts are available only through the Army Communications Service.

b. In the h-f band, tactical radio sets are frequently equipped to provide either continuous-wave radiotelegraph (c-w), tone modulation[2] telegraph, or voice modulation; the desired mode of operation being selected by means of control switches. The long range heavy traffic administrative installations, generally engineered by Army Communications Service, also provide for high speed Morse and radioteletype operation. Chapter 3 discusses the various types of modulation which can be used for radiotelegraph operation.

c. In the v-h-f band, most of the Signal Corps tactical radio sets are designed for voice operation only and use frequency modulation (fm). Amplitude modulation (am) is used in all radio sets equipped for voice communication with aircraft. Amplitude modulation is also used in practically all similar types of U. S. Navy and British radio equipment.

d. V-h-f multichannel radio relay systems may be used in the same manner as wire carrier circuits to form a part of the regular telephone network, provided security rules for radio are observed. Such systems have important advantages in speed of installation and in weight and bulk of equipment, and have

[1] Refer to TM 11–487 which gives descriptive, technical, and logistical data for Signal Corps tactical and fixed plant radio equipment for ground use. Requests for further information on fixed plant equipment should be addressed to Office of the Chief Signal Officer, SPSLP.

[2] Tone modulation may be of either of two types. In the first type, which is the one described in chapter 3 as single-tone modulation, the radio carrier is modulated with an audio-frequency tone when the telegraph key is closed and is transmitted without modulation when the key is open. The second type differs from this in that when the key is open, neither the carrier nor the modulation is transmitted. The second type is the one generally furnished with tactical radio sets operating in the h-f band. The terms *mcw* and *A-2 emission* which appear as modulation characteristics associated with some of the radio sets listed in section VIII, are usually equivalent to tone modulation. The terms *A-1 emission* and *A-3 emission* are equivalent to cw and voice modulation, respectively. *A-0 emission* is steady carrier alone.

many tactical uses, such as in a rapid advance, or for spanning short island-to-island jumps. They are described in paragraph 622.

e. Means of obtaining multichannel teletypewriter operation, or simultaneous teletypewriter and voice operation (speech plus duplex) on various types of radio sets are discussed in chapter 3.

604. CHOICE OF FREQUENCY BAND.

a. General Considerations.

(*1*) The signal system in an active theater of operations may include several hundred radio nets and communication circuits. The operation of such a large number of radio stations without serious interference requires the highest order of supervision and control. The allocation of frequency assignments in each theater is usually controlled by a central authority with due regard for type of equipment, mode of operation, power output, and method of tactical employment. From a transmission standpoint the choice of frequency band suitable for use in a given situation depends primarily upon the distance involved, the nature of the terrain in the transmission path, and the noise and interference conditions prevailing at the receiving stations. In practice, other factors must also be considered, such as: type of message traffic to be handled, desired reliability of service, availability of equipment and frequency assignments, and the prevailing tactical situation. Because of the relatively larger number of radio sets used in the h-f band, where both ground-wave and sky-wave propagation are used, communication in this band may be subject to severe interference from both local and distant radio stations, as discussed in subparagraph b below. For this reason every effort should be made to avoid use of the h-f band whenever practicable, that is, the v-h-f band should be used for communication over short or moderate distances.

(*2*) For purposes of uniformity and convenience in the terminology used in designating the various bands or ranges into which the radio-frequency spectrum may be divided, the terms listed in the following table have been adopted by the Armed Forces.[3] Sections II to V of this chapter conform approximately to these designations.

[3] These terms are the same as those used by the Federal Communications Commission.

Frequency (mc)	*Description*	*Abbreviation*
0.03 to 0.3	Low frequency	lf
0.3 to 3.0	Medium frequency	mf
3.0 to 30	High frequency	hf
30 to 300	Very high frequency	vhf
300 to 3,000	Ultra high frequency	uhf
3,000 to 30,000	Super high frequency	shf

b. Transmission Characteristics at Various Frequencies.

(*1*) Radio transmission between two points takes place by means of ground waves or sky waves. Sky waves are radio waves which reach the receiver after reflection from the ionosphere. Ground waves reach the receiver through the earth's lower atmosphere. These modes of transmission and properties pertaining thereto are discussed more fully in sections II and IV.

(*2*) Frequencies in the 0.03- to 0.3-mc band are used for ground-wave transmission over long distances, primarily in northern latitudes, as an alternative to h-f sky-wave transmission which is subject to *blackouts* because of auroral disturbances prevalent at latitudes above 60° N. Frequencies from 0.1 to 3 mc are used mainly for ground-wave transmission for moderately long circuits over water and for moderate to short distances over land. Frequencies from about 1 to 3 mc are generally suitable for night-time sky-wave transmission over relatively short distances (0 to 200 miles) and frequencies from about 3 to 8 mc are generally satisfactory for daytime use over such distances, provided antennas are used which radiate well in a nearly vertical direction. Long-distance sky-wave transmission at night generally utilizes from 3 to 12 mc, while during the day 6 to 25 mc is usually the preferred range. Frequencies from 3 to 30 mc are also used for ground-wave transmission for relatively short distances over land or moderate distances over water. Frequencies from 30 to 300 mc are used for ground-wave transmission over short distances; sky-wave transmission in this frefrequency band is absent or sporadic. At these frequencies, transmission is not necessarily confined to *line-of-sight*, but may extend to somewhat greater distances because of the bending (diffraction) of waves over obstacles, and to considerably greater distances where certain meteorological conditions are favorable.

(3) In evaluating the relative performance of radio sets utilizing the various portions of the frequency spectrum, antenna efficiency is an important item. The short antennas used on many tactical radio sets in the h-f band, in order to meet mobility requirements, are very inefficient at the lower frequencies. For example, a transmitter rated at 500 watts output may radiate as little as 5 watts at some frequencies when standard whip antennas are used. On the other hand, antennas in the v-h-f range are very efficient, that is, practically all of the rated output power is radiated. However, as discussed in section V, relatively efficient h-f antennas can sometimes be substituted for whips on tactical sets when operating conditions permit semifixed installations.

c. U.S. Army Allocation of Frequencies.

(*1*) The frequencies from about 1.5 to 8 mc are widely used at present by all services for both short- and long-haul communication.

(*2*) Long-haul administrative and special service traffic via skywave in the 100-kc to 25-mc frequency band is generally handled by Army Communications Service equipment with more elaborate antenna installations than are involved in tactical networks.

(*3*) Some of the principal U. S. Army tactical frequency assignments above 20 megacycles are:

20 to 27.9 mc, armored forces, mechanized cavalry.
27 to 38.9 mc, field artillery, tank destroyers.
27 to 40 mc, air warning (temporary).
40 to 48 mc, infantry.
70 to 100 mc, air forces, ground forces.
100 to 156 mc, ground-to-aircraft and aircraft-to-aircraft.

These assignments may not be rigorously adhered to in all cases, but should be followed whenever practicable in order to avoid interference and resulting confusion.

d. Frequency Control. One of the most important prerequisites to the successful operation of radio communication systems is the accuracy with which assigned operating frequencies are adjusted and maintained. Although accurate control of operating frequencies of most radio sets is assured by the use of appropriate crystal control units, a considerable number of tactical ground and aircraft radio sets use self-excited oscillators which are inherently less stable than crystal-controlled oscillators. Many of these latter radio sets incorporate built-in crystal calibrators which are used in conjunction with a calibrated tuning dial to adjust the radio set to the required operating frequency. Other radio sets, however, are adjusted to frequency by means of tuning dials, the calibration of which must be frequently checked against an external frequency standard.

605. FACTORS PERTAINING TO USE OF FREQUENCY MODULATION AND AMPLITUDE MODULATION FOR TELEPHONY.

a. In this chapter no distinction is made between amplitude modulation and frequency modulation in giving v-h-f distance ranges of point-to-point radio circuits. This is because these distance ranges are based on signal-to-noise ratios for radio telephone circuits which are operating at or near the limit for the transmission of intelligible speech. At this limit, the difference between a-m and f-m communication ranges, while favoring frequency modulation, is quite small, assuming equal unmodulated transmitting powers. However, frequency modulation has the ability to reduce noise in the presence of a strong r-f signal, whereas in amplitude modulation the only improvement lies in the increased radio-frequency signal, the noise remaining constant. Hence, where received field intensities are higher than the minimum required, as at short distances or with favorable antenna siting, frequency modulation provides a substantially better signal-to-noise ratio than amplitude modulation. Furthermore, f-m transmitters are substantially lighter in weight and require less power supply than a-m transmitters having the same unmodulated power output. Accordingly, f-m sets are widely used in the v-h-f band, where sufficient frequency space is available to obtain a relatively wide swing. Frequency modulation has not as yet been used by the U. S. Army for telephone transmission in the frequency region below 20 mc. However, the frequency-shift teletypewriter service provided for h-f circuits, as discussed in chapter 3, may be considered a form of narrow-band frequency modulation.

b. The characteristic of an f-m receiver which permits the stronger of two signals to take control or *capture* the set is advantageous in the usual case where the desired signal is the stronger. In situations where several transmitters and receivers are in close proximity, however, a receiver may be captured by spurious transmitter radiations which are stronger than the desired signal. To avoid mutual interference under these circumstances requires careful selection of frequencies, as discussed in section VI.

606. RELIABILITY CONSIDERATIONS.

a. The reliability of a radio circuit is generally defined as the percentage of the total service time that communication is satisfactory. Satisfactory communication exists when the signal-to-noise ratio is sufficient to meet requirements for the type of facilities involved, that is, voice, hand telegraph, teletypewriter, etc.

b. On important routes it may be essential that the radio circuits operate satisfactorily at practically all times, that is, that performance should approach 100 percent reliability on the basis of 24-hour service. In other cases, satisfactory communication over the entire 24-hour period may not be essential, or frequent repeats may be tolerable. The problem confronting a Signal Officer is that of choosing specific sets which will provide the grade of service required in a given situation, or of recognizing the limitations of available equipment so that all concerned will understand the degree of reliability to be expected.

c. For reasonable distance ranges, reliability of v-h-f systems is largely determined by equipment failures rather than by transmission difficulties. H-f reliability in the ground-wave range is affected largely by static, and in the case of sky-wave transmission, by the variability of the sky-wave signals. H-f reliability is also considerably affected by interference from other stations, especially at night.

d. In the event of enemy jamming or excessive interference, the use of c-w hand telegraph rather than voice or tone modulation is the more effective way to increase reliability. The advantage gained is sufficient in many cases to provide a high percentage of reliability on circuits where tone or voice modulation is practically unintelligible. Another alternative is to increase the power which is transmitted. This may be accomplished either by use of a set having higher power, the use of a more efficient antenna, or the use of an antenna which is directive and, therefore, transmits more power in the desired direction. Receiving directivity is also advantageous in improving the signal-to-noise ratio.

Section II. V-H-F TRANSMISSION

607. GENERAL.

a. V-h-f (30-300 mc) radio communication of the sort which is reliable 24 hours of the day is confined to ground waves, that is, waves which travel near the earth's surface. Only this type of propagation is considered in this section. Sky-wave transmission (via reflection from the ionosphere) sometimes occurs, particularly at frequencies near the lower end of the band, but such instances are likely to be infrequent and generally unpredictable. Since ground waves attenuate rapidly, useful v-h-f transmission is generally limited to relatively short distances unless exceptional antenna sites on high hills are available at both ends of the path. Transmission distances can be extended by means of automatic radio relay sets.

b. The distance range and performance estimates given herein are based entirely on standard propagation. Recent experience in war theaters and elsewhere has indicated that meteorological conditions (temperature and humidity of the troposphere, that is, the lower atmosphere) sometimes give rise to what is termed *guided* propagation, which may have the effect of greatly extending the distance over which usable field intensities are received. Such conditions are most frequently encountered where stations are located near the shore of an ocean or other large body of water, and may be present for either long or short periods of time. It is believed that meteorological effects are most pronounced at frequencies above 30 mc, although some experience indicates a substantial influence below this frequency. Sufficient information is not available on guided propagation to permit the inclusion of this factor in estimating transmission ranges or performance.

c. In this section the limitations and advantages of v-h-f transmission are reviewed first, followed by a brief summary of transmission ranges generally experienced under various field conditions (pars. 608, 609, and 610). After a brief discussion of the characteristics of v-h-f radio wave propagation over smooth and hilly terrain, computed distance-range curves for single-channel voice communication over *flat* land and over sea water are given to illustrate the effects of transmitter r-f output power and moderate antenna elevations on distance-range (pars. 611, 612, and 613). Generalized distance-range curves cannot be plotted for hilly or mountainous terrain, since here the particular topography of the path between stations is a controlling factor with respect to the intensity of received signals.

d. To compute distance ranges such as given above, or performance over any sort of terrain for a particular set of conditions, it is necessary to estimate the received field intensity between specific station sites and then to compare this value with the required field intensity. Minimum operating field intensities required for various types of radio circuits are given in paragraph 614. Two sets of nomograms for use in making field intensity estimates are given next. One set is for use with antennas at moderate elevations for transmission over smooth land or sea water, or in terrain where hills intervene between stations (par. 615); the other set applies to situations in which the antennas are sited on aircraft or on mountainsides well above the intervening terrain (par. 617). Both sets of nomograms are based on certain specified conditions regarding radiated power, antenna gain, etc.; corrections for other conditions are given in paragraph 616.

e. The important factors involved in antenna siting and in choice of polarization are summarized next, followed by a discussion of miscellaneous transmission considerations (pars. 618, 619, and 620). The section concludes with a description of methods for setting up v-h-f single-channel and multichannel radio relay systems, including a discussion of their fields of use and their limitations (pars. 621 and 622).

608. OPERATIONAL ADVANTAGES OF VHF. Several advantages to be gained by using the v-h-f band for communication requirements over short to moderate distances are as follows:

a. Congestion in the h-f range is relieved.

b. The general absence of sky waves permits v-h-f assignments to be duplicated in adjacent areas with less likelihood of interference, and tends to reduce the chance of interception at a distance by the enemy. However, *freedom from interception cannot be safely assumed.*

c. When a satisfactory v-h-f radio circuit is once established, a high percentage reliability is assured even in areas where high atmospheric static prevails.

609. FACTORS AFFECTING V-H-F TRANSMISSION. a. V-h-f transmission, in contrast with h-f (3–30 mc), is favored by a number of factors, which are:

(*1*) Frequencies in the v-h-f band are usually free from atmospheric static noise except during local storms.

(*2*) There are no seasonal or diurnal variations in the transmission path of the magnitude encountered in h-f sky-wave transmission via the ionosphere. Signals are therefore *solid* except when affected by changes in meteorological conditions.

(*3*) Quarter wavelength or half wavelength antennas in the v-h-f band are small and are much more efficient than h-f antennas of comparable physical size.

(*4*) Performance of v-h-f circuits may be improved substantially, except under certain conditions, by raising antennas to moderate elevations above ground. Thus, masts of a height practical for tactical work may be used to good advantage. Greater elevations, obtainable by utilizing hills for antenna sites, provide further improvement.

(*5*) Directional antennas for improving transmission in the desired direction are of relatively small dimensions in the upper part of the v-h-f band and directivity gains equivalent to raising the transmitting power by four times or more are not hard to attain.

(*6*) Good ground connections for the antennas are usually not essential, unlike the case for some h-f antenna types.

b. Other factors tending to counteract the advantages listed above are as follows:

(*1*) Shadow losses introduced by the earth's curvature and by intervening hills are greater than with h-f radio waves.

(*2*) Trees or dense jungles in the vicinity of the antennas cause more loss than at lower frequencies.

(*3*) Fading occurs at times in the v-h-f band, especially at extended distances. Reflections from airplanes in or near the transmission path may also cause severe signal variations on occasion.

610. V-H-F TRANSMISSION RANGES GENERALLY EXPERIENCED.

a. General.

(*1*) The problem of determining the maximum usable communication range of a given type of radio set is complicated by the fact that performance depends not only on such factors as the r-f power output, frequency, and type of antennas used, but also on a variety of external factors. Among these are the manner in which antennas are sited with respect to elevation and proximity to hills, buildings, vegetation, and sources of electrical noise; as well as the nature of the terrain along the transmission path. Terrain characteristics are classified below as *flat, jungle, mountainous,* and *sea water*. The maximum permissible distance between two stations also depends on the type of circuit, since the minimum required field intensity is greater for multichannel than for single-channel operation, and may also be greater when the section involved is one of several in tandem rather than a single section (par. 614d).

(*2*) An indication of the transmission distance ranges generally experienced with available Signal Corps v-h-f apparatus during maneuvers and in the war theaters is given below. This experience has involved mainly single-channel f-m sets operating in the 20-to 40-mc band, but theoretical considerations indicate that similar distances are to be expected from 20 to 100 mc and possibly higher if suitably elevated antennas are used and if directional types are provided at the higher frequencies. The information immediately following is merely a summary to indicate roughly the distance limitations for single-channel point-to-point operation with no intermediate radio relay sets. Detailed methods for estimating performance for specific situations are given later, including multichannel systems and circuits using automatic radio relay sets.

b. Flat Terrain.

(*1*) In so-called flat country (exclusive of jungles), reasonably satisfactory v-h-f single-channel radio-telephone transmission results on the average for distances of 30 to 35 miles, using 50-watt transmitters and half-wave dipole antennas centered at heights of 40 to 50 feet above the earth.[4]

(*2*) The use of antennas on masts implies fixed or semifixed installations. For mobile or portable service with vertical whip antennas near the ground, the distance range in the 20- to 40-mc band for 30-watt sets such as Radio Sets SCR–508 and SCR–608 is reduced to about 10 to 15 miles, and to about 5 miles for 2-watt sets such as Radio Sets SCR–509 or SCR–510 and SCR–609 or SCR–610. Radio Set SCR–300 (0.5 watts) has a range of about 3 miles. Figures 6-1 to 6-5, inclusive, show some of these sets under various field operating conditions.

Figure 6-1. Radio Set SCR–300 in walkie-talkie operation.

[4] For tactical purposes, masts exceeding 40 feet are considered impractical although in some cases provision is made for extending the heights to 50 feet.

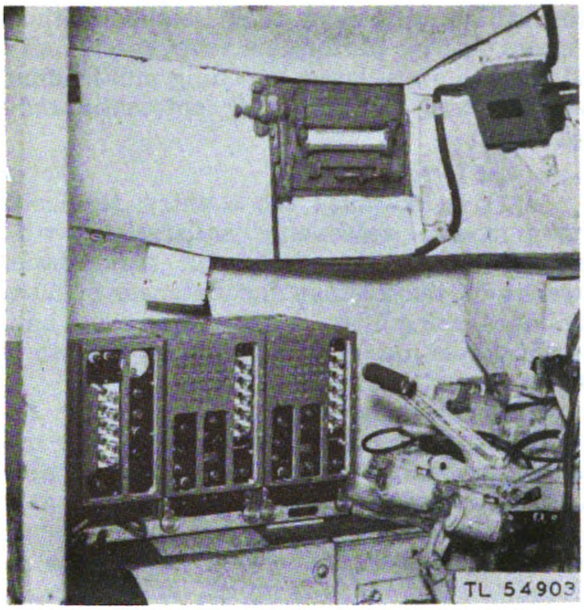


Figure 6-2. Radio Set SCR–508 installed in Tank, Medium, M3A1 (showing its two radio receivers, interphone control box, and a part of its radio transmitter).

c. Jungles. In dense humid jungles, with antennas located in and well below the top of the jungle growth, transmission with any ordinary amount of power is sometimes limited

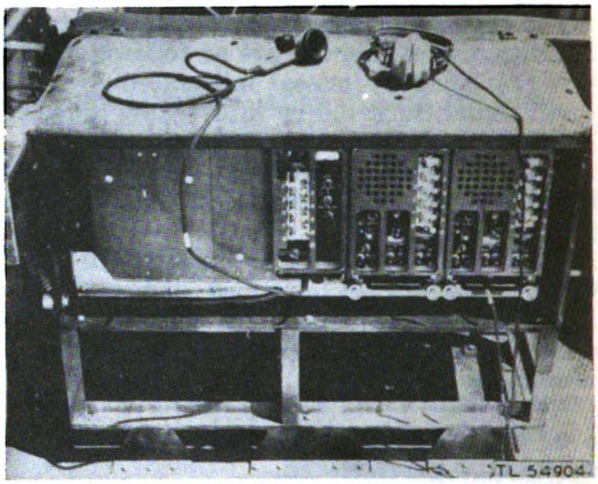


Figure 6-4. Radio Set SCR–608 in Chest CH–74 installed in Truck, Command, ¾-ton, 4 x 4.

to distances of only 1 mile or less. The range can be improved materially if the antennas are placed in open clearings 100 yards or so across or, better still, supported high enough to protrude above the jungle growth.

d. Mountainous Terrain. In mountainous country, *unless measures can be taken to site antennas properly*, it may be impossible to transmit more than 5 to 10 miles without intermediate radio relays even with 50-watt sets and antennas on masts. For low-powered sets with whip antennas, the range will naturally be much shorter. Such poor performance occurs if the transmitting and receiving antennas are located close to the base of high intervening hills. However, when antennas

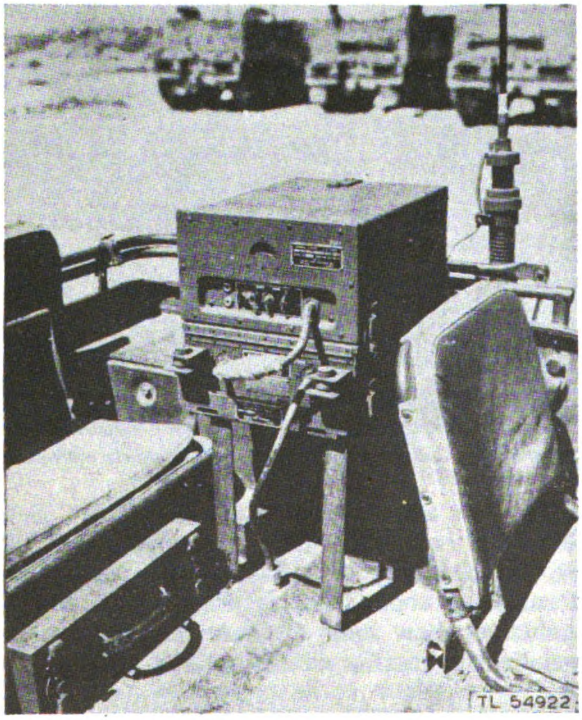


Figure 6-3. Radio Set SCR–510 installed in Truck, ¼-ton, 4 x 4.

Figure 6-5. Radio Set SCR–609 in use reporting artillery hits.

are sited favorably, satisfactory transmission in hilly country, exclusive of jungles, is common for distances of 40 to 50 miles with 50-watt sets. Under favorable conditions where line-of-sight paths can be approximated by using high mountains for antenna sites, it has been found possible to operate 50-watt sets over paths 70 miles or more in length. In other instances, using 250-watt sets and directional antennas, distances slightly over 100 miles have been covered successfully using frequencies between 30 and 40 mc. Greater distance ranges than these are possible if antenna sites elevated 500 feet or more above intervening terrain are available. On such long circuits, fading, caused by changes in meteorological conditions, may present a problem.

e. Sea Water. Distance ranges over sea water may be considerably greater than over land when using frequencies in the lower part of the v-h-f band with antennas centered at normal mast heights. Limited observations indicate ranges in the order of 150 miles at 30 to 100 mc, with directional antennas elevated on hills or cliffs along the seacoasts and using a power output of 250 watts. In the higher part of the v-h-f band, flat land and sea distance ranges should be generally much alike for comparable siting conditions.

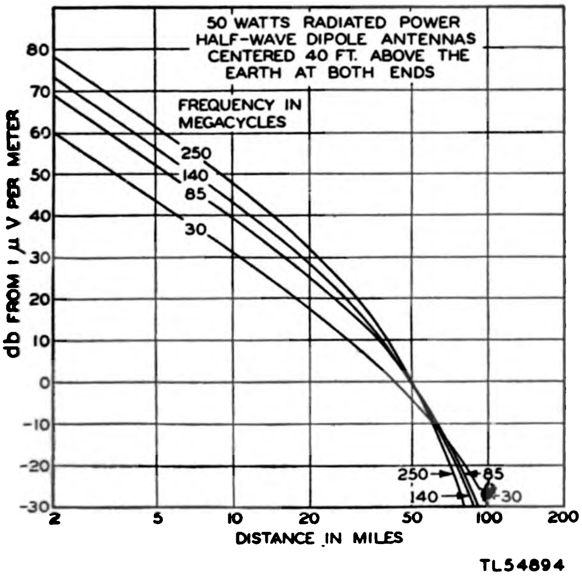


Figure 6-6. V-h-f propagation over smooth land.

611. PROPAGATION OF V-H-F RADIO WAVES.

a. Over Smooth Earth or Water.

(*1*) Under the ideal condition of smooth earth, the intensity of the transmitted signal, beyond the first mile or so, diminishes in a regular and uninterrupted manner as the distance from the transmitter is increased. Similar propagation characteristics are found in so-called *flat* country and over water, since here the surface is smooth enough to approach the ideal.

(*2*) Figure 6-6 illustrates this theoretical relationship between field intensity and distance over smooth land for either horizontal or vertical polarization (par. 619) and 40-foot antenna elevations. (These curves also apply for sea water when using horizontal polarization.) The field intensities obtained in practice, using this power and these antenna elevations, generally will be less than shown, because of irregularities in terrain, the presence of trees, and possibly other factors which cause the actual conditions to differ from the theoretical. With allowance for these factors, it is possible to calculate the distance ranges to be expected with radio transmitters of various power outputs. Such ranges are described for smooth earth and sea water in paragraphs 612 and 613, respectively.

b. Over Irregular Terrain.

(*1*) Propagation characteristics over irregular terrain are in marked contrast with those for smooth earth or sea water. Here, the variation of field intensity with distance depends largely on the profile of the terrain between transmitting and receiving antennas. An increase in distance may result in either decreased or increased field intensity, depending on the particular topography involved. Substantial changes in field intensity may result

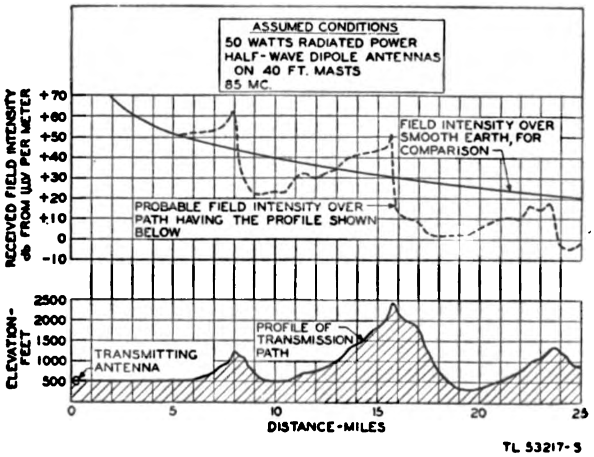


Figure 6-7. V-h-f propagation in hilly terrain, illustration of the character of field intensity variations to be expected.

from relocating stations, even without any change in the distance between them.

(2) This is illustrated by figure 6-7 which shows, in profile, an assumed transmission path over hills, together with values of field intensity likely to be received at various points along the path. This emphasizes two facts regarding transmission in hilly country; first, that *the choice of antenna sites is very important*, and second, that *there is no satisfactory basis for calculating general distance ranges*. Instead, the received field intensity may be estimated for a given site involving a path of known profile, and thus the selection of antenna sites may be based on the circuit performance estimated for various available locations. A detailed method for determining received field intensities, in such terrain, and also over smooth earth and sea water, is given in paragraphs 615 and 616, and a general summary of siting considerations is presented in paragraph 618.

612. TYPICAL V-H-F DISTANCE RANGES IN FLAT COUNTRY.

a. Distance ranges typical of operation in flat country for various antenna elevations and transmitter powers are given in figure 6-8 for general reference purposes. These calculated curves are based on operating conditions explained below and serve to illustrate the effects of changes in antenna elevation or power on distance range in flat country. Methods for computing distance ranges for situations differing from those illustrated by the curves are given in paragraphs 615 and 616.

b. The distances indicated are those at which the estimated field intensity reaches the minimum operating values which are defined later in paragraph 614 as *satisfactory* for single-channel use. The curves are computed for smooth earth propagation with nominal allowances (4, 7, and 10 db for 30, 85, and 140 mc) for transmission line losses and losses caused by trees and small topographical irregularities. The distances shown are in general agreement with experience.

c. For frequencies between 70 and 160 mc, directional antennas commonly used have gains of the order of 6 db as compared with conventional half-wave dipole antennas, and the distance ranges shown in figure 6-8 are based on this amount of gain at each end, except as noted thereon.

d. Figure 6-8 distinguishes between vertical and horizontal polarization (par. 619) and between poor and good soil at antenna elevations and frequencies for which these factors have a significant effect on the range.[5] Equal elevations are assumed for both transmitting and receiving antennas; however, for elevations above 40 feet with a frequency

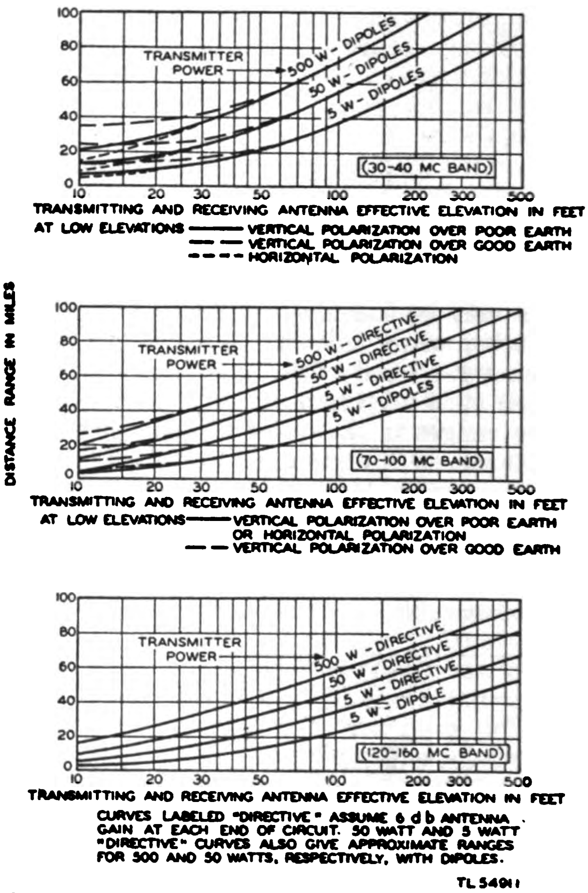


Figure 6-8. Tyical v-h-f distance ranges in flat country.

below 100 mc or for any elevation with higher frequencies, the ranges shown apply if the product of the two antenna elevations is unchanged. For example, the range with one antenna at 200 feet and the other at 50 feet is the same as that with both at 100 feet.

[5] The terms *poor* soil and *good* soil as used throughout this section are defined as follows. *Poor* soil means soil of relatively low conductivity and dielectric constant, such as that consisting largely of rocks, gravel, sand, or coral. *Good* soil means soil of relatively high conductivity and dielectric constant, such as clay, loam, marsh or swamp, and alkali soil.

613. TYPICAL V-H-F DISTANCE RANGES OVER SEA WATER.

a. General reference curves for distance ranges over sea water are given in figure 6-9 for both horizontal and vertical polarization. With horizontal polarization the curves are identical with those given for land in figure 6-8. The operating conditions assumed are explained below. General methods for computing distance range over sea water with antennas at moderate elevations are given in paragraphs 615 and 616. For antennas at great elevations see paragraph 617.

b. The basis for the typical ranges shown is identical to that outlined in paragraph 612 in connection with the over-land ranges of figure 6-8; that is, nominal allowances are included for transmission line losses and miscellaneous effects. The ranges shown are those at which the estimated field intensity reaches the minimum operating values which are defined as *satisfactory* for single-channel operation in paragraph 614. Equal effective antenna elevations are assumed for the transmitting and receiving antennas, but with *vertical* polarization, this may be disregarded in many cases, as discussed in subparagraph c below.

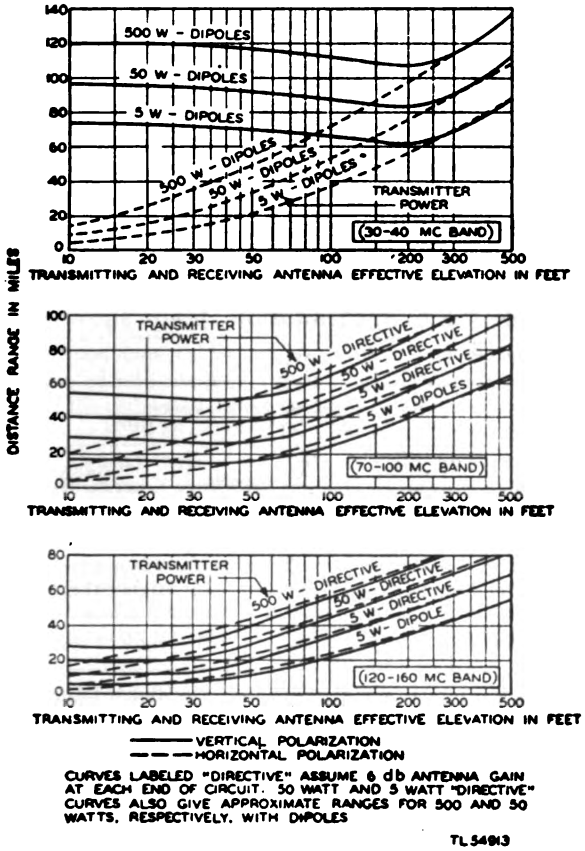


Figure 6-9. Typical v-h-f distance ranges over sea water.

c. For vertical polarization over sea water, distance range at a given frequency is not much affected by changes in antenna elevation until certain elevations are exceeded. These elevations are about 300, 60, and 25 feet in the 20 to 40, 70 to 100, and 120 to 160 mc bands, respectively. Above these elevations, distance range is about the same for horizontal and vertical polarization. Below these elevations vertical polarization is preferable, and the low heights are advantageous from the standpoint of convenience and concealment.

d. It is apparent from figure 6-9 that horizontal polarization should not be used with low antennas over sea water in the lower part of the v-h-f band. This disadvantage disappears as the antenna is raised above the elevations indicated in subparagraph c above.

614. REQUIRED V-H-F FIELD INTENSITIES.

a. General.

(*1*) Before discussing general methods for estimating distance ranges and transmission performance it is necessary to establish values for the minimum signal intensities required for satisfactory reception. For this purpose, the reference circuit used here is a single-channel a-m or f-m (par. 605) point-to-point circuit without automatic radio relay sets, and the minimum required signal is that required to give a signal-to-noise ratio which is at or near the limit for the reception of intelligible speech. *It should not be inferred from this that radio systems should always be engineered to operate under this limiting condition. Stronger field intensities are always desirable and will be needed when external interference is present.*

(*2*) Signals required for other types of circuits, such as in multichannel systems or in circuits using radio relay sets, are greater than those required for the reference single-channel circuit. These requirements are discussed later.

b. Minimum Operating Field Intensities, Single-channel Point-to-point Circuit with No Automatic Radio Relay Sets.

(*1*) Experience indicates that for practical *single-channel* voice operation in the v-h-f band under field conditions, a minimum signal of about 1 to 2 microvolts across the receiver input is required *in the absence of external interference.* (With some sets and with good lineup of the receiver stages, lower signals may give comparable results; conversely, with other sets or with poorer lineup, greater signals are sometimes required.) Assuming a half-wave dipole receiving antenna working into a matched receiver through a transmission line of negligible loss, the required field intensities to produce this minimum input signal are approximately as given in figure 6-10.

Frequency band (mc)	*Db above 1 microvolt per meter*
30–40	0
70–100	10
120–160	15
220–260	20

Figure 6-10. Minimum operating field intensities, voice transmission using single-channel sets for point-to-point communication.

(*2*) The reason that the required values of field intensity increase with frequency is because at higher frequencies the half-wave receiving dipoles are shorter and a given field intensity in microvolts per meter therefore converts to fewer microvolts across the receiver (ch. 12).

(*3*) In situations where man-made interference, static, jamming, or other interference over-rides normal set noise, stronger field intensities will, of course, be required for satisfactory voice operation.

c. Classification of Estimated Field Intensities. Performance of a proposed radio circuit generally has to be estimated from preliminary studies of the terrain involved and the antenna sites available. Estimated field intensities for a given path may differ from the field intensity actually obtained after installation, since it is not possible to take all factors into account in the initial computations. Consequently, if an estimated intensity is near a minimum value required for single-channel operation given in figure 6-10, the actual circuit may or may not work. For *estimated* field intensities, therefore, the range ± 5 db from the values given in figure 6-10 is termed *questionable.* If the estimated field intensity exceeds the values in figure 6-10 by a margin of more than 5 db, the performance will probably be *satisfactory,* that is, it will probably meet the minimum requirements for single-channel voice operation as defined in subparagraph a(1) above; if it is poorer by more than 5 db the performance will probably be *unsatisfactory.* These performance classifications are summarized in figure 6-11.

d. Requirements for Other Types of Circuits.

(*1*) The received field intensities required for *satisfactory* performance given in figure 6-11 are for a single-channel single-radio-section voice circuit used for point-to-point traffic. Requirements for each radio section under other conditions are given in figure 6-12. These requirements are explained in paragraphs 621e, 622e, and f. For 4-channel f-m systems, the values shown indicate minimum field intensities required to produce performance in channel No. 4 equal to that assumed for single-channel operation, that is, a signal-to-noise ratio near the limit for intelligible speech. The lower channels will then have better signal-to-noise ratios than channel No. 4. For higher signal-to-noise ratios, the received fields must be further increased. Cases where more than one trunk in the over-all circuit is specified in figure 6-12 refer to the telephone transmission plan shown in chapter 2.

Frequency band (mc)	*Estimated field intensity (db referred to 1 microvolt per meter)*		
	Probably unsatisfactory	Questionable	Probably satisfactory
30 to 40	Less than −5	− 5 to + 5	Higher than + 5
70 to 100	Less than +5	+ 5 to +15	Higher than +15
120 to 160	Less than +10	+10 to +20	Higher than +20
220 to 260	Less than +15	+15 to +25	Higher than +25

Figure 6-11. Expected performance versus estimated field intensity, (based on figure 6-10, minimum operating field intensities for voice transmission, using single-channel sets for point-to-point communication).

(*2*) When multichannel v-f telegraph (Telegraph Terminal CF–2–( )) is applied to 4-channel radio relay systems, the required field intensities given in figure 6-12 will suffice. However, when multichannel radio-teletypewriter arrangements for tactical use are applied to single-telephone-channel radio relay systems, the required field is somewhat greater than given in the top line of figure 6-12. This is discussed in chapter 3.

e. Use in Performance Estimates. The tabulated values in figures 6-11 and 6-12 assume half-wave dipole receiving antennas. The use

Circuit conditions			*Required minimum values of estimated field intensity for satisfactory performance (db referred to 1 microvolt per meter)* [a]	
No. of channels	*No. of radio sections per trunk*	*No. of trunks in over-all circuit*	*70 to 100 mc*	*220 to 260 mc*
1	1 or more (par. 621e)	1	+15[b]	+25
4	1	1	+25	+35
4	2	1	25 to 28	35 to 38
4	3	1	25 to 30	35 to 40
4	4	1	25 to 31	35 to 41
4	1	2	+31	41
4	2	2	31 to 34	41 to 44
4	3	2	31 to 36	41 to 46
4	4	2	31 to 37	41 to 47
4	1	3	37	47
4	2	3	37 to 40	47 to 50
4	3	3	37 to 42	47 to 52
4	4	3	37 to 43	47 to 53

[a] When two values are given, the lower value is the estimated field intensity required in the poorest radio section when the estimated intensities in all other radio sections are 10 db or more stronger. The higher value is the estimated field intensity required per radio section when the estimated intensities in all sections are nearly equal (pars. 622e and f). For other conditions, interpolate.

[b] For f-m sets in the 30 to 40 mc band, the corresponding single-channel value is +5 db.

Figure 6-12. Required minimum values of estimated field intensity for satisfactory performance for various circuit types.

of a directional receiving antenna having gain (with reference to the performance of a dipole) reduces the required field intensity. However, in making performance estimates as outlined later in paragraphs 615, 616, and 617, it is convenient to use figures 6-11 and 6-12 as they stand, and to consider receiving antenna gain as equivalent to a gain in received field intensity. In these transmission performance estimates, allowances are made for transmission line losses, losses caused by tree foliage, and gains arising from antenna elevation; but no allowance is made for external interference or man-made noise.

615. METHOD FOR ESTIMATING RECEIVED FIELD INTENSITIES, ANTENNAS AT MODERATE ELEVATIONS.

a. General.

(*1*) The information given in this paragraph, together with other data in paragraph 616, furnishes means for estimating received field intensity in the usual ground station situation where the effective antenna elevations (defined in paragraph 616b(2)) do not exceed 500 feet. Methods for estimating received field intensity when the antennas are at great elevations with respect to the terrain along the transmission path, as when on aircraft or on high mountainsides, are given in paragraph 617.

(*2*) The method given here permits estimates of the field intensity received over smooth land or sea water paths, and also over paths in hilly or mountainous country where line-of-sight is blocked by intervening hills which cause a *shadow loss*. For the latter paths, it is necessary that the profile (that is, a side or cross-sectional view) of the hills and valleys between transmitting and receiving antennas can be reasonably approximated.

(*3*) The method results in estimated field intensities received over smooth terrain which are in general agreement with experience, and sufficient agreement has been found with measured results in mountainous country to indicate that the information will serve as a useful guide in laying out v-h-f circuits in such terrain. These field comparisons have been confined to frequencies below about 150 mc.

b. Nomograms for Use in Estimating Field Intensity.

(*1*) The nomograms on figures 6-14 to 6-17, inclusive, provide a basis from which field intensity may be estimated in the 20–40, 70–100, 120–160, and 220–260 mc bands, using either horizontal or vertical polarization (par. 619) over land or sea.

(*2*) These nomograms apply specifically to the field intensity arriving at a receiving antenna which is elevated 40 feet above the earth. They are based on 50 watts of power *radiated* from a half-wave dipole transmitting antenna which is also centered 40 feet above the earth; no allowance is made for losses caused by trees in the vicinity of either antenna. In the v-h-f band the *radiated* power may be taken as the *rated* transmitter output power minus the antenna transmission line loss. When actual conditions differ from the above reference conditions, the field intensity as read from the nomograms must be corrected. The correction factors are those enumerated below, all of which are expressed in db and evaluated in paragraph 616.

H_a = antenna elevation correction (par. 616b)

P = transmitter output power correction (par. 616c)

L_l = transmission line loss correction (par. 616d)

G = directional antenna gain correction (par. 616e)

L_t = tree loss correction (par. 616f)

Thus,

Nomogram reading $\pm H_a \pm P - L_l + G - L_t$ = Estimated field intensity in db from 1 microvolt per meter.

The plus and minus signs indicate that G is always added, L_l and L_t are always subtracted, and H_a and P are either added or subtracted, as determined from figures 6-18 and 6-20 and discussed in paragraph 616. Since $G - L_l - L_t$ usually tends to be small for antenna types ordinarily used, and since rated transmitter output powers of 50 watts and antenna elevations of at least 40 feet are normally used in v-h-f point-to-point and radio relay operation, the values of field intensity read from the nomograms may often be compared directly with the required values in figure 6-12 to roughly estimate performance. If a 10-db margin or so is indicated, detailed computations need not be made. However, the complete solution of a typical problem, making allowance for all factors, is a simple process, as illustrated step-by-step in figure 6-22.

c. Procedure for Using the Nomograms (figs. 6-14 to 6-17).

(*1*) The procedure outlined in subparagraphs (2) to (7) below applies to transmission paths which involve obstructing hills between stations. For paths over flat country or sea water the procedure is much simpler, and is described in subparagraph (8).

(*2*) Draw an approximate profile of the terrain involved in the straight line path be-

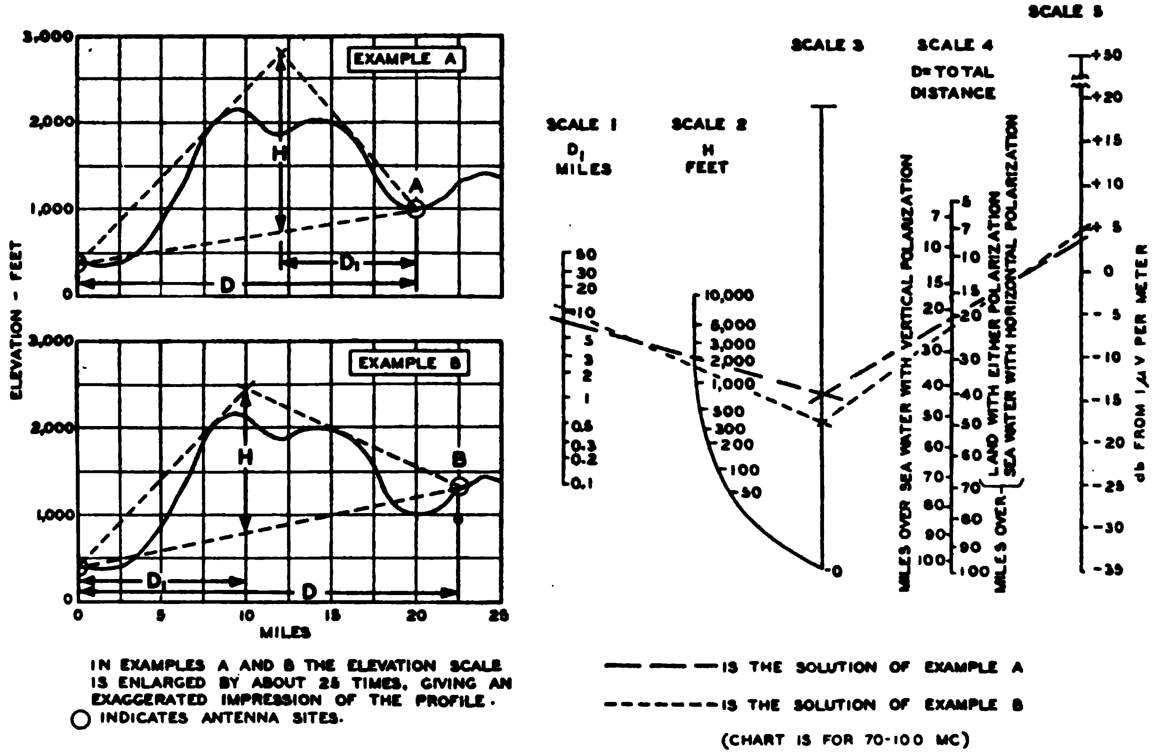


Figure 6-13. Example: Use of field intensity nomograms.

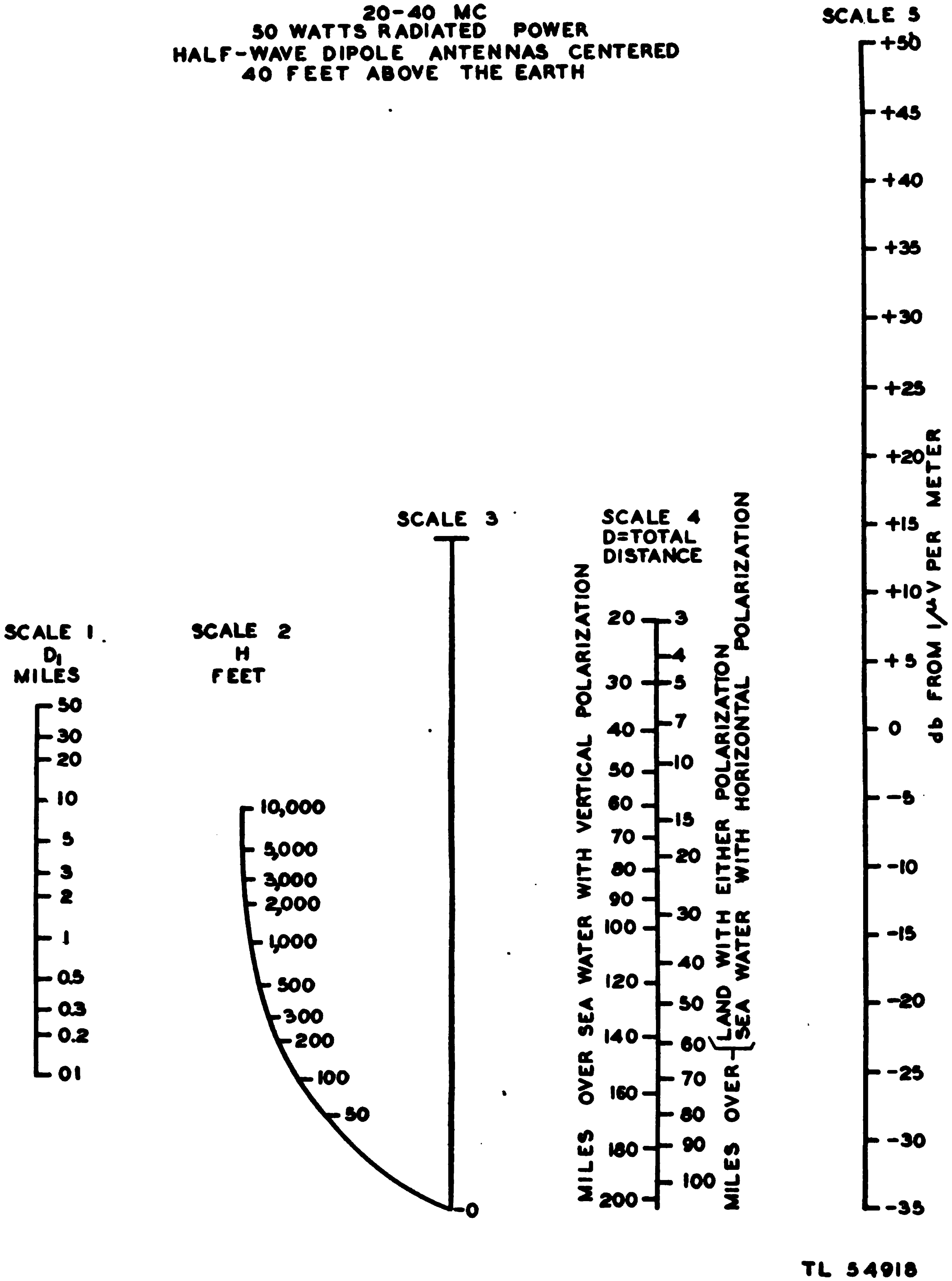


Figure 6-14. Nomogram for estimating field intensity, 20 to 40 mc.

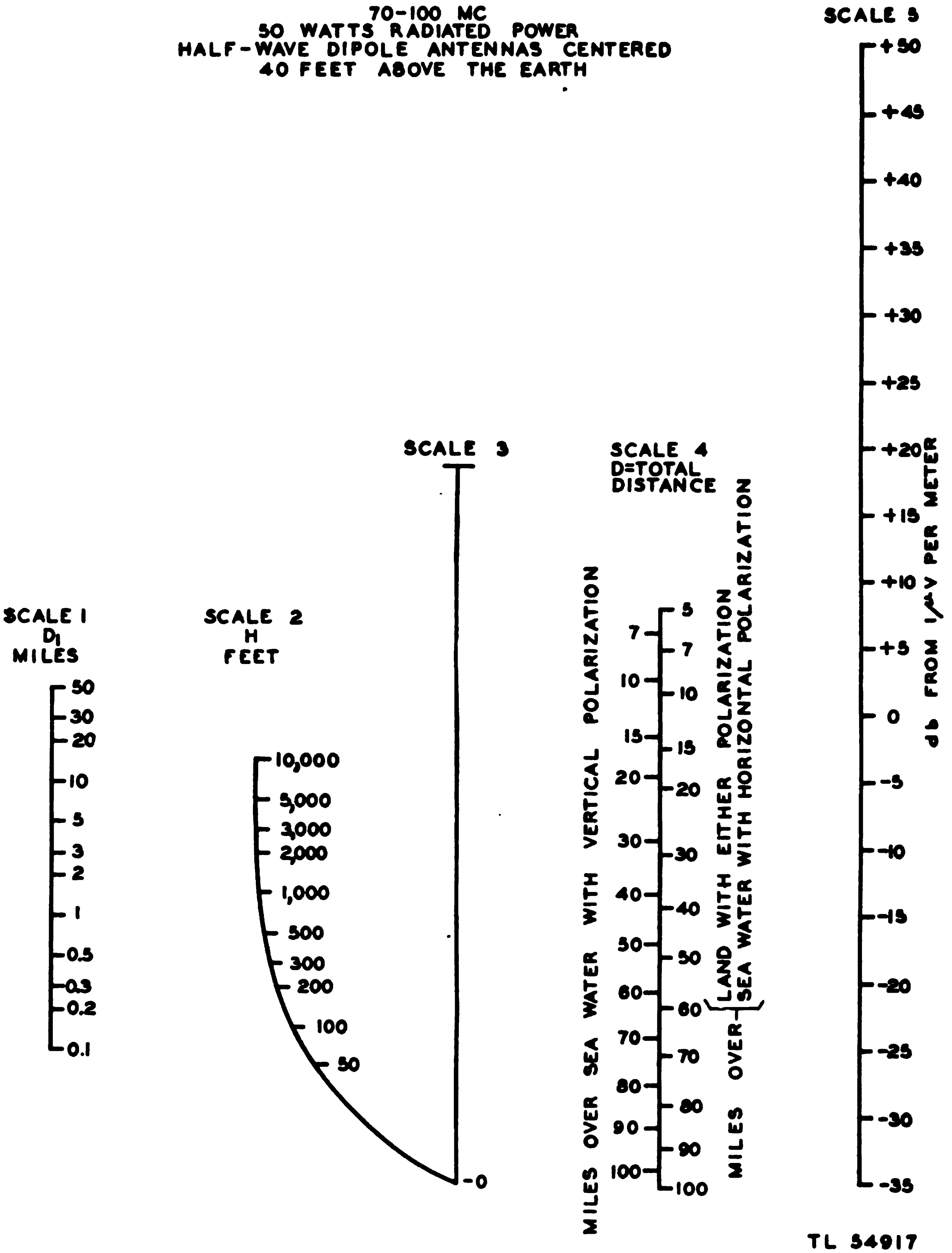


Figure 6-15. Nomogram for estimating field intensity, 70 to 100 mc.

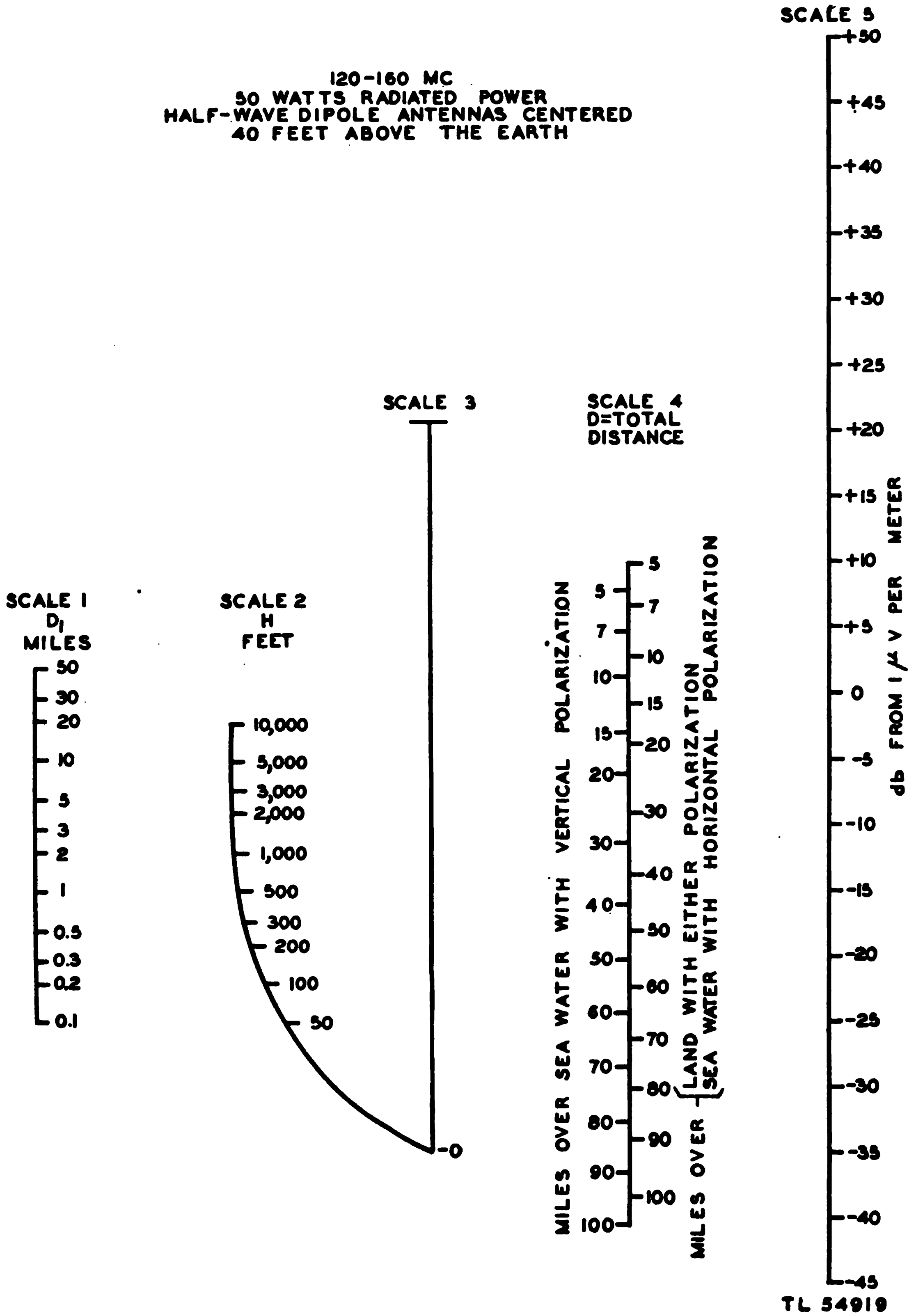


Figure 6-16. Nomogram for estimating field intensity, 120 to 160 mc.

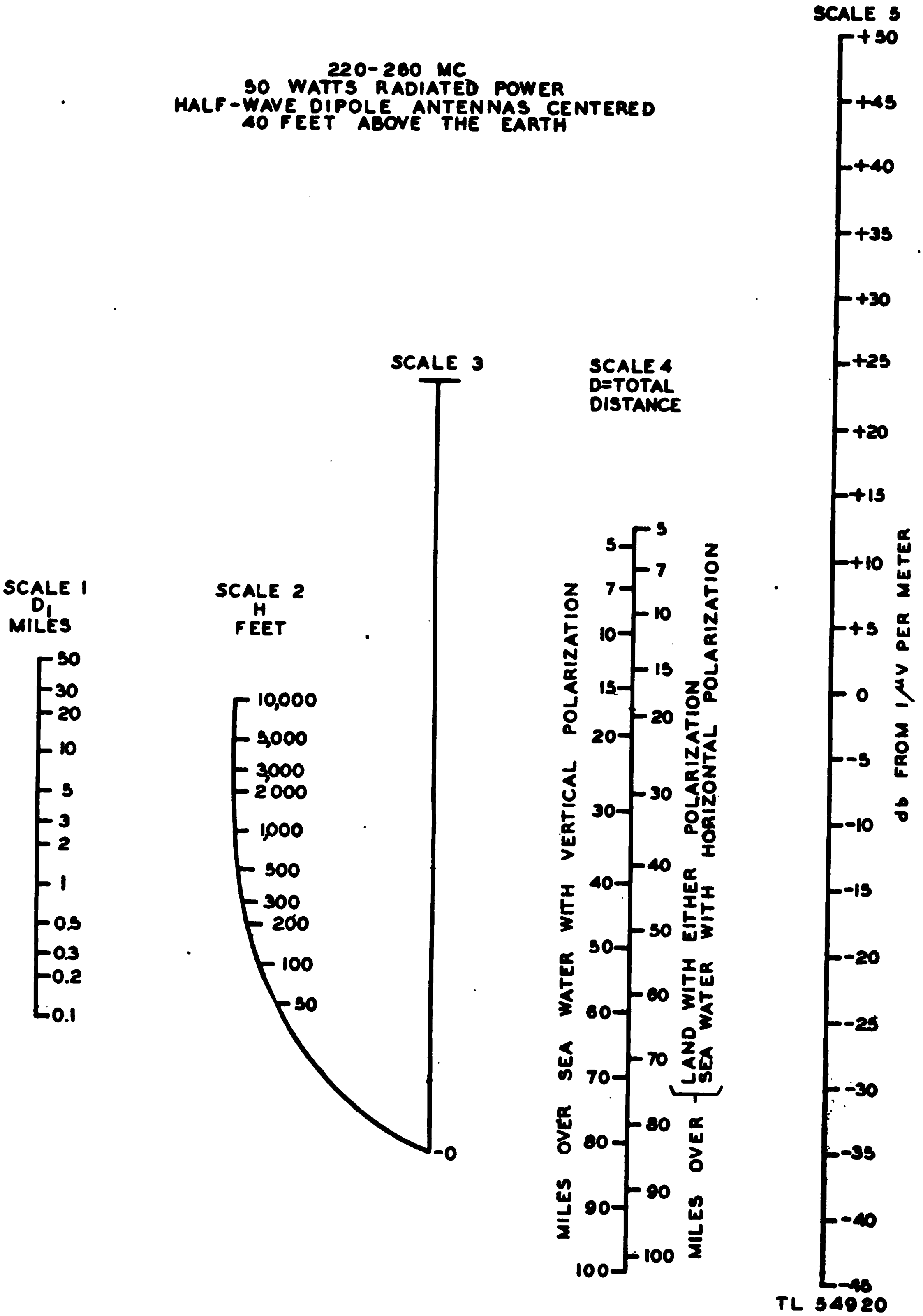


Figure 6-17. Nomogram for estimating field intensity, 220 to 260 mc.

tween the proposed locations of the two radio terminals, using the elevations obtained from contour maps. In doing this, it is usually desirable to magnify changes in elevation by drawing these to a scale which is greatly enlarged as compared to the distance scale. The result gives an exaggerated impression of the profile, but aids in following the steps given below.

(*3*) On this profile, draw a triangle similar to the ones drawn for the examples in figure 6-13. This triangle is formed by a line joining the *base* of the transmitting antenna mast with the *base* of the receiving antenna mast and a line from each mast base tangent to the hill or hills that block line-of-sight transmission.

(*4*) From this triangle note three quantities, namely: the distance D between the radio terminals, the distance D_1 from the projection of the apex of the triangle to the *nearer* terminal, and the height H from the baseline of the triangle to the apex.

(*5*) Next select figure 6-14, 6-15, 6-16, or 6-17, depending on the frequency of the radio system. Draw a straight line through the point representing the distance D_1 on scale 1 and the point representing the height H on scale 2, and extend it to cross scale 3 (the plain vertical line). Draw a second straight line through the point where the first line crossed scale 3 and the point representing the total distance D on the appropriate side of scale 4, extending it to cross scale 5. The intersection of this second line with scale 5 indicates the estimated field intensity in db above 1 microvolt per meter for the reference condition.

(*6*) For large values of D_1 and small values of H, a straight line through these points may fall below the lower end of scale 3. This means that the profile is smooth enough for the effect of intervening hills to be negligible insofar as this method is concerned. In this case the field intensity is estimated by drawing the second straight line from the lower end (marked zero) of scale 3 through the appropriate value on scale 4 and over to scale 5, from which the estimated intensity is obtained as before.

(*7*) As an example of the above procedure, assume the profile given for example A on figure 6-13 and the frequency between 70 and 100 mc. The total distance D is 20 miles, D_1 is 8 miles, and H is 2,000 feet. Referring to the chart in figure 6-13, which is the same as figure 6-15, the estimated field intensity is shown by the dashed lines constructed to illustrate this example to be 4 db above 1 microvolt per meter. Example B on figure 6-13 is discussed in paragraph 616b(3).

(*8*) For smooth land or sea water, or in the absence of any *obstructing* hill along the transmission path, scales 1 and 2 may be disregarded and a straight line drawn from scale 3 across scale 4 to scale 5, hinged on the 0 point at the lower end of scale 3. For a given field intensity on scale 5, the two distance scales on scale 4 of figure 6-14 indicate the substantial advantage of using vertical rather than horizontal polarization for sea-water transmission at frequencies in the lower part of the v-h-f band with antenna elevations as low as 40 feet.

(*9*) If the conditions for which the field intensity is to be estimated differ in any way from the reference conditions specified in subparagraph b(2) above, as will very frequently be the case, make the necessary corrections as outlined in paragraph 616.

616. CORRECTION FACTORS FOR USE WITH FIGURES 6-14 TO 6-17.

a. General. The correction factors given in this paragraph are the same for single-channel and multichannel operation. However, as stated in paragraph 614d, the required field intensities for various types of circuits differ, and the estimated values must be compared with the proper required values on figure 6-12 in order to evaluate expected performance.

b. Correction for Antenna Elevation: Factor H_a.

(*1*) When the antennas have effective elevations (defined in subparagraph (2), below) other than the reference elevation of 40 feet, the field intensity obtained from the nomograms should be corrected by the *sum* of the amounts shown in figure 6-18 corresponding with the effective antenna elevations at the transmitter and receiver. This corrected value of field intensity is subject, however, to the limitation noted under subparagraph (4) below, which prevents the corrected field intensity from exceeding the *free space* value.

(*2*) The effective elevation of an antenna at the top of a mast is usually equal to the mast height, provided that the ground is level for a half-mile or more in the direction of the distant station. The effective elevation of an antenna on the edge of a precipice (falling off in the direction of the other antenna) can usually be taken as the difference in elevation between the center of the antenna and the bottom of the precipice. In the intermediate case where the mast is placed on a hill sloping downward in the direction of the distant terminal, the effective elevation of the antenna depends on the steepness and uniformity of this slope. A rough, general purpose rule for field use in connection with the nomograms of figures 6-14 to 6-17 is to assume that the effective elevation is the mast height plus ½ of the difference in elevation between the mast base and the ground level ½-mile distant in the foreground. This rule is limited principally to the case of antennas sited below or only slightly above the elevation of intervening land. When high mountains exceeding the maximum elevation of the intervening terrain are available for antenna sites, reference should be made to the information in paragraph 617. For transmission paths over sea water, island-to-island for example, the effective elevation of antennas situated on hillsides with an unobstructed view of the sea is usually the full elevation of the antenna above sea level. Paragraph 617 should be consulted for such cases also. For other cases, such as the back slope of a hill, see paragraph 618d(3).

(3) To illustrate use of the general purpose rule, consider example B of figure 6-13 which is identical to example A except that one antenna has been moved to point B. For this situation D is 22½ miles, D_1 is 10 miles, and the height H is 1,600 feet. The estimated field intensity obtained as illustrated by the dotted lines on the chart of figure 6-13 is 5 db above 1 microvolt per meter. However, the antenna in example B is not at reference elevation, but instead is on a hill which slopes away 100 feet in the first half mile. The effective elevation of the antenna is now 40 (mast height) $+ \frac{100}{2} = 90$ feet, and figure 6-18 indicates a gain of about 7 db. Consequently, the total estimated field for a frequency in the 70 to 100 mc band is $5 + 7 = 12$ db. The improvement over the 4 db value of example A (par. 615c(7)) is due to moving the antenna to a location where its effective elevation is increased and the height of the intervening hill is effectively less.

(4) The corrections of figure 6-18 may be in error at the greater antenna elevations. If the nomogram value corrected by values in figure 6-18 exceeds the *free space* field intensity given in figure 6-19 for the same distance D, the field intensity from figure 6-19 should be used instead. Having observed this precaution, the other corrections from subparagraphs c to f below may be made regardless of whether figure 6-19 was or was not limiting.

Effective antenna elevation (feet)	Correction for antenna elevation (db)									
	Horizontal polarization	Vertical polarization								
	20–300 mc	20–40 mc			70–100 mc		120–160 mc		220–260 mc	
	Any land or sea water	Poor land	Good land	Sea water	Any land	Sea water	Any land	Sea water	Any land	Sea water
10	Sub[a] 12	Sub 8	Sub 4	Add 1	Sub 10	Add 1	Sub 11	Sub 3	Sub 12	Sub 11
25	Sub 4	Sub 3	Sub 2	0	Sub 4	0	Sub 4	Sub 3	Sub 4	Sub 4
40	Reference condition, no correction									
60	Add 3	Add 3	Add 2	0	Add 3	Add 1	Add 3	Add 4	Add 3	Add 4
100	Add 8	Add 8	Add 7	Sub 1	Add 8	Add 5	Add 8	Add 9	Add 8	Add 9
200	Add 14	Add 14	Add 13	Sub 2	Add 14	Add 12	Add 14	Add 15	Add 14	Add 15
500[b]	Add 22	Add 22	Add 21	Add 4	Add 22	Add 21	Add 22	Add 24	Add 22	Add 23

[a] Sub = subtract.
[b] See paragraph 617 for antennas at great elevations.

Figure 6-18. Corrections for antenna elevation, transmission over land or sea.

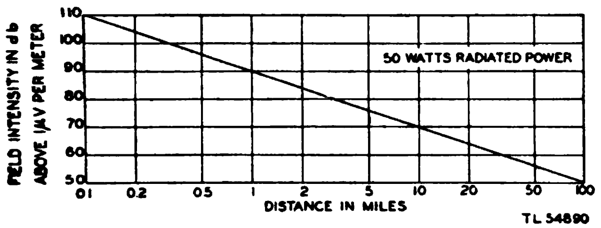


Figure 6-19. Free space field intensity curve.

c. Correction for Transmitter Power: Factor P. When the transmitter power differs from the reference value of 50 watts, an appropriate correction from the table of figure 6-20 must be made.

Transmitter power (watts)	*Correction factor (db)*
0.5	Subtract 20
1	Subtract 17
2	Subtract 14
5	Subtract 10
10	Subtract 7
20	Subtract 4
50[a]	0
100	Add 3
250	Add 7
500	Add 10
1,000	Add 13

[a] Reference condition.

Figure 6-20. Corrections for transmitter power.

d. Corrections for Transmission Line Loss: Factor L_t.

(*1*) Antenna transmission lines of appreciable length introduce a significant loss, particularly at the higher frequencies of the v-h-f band. Typical losses per hundred feet for flexible coaxial cable of the type in general use are given in figure 6-21. These values should

Frequency (mc)	*Correction for transmission line loss (db per 100 feet)*
20 to 40	Subtract 1
70 to 100	Subtract 2
120 to 160	Subtract 3
220 to 260	Subtract 5

Figure 6-21. Corrections for transmission line loss.

be assumed unless other information is available relating to the specific type of line used. Some information on coaxial cables is given in figures 6-146 and 6-147; detailed information on all standard types is given in TM 11–487.

(*2*) A transmission line loss should always be included for the transmitting antenna, since this loss represents a reduction in radiated power. For receiving antennas, inclusion of a line loss is also necessary in the usual case when set noise, rather than external noise, is controlling.

e. Correction for Directional Antenna Gain: Factor G.

(*1*) Field intensities indicated on the nomograms of figures 6-14 to 6-17 are those obtained with a vertical or horizontal dipole antenna in a direction perpendicular to the antenna elements. When any other type of antenna or some other direction of propagation is involved, a correction should be made for the gain or loss of the actual antenna relative to this reference condition. For example, when an antenna having a 6 db gain in the forward direction is used at each end of a circuit and each antenna is properly oriented, the estimated field intensity should be increased by 6 + 6 = 12 db, assuming set noise is the controlling noise.

(*2*) Actually, as discussed in paragraph 614e, the received field intensity in the above example is increased only 6 db, which is obtained from the directional *transmitting* antenna, but at the same time the field intensity required is decreased 6 db because of the gain of the receiving antenna. Treatment of receiving antenna gain as a gain in field intensity is a matter of convenience in using the procedure given herein in conjunction with the required field intensities of figures 6-11 and 6-12.

(*3*) In situations where external noise or radio interference is present to such an extent that it would predominate over set noise when receiving on a nondirectional antenna, the effect of substituting a directional antenna will depend on whether or not this improves reception of the noise as well as the signal. When the noise source lies in the same direction from the receiver as the distant transmitter, a directional receiving antenna increases the received noise as well as the received signal and there is no net gain in signal-to-noise ratio. When the external noise source is in some other direction, the improvement in signal-to-noise ratio depends on the relation of the efficiency of the antenna in the

ASSUMED CONDITIONS

	Example 1	*Example 2*
Radio Set	AN/TRC-1,-3, or-4	AN/TRC-1,-3, or-4 with Amplifier AN/TRA-1
Frequency band	70–100 mc	70–100 mc
Rated transmitter power	50 watts	250 watts
Antenna type, gain, and polarization	AS-19/TRC-1, 6-db gain, horizontal	AS-19/TRC-1, 6-db gain, horizontal
Antenna effective elevation	Mast height, 40 ft.	Mast height, 40 ft. at one end; 90 ft. effective elevation at other end
R-f transmission line type	100 ft. flexible coax. cable at each end	100 ft. flexible coax. cable at each end
Type of operation	Single channel, voice	4-channel, voice
Type of circuit	Point-to-point, one radio section	Point-to-point, one radio section
Profile of radio path	As in example A, figure 6-13	As in example B, figure 6-13
Remarks	No external noise expected. Antenna in trees at one end of circuit.	No external noise expected. Antenna in clear at both ends of circuit.

CALCULATIONS FOR EXAMPLES 1 AND 2

Profile characteristics figure 6-13	$D_1=8$, $D=20$, $H=2{,}000$	$D_1=10$, $D=22.5$, $H=1{,}600$
Reference field intensity (fig. 6-13)	+4 db	+5 db
Antenna elevation corrections (fig. 6-18)	0	+7
Sum[a]	+4[a]	+12[a]
Transmitter power correction (fig. 6-20)	0	+7
R-f transmission line corrections (fig. 6-21)	−4	−4
Antenna directional gain corrections (par. 616e)	+12	+12
Approx. tree loss correction (par. 616f)	−2	0
Estimated field intensity (sum of above items)	+10 db from 1 mv/meter	+27 db from 1 mv/meter
Min. required field for *satisfactory* (figures 6-11 and 6-12)	+15	+25
Difference (last 2 items)	−5	+2
Estimated performance from figures 6-11 and 6-12	*Questionable*	*Satisfactory*

[a] Examine figure 6-19 before proceeding further to be assured that the *free space* field exceeds this value (par. 616b (4).

Figure 6-22. Sample v-h-f performance estimates.

direction of the signal to its efficiency in the direction of the noise, that is, on the horizontal directional pattern of the receiving antenna (par. 624c).

f. Correction for Loses Caused by Trees: Factor L_t.

(*1*) Trees in close proximity to an antenna ordinarily cause some loss in field intensity and it may be necessary to include an allowance for this in arriving at the resultant estimated field intensity. Present information merely indicates the approximate magnitude of loss to be expected.

(*2*) Recent measurements using antennas somewhat below treetop level in densely wooded areas indicate that with both the transmitting and receiving antennas so situated, the loss when using vertical polarization is about 3 or 4 db for frequencies in the 20- to 40-mc band, and 10 db in the 70- to 100-mc band. With horizontal polarization, losses are negligible at 20 to 40 mc and quite small at 70 to 100 mc. Higher losses occur in the higher frequency bands. For scattered trees these losses are not as severe but are usually present in some degree. In dense humid jungles with antennas located well down in the jungle growth, losses are very high and seriously limit v-h-f transmission with either horizontal or vertical polarization.

g. Sample Performance Estimates Showing Use of Correction Factors. The upper portion of figure 6-22 states conditions assumed for two examples. The lower portion of figure 6-22 shows, step-by-step, the calculations involved in estimating performance for each of the examples. The procedure is a straightforward application of the equation given in paragraph 615b (2) for estimating field intensity. The estimated value is then compared with values in figures 6-11 and 6-12, from which the performance classification is determined as *satisfactory, questionable,* or *unsatisfactory* for the type of circuit involved.

617. V-H-F TRANSMISSION WITH ANTENNAS AT GREAT ELEVATIONS.

a. General.

(*1*) The foregoing information and the nomograms of figures 6-14 to 6-17 relate to v-h-f transmission with antennas at effective elevations of 500 feet or less. The corresponding distance ranges are generally limited to less than 100 miles over smooth earth or sea water and frequently to much less than 50 miles when intervening hills are present. However, greater distance ranges are possible when one or both antennas are raised to considerable heights as on an aircraft or on mountains.

(*2*) General experience indicates that with antennas at great elevations the useful v-h-f communication range is approximately the line-of-sight distance (fig. 6-23) or somewhat beyond for transmitter powers of the order of 5 to 50 watts.[6] Most of this experience has been obtained with antennas on aircraft. The nomograms in figures 6-24 and 6-25, which are discussed in the following subparagraphs, give field intensity data for transmission from an aircraft to a ground station and from one aircraft to another, over smooth earth or water with either horizontal or vertical polarization.

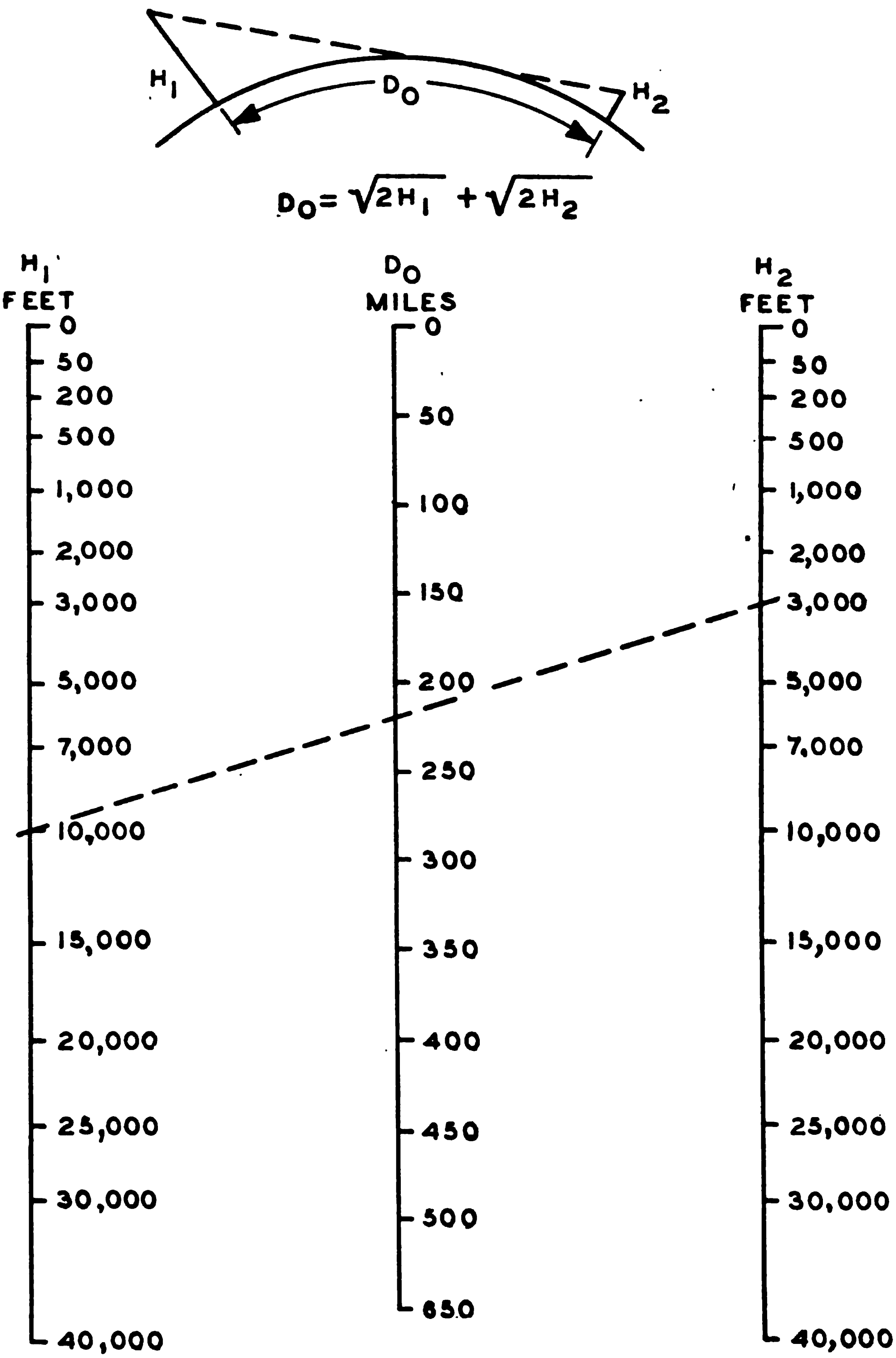
(*3*) Limited experience with antennas located on mountains indicates that *under favorable conditions,* defined in subparagraph d, below, the transmission performance is similar to what would be expected for antennas on aircraft at the same elevation above the intervening terrain. The nomograms in figures 6-24 and 6-25 can therefore be used as guides in estimating the communication possibilities of mountain-to-mountain transmission, *where the mountain sites are well above the intervening terrain* as in island-to-island paths, but should be used with caution until more experience indicates their degree of reliability.

(*4*) The nomograms in figures 6-24 and 6-25 indicate usable field intensities at distances sometimes well beyond line-of-sight. On such circuits fading becomes serious and the circuits may be inoperative part of the time (subpar. e below). *Circuits should not be overextended to distances greater than indicated by the nomograms;* instead, h-f facilities should be used.

[6] The *line-of-sight* distance, D_0, is defined by the following equation for standard propagation over smooth earth:

$$D_0 = \sqrt{2H_1} + \sqrt{2H_2}$$

where D_0 is in miles and H_1 and H_2 are the antenna elevations in feet above ground at the two ends of the circuit. This equation includes the effect of a gradual change in the dielectric constant of the earth's atmosphere which, for standard conditions, causes a refracting effect equivalent to increasing the earth's radius by one-third.



NOTE:
THE DASHED LINE ILLUSTRATES USE OF THE CHART FOR THE CASE OF A 10,000-FOOT ELEVATION AT ONE END OF THE PATH AND A 3,000-FOOT ELEVATION AT THE OTHER END, FOR WHICH THE LINE-OF-SIGHT DISTANCE IS 220 MILES.

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Figure 6-23. Maximum distance for line-of-sight path.

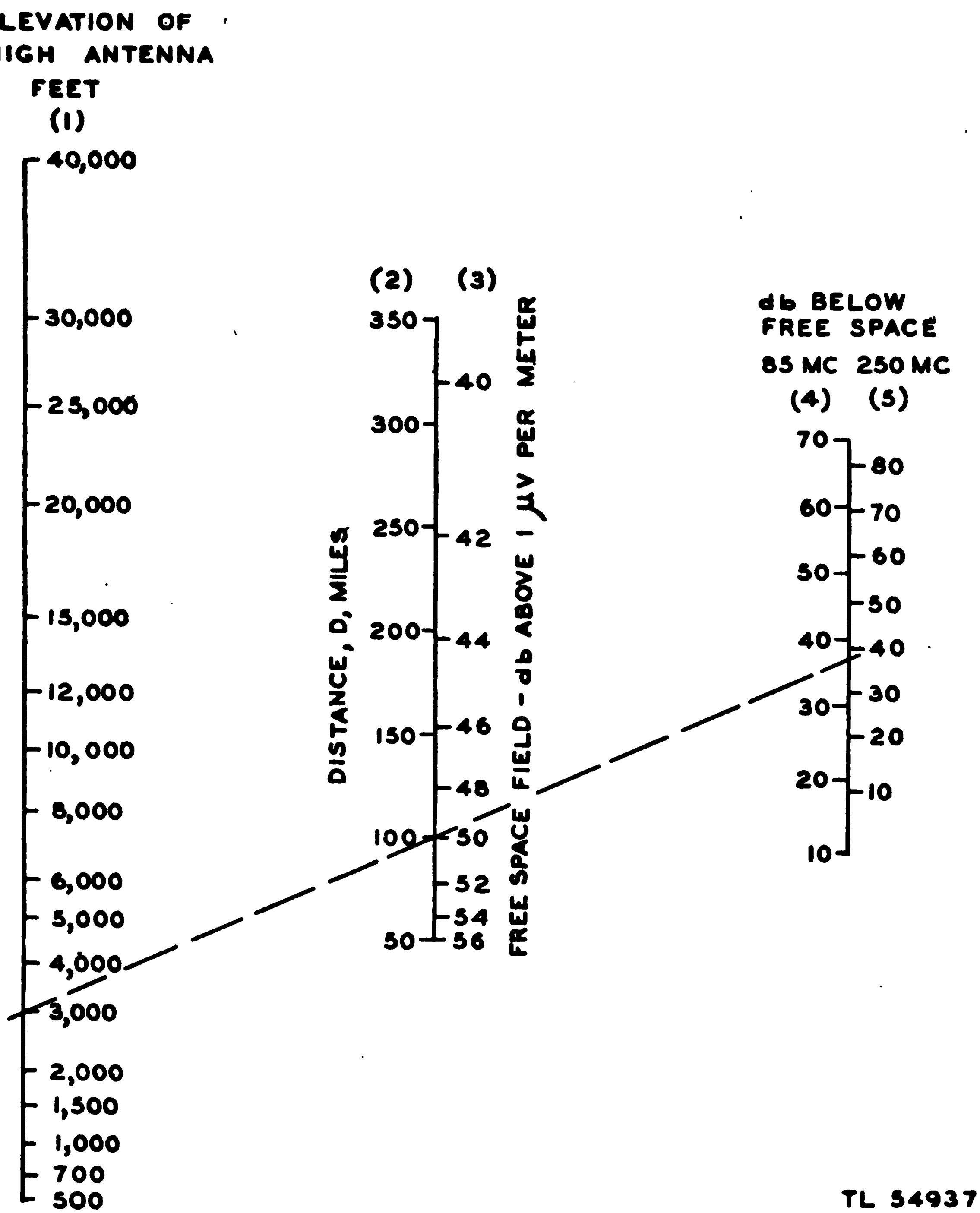

Figure 6-24. Nomogram for estimating field intensity, one antenna at elevations exceeding 500 feet (other antenna at 40 feet. 50 watts radiated from half-wave dipole).

b. Method for Estimating Received Field Intensity, One Antenna Higher Than 500 Feet.

(*1*) When the elevation of one antenna is more than 500 feet, the estimated field intensity over smooth earth or water can be obtained from figure 6-24. The values shown assume that the lower antenna is on a 40-foot mast and that the radiated power is 50 watts. A straight line connecting the elevation of the higher antenna on scale 1 with the distance

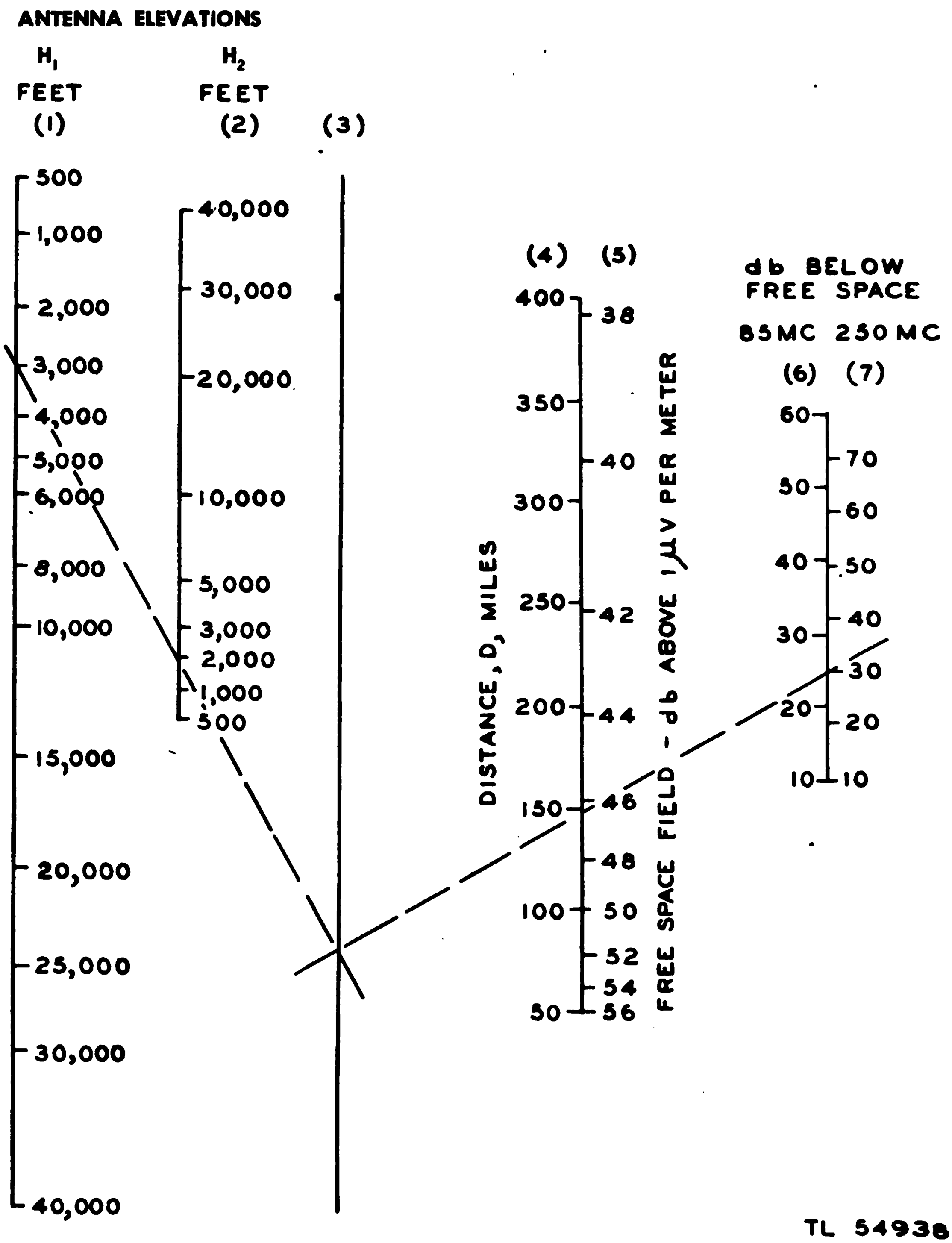

Figure 6-25. Nomogram for estimating field intensity, both antennas at elevations exceeding 500 feet, 50 watts radiated from half-wave dipole.

between antennas on scale 2 determines values on scales 3, 4, and 5. The estimated field intensity at 85 mc, for example, is equal to the reading on scale 3 less the value on scale 4. In a similar manner, the estimated field intensity at 250 mc is equal to the value on scale 3 less the reading on scale 5. The field intensity at 150 mc is approximately midway between the values for 85 and 250 mc. When the effective elevation of the lower antenna lies between 40 and 500 feet, the field intensity obtained from the nomogram should be corrected by adding 3, 8, 13, or 22 db for elevations of 60, 100, 200, or 500 feet, respectively. These are average values, applicable to either horizontal or vertical polarization within the precision of the nomogram method. If the addition of such height-gain corrections should cause the resultant field intensity to exceed the free-space value as read on scale 3 of the nomogram on figure 6-24, the free space value should be used. Corrections for transmitter power, directional antenna gain, transmission line losses, etc., should also be made as in paragraph 616. When the effective elevation of the lower antenna exceeds 500 feet, figure 6-25 should be used, as explained in subparagraph c, below.

(*2*) The example indicated on figure 6-24 shows that for antenna elevations of 40 and 3,000 feet the estimated field intensity at 85 mc at a distance of 100 miles is 50 —37 = 13 db above 1 microvolt per meter for 50 watts radiated power. The corresponding field intensity for 250 mc is 50 —38 = 12 db. This value can be compared with the required value on figure 6-11 or 6-12 to estimate performance.

(*3*) For distances within line-of-sight the line drawn from scale 1 through scale 2 may fall below a value of 10 on scales 4 or 5. In such cases it is sufficient to know that the estimated field is within 10 db of the free space value on scale 3.

c. Method for Estimating Received Field Intensity, Both Antennas Higher than 500 Feet.

(*1*) When both antennas are at elevations greater than 500 feet, the field intensity over smooth earth or water can be estimated from figure 6-25. A straight line connecting the antenna elevations H_1 and H_2 on scales 1 and 2, determines a point on scale 3. A second straight line through this point on scale 3 and the distance on scale 4 indicates values on scales 5, 6, and 7. The estimated field intensity at 85 mc is the value on scale 5 less the value on scale 6; similarly, the field intensity at 250 mc is the value on scale 5 less the value on scale 7. Corrections from paragraph 616 for other transmitter powers, directional antenna gains, etc., should be applied to the values read from this nomogram.

(*2*) The example shown in figure 6-25 indicates that for antenna elevations of 3,000 and 2,000 feet the estimated field intensity at 150 miles for 50 watts radiated power is 46 —25 = 21 db above 1 microvolt per meter for 85 mc and 46 —30 = 16 db for 250 mc.

(*3*) For some combinations of high antenna elevations, such as may exist from aircraft-to-aircraft, figure 6-25 cannot be used; that is, the lines drawn will fall outside the range of one or more of the scales. For such conditions, the line-of-sight distance obtained from figure 6-23 is a good approximation for distance range with v-h-f sets in the 100- to 156-mc band ordinarily used in aircraft.

d. Effective Antenna Elevations for Use with Figures 6-24 and 6-25.

(*1*) The nomograms in figures 6-24 and 6-25 are computed on the basis of propagation over smooth earth or water. Under such conditions, the antenna elevation to use in the nomograms is easily defined. For example, the effective antenna elevation of an antenna on an aircraft is the height of the aircraft above the land or water. Similarly, if the antenna is located on a mountain side, with only smooth earth or water between it and the distant station, the effective antenna elevation is the difference between the elevation at the antenna site and the elevation of the smooth terrain or water; provided, that the antenna is centered at the top of a mast at least one or two wavelengths high and that the foreground looking toward the distant station from the base of the antenna mast slopes downward toward the level terrain or water at a rate of at least 10 feet in 100 feet (about 5 degrees). These conditions are usually met with in island-to-island transmission, with antennas on the forward sides of hills, not on the summits.

(*2*) When the terrain between stations is mountainous, rather than smooth, effective antenna elevations cannot be defined as clearly as above. However, it is reasonable to assume that the effective antenna elevation of an antenna on an aircraft, or on a mountain side, equals the difference between the elevation at the antenna site and the *average* elevation of the terrain between stations (or between the one station and the horizon, if the distant station is beyond the line-of-sight distance limited by earth curvature). This relationship should hold approximately, provided, in this case, that the top of any mountain along the path between stations, or to the horizon, is below a line sloping downward from the base of the antenna mast at an angle of about 5 degrees with the horizontal.

(3) When the above conditions are not met, the effective elevation of an antenna is less than defined above in the subparagraphs (1) and (2), and becomes equal to the mast height only, as the downward slope of the foreground approaches zero.

e. Variations of Field Intensity with Weather Conditions.

(1) Some variations of field intensity with meteorological (weather) conditions are to be expected, particularly at the longer distances made possible with high antenna elevations. Under some conditions, stronger field intensities than indicated by use of figures 6-24 and 6-25 will be received; under other conditions the received field intensities will be less. The range of variation in field intensity to be expected may be determined from the nomograms by means of the considerations given in subparagraph (2), below.

(2) Assume that the effective antenna elevations have been determined for a given transmission path. Now, for one kind of weather deviation from standard, the effect on field intensity may be regarded as roughly equivalent to doubling these antenna elevations, while with changes of an opposite variety, the effect on field intensity is equivalent to halving the antenna elevations. The range between the maximum and minimum field intensities obtained from nomograms for these equivalent antenna elevations represents the range in received field intensity likely to be encountered on a given circuit.

618. V-H-F ANTENNA SITING.

a. General. Factors concerning antenna siting are discussed throughout the foregoing material. The importance of proper location of antenna sites in v-h-f radio circuits can hardly be overemphasized. Unless this fact is appreciated by field personnel, communication reliability of these circuits may be greatly impaired. The choice of an antenna site will depend largely on the nature of the local and intervening terrain, and the tactical situation. The longer circuits, especially those over difficult terrain, will require better siting at each end than a circuit which is to operate over a more favorable path. Similarly, multichannel circuits require better antenna siting than single-channel circuits, for a given distance between stations. For these reasons, planning of v-h-f radio circuits and the selection of sites for installation of the radio sets should always be preceded by a careful study of terrain maps and, wherever possible, by reconnaissance in order to obtain detailed information concerning the nature of the terrain and the accessibility of desirable sites. This is particularly important when the proposed circuit requires the installation of intermediate radio relay stations in isolated areas or where several radio circuits in diverse directions must be terminated at one location. Although terrain characteristics and their effect on radio transmission vary, careful consideration of the factors summarized below should enable field personnel to select suitable antenna sites and establish satisfactory v-h-f radio circuits in any theater.

b. Woods and Jungles.

(1) The following rules apply regardless of the topography:

(a) Avoid dense woods, particularly when using the higher frequencies in the v-h-f band. If this is impossible, locate antennas in sizable clearings.

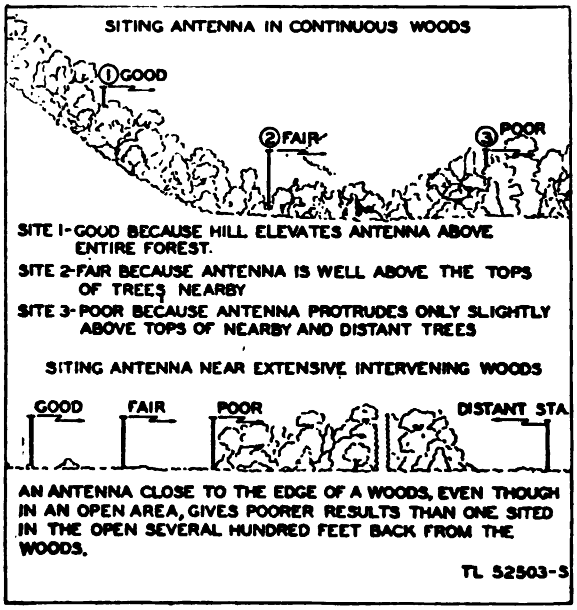

Figure 6-26. V-h-f antenna siting in trees or jungle.

(b) When in proximity to woods or scattered trees, if vertical polarization is to be used, try several sites a short distance apart, and select the one which gives the best results.

(c) In jungles, support antennas on masts extending above the jungle growth, or locate in clearings at least 100 yards in diameter and use the highest mast available. Transmission over open paths across a river or along open river valleys is recommended, where feasible.

(2) Figures 6-26 and 6-27 illustrate good and bad siting in the presence of trees.

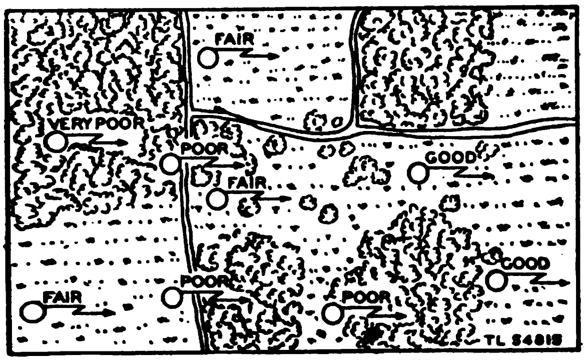

Figure 6-27. V-h-f antenna siting near scattered woods.

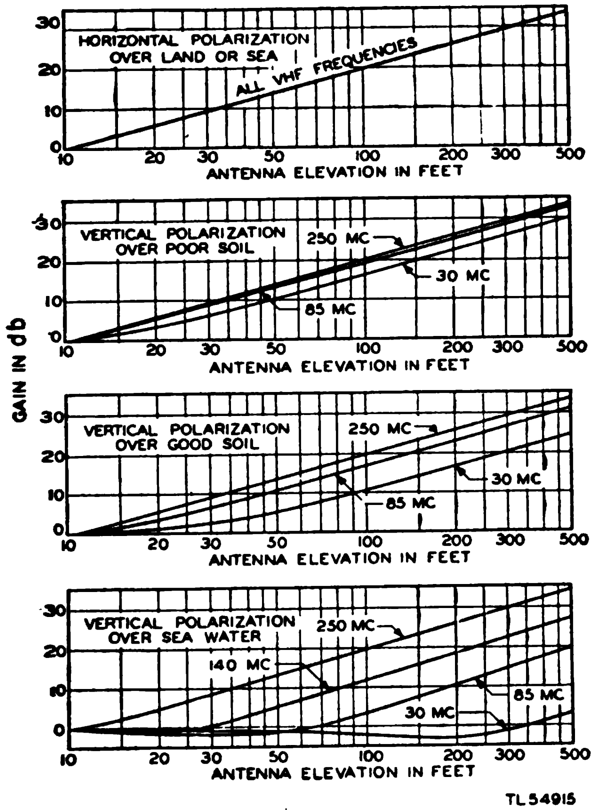

Figure 6-28. Gain in field intensity obtained by raising one antenna from a low elevation (10 feet).

c. Flat Terrain.

(1) In flat country, best performance will result if these rules are followed:

(a) Place the antennas as high above ground as practicable, using masts or tall trees.

(b) Avoid depressions; select any slight rise of terrain in the vicinity.

(2) Increasing the antenna elevation is often the simplest way to improve circuit performance. The gain in field intensity when a dipole antenna is raised from a low elevation is shown in figure 6-28. These gains apply to both the transmitting and receiving antennas, and the sum for both antennas represents the gain in r-f signal-to-noise ratio as long as set noise is controlling. When external noise is controlling, the gain in signal intensity obtained by raising the *receiving* antenna may be ineffective in improving the r-f signal-to-noise ratio since the received noise may be increased along with the signal. At 30 mc, for example, over poor soil with vertical polarization, raising both transmitting and receiving antennas from 25 feet to 50 feet increases the received signal by (10-5) x 2 = 10 db, which is equivalent to increasing the transmitter power 10 times. The corresponding r-f signal-to-noise ratio will be increased 10 db when set noise is controlling, but it may be increased only 5 db (by raising the transmitting antenna) when external noise is controlling. With f-m sets, an improvement in the r-f signal-to-noise ratio should provide at least a corresponding improvement in audio signal-to-noise, and more in some cases.

d. Mountainous Terrain.

(1) The following rules are useful guides to good siting in mountainous terrain:

(a) Locate the antennas on the forward sides of hills high enough to provide line-of-sight paths, if possible.

(b) If line-of-sight locations are not available, choose antenna sites at each end so that the least *bending* of the radio wave is involved in clearing an obstructing hill. Avoid sites at the base of high intervening hills.

(c) The presence of river valleys and gaps between mountains should not be overlooked as means of obtaining transmission paths devoid of high intervening hills.

(2) The above rules are probably best demonstrated by means of the example shown in figure 6-29. Location 1 is obviously the best

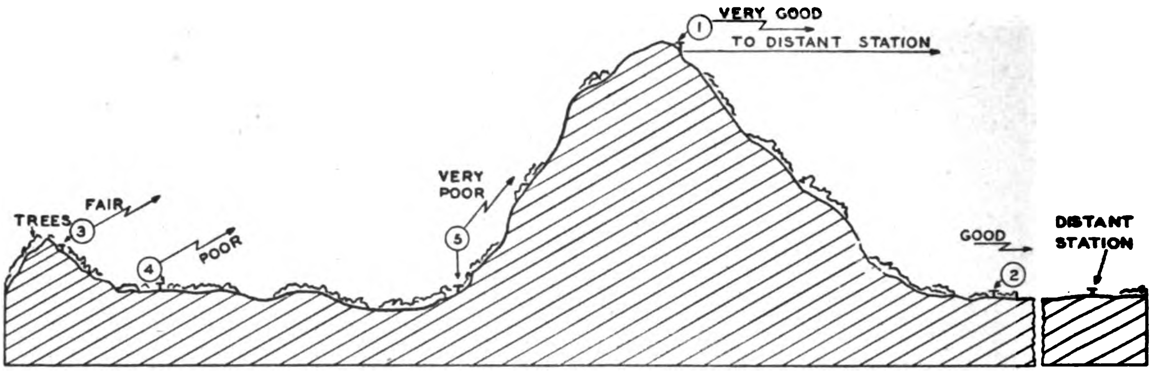

Figure 6-29. V-h-f antenna siting in hilly country.

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of the five sites shown, and is quite probably the best available, since experience has shown that sites directly on the summit of a hill are frequently inferior to those on the brow. Location 2 is usually preferable to any shown behind the hill. The worst choice would be location 5. Location 4 is better than 5 in spite of the fact that the antenna is farther away from the distant station because the angle through which the wave bends is reduced appreciably. Location 3 is much better than any of the others back of the hill because the antenna is located on another hill, a condition which not only reduces the angle of bend (thus coming a little closer to line-of-sight) but also increases the effective antenna elevation, thereby improving the received field intensity as indicated earlier in figure 6-18.

(*3*) There are some kinds of antenna sites where the signal improvements arising from increased antenna elevation given in figure 6-18 are not always applicable. Such sites include locations on the back slope of a hill, or in a narrow river valley between ridges, one of which blocks transmission, or on an extended level plain behind an intervening hill but close to its base (less than a half mile away), as in the case of location 5 of figure 6-29. All such sites are undesirable but are sometimes unavoidable. In such situations the field intensity may vary considerably from one location to another nearby, and may be stronger for antennas located on low masts than for antennas located on high masts. The best location and antenna elevation is determined by trial and error, an increase in r-f signal intensity being observed either by noting improved audio signal-to-noise ratio on reception or by observing changes in squelch control settings or in limiter grid current (fm), when the radio receivers are provided with such facilities. The more positive indications of r-f signal change obtained by the latter methods are to be preferred, since a set may not show much audio signal-to-noise improvement in rough listening tests when the field intensity is increased by a change in location. However, the improvement may be of considerable value should interference or jamming develop.

(*4*) On several occasions, when using a directional antenna in mountainous terrain, it has been found that in situations where the straight-line path between stations crosses the peak of a nearby hill, best results are obtained with the antenna oriented so that it points at a small angle off to the side of the straight-line course, rather than directly towards the distant station, particularly if the off-course direction involves lower terrain such as a mountain pass. Presumably more signal energy is reflected from the sides of neighboring hills than is diffracted over the top of the obstructing hill. On the basis of this experience, it appears desirable to experiment with the aiming of directional antennas when establishing circuits over irregular terrain.

e. Sea Water. In transmitting or receiving over sea water using vertical polarization, increased antenna elevation, up to several hundred feet, is of no advantage with frequencies in the lower portion of the v-h-f band, as shown by figure 6-28. Thus, antenna sites on the beach, using low masts if desired for concealment purposes, are as good as any obtainable unless high hills are available a short distance inland. For higher frequencies, there is an advantage in raising an antenna even a small amount above beach level, and even small hills provide better sites. With horizontal polarization, the higher the hill or mast, the better, regardless of frequency.

619. POLARIZATION.

a. General.

(*1*) Transmission characteristics for horizontal and vertical polarization have been outlined in various places throughout this section, and are collected and reviewed here.

(*2*) For practical purposes, in the v-h-f band, radio waves transmitted from a vertical antenna are usually regarded as being vertically polarized, and those from a horizontal antenna are normally regarded as being horizontally polarized.[7] Either type of polarization may be used for v-h-f transmission, but the performance will be different under certain situations. In all cases, the orientation of the receiving antenna, that is, horizontal or vertical, should be the same as that of the transmitting antenna at the distant station.

b. Advantages of Vertical Polarization. Advantageous characteristics of vertical polarization for v-h-f transmission are as follows:

(*1*) Simple vertical dipole or whip antennas are nondirectional in a horizontal plane. This feature is advantageous when good communication is desired in several directions from a station.

(*2*) Where antenna elevations are limited to 10 feet or less, as for motor vehicle applications in transmitting over land, vertical polarization results in a signal at least twice as strong in the 20- to 40-mc band as would be obtained with horizontal polarization using antennas at the same elevation. This difference is less pronounced with frequencies in the 70- to 100-mc band and is negligible when using higher frequencies.

(*3*) For transmission over sea water, vertical polarization is decidedly better than horizontal when antennas are below a certain elevation. This elevation is about 300 feet at 30 mc, but only 50 feet at 85 mc and still lower at the higher frequencies. This means that with ordinary antenna mast heights of 40 feet, vertical polarization is advantageous at frequencies less than about 100 mc. At higher frequencies there is little if any difference.

(*4*) From limited observations it appears that vertical polarization is less subject than horizontal to variations in received field intensity caused by reflections from aircraft flying over the transmission path. This may be of importance in locations where aircraft traffic is heavy, as at air fields.

c. Advantages of Horizontal Polarization. Advantageous characteristics of horizontal polarization are:

(*1*) A simple horizontal antenna pointed east and west, for example, transmits and receives best in north and south directions and performs poorly by comparison, in east and west directions. This inherent directivity is sometimes of advantage as a means of minimizing interference.

(*2*) Horizontal antennas are less apt to pick up man-made interference, which is ordinarily vertically polarized.

(*3*) Indications are that when antennas are located in fairly dense forests, horizontally polarized waves usually suffer lower losses than vertically polarized waves, especially in the higher portion of the v-h-f band. Also, standing wave effects which cause relatively large changes in the field intensity of vertically polarized waves for small changes in antenna location among trees or near the edge of a forest are not nearly so pronounced with horizontal polarization. In very dense jungles, performance is poor and probably not much affected by polarization.

620. MISCELLANEOUS TRANSMISSION CONSIDERATIONS.

a. Security.

(*1*) Any radio transmission is subject to enemy interception. However, several measures may be used which contribute toward making interception of signals by the enemy more difficult. These measures are also of value in reducing the possibility of causing interference with the reception of friendly signals.

(*2*) When received signals are well above the required values, the *transmitting* antenna should be lowered in elevation and the transmitter power reduced when feasible. This will impair reception by the enemy without materially affecting performance on circuits operating with considerable transmission margin. Also, lowering the antenna may afford some degree of concealment of radio sets from enemy observation, and lessen the danger of antenna breakage during stormy weather.

[7] A more technical definition of polarization is given in chapter 12.

(3) Advantage may be taken of the shadow loss caused by hills obstructing a transmission path when it is possible to locate the transmitting station so that hills will intervene in the direction of the enemy but not in the desired path. The effectiveness of this measure in a given situation may be estimated from the charts of figures 6-14 to 6-17.

(4) The use of directional transmitting antennas ordinarily provides higher signal intensities in the forward direction than would be obtained with nondirectional types. In other directions, in back or off to the side, interception is made more difficult because the transmitted signals are relatively weak. It is sometimes practical to orient the antenna so as to obtain a very weak signal in a particular direction where transmission is unwanted, at a fairly small cost to transmission over the wanted path.

b. Noise and Interference.

(1) *General.* The radio communication range is inversely related to the amount of noise or radio interference at the receiving antenna location. In other words, the more noise or interference present, the shorter the distance over which satisfactory communication can be established, assuming other factors remain the same. High noise will cause errors in superimposed voice-frequency telegraph (teletypewriter) circuits; and on channels used for voice communication, it will reduce intelligibility and make the channel more difficult to use satisfactorily. Common sources of noise are industrial plants using electrical equipment, radio transmitting stations, power lines, motor ignition systems, etc. In addition to these sources, spurious radiation from associated transmitters may cause considerable interference, as discussed in section VI. Every reasonable effort should be made to select installation sites in quiet country locations, away from industrial or concentration areas and repair stations or heavily travelled highways. Remote control facilities may be used to obtain separation between the radio terminal and the signal center, which is often in a congested area. In general, the use of horizontal polarization will considerably reduce the effect of man-made interference, since usually such interference is predominantly vertically polarized. Suitable chokes or filters in power leads will reduce direct noise pick-up in the receiver from motor-generator sets or power lines. The importance of using *all* of the power available on a *marginal* circuit should not be minimized. If, because of faulty line-up, damaged transmission lines, or incorrect adjustment of antenna elements, a radio set rated at 50 watts only radiates half that amount, the resulting loss of power may cause failure of the circuit.

(2) *Static Noise.* Available data on the effect of atmospheric static interference on telephone transmission in the v-h-f band indicates that the problem is not serious in many parts of the world during most of the year. The worst static occurs during local thunderstorms, and causes most trouble on circuits which are operating with only marginal field intensities. In such cases there may be instances where the message will have to be repeated.

(3) *Ignition, Teletypewriter, and Cipher Machine Noise.* A fairly common type of interference is ignition interference from motor vehicles or gasoline-driven motor-generator sets. It is believed that such noise sources in military equipment in good condition will be sufficiently suppressed. In cases where shielding and suppression measures prove inadequate, the source should be physically separated from the receivers affected. Interference from the sparking of contacts in teletypewriter equipment and from cipher machines is of a similar nature.

(4) *Tube and Contact Noise.* Perhaps the most common source of noise is that due to poor maintenance, that is, noisy tubes and poor contacts in radio receivers. Another source of noise on radio telephone circuits is burning noise between carbon granules in a defective microphone at the radio transmitter. Unless these troubles are located and cleared, performance may be considerably impaired. Noisy tubes in the receiver input stages will cause more trouble than elsewhere in the circuit.

(5) *Noise Reduction.* Some further general suggestions on noise reduction are in paragraph 654.

621. SINGLE-CHANNEL AUTOMATIC AND MANUAL RADIO RELAYS TO EXTEND THE V-H-F DISTANCE RANGE.

a. General. Frequently communication at very high frequencies is required over distances greater than can be spanned by a single radio jump over the particular terrain encountered in a given situation. In such cases radio relays can be used. Several standard radio sets have been designed to provide such operation automatically, including Radio Sets AN/TRC-1 (70 to 100 mc), AN/TRC-8 (230 to 250 mc), and AN/CRC-3 and AN/CRC-3A (30 to 40 mc).[8] When any of these sets is used as a single-channel radio relay set for push-to-talk operation, the transmitter and receiver are connected together in such a way that the transmitter carrier is automatically controlled by a relay in the radio receiver which is actuated by the received signal. Several radio relay arrangements requiring no modification of these standard radio sets are described in the following paragraphs. Other arrangements have been improvised in the field, but such schemes usually involve set modifications or auxiliary apparatus and will not be covered here.

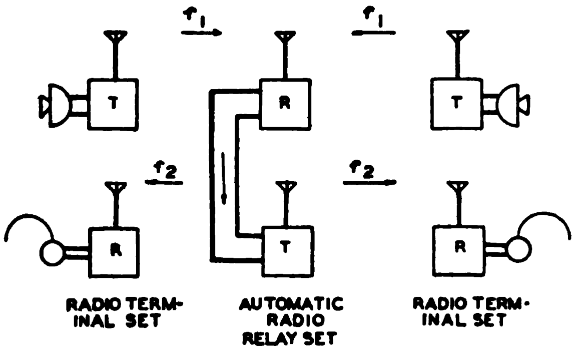


Figure 6-30. Two-section radio communication system for simplex operation with automatic radio relay set.

b. Single Automatic Radio Relay, Simplex Operation.

(*1*) Where only two radio sections are to be worked in tandem, a simple form of automatic radio relay may be used as shown in figure 6-30. Such a system requires only one transmitter and one receiver (each with its own antenna and mast) at the automatic radio relay station. Because of the simultaneous operation of the transmitter and receiver at the radio relay, different frequencies are required for the two directions of transmission. The system operates in the following manner. Frequency f_1 is assigned to the radio transmitter at each terminal and also to the receiver at the automatic radio relay. Frequency f_2 is assigned to the transmitter at the automatic radio relay and to the receivers at the two radio terminals. At the radio relay set, the output of the radio receiver is connected to the input of the radio transmitter. At both terminals and also at the radio relay the transmitters are normally not radiating. When a person desires to talk from one of the terminals, he operates the push-to-talk button on his microphone which puts his radio transmitter on the air and makes his radio receiver inoperative. His speech will then be transmitted at radio frequency f_1 to the receiver at the automatic radio relay point, applied to the radio transmitter at that point and delivered by that transmitter at frequency f_2 to the radio receiver at the distant station.

(*2*) The frequencies f_1 and f_2 must be so chosen that the transmitter at the radio relay station cannot capture the receiver at that point because of spurious transmitter radiations or spurious receiver responses (sec. VI). With present sets such as Radio Relay Set AN/TRC-4 and with convenient antenna spacing, such interference is more easily avoided if f_1 and f_2 are at opposite ends of the operating frequency band. Because of the desirability of this frequency separation, individual receiving and transmitting antennas are shown for the terminals also, although a common antenna might be used if the received signals are strong enough to compensate for the fact that the single antenna cannot be adjusted for optimum performance at both f_1 and f_2.

c. Several Radio Relay Sets in Tandem.

(*1*) When more than one radio relay is required, the arrangement shown in figure 6-31 may be used. Two transmitters and two receivers, each with its own antenna, are required at each radio relay point. In order to avoid interference from the transmitters of adjacent sections, which might cause the sys-

[8] The AN/TRC-1 consists of the basic radio components of multichannel radio sets AN/TRC-3 and AN/TRC-4, differing only in that spare transmitters, receivers, and power units are omitted and only the minimum apparatus necessary for single-channel communication is provided. Similarly, the AN/TRC-8 consists of the basic radio components of multichannel radio set AN/TRC-11 and AN/TRC-12.

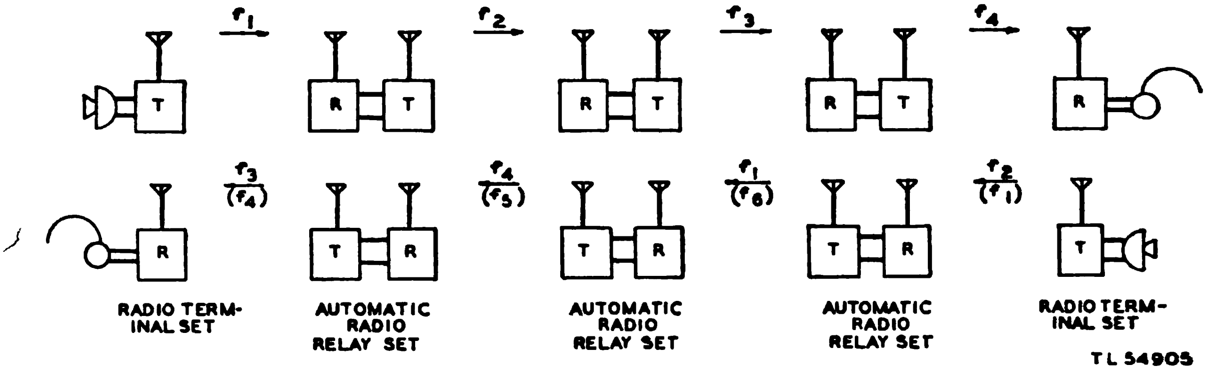


Figure 6-31. Four-section radio communication system for operation with automatic radio relay sets.

tem to lock up, different frequencies must be used in the different sections. However, subject to the distance between radio sets and their disposition within the system, operating frequencies may usually be repeated after the second section, as illustrated in figure 6-31, especially if directional antennas having good front-to-back ratios are used. Four frequencies, as shown, would therefore be sufficient for proper operation if it were not for mutual interference between transmitters and receivers at the radio relay points. With present sets, such as Radio Relay Set AN/TRC-4, it is difficult to avoid such interference unless transmitters and receivers operate in widely different portions of the 70- to 100-mc band, or are separated physically more than is usually convenient (sec. VI). In such cases six frequencies may be required, as indicated by the bracketed values on figure 6-31, where f_1, f_3, and f_5 are at one end of the frequency band and f_2, f_4, and f_6 are at the other end. The number of sections probably can be increased beyond four without increasing the number of frequency assignments beyond six by using the sequence in this manner:

$$f_1-f_2-f_3-f_4-f_5-f_6-f_1-f_2, \text{ etc.}$$

$$f_4-f_5-f_6-f_1-f_2-f_3-f_4-f_5, \text{ etc.}$$

where the upper and lower series correspond with the upper and lower directions of transmission indicated in figure 6-31. The arrangement shown can be used push-to-talk and also permits full duplex operation (both directions simultaneously); the latter is a requirement for multichannel operation. If used for multichannel operation the radio sets must be capable of continuous operation without overheating.

(*2*) With this full duplex arrangement using different frequencies for the two directions of transmission, Telegraph Terminals CF-2-( ) and CF-6 can be used directly on some single-channel radio sets to provide 4 to 12 2-way voice-frequency telegraph circuits (ch. 3).

d. Combination of Automatic and Manual Radio Relays.

(*1*) Another method which requires less equipment is to break the circuit into two or more parts, with each part limited to two sections, and to relay the message by means of

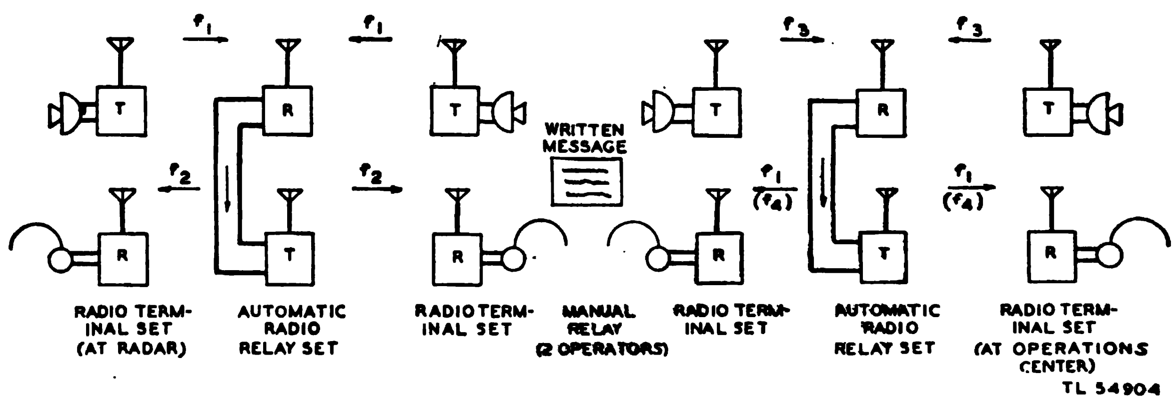


Figure 6-32. Four-section radio communication system, one manual and two automatic radio relay sets.

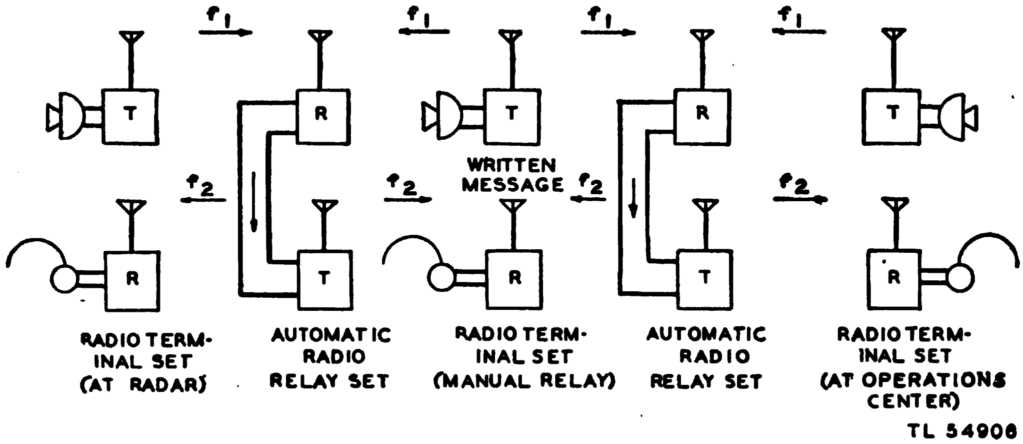


Figure 6-33. Four section radio communication system for light traffic, one manual and two automatic radio relay sets.

operators. For spanning a length of 100 miles over terrain permitting jumps of only 25 miles, the circuit would be broken into two parts with manual relaying at the middle point. The number of frequencies required will depend on the quantity of traffic which the circuit is required to handle.

(*2*) Figure 6-32 shows a 3-frequency arrangement such as might be used at an air warning system operations center for handling heavy traffic incoming from a radar. Frequencies f_1 and f_2, also f_1 and f_3, must be chosen to avoid capture of the radio receiver by its associated transmitter at the automatic radio relay stations (sec. VI). It is believed that most satisfactory operation would be secured by using two operators. In the direction from a radar to the operations center, one of the operators at the manual relay station can continuously receive information from the radar, while the other operator can continuously transmit to the operations center the information written down by the first operator. Thus, the manual relay operation does not impede the traffic flow although it does introduce a small time lag. If the direction of traffic flow should reverse, a frequency f_4 would have to be used, as shown in brackets in figure 6-32; otherwise interference would result at the manual relay point unless special operating procedures were used.

(*3*) Figure 6-33 shows the 2-frequency arrangement for handling light traffic. Frequencies f_1 and f_2 must be so chosen as to avoid capture of the radio receiver by its associated transmitter at the automatic radio relay station (sec. VI). In this case the operator at the manual relay point would no longer be able to receive and send at the same time. This arrangement, therefore, appears unsuitable for general use where speed is required, although it might be satisfactory in some emergencies. It should be noted that this method of manual relaying requires only one radio transmitter and one radio receiver at the manual point, but one operator would be able to handle the traffic without undue fatigue for only limited periods.

e. Received Field Intensities Required for Several Single-channel Radio Relay Sections in Tandem.

(*1*) For f-m systems, when the field intensity is close to the minimum permissible for single-channel point-to-point telephone circuits, a small increase in field intensity will produce a large increase in audio signal-to-noise ratio. For this reason and for reasons outlined in subparagraph (2) below, the increase in received field necessary for such circuits to allow for several radio relay sections, or jumps, in tandem, is generally negligible. Single-channel v-h-f radio telephone systems are generally operated on a point-to-point basis or on a basis equivalent to this from the standpoint of required signal-to-noise ratio.

(*2*) When there are several jumps it is frequently the case that one of the jumps will contribute a controlling amount to the noise at the terminal. In this case, the allowance for the contribution of the other jumps is negligible, whether the transmission is amplitude modulation or frequency modulation.

(*3*) For amplitude-modulated systems, when a number of jumps contribute an approximately *equal* amount to the noise at the terminal, the required received field intensity at each radio receiver is increased, the amount of increase in db being 10 log N, where N is the number of jumps. The necessary increase for particular values of N is as follows:

N	2	3	4	5	6	8	10
db increase	3	5	6	7	8	9	10

622. V-H-F MULTICHANNEL SYSTEMS.

a. General.

(*1*) Radio systems, like wire circuits, can be designed to transmit several telephone conversations simultaneously by the addition of carrier equipment. Such radio systems must be in operation continuously rather than on a push-to-talk basis and must use different frequencies for the two directions. Telephone circuits obtained in this way may be connected to a switchboard in the same manner as wire circuits and thus form a part of the regular telephone network. Such radio systems may be used in tandem with wire circuits, with the carrier frequencies passing over both the wire and radio sections. *In such cases security rules for radio rather than for wire lines must be observed by users.* Such a system may be used as an adjunct to wire in order to span some difficult terrain, such as a water crossing, or it may be used as a complete unit in order to obtain long-distance trunks which are primarily radio. The discussion below relates primarily to the latter type of use.

(*2*) The use of 4-channel radio relay systems instead of wire systems provides substantial savings in installation time and weight and bulk of equipment, including outside plant, required for a given number of communication channels. The radio relay systems have been found very advantageous for use during a rapid advance. A comparison between them and wire systems is given in TM 11–487. A general comparison between wire and radio is in chapter 1 of this manual.

b. System Using Radio Terminal Sets AN/TRC–3 and Radio Relay Sets AN/TRC–4.

(*1*) An available 4-channel radio relay communication system consists of Radio Terminal Sets AN/TRC–3 and Radio Relay Sets AN/TRC–4, together with Telephone Terminal Sets TC–21 and Ringer Sets TC–24 for obtaining four telephone channels, and Telegraph Terminal Sets TC–22 if it is desired to superpose voice-frequency telegraph on one or two of the telephone channels (preferably on channel 3). The system operates with frequency modulation in the frequency band 70 to 100 megacycles, with a nominal power output of 50 watts. The modulating frequencies range from about 200 to 12,000 cycles. A schematic illustration of a system is given in figure 6-34. The radio relay sets and radio terminal sets are described in TM 11–2601. Photographs of these sets are in figures 6-35 and 6-36. System line-up procedures are described in TB SIG 78.

(*2*) The nominal spacing between radio sets is 25 miles, but the actual spacing will depend considerably on the type of terrain, an-

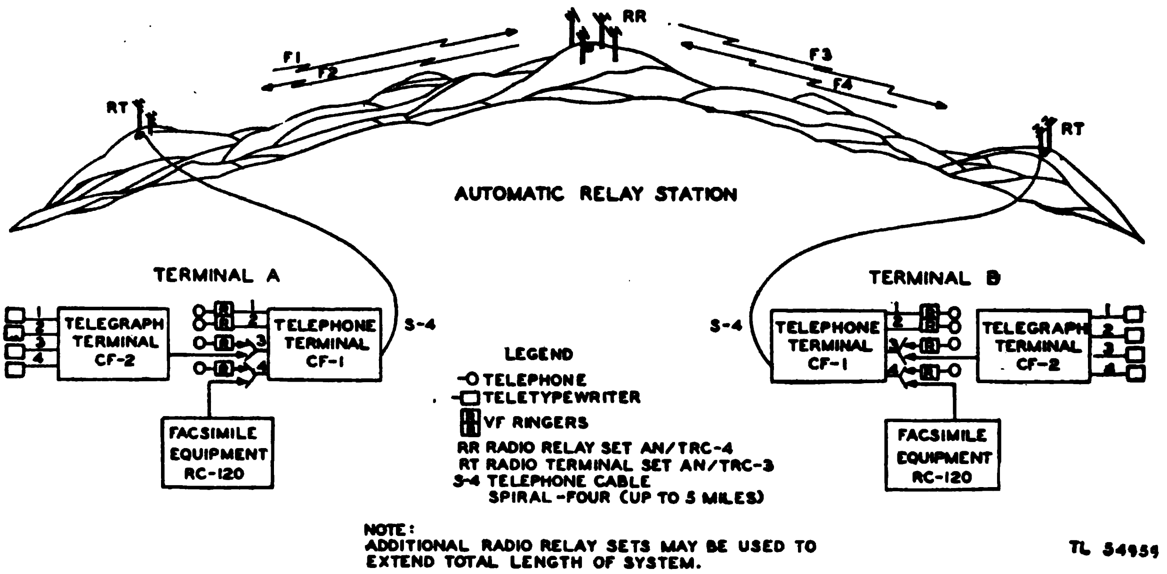


Figure 6-34. Schematic illustration of 4-channel radio relay communication system.

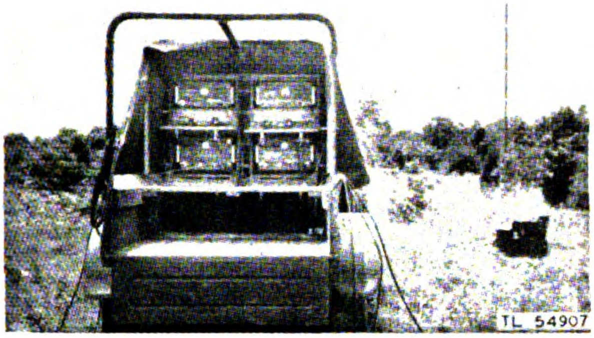


Figure 6-35. Radio Relay Set AN/TRC-4 prepared for operation in Truck, Weapons Carrier, ½-ton, 4 x 4.

tenna siting, and method of using the circuit, as discussed earlier in this section and in following subparagraphs. A 250-watt amplifier designated as Amplifier Equipment AN/TRA-1, described in TM 11-2601, gives a nominal transmitting gain of 7 db. In general, four or more radio frequencies are required for radio relay operation, as discussed in paragraph 621c. These frequencies must be very carefully chosen to prevent mutual interference between the various radio transmitters and receivers (sec. VI). Because of the use of different operating frequencies in the two directions of transmission, four antenna systems are required at each radio relay set and two at each radio terminal set.

(*3*) Channel 1, which is the voice channel of the spiral-four carrier system using Telephone Terminal Sets TC-21, is the only channel which is brought down to voice frequency at radio relay points, and is therefore the only one available for use as an order wire between these points and the radio terminal sets. When channel 1 is also used as a telephone circuit connected into switchboards, routines for message priority between switchboard and order wire must be established. Channel 1 is normally not used to provide facsimile or voice-frequency telegraph circuits.

(*4*) In order to permit advantageous siting of radio terminal sets, provision is made for separating them from the telephone terminals by as much as five miles of spiral-four cable (Cable Assemblies CC-358-( )). In such cases, local order wire circuits between telephone and radio terminals are provided over the phantom of the spiral-four cable.

c. System Using Radio Terminal Sets AN/TRC-11 and Radio Relay Sets AN/TRC-12. Another 4-channel radio relay system consists of Radio Terminal Sets AN/TRC-11 and Radio Relay Sets AN/TRC-12, used together

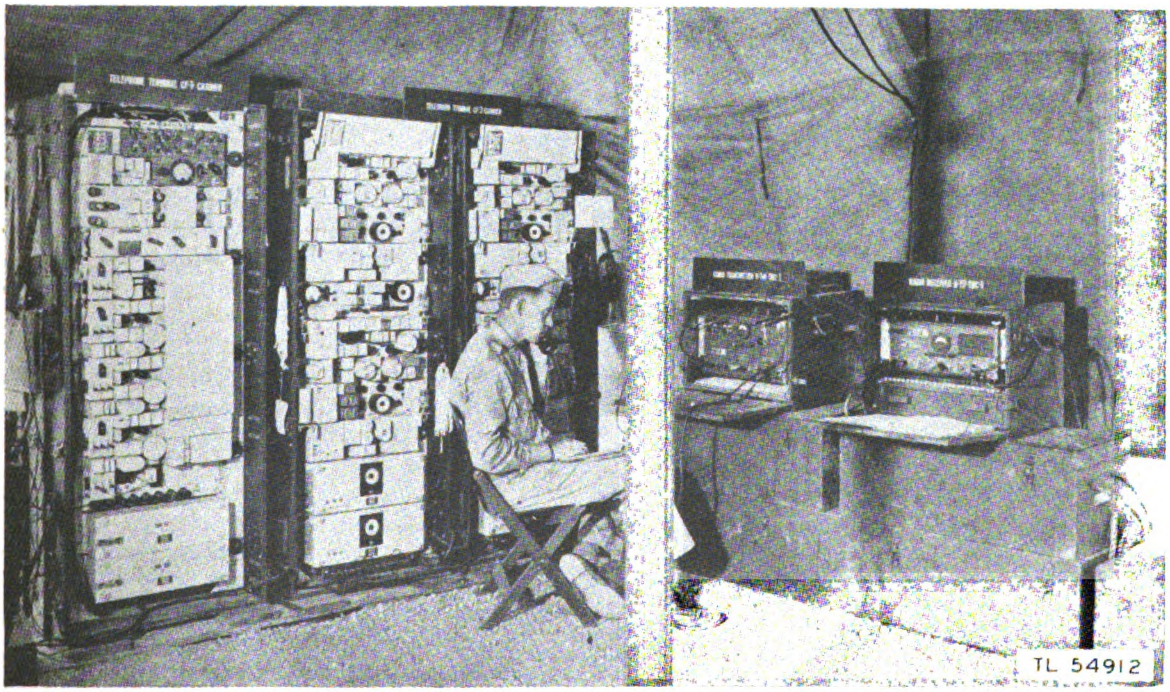


Figure 6-36. Radio terminal station of 4-channel radio relay system, (showing Telephone Terminal CF-1-( ), Telegraph Terminal CF-2-( ), and Radio Terminal Set AN/TRC-3).

with Telephone Terminal Sets TC–21 and Ringer Sets TC–24 to derive the telephone channels and with Telegraph Terminal Sets TC–22 for superposed voice-frequency telegraph. This system operates with frequency modulation in the frequency band 230 to 250 megacycles with a nominal output power of 12 watts. Further details are in TM 11–618.

d. Multichannel Versus Single-channel Operation. When several radio circuits are required between two given points, multichannel operation will result in a considerable saving in required equipment and personnel, and in the number of radio frequency assignments, as compared to what would be needed for single-channel operation. The advantage is not, however, as great as might be expected on first thought, since the percentage modulation of each channel must be substantially less than would be permissible for single-channel operation; otherwise the total modulation resulting from signals on the different channels would exceed 100 percent, thus overloading the system and causing excessive interference from one channel into another. The required lowering of modulation level per channel, for the 4-channel systems discussed above, is of the order of 12 db. As a result of this, together with the higher noise on the top channel of a multichannel f-m system, the received field intensity must be higher for multichannel than for single-channel operation, by an amount depending on the quieting action of the f-m receiver under the particular circumstances. It is thought that on the average a 10-db increase in received field intensity, for 4-channel compared to single-channel operation, will suffice to make the signal-to-noise ratio on channel No. 4 as good as that for single-channel operation. (Channels 1 to 3 will be better than channel 4 by various amounts. Effects of imperfect equalization are considered separately in subparagraph h below.) Hence the allowable distance between relay points, and the total distance which can be satisfactorily spanned with a given number of sets, is less for 4-channel than for single-channel operation. Also a 4-channel system requires more careful maintenance than a single-channel system.

e. Received Field Intensities Needed for Multichannel Multijump Operation.

(*1*) With the received field intensity required for satisfactory 4-channel operation with existing sets, it is thought that further increases in received field intensity will result in roughly equal increases in audio signal-to-noise ratio in the upper channels. With more than one relay section or jump per system, if all of N jumps have the same received field intensity, the required db increase in received field intensity for each jump is 10 log N, while if one of the jumps controls the received audio noise, which is more apt to be the case, no increase is necessary. For values of 10 log N, see paragraph 621e (3).

(*2*) When a trunk consists of one or more radio relay sections (jumps) in tandem with one or more wire repeater sections, each wire repeater section can be considered as the equivalent of a radio jump in finding the required received field intensity on the radio portion of the circuit.

f. Operation as Via Trunks.

(*1*) When radio relay systems form a part of the regular telephone network and are used as via trunks for switched telephone service, a further increase in received field intensity is necessary in order to provide an adequate speech-to-noise ratio when the trunks are operated in tandem. When the trunk in question is the end trunk in the circuit, the speech from the distant talker is attenuated by the loss of the intervening trunks. In the typical arrangement shown in the transmission plan in chapter 2, there are three 6-db trunks in tandem, and the distant talker's speech would be lowered by the loss of two intervening trunks, or 12 db, before reaching the trunk in question. In order to compensate for this loss, the noise on this trunk must be lowered 12 db. That is, in order to provide a just tolerable ratio of received speech-to-noise on the built-up connection, the last trunk must be designed such that its noise contribution is 12 db lower than if it were not designed for use in tandem with two other trunks. In general, if the trunk is designed for use as an end trunk in tandem with other trunks whose net losses total X db, the noise requirement on the end trunk is stiffened by X db. In the above, the contribution of trunks other than the end trunk to the noise received by the listener is small and has been disregarded. To obtain a 12-db improvement in audio signal-to-noise ratio on a given multichannel radio system, the received field intensity should be increased by about 12 db. The resulting required field intensities are high enough to require excellent antenna siting in order to obtain radio relay systems as long as 100 miles and capable of operating as via trunks in the regular telephone network.

(*2*) When v-f telegraph is used on one or two of the four telephone channels, the above requirements are not changed.

g. Interchannel Crosstalk, General. In the existing multichannel radio relay systems, the interference from one channel into another (interchannel crosstalk) is relatively high compared to that on comparable wire systems. This depends on the linearity of the system; it is approximately independent of the length of radio relay sections, but increases with the number of relay sections. Overloading of the transmitters increases the interchannel crosstalk. On this account it is very important to carry out the line-up procedures given in TB SIG 78.

h. Equalization Limitations. Another limitation of these systems is equalization of the transmission of different frequencies. If the gain in a particular channel is greater than that at the line-up frequency of 4,900 cycles (which corresponds to 1,000 cycles at voice frequency in channel 2), signals in the channel in question tend to overload the system. If the gain in a particular channel is lower than that at the line-up frequency, the gain deficiency can be made up only at the receiving end if standard arrangements are employed, and when it is made up, the noise and interchannel crosstalk are increased about as much as the received speech. Frequency characteristics of individual radio relay and radio terminal sets vary; but there is a general tendency for channel 3 to have higher gain, and channels 1 and 4 lower gain, than that at the line-up frequency. On the basis of early production models it has been estimated that channel 4 of AN/TRC–3 and –4 should not be used for more than three jumps between terminals (later models may do somewhat better than this) and that channels 1 to 3 should not be used for more than seven jumps between terminals. Comparable data on AN/TRC–11 and –12 were not available at the time when this manual was prepared.

i. Methods of Improving Equalization or Interchannel Crosstalk.

(*1*) The first steps to take are careful maintenance procedures: to see that the circuit is kept carefully lined-up (per TB SIG 78 in the case of Radio Terminal Set AN/TRC–3 and Radio Relay Set AN/TRC–4); that adequate signal voltages are being received, through proper siting, careful adjustment and orientation of antennas, and careful alignment of individual receiver stages; and that vacuum tubes and line voltages have been carefully checked.

(*2*) If interchannel crosstalk is objectionably high after the above steps have been taken, and if other noise is relatively low (for example, if this noise is mainly set noise and if the received field intensity is safely above the required minimum values given in figure 6-12), then an improvement can be obtained by lowering the degree of modulation. It has been found that if the audio signals fed into the radio system are lowered in level by 5 db the interchannel crosstalk will be reduced by about 10 db, and thus the ratio of speech to interchannel crosstalk will be improved by about 5 db. In order to keep the net loss of the circuit unchanged, the audio gain at the receiving radio terminal is increased by the same amount (5 db) that the audio transmitting level is lowered. This produces a 5-db increase in the noise (other than interchannel crosstalk) on the radio channel; however, if this noise was small to begin with, there is a net improvement in the circuit. Methods of lowering the audio signal level fed into the radio system are as follows. Where there is sufficient spiral-four cable between carrier terminal and radio terminal, the levels on the system may be lowered by setting the *cable compensator* in the transmitting radio terminal at an increased loss (that is, on a lower step). When the *cable compensator* is on the lowest step and still more loss is required, a balanced pad (ch. 12) may be inserted just ahead of the transmitting radio terminal.

(*3*) The *0 dbm* mark on the panel meter on some Radio Receivers R–19/TRC–1 may be as much as 2 db in error. If this condition occurs the radio transmitters may be inadvertently overmodulated. This can be avoided by making an accurate recalibration of the panel meters.

(*4*) Channel 4 can be discarded if the number of jumps is too great to permit its use.

(*5*) With a large number of jumps, the equalization can be improved by inserting, at the relay station nearest the middle, two Telephone Terminals CF–1–( ), back to back, that is, with their voice-frequency sides connected together. This permits the level at the 1,000-cycle point of each telephone channel to be adjusted independently. The telephone terminals should be connected on a 4-wire basis (ch. 5); or if temporarily connected on a 2-wire basis they should be mounted close to each other and connected directly to each other with no bridged apparatus, and the monitoring jacks of the two Telephone Terminals CF–1–( ) should not be used, so as to prevent singing of the telephone circuits. The transmission levels should be adjusted so that each jump except the last is operating at 0-db nominal net loss and the last is operating at 6-db net loss. In some cases it may be possible to use, instead of the two Telephone Terminals CF–1–( ), a single Telephone Repeater CF–3–A; the adequacy of this expedient will depend on the transmission-frequency characteristics of the particular radio relay and terminal sets which happen to be included in a given system, and can be determined only by trial.

(*6*) Where traffic conditions warrant, it may be practicable to arrange radio relay systems so as to provide direct rather than switched connections between long-distance centrals, thus avoiding the 6-db loss in received speech volume produced by each added tandem trunk.

(*7*) Where very many jumps are required, it may be practicable to employ v-f telegraph instead of speech transmission. For this purpose, Telegraph Terminal Sets TC–22 can be used directly into Radio Terminal Sets AN/TRC–3. By using two telegraph terminal sets at each radio terminal, eight 2-way telegraph channels can be used for about ten jumps. Further information on the use of carrier telegraph over radio circuits is in chapter 3.

Section III. V-H-F ANTENNAS

623. GENERAL.

a. Antennas for use in the v-h-f band may be classified as either directional or nondirectional. Nondirectional antennas transmit and receive equally well in all horizontal directions. Directional antennas transmit and receive better in some horizontal directions than in others, and are usually more efficient in the desired direction than a nondirectional antenna at the same elevation. (The word *directional* is used with a different meaning in the h-f band, where vertical directivity for sky waves is important.) Directional antennas which consist of multiple elements are sometimes called *arrays.*

b. The nondirectional types are used in situations where communication is required in a variety of compass directions. This requirement, plus mechanical advantages, is the reason for using vertical whip antennas on mobile and portable radio sets where the tactical situation is apt to involve communication in any direction. The directional types provide more efficient transmission over fixed paths.

c. Antennas are available for transmitting and receiving either horizontally or vertically polarized waves (par. 619). In areas where numerous v-h-f sets must operate with little separation between antennas, the use of vertical polarization on some circuits and horizontal polarization on others is one measure which may be used to reduce mutual interference. In all cases, however, antennas capable of utilizing the same type of polarization should be used at both ends of a radio circuit, or serious loss in transmission will result.

d. In this section, the advantages of directional antennas are summarized briefly before discussing specific antenna types. Descriptions of a number of the more common antenna types are then given, including some nonstandard types which might be used in an emergency. The nondirectional types are discussed in paragraphs 626 to 631, and paragraphs 632 to 636 cover the directional types. General information on v-h-f antenna dimensions follows, and the section concludes with data on r-f transmission lines, including a line which may be improvised from field wire (pars. 637 and 638). Further information on antennas and antenna coupling arrangements is available in TM 11–314 and TM 11–487.

624. ADVANTAGES OF DIRECTIONAL ANTENNAS.

a. General. For communication between fixed or semifixed installations, directional antennas may be used to increase the distance range. Such antennas can be obtained in convenient size for the middle and upper portions of the v-h-f band.

b. Signal Gain. As transmitting antennas, the directional types radiate stronger fields in the desired direction than simple dipole antennas at the same effective elevation above the earth, and as receiving antennas they extract more energy from the passing field. These gains amount to from 6 to 10 db at each end of the circuit for some of the types illustrated in later paragraphs.

c. Signal-to-noise and Signal-to-interference Ratio.

(*1*) *General.* The gain of a directional receiving antenna provides an equivalent improvement in r-f signal-to-noise ratio when set noise is the controlling source of noise. When external random noise coming in from all directions is controlling, the use of a directional antenna may also improve the r-f signal-to-noise ratio by as much as 10 db, by rejecting noise from many directions. When radio interference exists, directional receiving antennas are of no advantage if the interfering source is in the same direction as the distant transmitter. However, large improvements in signal-to-interference are possible if the interfering source is localized in a given direction and the antenna can be oriented so that this direction corresponds with a minimum in the directional pattern.

(*2*) *Effect of Unbalanced R-f Transmission Line.* Some tactical v-h-f balanced antennas are fed through directly-connected unbalanced coaxial transmission lines. With such unbalanced connections, currents will tend to flow on the outer surface of the coaxial lines, and undesired radiation (or response) will take place. This radiation may not seriously affect the major lobes in the directional pattern of an antenna, but will tend to fill in the nulls. For example, if the antenna is horizontal and the coaxial down lead is vertical, measurements of the horizontally polarized directional pattern will probably indicate little difference from that obtained using a well balanced transmission line. The down lead, however, may be radiating relatively strong *vertically* polarized waves. Thus, in situations where directivity is a means utilized to reduce mutual interference between nearby sets, orientation of antennas to take advantage of expected nulls in the antenna patterns may be ineffective, since the major coupling may be between the down leads, the radiation patterns of which are nondirectional. Also, with sets in close proximity in the same building, stray currents on the transmission lines may cause direct coupling at the sets, independent of that caused by radiation. Balancing arrangements which reduce current flow on the outer surface of the coaxial line are standard with some antenna types described below, and are recommended for use in the above situations.

d. Security. The use of a directional antenna does not guarantee security. However, directivity of a transmitting antenna is desirable, since the energy may be concentrated in a given direction, thus reducing the chances of interception.

625. TACTICAL V-H-F ANTENNAS.

a. There are a variety of v-h-f antennas whch are used both for transmitting and receiving. In many applications the antenna associated with a set is switched from receiver to transmitter on a push-to-talk basis.

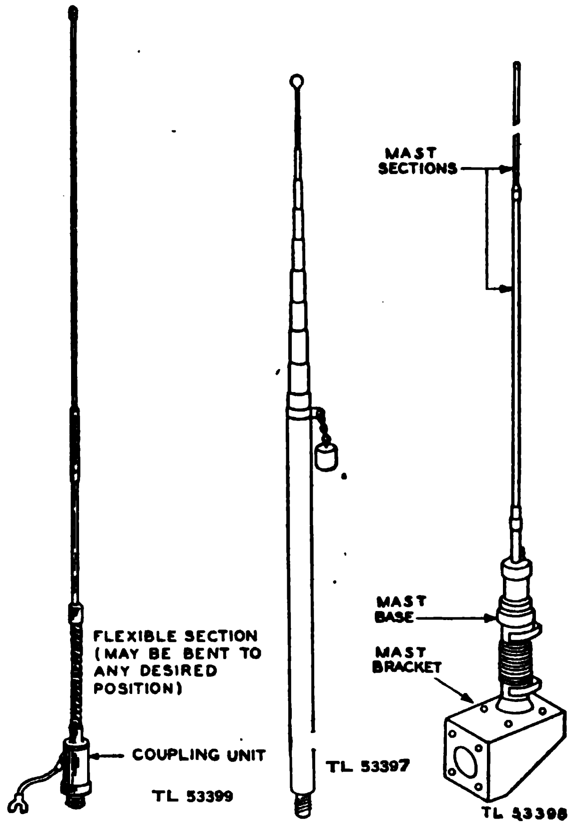


Figure 6-37. Typical whip antennas.

b. Tactical radio sets are equipped with specific antennas for which the output circuits were designed. The use of a different antenna in an effort to improve transmission may make matters worse, unless proper leads and coupling units are used to match the new antenna impedance. Standard antenna couplers have been provided for some sets which permit the use of antennas other than those for which the sets were designed. These arrangements are briefly discussed in connection with the antenna types involved.

626. WHIP ANTENNA.

The whip antenna illustrated in figure 6-37 is the most commonly used v-h-f antenna where the distances to be covered are relatively short, and where portable or mobile operation is of primary importance. Since a considerable portion of tactical radio communication comes within this category, the whip antenna finds wide application. This antenna should be used in a vertical position, and is then nondirectional. As commonly used, the antenna length may lie between quarter-wave and half wavelength for frequencies in the neighborhood of 30 megacycles, and half wavelength for frequencies above about 40 megacycles. (Half-wave whips have a gain in horizontal directions, of about 2 db over a quarter-wave whip at all frequencies, but are of prohibitive size at the lower frequencies.) If a standard whip is broken, a piece of wire of equal length supported vertically may be used.

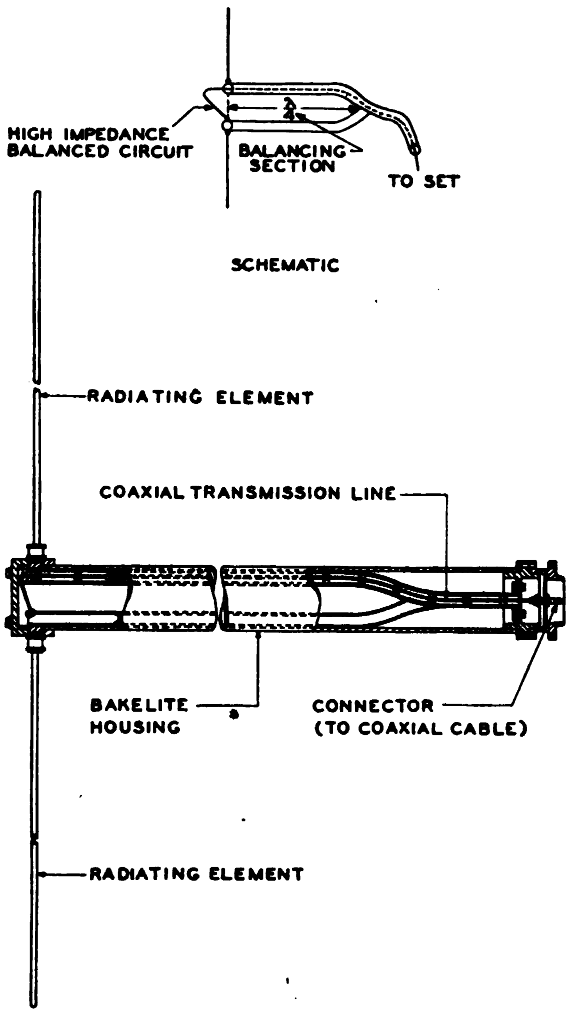


Figure 6-38. Balanced half-wave dipole antenna (part of Antenna Equipment RC-81).

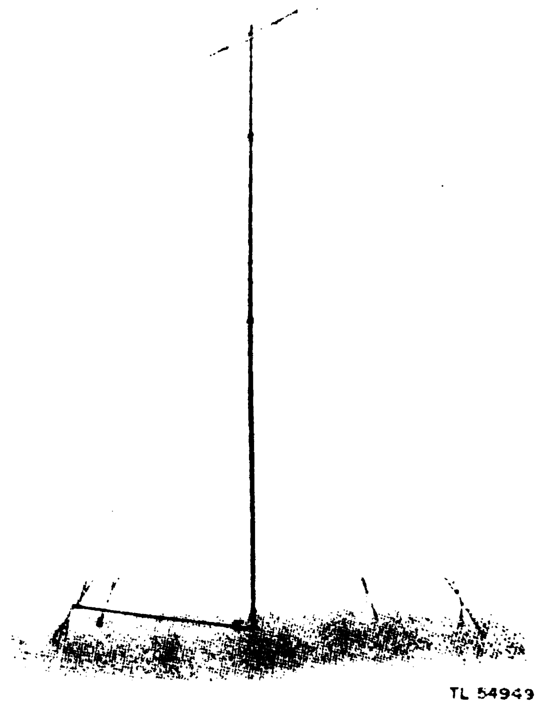


Figure 6-39. Antenna Mast AN-56-A supporting two Antenna Equipments RC-81.

627. HALF-WAVE DIPOLE ANTENNA.

a. The vertical half-wave dipole antenna illustrated in figure 6-38 is fed at the center with a low impedance (50 to 70 ohms) coaxial cable through a balancing section illustrated more clearly in the schematic. The balancing section is approximately one quarter wave in length shorted at the point where

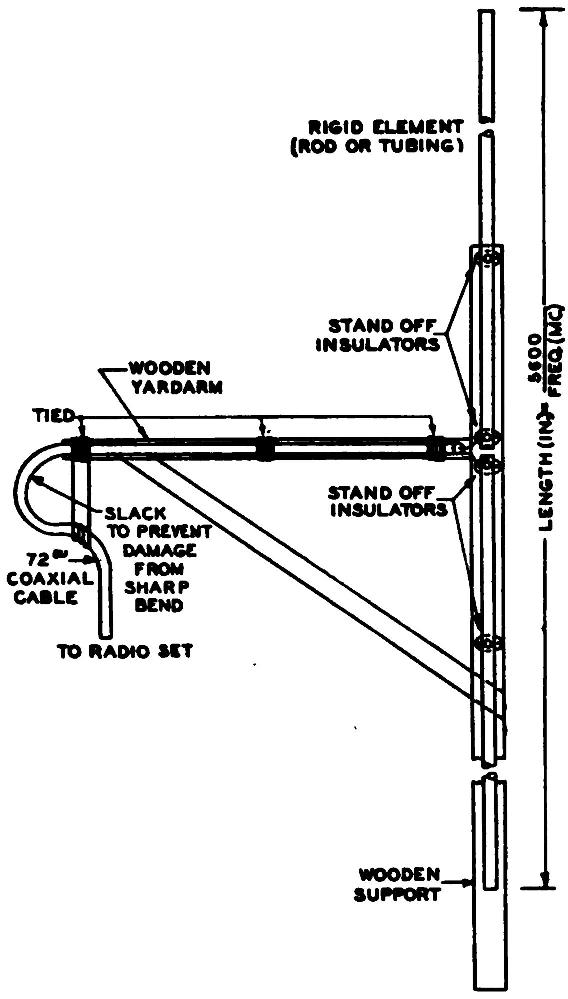


Figure 6-40. Improvised half-wave dipole antenna.

the flexible transmission line connects, thus presenting a high balanced impedance as seen from the dipole. Such construction minimizes current flow on the outer surface of the transmission line. This antenna is supplied as Antenna Equipment RC–81 with Radio Transmitting Equipment RC–257 operating in the 100- to 156-mc band. Figure 6-39 illustrates two such antennas mounted on Antenna Mast AN–56–A.

b. Dipole antennas may be improvised for emergency use, using materials found in the field. Such antennas are shown in figures 6-40 and 6-68. When used vertically, this antenna type should be provided with a wooden support to the feed cable (as illustrated), extended out at right angles to the antenna for a distance of a quarter wavelength or so. This spacing is to reduce the effect of the vertical transmission cable on the radiation field of the antenna. The total length of the antenna should be adjusted to 95 percent of half wavelength for the operating frequency, but this length is not crictical of adjustment and may vary ± 5 percent without adverse effects on transmitting or receiving, provided that the transmitter will load properly. When used vertically, the antenna is nondirectional in a horizontal plane. When used horizontally, the antenna has directional characteristics, the optimum direction being at right angles to the

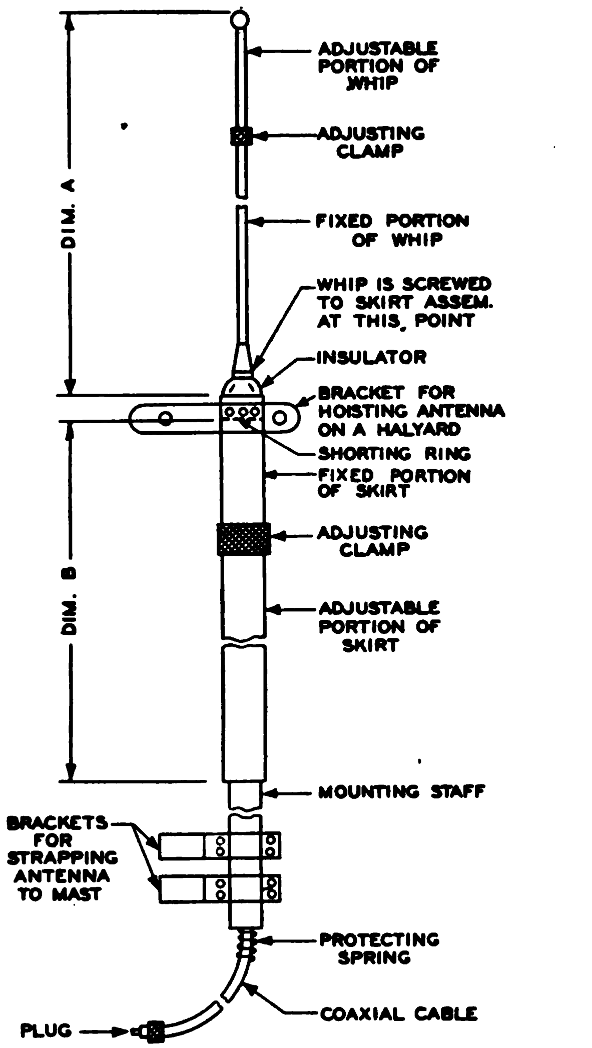


Figure 6-41. Adjustable vertical coaxial antenna.

antenna wire on either side. The pattern width is 90 degrees at points 3 db down from maximum and 120 degrees at points 6 db down from maximum.

628. VERTICAL COAXIAL ANTENNA.

a. The type of antenna illustrated in figure 6-41 is provided in P–8212 antenna kit (Galvin Manufacturing Company nomenclature, Signal Corps stock No. 2A1640) as part of the equipment associated with Radio Sets AN/CRC–3 and AN/CRC–3A (30 to 40 mc); similar antennas type 1509 (F. M. Link Company nomenclature, Signal Corps stock No. 2A272–3) are also used with type 1498 and 1505 radio transmitter-receivers (70 to 100 mc). It is essentially a vertical half-wave dipole antenna constructed so as to provide a convenient mechancial feed arrangement by means of a 50-ohm flexible coaxial cable transmission line which runs up through the supporting staff. The skirt, when adjusted in accordance with instructions, acts as the lower half of the radiator and also minimizes current flow on the outer surface of the transmission cable. For optimum performance, this antenna requires readjustment of the whip and skirt lengths when the frequency is changed more than ± 1 percent from that for which the antenna was previously tuned; the skirt length adjustment is more critical than that of the whip. Complete instructions for these adjustments are packed with each antenna, and the elements of the P-8212 antenna kit are marked at quarter-megacycle intervals. These adjustments are approximately 95 percent of a quarter wave for the whip and about 100 to 103 percent of a quarter wave for the skirt. The latter dimension is measured from the bottom of the shorting ring, and if a calibration is not available or is illegible, a cut and try procedure in the 100 to 103 percent range to obtain an optimum adjustment may be worthwhile on a marginal circuit. Although constructed for vertical operation, this antenna may be operated horizontally, at some inconvenience in mounting, if horizontal polarization is required.

b. If this antenna is used with sets designed to operate into high impedance antennas, an impedance matching transformer should be used between the set and the 50-ohm antenna r-f transmission line. For example, such a coupling unit is included in P-8212 antenna kit (Galvin Manufacturing Company nomenclature) for use with Radio Set SCR-609, as illustrated in figure 6-42.

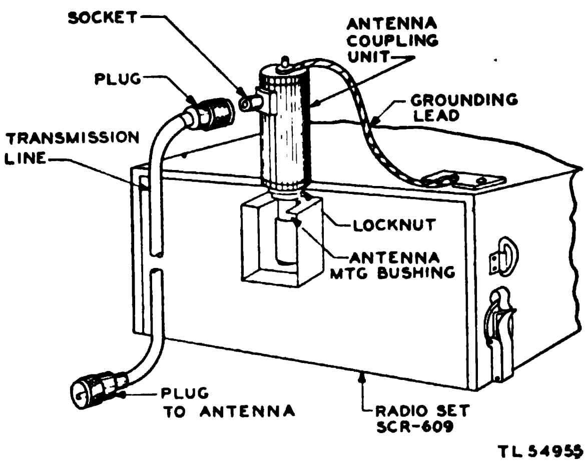


Figure 6-42. Coupling unit, used to match Radio Set SCR-609 transmitter output impedance to 50-ohm coaxial transmission cable.

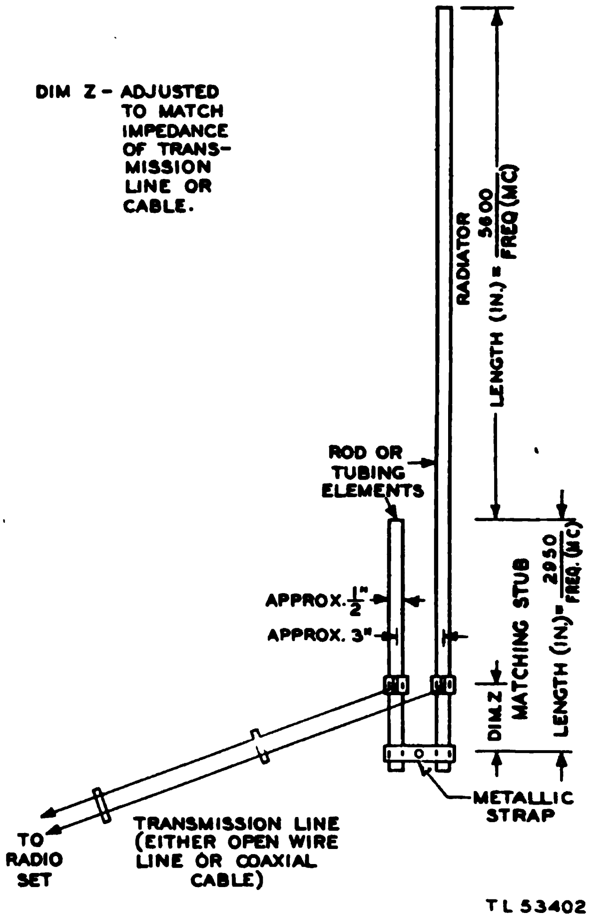


Figure 6-43. Improvised vertical "J" antenna.

629. VERTICAL "J" ANTENNA.

The nondirectional antenna illustrated in figure 6-43 consists of a vertical half-wave antenna with a quarter-wave matching stub directly connected to the lower end. This stub acts as a transformer for matching the impedance of the transmission line to the antenna. The transmission line may be an open wire line or coaxial cable. For low-impedance transmission lines, the connection for optimum impedance matching will be close to the metallic strap, and for cables of 70-ohm impedance or less it will usually be necessary to remove the strap and connect directly to the lower end of the matching stub. The location of the transmission line on the stub, the length of the stub, and the length of the half-wave radiator all require adjustment when the operating frequency is changed. The antenna illustrated in figure

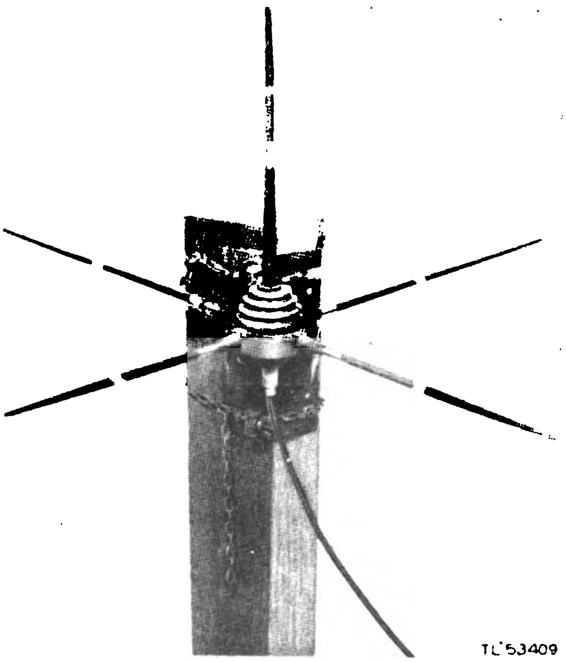


Figure 6-44. Ground-plane antenna (antenna of Antenna Equipment RC–291).

6-43 is one which may be improvised. An adjustable antenna of this general type is used with Radio Set SCR–624–A.

630. GROUND-PLANE ANTENNAS.

a. The antenna illustrated in figure 6-44 consists of a quarter-wave vertical whip working against a rod structure simulating a ground plane (Antenna Equipment RC-291).

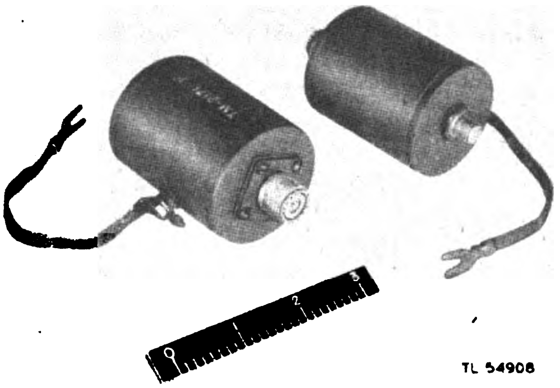


Figure 6-45. Coupling unit (Terminal Box TM–217), used to match Radio Set SCR–300 transmitter output impedance to a 50–ohm coaxial transmission cable.

This antenna is nondirectional and is to be used with Radio Set SCR-300 (40 to 48 mc) in applications where elevated antennas rather than whips are especially desired, as in a jungle. It is assumed that a suitable support will be found available in the field. The antenna is fed through a 50-ohm flexible coaxial cable, and the equipment includes an impedance-matching coupling unit (Terminal Box TM-217) for connection between the set and the coaxial transmission line, as shown in figure 6-45.

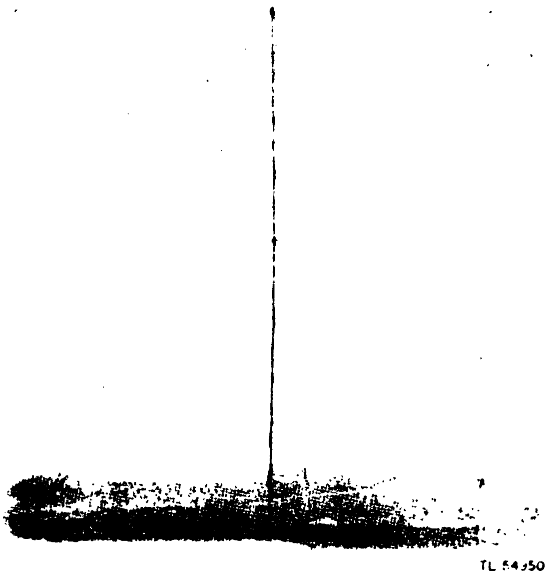


Figure 6-46. Antenna Equipment RC–292 (for use in fixed installations of Radio Sets SCR–508 and SCR–608).

b. The antenna illustrated in figure 6-46 is a nondirectional vertical antenna designed for use in the 20- to 40-mc band with Radio Sets SCR-508, SCR-528, SCR-608, and SCR-628 in fixed locations where elevated antennas can be used to advantage. It is directly connected to these sets through a flexible coaxial cable and is supported on a 30-foot mast. While classified as a ground-plane antenna, radiation also takes place from the lower elements as well as the whip. The model shown is known as Antenna Equipment RC-292; a similar antenna coded Antenna Equipment RC-296 is under development for use with Radio Set SCR-300 and will include a coupling unit (Terminal Box TM-217) between the set and the coaxial transmission line.

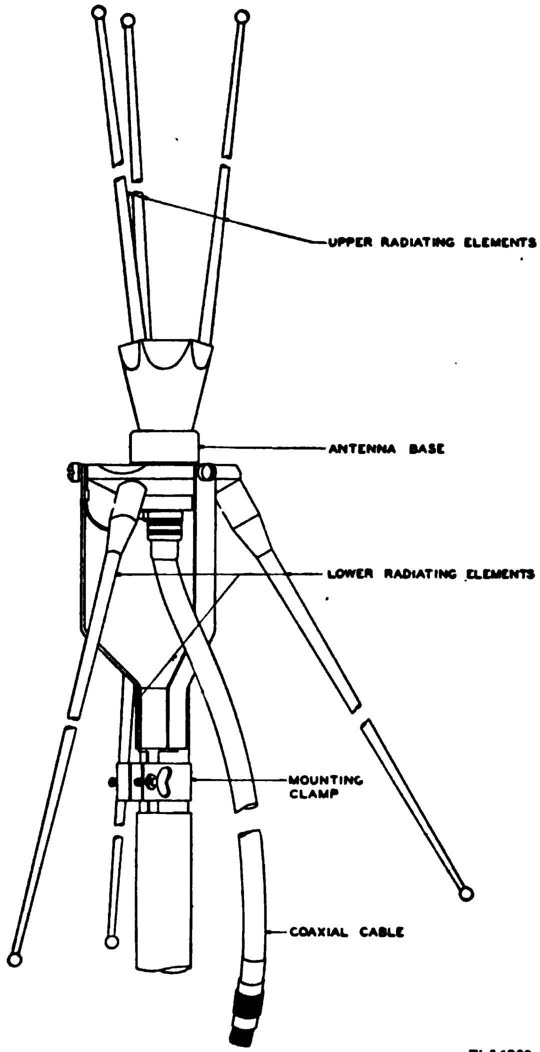


Figure 6-47. Antenna of Antenna Assembly AS-110-( )/TRC-7 (used with Radio Set AN/TRC-7).

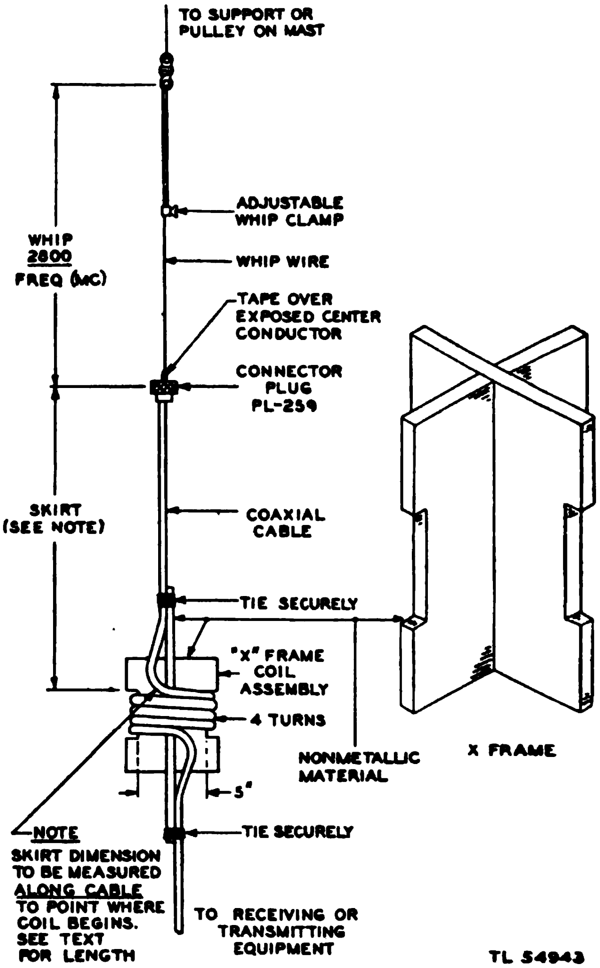


Figure 6-48. Improvised flexible dipole antenna.

c. The antenna illustrated in figure 6-47 is a broad-band, light-weight, nondirectional antenna for use in the frequency band of 100 to 156 mc. It is classified as a ground-plane antenna, but in this construction the lower elements contribute to the radiation as well as the upper elements. Antenna Assembly AS-110-( )/TRC-7, normally furnished as a part of Radio Set AN/TRC-7, includes an antenna of this type. The antenna is fed through a 50-ohm solid dielectric flexible r-f cable.

631. FLEXIBLE DIPOLE ANTENNAS.

a. The flexible dipole or *limp* antenna, illustrated in figure 6-48, is a nonstandard antenna similar to the coaxial type in that the feed is introduced up through the lower half of the antenna. The illustration is for an antenna designed to operate in the 27- to 40-megacycle band. The coil which is wound in the coaxial transmission line provides a tuned circuit consisting of inductance and distributed capacitance, and as such introduces a high impedance which forms the base of the skirt and reduces undesirable radiation from the transmission line below the coil. The input impedance is similar to that of a half-wave dipole.

b. This antenna is not a production item, but is described here because it provides an antenna which can be improvised in the field in an emergency, with material which is frequently available.

c. For the 27- to 40-mc antenna, the coil consists of *exactly* four turns of coaxial cable closely wound on an X-frame consisting of two 5-inch boards at right angles to each other (or on a cylindrical nonmetallic form 5 inches in diameter). The coil remains fixed at four turns and the whip wire and skirt lengths are adjusted to appropriate values over the frequency band, as shown in figure 6-49.

Megacycles	Length (inches)	
	Whip	Skirt
27	108	119
28	103	111
29	98	103
30	94	96
31	91	89
32	88	82
33	85	77
34	82	72
35	80	67
36	78	64
37	76	62
38	74	59
39	72	58
40	70	56

Figure 6-49. Dimensions of 27- to 40-mc flexible dipole antenna.

d. For the 40- to 48-mc antenna, the coil is wound on a 3-inch cylindrical form (or X-frame of equivalent diameter). In this more recent design, the skirt length remains fixed at 57.5 inches, the whip length is adjusted to 95 percent of a quarter wave, and the number of coil turns are varied. The coil turn adjustment is much simpler to make in the field than the skirt length adjustment outlined above for the 27- to 40-mc antenna. The calibration over the frequency band is given in figure 6-50.

Megacycles	Whip length (inches)	Number of coil turns
40	70	12
41	68.5	11
42	67	9
43	65.5	8
44	64	7
45	62.5	6
46	61	6
47	59.5	5
48	58.5	5

Figure 6-50. Dimensions of 40- to 48-mc flexible dipole antenna.

e. For the 70- to 100-mc antenna, the coil is wound on a 2-inch cylindrical form (or X-frame of equivalent diameter). The skirt length is fixed at 29.5 inches and the whip length and number of coil turns are varied over the frequency band as shown in figure 6-51.

Megacycles	Whip length (inches)	Number of coil turns
70	40	12
75	37.5	8
80	35	6
85	33	5
90	31	4
95	29.5	3.5
100	28	3

Figure 6-51. Dimensions of 70- to 100-mc flexible dipole antenna.

f. The main advantage of this emergency antenna over a simple half-wave dipole made of two pieces of wire is that the coaxial feed line does not require a yard arm support when the antenna is hung vertically; also, radiation from the coaxial transmission line may be somewhat less. At some sacrifice of convenience in mounting, it may be used horizontally, if required.

632. THREE-ELEMENT DIRECTIONAL ARRAY.

a. The type of antenna illustrated in figure 6-52 consists of a half-wave dipole radiator plus a parasitically excited director and reflector, each a quarter-wave away from the radiator. Antenna AS–20/TRC–1, part of Antenna System AS–19/TRC–1 (used with Radio Sets AN/TRC–1, –3, and –4) is of this type. Figure 6-53 shows the complete antenna system in the process of erection. All elements are calibrated and should be adjusted for each operating frequency. The dipole elements are all interchangeable and the parasitic support members are demountable in such a manner that the antenna may be used as a one-, 2-, or 3-element system. The complete antenna array has a forward gain (in the direction of the director, or shorter element) of approximately 6 db above that of a half-wave dipole alone, and a front-to-back ratio of about 6 to 8 db. The antenna array has a beam width of 55 degrees between points 3 db down from maximum, and a width of 80 degrees between points 6 db down from maximum. The antenna system is connected to the radio set by means of a 50-ohm solid dielectric flexible coaxial transmission line. No balancing section is provided between the dipole radiator and the unbalanced coaxial transmission line, hence undesired currents probably flow on the outer surface of the transmission line. To reduce this effect when it is responsible for mutual interference between nearby sets, a quarter-wave conducting sleeve may be placed coaxially around the coaxial transmission line at the antenna, with the sleeve insulated at the end adjacent to the antenna and shorted to the coaxial outer conductor at the other end.

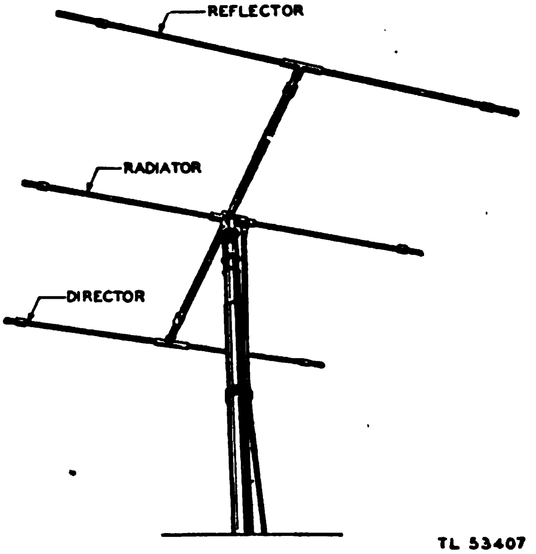


Figure 6-52. Three-element horizontal directional array (part of Antenna System AS–19/TRC–1).

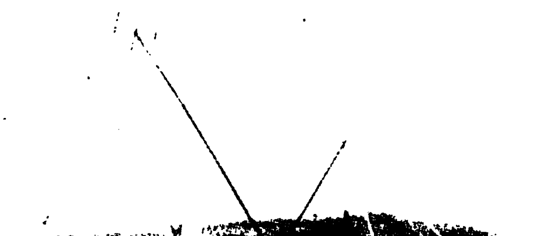


Figure 6-53. Antenna System AS–19/TRC–1 in process of erection (part of Radio Sets AN/TRC–1, –3, and –4).

b. Other varieties of this antenna type may be constructed having the spacing between radiator and director and reflector equal to about 0.1 to 0.15 wavelength. With these reduced dimensions the input resistance is lower, and the adjustment of the element lengths in order to obtain optimum radiation is more critical. Because of the reduced dimensions, this antenna occupies less space, which may be of some importance from a structural standpoint in the lower part of the v-h-f band.

c. In cases where interference between circuits makes desirable a greater front-to-back ratio than the 8 db afforded by the standard length adjustments for Antenna AS–20/TRC–1, spacings between the radiator and the director and reflector can be reduced. If these spacings are reduced to the minimum permitted by the physical construction of the antenna, and if the director length is shortened and the reflector length is increased by the amounts shown below, the expected front-to-back ratio is around 30 db at the lower end of the 70- to 100-mc band and around 20 db at the upper end of this band. When these ad-

Frequency (mc)	*Change in director and reflector lengths (inches)* *
75	3
85	2
95	1
F	0.5+0.1 (100–F)

* Shorten the director length and increase the reflector length by this amount, as compared to the standard settings.

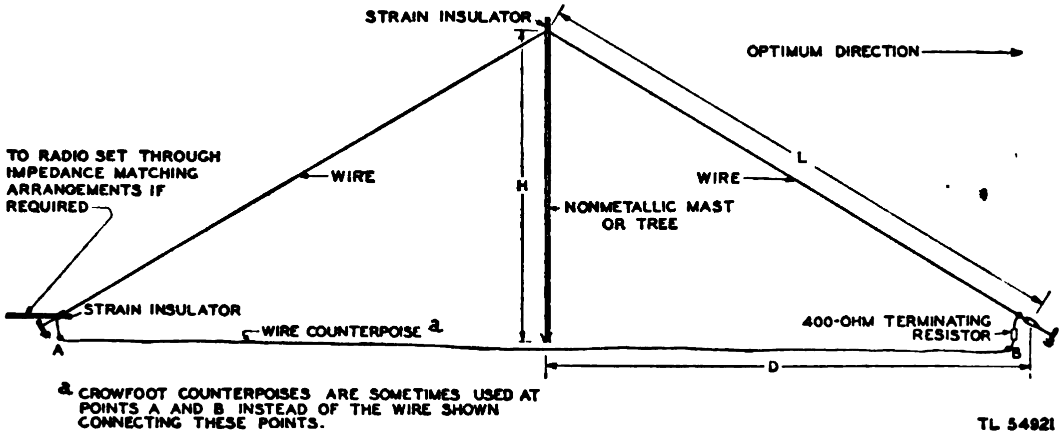


Figure 6-54. Vertical half-rhombic antenna (inverted vee), (similar to Antenna Equipment RC–63).

justments have been made, the impedance at the antenna terminals will be lowered, as noted in subparagraph b above, and the transmitter tuning adjustments will need to be changed, the amount of change depending on the length of transmission line between transmitter and antenna. The forward gain of the antenna will not be appreciably changed, according to available measurements.

d. In some applications, nondirectional antennas are needed and in the absence of a standard antenna for this purpose, resort has sometimes been made to improvised vertical half-wave dipoles such as described in paragraphs 627b and 631. To avoid such improvisation and to get the benefit of directivity when desired, a vertical 3-element directional array (AS–99/TRC–1) is under development for use with radio sets AN/TRC–1, –3, and –4. In this antenna the radiator is an adjustable coaxial antenna similar to that shown in figure 6-41; when used without director and reflector, this provides nondirectional operation. With this coaxial construction, undesired radiation due to current flow on the outer surface of the transmission line will probably be small.

633. VERTICAL HALF-RHOMBIC ANTENNA (INVERTED VEE).

a. The vertical half-rhombic antenna, an improvised version of which is illustrated in figure 6-54, is typical of the antenna supplied with Antenna Equipment RC-63 (TM 11–2616) for use with various radio sets operating in the 20- to 40-mc band, when directivity of vertically-polarized signals is required. Such antennas may be improvised readily in the field, using copper antenna wire when available, Wire W–110–B, or other field wire, if necessary. Only one mast is required for a center support. Antennas of this sort can be used over a 2 to 1 frequency range without adjustment, where a loss in efficiency of several db is tolerable in the lower part of the range. As the frequency is increased the beam width becomes narrower and the efficiency in the direction of the beam is improved. Above about 60 mc, the full-rhombic antenna is usually preferable, as discussed in paragraph 634.

b. When limited to a fixed length of wire per leg, the optimum rhombic construction is obtained when the apex height is chosen so that the projection of the wire on the ground (dimension D of figure 6-54) is a half wavelength shorter than the leg length (dimension L) at about the midfrequency of the band under consideration. This is the rule-of-thumb method usually quoted for dimensioning such antennas.

c. In practice, however, it is the height of the apex which often is limited by available mast heights and the requirement is to choose a wire length for each leg which will give optimum gain. For this situation, the rule to follow is to use a length of wire (minimum of two wavelengths) such that its projection (dimension D) is 0.371 wavelength less than the leg length at the midfrequency of the band under consideration. This rule may be followed by using the equation:

$$L = \frac{H^2F}{730} + \frac{183}{F}$$

where L is the optimum leg length in feet, for use with a pole H feet high and a frequency of F megacycles.

d. The optimum dimensions to be used and the computed gain over a half-wave vertical dipole centered at the apex of the rhombic and assuming flat terrain are tabulated in figure 6-55 for several mast heights and a frequency of 30 mc. If these designs are used over a band of frequencies, the gains will be affected, particularly at lower frequencies. For example, at 20 mc, gains are 3 to 4 db less over land and 5 db less over sea. At 40 mc, gains are 1 to 2 db higher than at 30 mc.

Mast height (feet)	*Leg length*		*Estimated 30-mc gain in forward direction over half-wave vertical dipole at the same elevation as the apex (db)*		
	(feet)	*(L/λ)* [a]	*Poor soil*	*Good soil*	*Sea water*
20	43	1.3	−3	1	3
40	72	2.2	−1	2	6
50	109	3.3	0	3	8
60	154	4.7	2	4	10

[a] L/λ = ratio of leg length to wavelength.

Figure 6-55. Dimensions and estimated gains of 30-mc vertical half-rhombic antenna over smooth terrain and over sea water.

e. The tabulation in figure 6-55 indicates that over flat land the gain of the half-rhombic antenna is not large. The computed gain over sea water is probably not fully realized unless the antenna is right on the beach. However, *if the antenna is installed facing out over the edge of a steep precipice, gains as large as those shown in the "sea water" column are probably realized, whether over land or sea.*

f. The horizontal directional pattern of this antenna depends on the dimensions and frequency, and to some extent on whether it is used over poor earth, good earth, or sea water. In general, as the leg length measured in wavelengths is increased, either by using the longer lengths of wire which go with the higher mast heights or by using a higher frequency, the width of the forward beam is narrowed. Figure 6-56-A shows the computed horizontal pattern, for vertically polarized waves, of the 30-mc antenna listed in figure 6-55 for a 50-foot mast, when used at 20, 30, and 40 mc over good earth. This illustrates the reduction in beam width which occurs when the frequency is increased and the antenna dimensions remain unchanged. Figure 6-56-B shows the change in the 30-mc pattern when this antenna is placed over

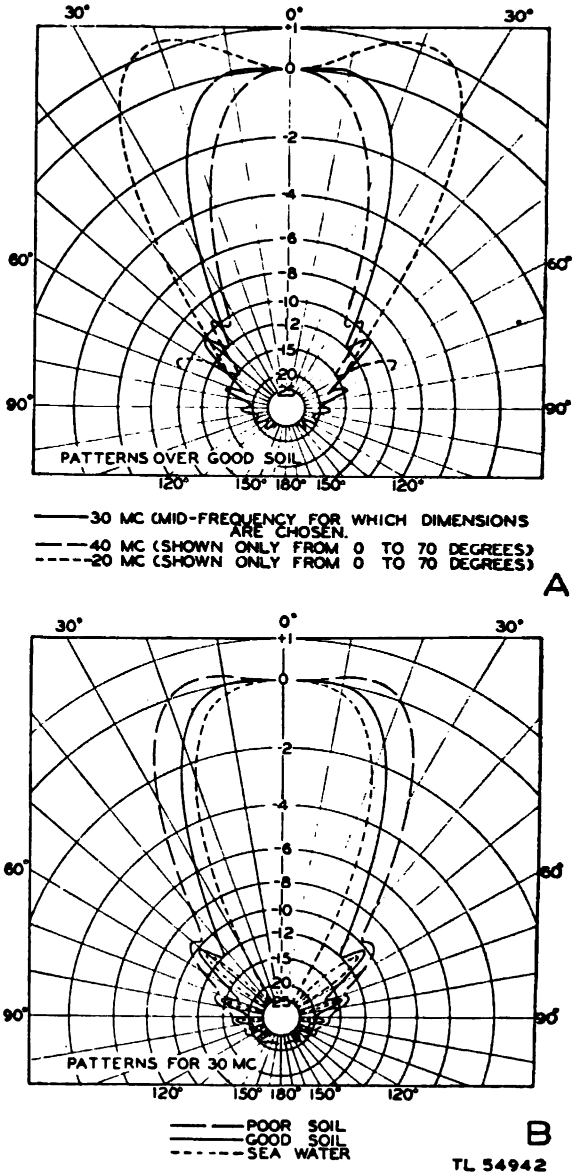


Figure 6-56. Horizontal directional patterns of vertical half-rhombic antenna using 50-foot mast.

poor earth or sea water, rather than good earth. It is noted that over sea water, which approaches a *perfect* earth, the computed patterns exhibit deep minima and prominent secondary lobes, similar to those shown for the full rhombic in figure 6-62. Over land, particularly poor soil, the computations indicate that these features tend to disappear with the half-rhombic. Portions of the patterns which are more than 25 db below the efficiency in the forward direction are omitted from figure 6-56.

g. These computed patterns assume the antenna to be terminated in characteristic impedance, about 400 ohms. In practice, the location of sharp minima and the magnitude and location of minor lobes may vary from those illustrated, and the best terminating impedance to use for maximum front-to-back ratio may be determined experimentally. When unterminated, the radiation and response in the forward direction is not materially affected, but a similar lobe in the pattern appears in the rear, with the maximum gain to the rear about 3 db less than in the forward direction. When used unterminated, it may be difficult to load the transmitter properly because of standing waves (ch. 12). Even when terminated, this antenna will not operate satisfactorily with certain sets designed to operate into a low-resistance load such as the impedance of a half-wave dipole antenna, unless steps are taken to match impedances by means of a transformer, a transforming line section, or a matching stub. Radio Sets AN/CRC–3 and –3A, for example, are equipped with the antenna coupling unit shown in figure 6-57. Among the radio sets listed in

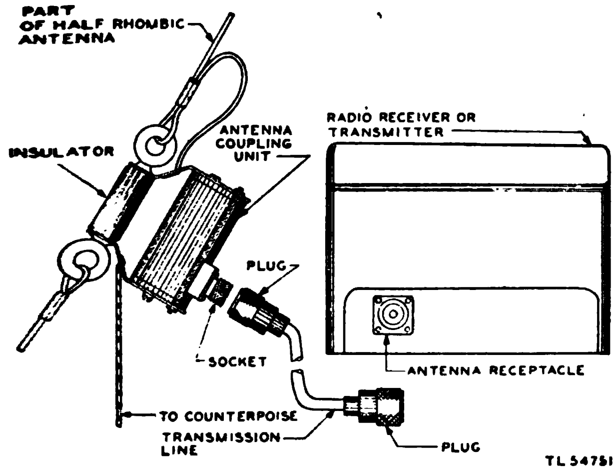


Figure 6-57. Coupling unit to match half-rhombic antenna to 50-ohm coaxial transmission line (used with Radio Sets AN/CRC-3 and -3A).

TM 11–2616 (Antenna Equipment RC–63) to which the vertical half-rhombic Antenna RC–63 may be directly connected without any external matching networks are Radio Sets SCR–300, SCR–508, SCR–528, SCR–608, SCR–609, SCR–610, and SCR–628.

h. Since there is less radiation or response to *vertical* fields broadside to these antennas, or to the rear when terminated, proper orientations, when the antenna is used for receiving, will minimize interference from sources emitting *vertically* polarized waves. For example, vertical half-wave dipole transmitting antennas in the vicinity should be placed at positions falling in or near null points in the patterns of receiving rhombics.

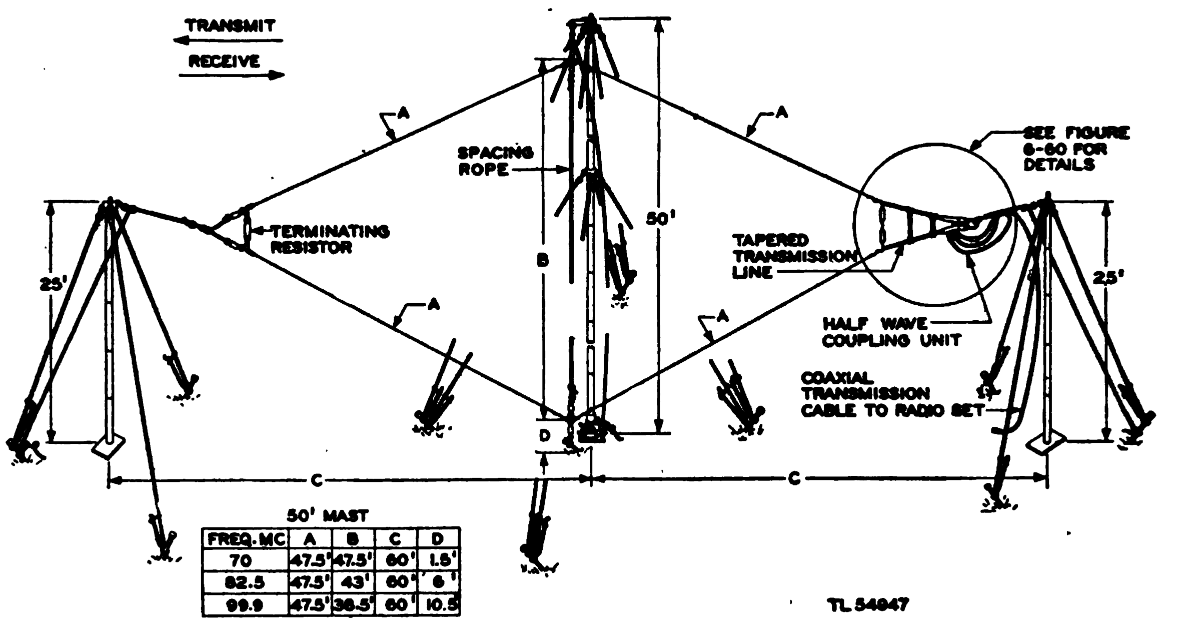
634. FULL-RHOMBIC ANTENNAS.

a. General. The full-rhombic antenna is a diamond-shaped configuration of wires, supported in either a vertical or a horizontal position as illustrated in figures 6-58 and 6-59, respectively. Dimensions of 4 or 5 wavelengths per leg, or side, are required in order to obtain a substantial part of the signal gain and directive capabilities of this type of antenna. This requirement generally precludes the use of these antennas, for tactical applications, at frequencies below about 50 mc. A full rhombic has an impedance of 600 to 800 ohms, and should be fed by a balanced transmission line from a transmitter having a balanced output circuit, or if used as a receiving antenna should be connected through a balanced line to a balanced receiver.

b. Construction Details and General Characteristics.

(*1*) The dimensions and construction details for rhombics intended ultimately to be standardized for use with radio sets AN/TRC–1, –3, and –4 are shown in figures 6-58 and 6-59. The output circuit of these sets is unbalanced, and the balancing arrangement illustrated in more detail in figure 6-60 is therefore provided to feed either the horizontal or vertical rhombic. The folded coaxial cable shown is one-half wave long at 85 mc, and provides a transformation from the 50-ohm unbalanced coaxial cable to a 200-ohm balanced output. It is used over the 70- to 100-mc band without change in dimensions. The tapered line section then provides a balanced matching section between this 200-ohm output impedance and the 600- to 800-ohm rhombic antenna impedance.

(*2*) The vertical rhombic shown in figure 6-58 may be expected to have gain and directivity characteristics comparable to those described in subparagraph c below, which gives general design and performance data for an



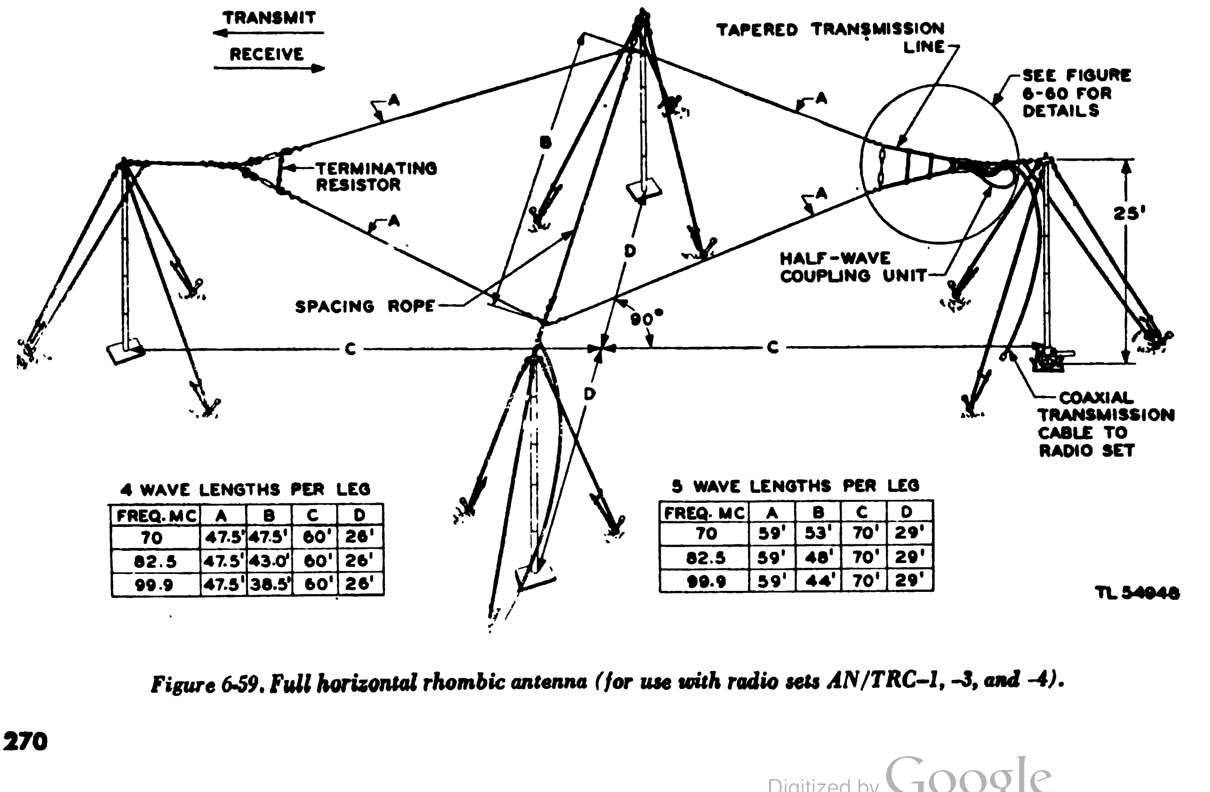
50' MAST

FREQ. MC	A	B	C	D
70	47.5'	47.5'	60'	1.5'
82.5	47.5'	43'	60'	6'
99.9	47.5'	38.5'	60'	10.5

Figure 6-58. Full vertical rhombic antenna (for use with radio sets AN/TRC-1, -3, and -4).

antenna of comparable design. In this illustration, the antenna is shown supported on steel masts. Wooden masts are ordinarily to be preferred in order that induced currents in and consequent radiation from the masts will not alter the antenna pattern. There is some evidence that any metal near the apex, other than the wire itself, has a detrimental effect. No data are available on the seriousness of these effects for the antenna as illustrated.

(3) The horizontal full rhombic shown in figure 6-59 has leg lengths comparable to those described for the vertical but requires four short poles instead of one long and two short ones. The gain of this antenna in the forward direction should be about 11 db for the



4 WAVE LENGTHS PER LEG

FREQ. MC	A	B	C	D
70	47.5'	47.5'	60'	26'
82.5	47.5'	43.0'	60'	26'
99.9	47.5'	38.5'	60'	26'

5 WAVE LENGTHS PER LEG

FREQ. MC	A	B	C	D
70	59'	53'	70'	29'
82.5	59'	48'	70'	29'
99.9	59'	44'	70'	29'

Figure 6-59. Full horizontal rhombic antenna (for use with radio sets AN/TRC-1, -3, and -4).

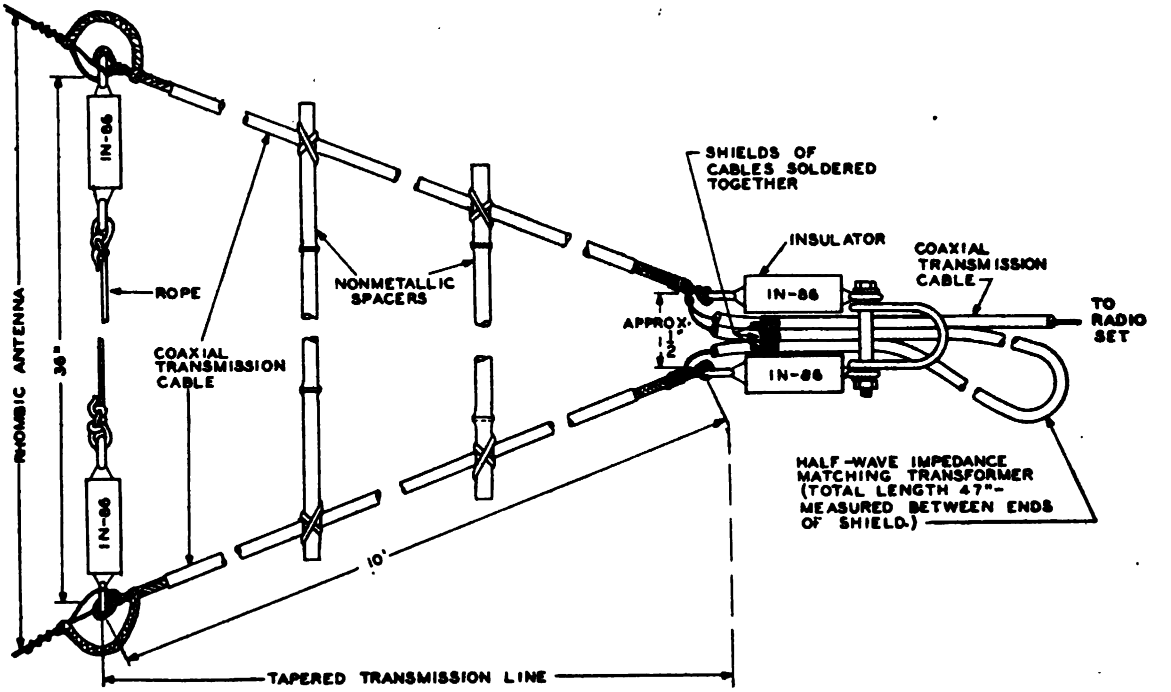


Figure 6-60. Balancing and impedance matching arrangement (used between unbalanced 50–ohm coaxial cable and balanced 600– to 800–ohm rhombic antenna).

4 wavelengths-per-side design, and 12 db for the 5 wavelengths-per-side design, referred to a half-wave horizontal dipole antenna at the height of the rhombic supporting masts. Corresponding gains referred to the standard horizontal 3-element directional array (par. 632a), are $11 - 6 = 5$ and $12 - 6 = 6$ db, with the 3-element array *at the height of the rhombic masts.* The directional pattern of the horizontal rhombic differs materially from that of the vertical, in that the beam of the forward lobe is narrower, having a width of about half, or less, of that of the vertical rhombic.

(*4*) In flat terrain or from beach-to-beach over sea water, it should be noted that the horizontal rhombic would have practically no gain over the 3-element horizontal array if the latter were mounted at the top of the 40-foot mast normally supplied for its use, rather than at the 25-foot elevation of the masts used for the rhombic. This is because a gain of about 4 db is obtained by raising the 3-element array from 25 feet to 40 feet (fig. 6-18). On the other hand, the gain resulting from increasing the height of the mast supporting the 3-element array would be negligible if the antenna were sited on a precipice, since the antenna is already at a high effective elevation; hence, the rhombic gain of 4 to 5 db over the array might be expected to apply at such a site.

c. Design and Performance of Vertical Rhombics.

(*1*) The dimensioning of vertical rhombic antennas to obtain optimum signal gain in the forward direction may be described quite simply if it is assumed that the size of the pole which supports the apex is a controlling factor. This will generally be the case where these antennas are constructed locally from materials at hand. The rule is as follows: make the length of each leg such that the horizontal distance from either end of the antenna to the center pole is 0.371 wavelength less than the leg length. With the further assumption that it will be desirable to have the lower apex about 10 feet off the ground, to give clearance for personnel and vehicles, solution of this rule may be obtained from the following equation:

$$L = \frac{(H-10)^2F}{2920} + \frac{183}{F}$$

where F is the frequency in megacycles, H the pole height in feet, and L the resulting optimum leg length in feet.

(*2*) In figure 6-61 optimum leg lengths are tabulated for center poles ranging from 30 feet to 60 feet in height, together with calculated gains for the resulting rhombic antenna. These gains are with respect to a half-wave vertical dipole centered at the *top* of the *center* mast, at a frequency of 85 mc. At 70 mc, gains are about 2 db less than shown, and at 100 mc they are about 1 db greater, assuming no change in the antenna design. The 50-foot case is closely representative of the rhombic shown in figure 6-58.

Height of center mast (feet)	*Height of end masts (feet)*	*Leg length*		*Estimated 85-mc gain over half-wave vertical dipole at center mast height (db)*	
		(feet)	*(L/λ)*[a]	*Poor or good soil*	*Sea water*
30	20	14	1.2	2	6
40	25	28	2.4	5	9
50	30	49	4.2	7	11
60	35	75	6.5	8	13

[a] L/λ = ratio of leg length to wavelength.

Figure 6-61. Dimensions and estimated gains of 85-mc full vertical rhombic antennas over smooth terrain and sea water.

(*3*) The data in figure 6-61 indicate appreciable gains over a vertical half-wave dipole over both land and sea water for realizable mast heights. At these frequencies, however, it is also feasible to build directional arrays such as described in paragraph 632d having gains of about 6 db over a half-wave dipole. Such standardized arrays are usually more flexible in their applicability, that is, take up less space and are less trouble to install under the various field conditions encountered. However, for fixed locations, the extra gain of the full vertical rhombic antenna may be used to advantage to increase range, especially over sea water.

(*4*) As in the case of the half-rhombic antenna, gains as large as indicated in the sea water column (fig. 6-61) are probably realized when the antenna faces out over a steep precipice, whether over land or sea.

(*5*) Figure 6-62 shows the computed horizontal directional patterns of the vertically polarized field of the four antennas tabulated in figure 6-61. These patterns illustrate the sharpening of the forward lobe as higher masts permitting longer wire lengths are used, and also the effect on the main lobe of using frequencies at the top and bottom of the 70- to 100-mc band. These drawings omit portions of the patterns for which the efficiency is more than 25 db below that in the forward direction.

d. Choice Between Vertical and Horizontal Rhombics. Rhombic gains, in the forward di-

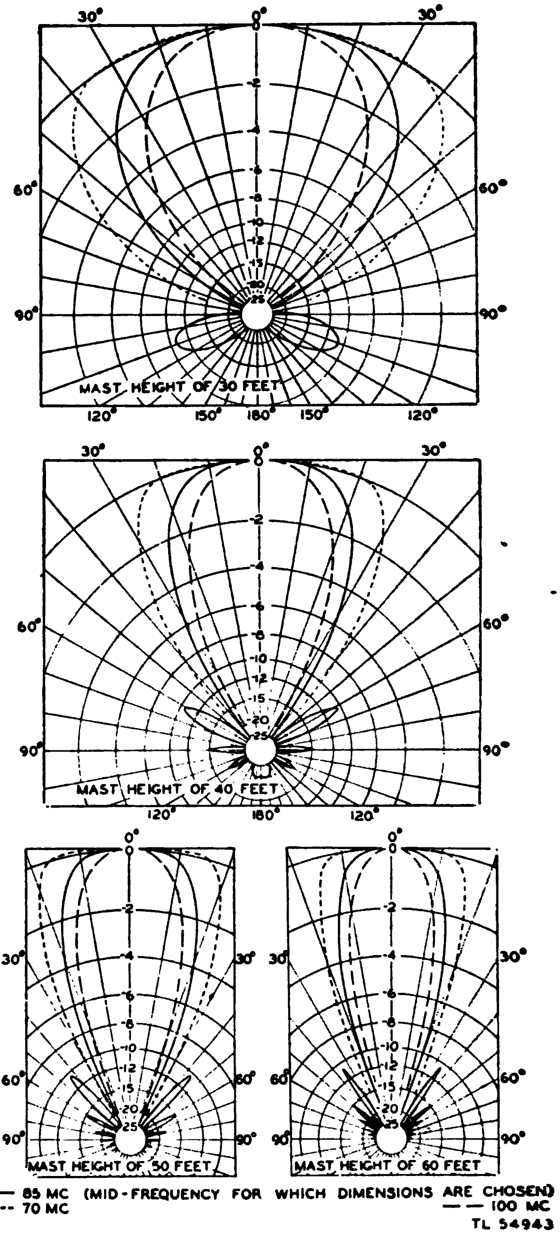


Figure 6-62. Horizontal directional patterns of vertical rhombic antenna having the dimensions given in figure 6-61.

rection, with respect to dipoles supported at the height of the horizontal axis of the rhombic, are independent of the position of the rhombic, that is, whether horizontal or vertical, and the type of soil, and are determined solely by the rhombic dimensions. (The gain of 7 db listed in figure 6-61 for a vertical rhombic of approximately 4 wavelengths per leg would become 11 db were it referred to a dipole at a height of 30 feet, which is the height of the rhombic's axis. This agrees with the gain given in subparagraph b(3), above, for a horizontal rhombic of comparable dimensions.) In situations where a high pole for supporting the center of a vertical rhombic is not available, best results will be obtained if a horizontal rhombic is constructed, since the leg length will not be limited as it would be for a vertical. The horizontal antenna will of course require more ground area. Also, more care in properly pointing the horizontal antenna toward the distant station is required than with the vertical rhombic, because of the narrower beam width of the forward lobe of the former. With a horizontal rhombic, a substantial impairment in transmission may result if it points as little as 10 degrees off course. A horizontal rhombic at a transmitter should be used in conjunction with a horizontal antenna at the distant receiver, and a vertical rhombic should be used in conjunction with a vertical antenna at the distant station.

635. HALF-WAVE DIPOLE ANTENNA WITH CORNER REFLECTOR.

a. The antenna type illustrated in figure 6-63 is a directional antenna associated with radio sets AN/TRC-8, -11, and -12, operating in the 230- to 250-mc band (TM 11-618). The antenna assembly consists of a driven dipole antenna, adjusted and mounted in front of a 90-degree corner reflector in such a manner that practically uniform gain is obtained over this complete frequency band. The entire assembly is supported on a 40-foot steel mast made up of 5-foot tubular steel sections which are assembled and mounted on a mast base in such a manner that the complete antenna system may be rotated to orient the antenna in the desired direction of transmission. The antenna is connected to the radio set by means of coaxial solid dielectric flexible r-f transmission cable. The antenna has a forward gain of approximately 7 db over that of a half-wave dipole and the front-to-back ratio is usually 20 db or better.

b. The antenna pattern has a width of about 78 degrees between points 3 db down from maximum, a width of 100 degrees between points 5 db down from maximum, and a width of 138 degrees between points 12 db down from maximum.

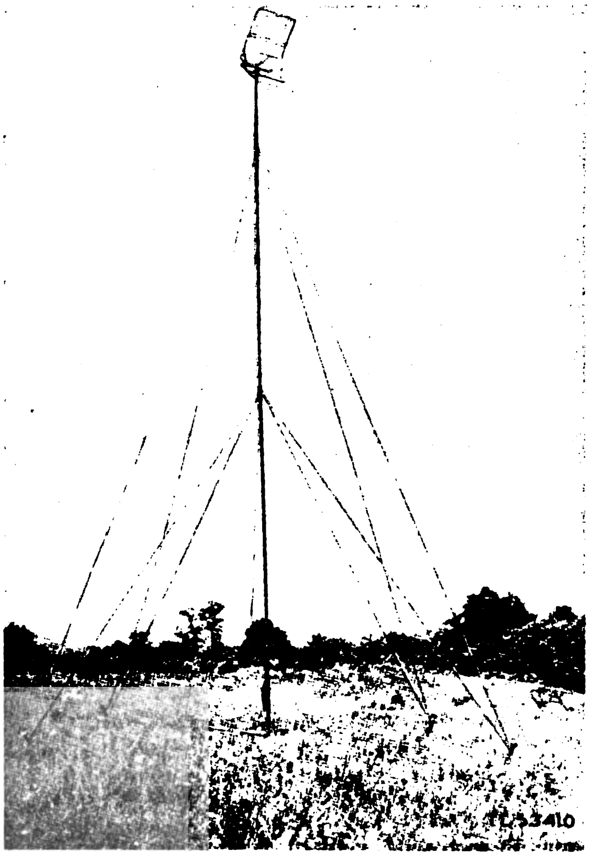


Figure 6-63. Dipole antenna with corner reflector (Antenna Assembly AS-52/TRC-8 mounted horizontally on portable 40-foot mast).

636. IMPROVISED ANTI-INTERFERENCE ANTENNA.

a. A directional antenna which has been used successfully in the field to minimize interference between nearby v-h-f radio sets is shown in figure 6-64. With dimension A adjusted to half wavelength, vertically polarized signals arriving along the line of the supporting poles will cancel in the two equal parallel vertical wires, while at other angles they will combine to give a resultant antenna voltage which reaches a maximum when the signal arrives from a direction perpendicular to the line of the supporting poles. The response pattern is similar to that of a loop antenna, that is, a broad maximum and a fairly sharp minimum, and thus some position, found by rotating the antenna, will give an optimum signal-to-interference ratio.

b. The antenna may be constructed of Wire W-110-B or other field wire at hand. In any case, the wires are brought to the center point, as shown, and knotted to hold them in position. The wires are then extended to the set, skinned, wrapped together, and connected to the antenna binding post, thus paralleling the two halves of the antenna.

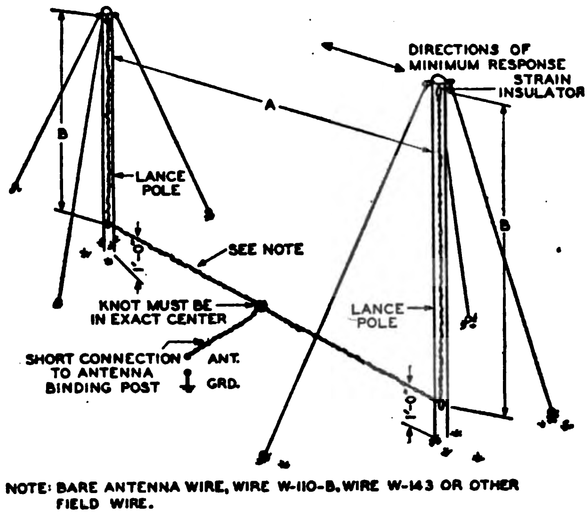


Figure 6-64. Improvised anti-interference antenna.

c. This antenna has been used specifically with Radio Sets SCR–509 and SCR–510, in which case dimension B was made 12 feet and dimension A made 24 feet, representing quarter-wave and half wavelengths, respectively, at 20 mc. Theoretically, dimension A should equal half wavelength at each operating frequency, but satisfactory minimum points were obtainable over the band of 20 to 27.9 mc. A similar antenna could probably be used with Radio Sets SCR–609 and SCR–610 by making dimension A about 18 feet and adjusting dimension B experimentally to permit proper loading of the transmitter.

637. ANTENNA DIMENSIONAL DATA.

a. The curves in figure 6-65 indicate dimensions for various v-h-f antenna elements. The dimensions plotted are approximate values; exact dimensions given in instructions accompanying specific antenna assemblies should be used in preference.

b. As a further aid in antenna computations, the following expressions are useful:

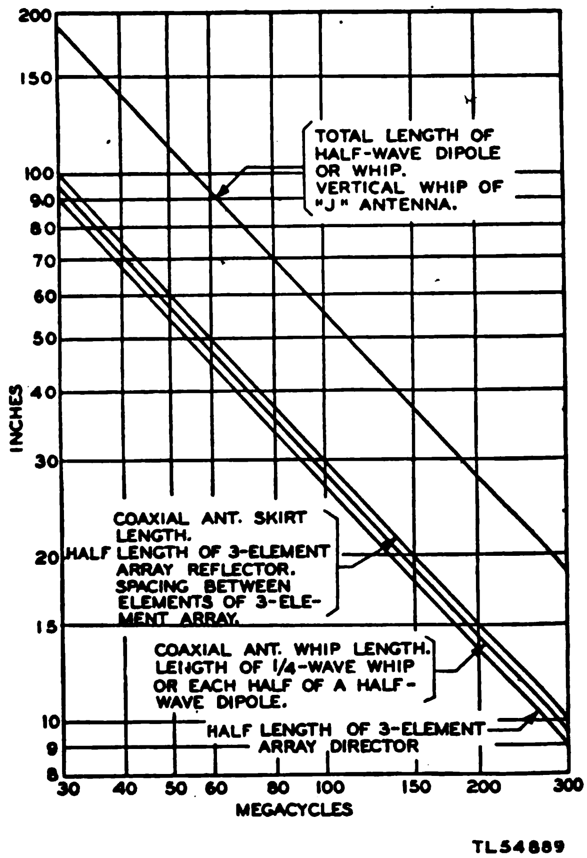


Figure 6-65. Approximate antenna dimensions versus frequency.

$$\text{One wavelength (feet)} = \frac{984}{\text{megacycles}}$$

The above expression is useful in rhombic antenna computations.

$$0.95 \text{ of one quarter-wave (inches)} = \frac{2{,}800}{\text{megacycles}}$$

This expression is the one used to determine the length of each half of a half-wave dipole, the factor 0.95 allowing approximately for end effect.

$$\text{Frequency (megacycles)} = \frac{300}{\text{Wavelength in meters}}$$

$$\text{Wavelength (meters)} = \frac{300}{\text{Frequency in megacycles}}$$

These expressions are useful in converting from wave length to frequency, or vice versa.

c. For further information on v-h-f antenna dimensions, consult TM 11–314.

638. ANTENNA R-F TRANSMISSION LINES.

a. Coaxial Cables. Both tactical and fixed plant radio equipment usually include a suitable type and length of r-f transmission line with which to feed the antenna associated with the set. Losses for several types of lines are given in paragraph 676. In the v-h-f band, 50- to 70-ohm solid dielectric flexible coaxial cable having relatively low loss is ordinarily used to feed elevated antennas. If such lines are damaged and cannot be replaced, the damaged coaxial cable may be used on an emergency basis if the parts in trouble are cut out and the center wire and braid respliced, using tape (preferably rubber) as insulation. *It is not necessary to retain the coaxial construction of the braid at the splice; but the two braids should be connected with a short piece of wire.* Such splices introduce slight impedance irregularities and some loss, but the performance will usually be better than with other improvised feeders.

b. Losses in Field Wire. The attenuation of field wires ordinarily available is very great in the v-h-f band, as shown in figure 6-146. For example, the present type of Wire W-143 has an attenuation of 7, 18, and 25 db per 100 feet at frequencies of 30, 100, and 150 mc, respectively. Wire W-110-B has still higher loss, especially when wet. In general, therefore, *field wires are poor substitutes for coaxial cable* and should be used as emergency r-f transmission lines only when the signals are sufficiently strong to withstand appreciable loss. The chances of successful operation with such wires are greatest in the lower part of the v-h-f band and with the line made as short as possible. It is much better to use spaced leads, as indicated below.

c. Improvised Spaced-wire Line.

(*1*) When coaxial cable cannot be salvaged, a spaced line such as shown in figure 6-66 may be improvised in an emergency for use with half-wave dipole or coaxial antennas. Figure 6-67 shows the constructional details and figure 6-68 shows several improvised horizontal and vertical antenna mountings, in case the standard dipole antenna as well as the coaxial cable is lost or damaged. The transmission line uses two conductors of any available type of insulated wire, separated by wood blocks (or better insulating material, if available) at about 2-foot intervals. Paired wire such as Wire W-110-B or Wire W-143 may be used, in which case the two conductors of each pair are connected together and used as one side of the spaced line. The wire can be fastened to the blocks with staples, tape, string, or wire.

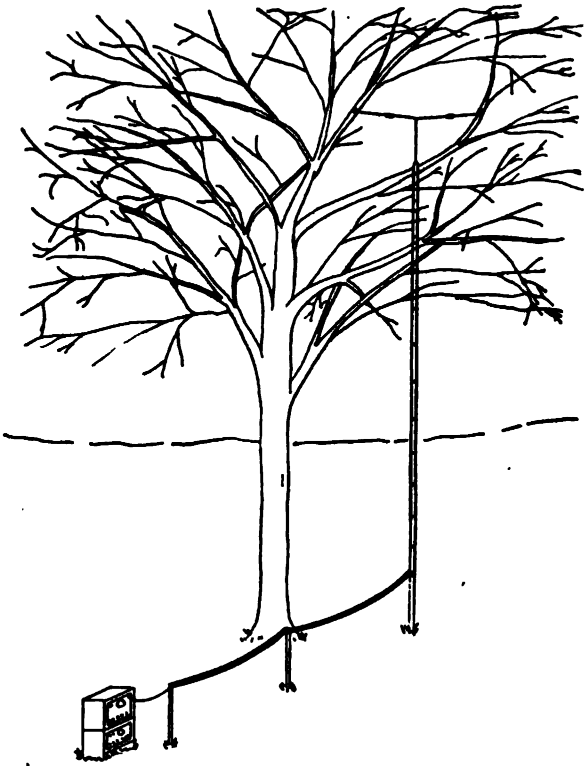


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Figure 6-66. Improvised spaced line and horizontal half-wave dipole antenna.

(*2*) The impedance matching line sections shown are made from one pair of Wire W-110-B cut to the dimensions indicated for B in the table of figure 6-67, which are approximately quarter wavelengths for this wire. Wire W-110-B has a characteristic impedance, Z_0, of about 150 ohms, which is about the correct value ($Z_0 = \sqrt{Z_1 Z_2}$) for a quarter-wave matching section between the spaced-line impedance (Z_1 = 400 to 500 ohms) and the impedance of a dipole (Z_2 = 50 to 70 ohms). When the line is used for transmitting, the lower matching section may not be required if the transmitter will load into a 400- to 500-ohm impedance; similarly, it should not be used if the receiver has a high impedance input. When the lower matching section is used and the transmitter does not load properly, the length of the section may be altered slightly to

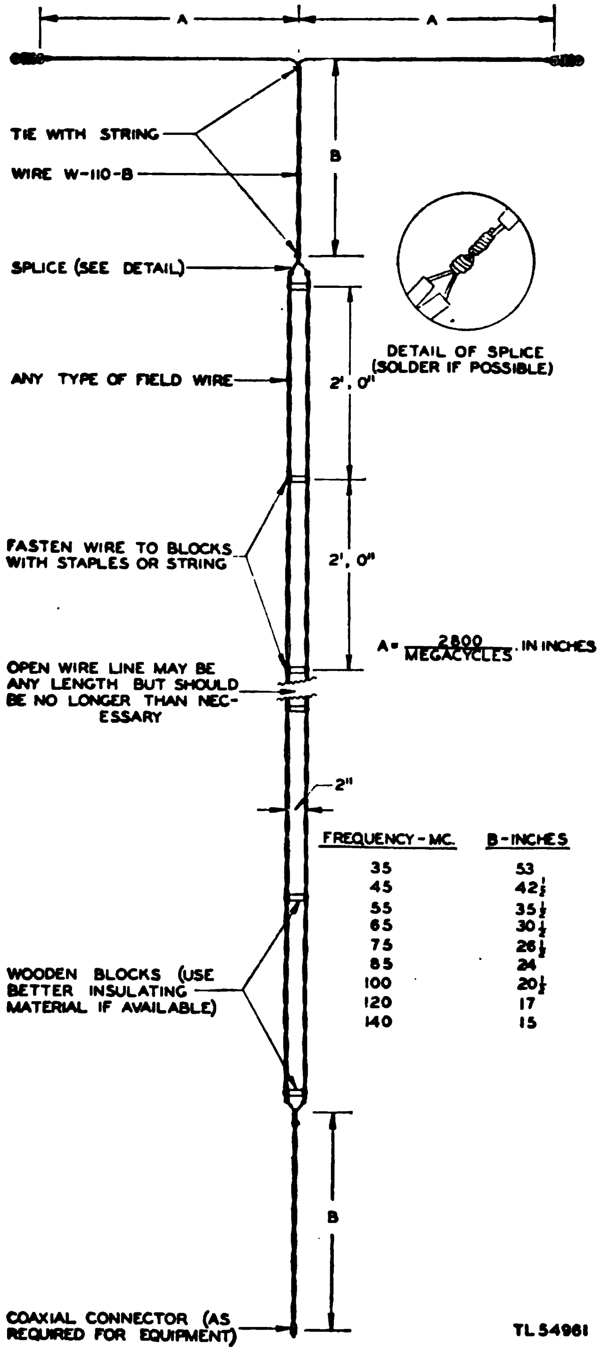
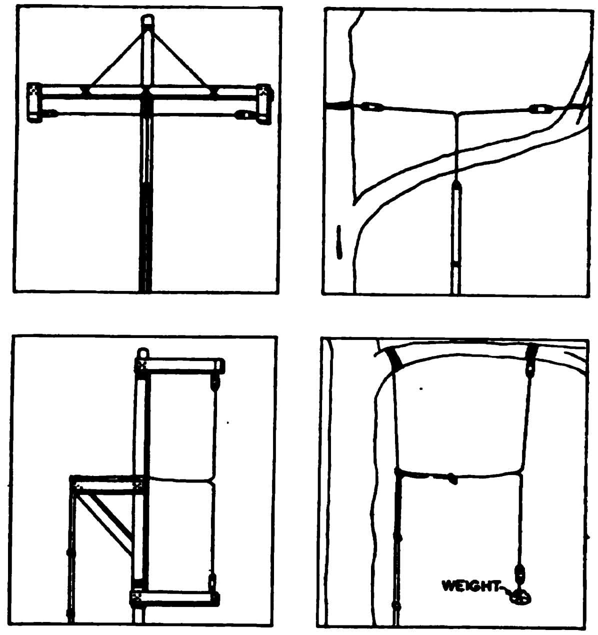


Figure 6-67. Construction of improvised transmission line and antenna.



NOTES:
1. USE STANDARD DIPOLE ANTENNA WHEN AVAILABLE.
2. USE ANTENNA POLE WHEN AVAILABLE OTHERWISE SELECT TREE OR OTHER SUITABLE SUPPORT AND PLACE ANTENNA AS HIGH AS POSSIBLE. CLEAR AWAY ANY FOLIAGE.
3. USE STANDARD INSULATORS WHEN AVAILABLE. ROPE OR STRING CAN BE USED IN PLACE OF INSULATORS WHEN NO OTHER INSULATING MATERIAL IS AVAILABLE.
4. WHEN THE TRANSMITTER IS LOCATED AT SOME DISTANCE FROM THE ANTENNA. THE TRANSMISSION LINE SHOULD BE RUN HORIZONTALLY, SUPPORTED SEVERAL FEET OFF THE GROUND.

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Figure 6-68. Installation of improvised transmission line and antenna.

provide the impedance required to permit loading.

d. Performance of Improvised Lines. Tests using AN/TRC–1 and AN/CRC–3 transmitters indicate that the impedance matching line sections need not be adjusted for each operating frequency. For example, using a 100-foot spaced line constructed with Wire W–110–B, the AN/TRC–1 transmitter could be loaded to full output at all frequencies tested in the 70- to 100-mc band with the matching sections cut to 24-inch lengths, corresponding with the 85 mc value shown in figure 6-67. The radiated field with the line dry was only 3 to 6 db less than with a 100-foot length of coaxial cable. With the line wet the loss increased another 1 to 3 db. With the AN/CRC–3 transmitter, full loading was obtained over the 30- to 40-mc band with the matching sections cut to lengths corresponding to 30, 35, or 40 mc. The radiated field with the line dry was 2 to 4 db less than with a 100-foot length of coaxial cable, and with the line wet the loss increased another 1 or 2 db. No tests were made with input powers exceeding 50 watts; the maximum power which the line can handle without overheating and breakdown is not known.

Section IV. H-F TRANSMISSION

639. GENERAL.

a. The main factors relating to ground-wave and sky-wave radio transmission in the h-f band (3 to 30 mc), including information on expected performance and on general methods for making performance estimates, are given in this section.

b. Important differences in the transmission characteristics of frequencies in the h-f band, as compared with those in the v-h-f band, are described first, followed by a general introduction to the subject of sky-wave propagation and a discussion of the fields of use of ground waves and sky waves (pars. 640, 641, and 642). The importance of making the proper choice of operating frequencies for h-f sky-wave transmission is emphasized, and reference is made to published periodic predictions of frequencies suitable for sky-wave use (par. 643). Estimated ground-wave transmission distance ranges, and sky-wave performance over distances of 0 to 200 miles are given next, assuming certain reasonably typical conditions. Attention is called to published periodic predictions of h-f ground-wave and sky-wave performance for particular tactical radio sets for different theaters of operation (par. 644).

c. Subsequent paragraphs (pars. 645 to 653) deal with the general methods used in making ground-wave and sky-wave performance estimates, including much of the background data required. This information is useful when the published periodic estimates for the particular area in question are unavailable and when the conditions differ materially from those assumed herein for the typical cases referred to above. Step-by-step solutions of representative problems are given.

d. The section continues with a brief description of measures which may be taken to reduce radio noise in receiving areas, and a short discussion of long-distance sky-wave reliability (pars. 654 and 655).

640. COMPARISON OF H-F AND V-H-F TRANSMISSION.

a. In the h-f band, the presence of useful sky-wave transmission makes it possible to provide communication over distances far beyond either the h-f or v-h-f ground-wave distance ranges. These same sky-wave effects also permit undesired signals from distant transmitters to interfere with the reception of desired h-f signals.

b. Atmospheric noise is important much of the time over a large part of the h-f band, unlike the situation in the v-h-f band where set noise is usually controlling. Ordinarily this static is due to sky-wave propagaton of the effects of storms in the tropics. During the summer months, effects propagated from storms in certain regions of the temperate zone, or nearby thunderstorms, may be controlling. In high latitudes, atmospheric static field intensities are generally low, but auroral disturbances affecting the reflecting properties of the ionosphere sometimes cause radio blackouts and force the use of high-powered l-f sets for ground wave (par. 641d (3)) in place of h-f sky-wave transmission.

c. The short antennas used on mobile h-f transmitters are relatively inefficient in the lower part of the h-f band where their physical length is only a small fraction of a wave length. V-h-f antennas of comparable physical size are relatively efficient.

d. Since the h-f band is usually crowded, proper assignment of frequencies is of great importance. Considerable increase in the total traffic capacity of the h-f band can be obtained by carefully coordinating the assignment of frequencies, transmitting powers, and type of propagation to the various users in a theater, giving due weight to the frequency limitations inherent in sky-wave transmission. When this is done and transmitters are maintained closely on their assigned frequencies, it has been found practicable to maintain a separation of as little as 4 kc between military radio-frequency assignments in the h-f band, when most of the channels use c-w telegraph.

641. SKY-WAVE TRANSMISSION, GENERAL.

a. **Ionosphere Layers.** Sky waves are waves which have been returned to the earth after being transmitted upward to one of several electrically conducting layers or regions (called the ionosphere) located from about 60 to 300 miles above the earth's surface. Waves are returned because of refraction in the ionosphere which bends them back towards earth. The effect is similar to a reflection from the ionosphere, and is commonly referred to as such.

Figure 6-69 shows an ionosphere consisting of a single layer, as is generally the case at night. The layer is then known as the F2 layer, and lies about 150 to 200 miles above the earth.[10] In the daytime, however, three layers generally appear, known as the E, F1 and F2 layers. The E layer is located 60 to 70 miles above the earth; the height of the F1 and F2 layers is somewhat more variable, lying in general from about 125 to 300 miles above the earth. The F1 layer, which is below the F2 layer, is of minor practical importance.

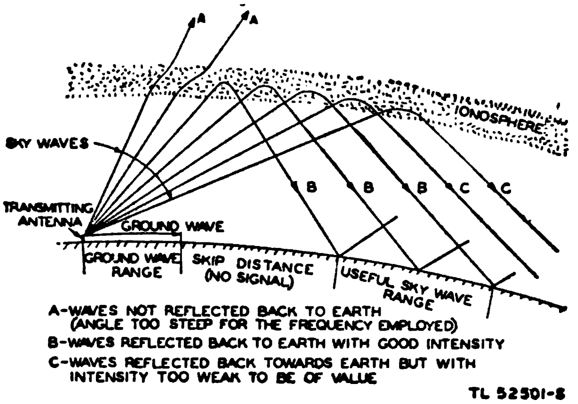


Figure 6-69. General representation of ground-wave and sky-wave transmission.

b. Maximum Usable Frequency and Optimum Working Frequency.

(*1*) The highest frequency which is reflected without much loss from a given layer of the ionosphere and returned to earth at a given distance, is known as the *maximum usable frequency* (muf) for that distance. The muf depends on the condition of the ionosphere, which, in turn, is a function of sunspot cycle, geographic region, and time of day and year. As defined above, the muf is independent of radiated power, type of antenna, and noise level. Predictions of maximum usable frequencies are made in advance and are available in publications referred to in paragraph 643. The term *muf* is ordinarily applied to the monthly average value; that is, the value of muf which is exceeded during about 15 days of the month in question, for a particular place, time of day, and transmission distance.

(*2*) For F2-layer transmission, the *optimum working frequency* (owf) is taken as 85 percent of the estimated muf. In the absence of ionosphere disturbances (subpar. d below), the actual maximum useful frequency will probably equal or exceed the owf about 95 percent of the time, and the use of the owf, rather than the muf, should thereby greatly increase the reliability of transmission. For transmission via the E layer, the owf is practically equal to the muf. A general idea of the numerical magnitudes of maximum usable frequencies is given in paragraph 643.

c. Skip Zone. A simplified picture of ground-wave and sky-wave propagation for a relatively high frequency in the h-f band is shown in figure 6-69. This figure shows a *skip zone* where no useful signal is received. The skip zone is the region between the maximum distance for which ground wave transmission is useful and the minimum distance (called the *skip distance*) at which sky waves of a given frequency are returned to the earth with useful field intensity. As the frequency decreases the skip distance decreases, and *at sufficiently low frequencies in the h-f band there is no skip zone, provided antennas suitable for high-angle radiation are used.*

d. Variations in Ionosphere Conditions.

(*1*) *General.* Besides the normal day-to-day deviations from average referred to above, and short-time variations which produce one type of *fading*, there are factors causing other irregularities in the characteristics of the ionosphere. Some of these aid and others hinder sky-wave transmission. A more complete description of these effects than is given below appears in TM 11–499.

(*2*) *Sporadic E.* Due to irregularities in the ionization of the E layer, the value of the highest frequency which may be reflected from this layer is sometimes raised much above normal. In certain areas this effect may occur for a large fraction of the time in a given month, but it is usually spotty in geographic extent and time duration. It often results in excellent transmission within the normal skip zone, and over long distances on frequencies much higher than those normally propagated by sky waves, occasionally even above 60 mc. Periodic predictions of sporadic E-layer transmission are given in publications of the TB 11–499–( ) series, entitled *Basic Radio Propagation Conditions*, which are issued through the Adjutant General's office.

(*3*) *Ionosphere Storms.* Periods of disturbed conditions in the ionosphere, developing in from a few minutes to several hours, and

[10] This night layer was formerly called the F layer.

dying away gradually in a few days, tend to reduce the number of frequencies in the h-f band which can be used for sky-wave transmission. Such ionosphere storms are most prevalent in the zones near the magnetic poles, where they are sometimes known as auroral disturbances. They cause radio blackouts which frequently make it advisable to use l-f instead of h-f, as indicated in paragraph 640, for radio paths which cross the auroral zones. Weekly predictions of ionospheric storminess are in *Radio Propagation Forecasts* reports, obtainable through the Office of the Chief Signal Officer, Plans and Operations Division, Communications Liaison Branch, Washington 25, D. C.

(*4*) *Sudden Ionosphere Disturbances.* Sudden complete cessation of sky-wave transmission at frequencies usually above one mc for periods of from a few minutes to an hour or more, sometimes occurs throughout the hemisphere illuminated by the sun. Both atmospheric static and signals disappear, and radio sets may appear to *go dead.* These sudden ionosphere disturbances are relatively rare and are frequently associated with magnetic storms. It is sometimes possible to communicate during such disturbances by raising the working frequency above normal. Somewhat longer periods of excessive absorption of signals occasionally occur, resulting in weak received fields but not in such severe effects as those caused by sudden ionospheric disturbances.

(*5*) *Scattered Reflections.* Irregular reflections caused by scattering of the radio waves in the ionosphere occur at all times, but are apt to be stronger during ionosphere storms. They may produce signals at unexpected places and frequencies and from unexpected directions. Such signals are often weak and are apt to fade rapidly.

e. Use of Predictions. Reasonably accurate predictions of which frequencies are good for sky-wave use under given conditions, and which frequencies will skip, are now available (par. 643d). *Failure to use such information has in the past given rise to instances of failure of radio communication at critical times.*

642. FIELD OF USE OF GROUND-WAVE AND SKY-WAVE TRANSMISSION.

a. Ground-wave field intensities decrease rapidly with increasing distance from the transmitter but are ordinarily steady, that is, do not fade or vary with time of day or season. Sky-wave field intensities decrease more slowly with increasing distance, but vary considerably with time of day, season of year, etc., and may not even exist at a given distance unless a proper frequency is used. In addition, sky waves are subject to *fading* (short-time variation). On this account, special apparatus is required to permit the use of teletypewriters on sky-wave circuits (ch. 3). Fading may be caused by interference between signal components arriving by different sky-wave paths, or between ground-wave and sky-wave components in the area in which the ground-wave and sky-wave field intensities are about equal; or it may be due to short-time changes in one path in the ionosphere, in which case it is apt to be less rapid than when due to interference between different components.

b. Ground waves can be used at frequencies in the h-f band for only relatively short distances over land or for moderate distances over sea water before the signals get lost in noise. However, *at distances where ground-wave transmission is adequate, plans should be based on using it rather than sky-wave transmission,* since ground-wave signals are steady and ground-wave frequencies may be chosen without reference to conditions of the ionosphere.

c. Sky waves can be used to increase the distance range provided certain principles as to choice of frequency, antenna, etc., are followed.

d. *In dense jungle, the ground-wave range is extremely short, and sky waves must be used to a great extent in order to provide useful radio communication.*

e. In the lower part of the h-f band, the precautions necessary for siting antennas to avoid losses are much more simple than those required in the v-h-f band. However, experience has shown that in mountainous regions the adverse effects of shadow loss on ground-wave transmission are often sufficient to warrant the use of sky waves.

f. Sky waves also can be used to advantage in cases where the directional properties of antennas suited to sky-wave transmission will reduce excessive noise or interference from other stations.

g. Large transmission benefits are obtainable by using antennas suited to the type of transmission. For ground waves, whip, inverted-L, or long wire antennas may be used. For short-distance sky waves, half-wave horizontal or low-sloping wire antennas are recommended. For long-distance sky-wave transmission, rhombic antennas are advantageous and are commonly used. Section V gives further information on h-f antennas.

h. A chart illustrating the general order of distance ranges obtainable with ground-wave and sky-wave transmission for a set of the general capabilities of Radio Set SCR–399, and in a subtropical region, is shown in figure 6-70. This figure is given for illustrative purposes rather than for specific use, and shows the applicability of ground waves over the shorter distances and sky waves over longer distances for the particular terrain and noise conditions assumed. In the few instances where both ground-wave and sky-wave signals would be received, ground-wave signals are indicated on the figure. Both voice and c-w transmission ranges are shown in figure 6-70. In this figure and elsewhere throughout chapter 6, c-w transmission is taken to imply manual sending, with reception by ear.[11] The use of teletypewriter on c-w circuits is covered in chapter 3.

i. The efficient use of frequencies in the h-f band in a theater requires rigid adherence to assigned frequencies. Off-frequency operation of transmitters may cause a variety of difficulties. To insure proper operation, Frequency Meter Set SCR–211, shown in figure 6-71, is widely used as a portable frequency standard for calibrating m-f and h-f radio transmitters and receivers in the field. It is also used at monitoring and intercept stations for measuring the frequencies received from distant stations.

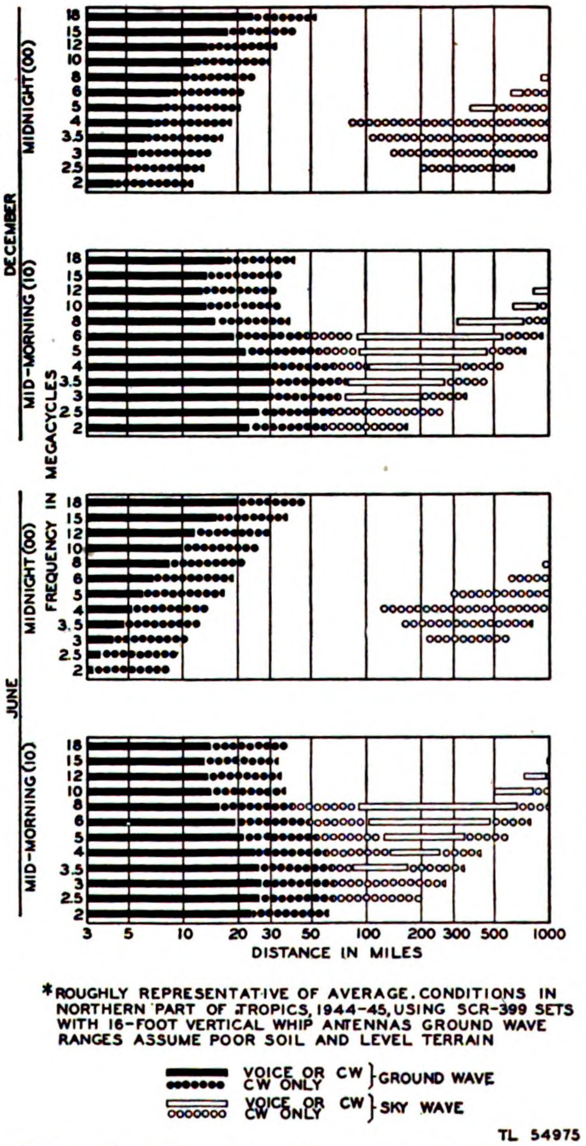


Figure 6-70. Illustration of frequency versus distance relationship for reliable communication.

Figure 6-71. Frequency Meter Set SCR–211–F.

[11] Ranges for tone modulation (par. 603, footnote 2) are not specifically covered. In the type of tone modulation where both carrier and sidebands are interrupted simultaneously, with reception by ear using a beating oscillator in the radio receiver in the same way as for c-w reception, the ranges will be of the same order of magnitude as for c-w reception; in other methods of tone modulation transmission or reception with a single modulating tone, stronger received fields will be necessary. For methods of modulation suitable for teletypewriter operation over radio see chapter 3.

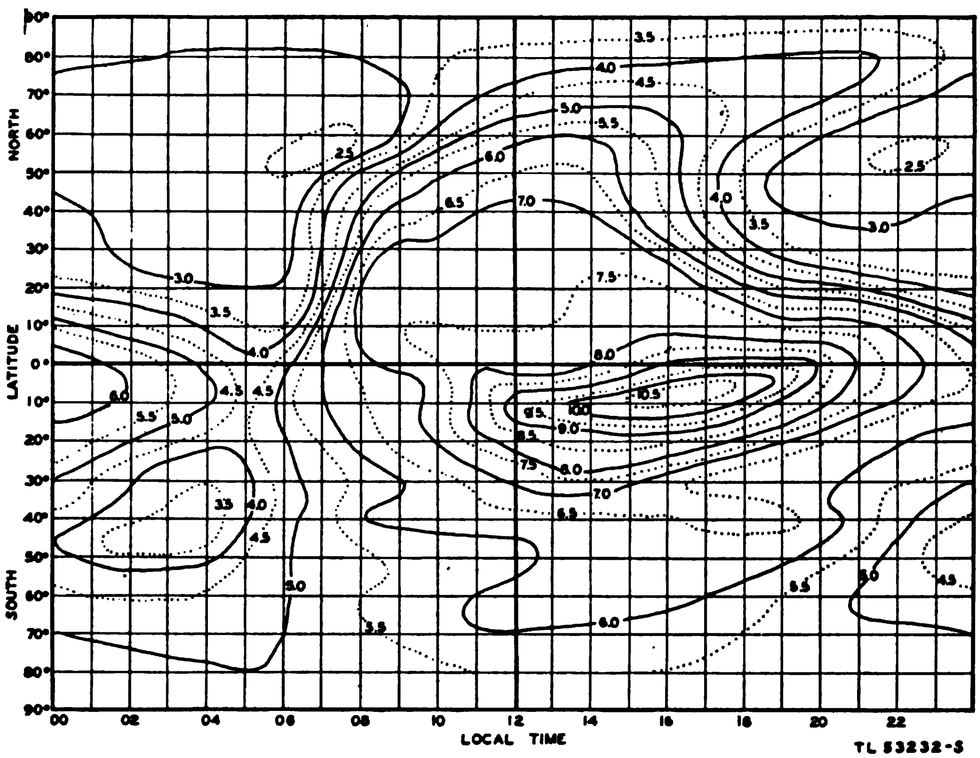


Figure 6-72. Sample chart from a TB 11-499-( ) series report, showing F2 muf, in mc, for transmission vertically upward; predicted for December, 1944, for the zone of longitude in which Europe lies.

643. CHOICE OF FREQUENCIES FOR SKY-WAVE TRANSMISSION.

a. A knowledge of the optimum working frequency (owf) for the conditions involved is perhaps the most useful single piece of information required for successful sky-wave transmission. In the absence of all other data, the choice of an operating frequency at or slightly below the owf, the selection of the best available types of radio sets, and the installation of antennas suitable for sky-wave use, are the major rules to follow.

b. The owf is lower at night than in the daytime, and is lower for short than for long distances. In general it is advisable to have a day frequency and a night frequency, each adapted to the conditions in question, and to change from one frequency to the other on a definite time schedule. Every reasonable effort should be made to obtain frequencies which are satisfactory for sky-wave transmission under the particular conditions; however, if a frequency is assigned which exceeds the muf, transmission at this frequency may be practical for a part of the time, because of the ionosphere variations described in paragraph 641.

c. At night, all frequencies in the h-f band below the muf which are radiated from a given transmitting station are returned to earth at the distant station with about equal intensities, assuming one reflection from the ionosphere and equal radiated powers. However, since atmospheric noise is higher at lower frequencies, it is always desirable to operate near the owf. For night operation over relatively short distances, the use of a frequency of half the muf will degrade the signal-to-noise ratio by about 10 db. In the daytime, ionospheric absorption causes more loss at the lower frequencies, hence it is again desirable to operate near the owf. For daylight operation over short or moderate distances, a 10-db degradation in signal-to-noise ratio will result if the operating frequency is roughly 2 or 3 megacycles below the muf.

d. Periodic predictions of owf and muf, three months in advance, are contained in publications of the TB 11-499-( ) series, entitled *Basic Radio Propagation Conditions,* which are issued through the Adjutant General's Office. Requests for these publications should state the month or months for which predictions are desired.

e. A rough idea of the value of the owf in several cases can be obtained by looking at the curves which form the top boundaries of the transmission charts shown in figures 6-87, 6-88, and 6-89, since these curves represent the optimum working frequencies for the conditions stated in the figure. In general, however, it is meaningless to attempt any interpolation between June and December values (such as those shown in the charts for 1944) to obtain optimum working frequencies for other months. In addition to seasonal trends, muf and owf values are subject to an 11-year cyclic variation; in 1948 or 1949 they are expected to reach a maximum, probably in the order of about twice what they were in 1944.

f. A sample muf chart from the TB 11–499–( ) series of reports is reproduced in figure 6-72 (preceding page), to illustrate the type of information available in these reports. The muf depends on local time and on latitude; it also varies somewhat with longitude and is given separately, in the reports, for three zones of longitude. Figure 6-72 applies to the zone in which the European war theater lies and gives the values of muf for F2 layer reflection (this layer gives the highest muf at short distances) for a radio wave transmitted vertically upward. For distances up to 200 miles between ground stations, this type of chart can be used with little error. Approximate corrections for longer distances are given in subparagraph g below; and detailed directions for using the charts are given in the TB 11–499–( ) series reports. The particular chart reproduced in figure 6-72 shows, for example, that for the month and the zone of longitude represented, the F2 zero-distance muf at latitude 10 degrees North varies from 7.5 megacycles at noon up to 7.9 megacycles at 1600 hours and then down to 5.3 megacycles at midnight and 3.4 megacycles at 0530 hours. This variation in muf suggests the use of different day and night frequencies. In the illustration above, assuming an owf of 85 percent of the muf (par. 641b), a frequency of 5 megacycles could be used from 0800 to 1600 hours, and 2.5 megacycles could be used from 0 to 0800 and 1600 to 2400 hours for a 0 to 200-mile sky-wave circuit. In planning the assignment of frequencies, it is wise to assign those near the owf for sky-wave use on circuits which are not expected to have much transmission margin, and to assign frequencies lower than this, where necessary, for sky-wave use on circuits which are expected to have some margin. Frequencies above the muf can be used for ground-wave transmission.

g. The muf is greater for long distances than for short distances. A rough idea of the ratio of the muf at various distances to that at zero distance is given in figure 6-73. Because of the ratios indicated, a frequency which is optimum for short-distance transmission at a given time is apt to be poor for long-distance transmission at the same time. This makes it unwise to set up a net including long-distance and short-distance paths operating at the same frequency. On this account, also, it may be necessary to change the frequencies assigned to a given organization when the circuit lengths which it uses change markedly from one military operation to the next.

Distance (miles)	*Approximate ratio of muf at given distance to that at zero distance*	
	F2-layer transmission	*E-layer transmission*
0	1.0	1.0
100	1.01	1.13
200	1.03	1.5
300	1.07	1.9
400	1.13	2.4
600	1.3	3.3
800	1.5	4.0
1,000	1.8	4.5
1,500	2.4	4.8
2,000	2.7	4.8
2,500	2.9	4.8

Figure 6-73. Approximate relations between maximum usable frequencies at various distances.

h. Further information concerning the detailed procedure for predicting suitable frequencies is in the TB 11–499–( ) series reports and in TM 11–499.

644. ESTIMATED GROUND-WAVE TRANSMISSION RANGES AND SKY-WAVE PERFORMANCE.

a. General.

(*1*) This paragraph contains approximate ground-wave transmission ranges, estimated for a number of reasonably typical conditions. For sky-wave transmission, the information is given in terms of the hours during which various frequencies below the muf will provide satisfactory communication, under the conditions assumed, over distances of 0 to 200 miles. The performance data given here may be used where the actual conditions approximate those specified and where more detailed information is not available. Reference is made to similar information on predicted performance which is now available in publications issued periodically by the Office of the Chief Signal Officer, as covered in subparagraph e below.

(*2*) Computations of transmission ranges are in general based on estimates of the distance at which the signal-to-noise ratio is just satisfactory. While the noise actually present may be atmospheric static, local man-made radio noise, set noise, or interference from friendly or enemy transmissions, the only interferences which can be estimated in advance are static and set noise; and these, particularly static, are subject to considerable variation and are not accurately known. Moreover, the computations of received signal intensities involve estimates of propagation via a varying ionospheric path in the case of sky-wave transmission, and they also involve judgment of the characteristics of the terrain in the case of ground-wave transmission. Predictions of transmission ranges are therefore necessarily inexact. This applies both to the information given in the present paragraph and to any other similar predictions. Such predictions can, however, be a valuable guide in planning if their limitations are recognized.

(*3*) The distance range and performance estimates given in this paragraph are for circuits over which communication should be reliable except for a small percent of the time in the period indicated, assuming that the equipment is functioning properly and that local noise and interference from friendly or enemy transmissions are negligible. Greater ranges could be obtained if operation is required during only a portion of the time.

b. Sample Ground-wave Distance Ranges. Figure 6-74 gives estimated ground-wave distance ranges for a number of tactical radio sets with specified antennas over smooth poor earth, good earth, and sea water, and with atmospheric noise conditions corresponding with noise grade areas 2 and 4 of figures 6-90 and 6-91. Illustrations of most of these radio sets and of a few other common tactical sets are in figures 6-75 to 6-85 inclusive. Tactical sets range from the small Radio Set SCR-536 (handie-talkie) with a rated power of 0.02 watt, to the large vehicular sets such as Radio Set SCR-399, with a rated power of 400-watts cw.

c. Limitations on Ground-wave Range Data.

(*1*) In the jungle, ground-wave ranges are much less than for the *poor earth* condition in figure 6-74. A rough approximation is that ground-wave ranges through dense jungle are of the order of one-tenth as great as over poor earth. Over sea water they are of the order of ten times as great as over poor earth.

(*2*) In the higher part of the h-f band, antenna siting precautions similar to those described for v-h-f (par. 618) are necessary in order to attain the estimated range. Such precautions are less important in the lower end of the h-f band.

(*3*) An estimate of the effect of hilly country in reducing ground-wave transmission range is shown in figure 6-86. To use this figure, obtain a profile of the proposed transmission path, draw the triangle as shown in the figure, and read the reduction factor. An example is shown for the case of $D_1 = 10$ miles, $H = 2{,}000$ feet and an operating frequency of 7 megacycles, the resulting reduction factor being 0.58. Multiply the expected ground-wave distance range, previously determined on the basis of smooth earth, by this reduction factor. If the product is greater than the actual distance between antennas, the siting is expected to be satisfactory. This *shadow* chart applies for distances up to about 100 miles; for greater distances the reduction in range is somewhat less than given by the chart. It is based on the assumption that the field intensity in the absence of hills would vary inversely as the square of the distance; this is a reasonable approximation for h-f transmission over land.

(*4*) Computed distance ranges for sea water apply when transmitting and receiving antennas are practically at the water's edge. There is evidence that considerable losses occur if they are inland more than a few hundred feet, except in marshy terrain. If inland sites must be used, placing the antenna on the for-

Type of set	Rated power (watts)		Type of antenna	Frequency (mc.)	Estimated ground-wave distance ranges (miles), based on atmospheric noise typical of middle latitudes[a]											
					Poor soil[b]				Good soil[b]				Sea water[c]			
					Midmorning		Midnight		Midmorning		Midnight		Midmorning		Midnight	
	Voice	Cw			Voice	CW	Voice	CW	Voice	CW	Voice	CW	Voice	CW	Voice	CW
SCR-177-( ), SCR-188-A	75	75	Inverted L as furnished	1.5	60	125	6	14	180	300	28	65	550	750	80	250
				4.5	22	55	6	16	70	125	22	50	380	500	200	330
				12.5[d]	8	21	9	24	21	50	24	55	170	240	175	250
SCR-193-( )	75	75	15′ whip	1.5[h]	12	30	3	7	60	120	12	35	220	420	20	100
				4.5	18	45	5	13	65	110	17	45	350	480	160	300
SCR-284-A	8	20	25′ whip	3.8	13	40	3	10	45	110	12	35	300	500	90	260
				5.8	9	28	4	12	28	75	12	35	230	370	130	270
SCR-299-( ), SCR-399-( ), SCR-499-( )	300	400	15′ whip	2.0[h]	23	60	5	13	90	170	23	55	400	600	100	280
				4.5	30	70	8	23	85	150	30	70	420	550	240	380
				8.0	16	40	11	30	45	90	30	70	280	380	240	340
				12.5[e]	13	35	15	40	35	70	35	75	200	280	200	280
				18[e]	20	45	25	55	45	80	50	90	180	240	200	250
			Inverted[g] L	2.0	70	140	8	20	180	300	35	80	600	800	160	370
				4.5	35	75	10	26	90	160	35	75	440	550	250	400
SCR-506	20	80	15′ whip	2.0[h]	10	35	2	7	45	115	9	35	220	470	22	160
				4.5	13	45	4	13	45	115	13	45	300	480	120	300
SCR-694-C, AN/TRC-2	7	20	15′ whip	2.0[h]	8	24	2	5	35	90	7	24	170	400	14	100
				3.8	11	35	2	8	40	100	10	30	280	470	70	225
				6.5	7	23	3	12	22	60	11	35	200	340	125	250

[a] Noise grade 2 assumed for middle latitudes (figs. 6-90 and 6-91).

[b] Applies to flat or gently rolling country; for hilly country see paragraph 644c.

[c] Ranges for sea water assume that transmitter and receiver are at the water's edge; otherwise ranges may be materially shortened.

[d] Upper frequency limit of SCR-177 is 4.5 mc. Rated power of SCR-188-A is less than listed value at frequencies above 4.5 mc.

[e] Upper frequency limit of SCR-299 is 8.0 mc. Rated power of SCR-399 and SCR-499 is less than the listed value at frequencies above 8.0 mc.

[f] Lower frequency limit of SCR-694-C is 3.8 mc.

[g] Ranges assume 65′ total antenna length for 2 mc., 35′ for 4.5 mc., with 20′ vertical portion in each case.

[h] Set noise, rather than atmospheric noise, assumed to be controlling at receiver during midmorning in these cases.

Figure 6-74. Estimated ground-wave distance ranges for specific radio sets (continued on opposite page).

Type of set	Rated power (watts)		Type of antenna	Frequency (mc.)	Estimated ground wave distance ranges (miles), based on atmospheric noise typical of tropical areas[a]											
					Poor soil[b]				Good soil[b]				Sea water[c]			
					Midmorning		Midnight		Midmorning		Midnight		Midmorning		Midnight	
	Voice	Cw			Voice	CW	Voice	CW	Voice	CW	Voice	CW	Voice	CW	Voice	CW
SCR-177-( ), SCR-188-A	75	75	Inverted L as furnished	1.5	24	60	3	7	100	180	14	35	360	550	25	120
				4.5	18	45	4	10	60	110	14	35	350	480	125	250
				12.5[d]	9	24	7	19	24	55	20	45	175	250	160	225
SCR-193-( )	75	75	15′ whip	1.5[h]	11	27	2	4	55	110	4	16	200	400	5	35
				4.5	14	35	3	8	50	100	11	28	320	450	95	225
SCR-284-A	8	20	25′ whip	3.8	10	32	2	6	35	100	7	22	260	450	40	180
				5.8	8	27	2	8	26	70	8	25	225	370	90	225
SCR-299-( ), SCR-399-( ), SCR-499-( )	300	400	15′ whip	2.0[h]	22	60	3	7	85	170	12	35	400	600	35	160
				4.5	23	60	5	14	70	130	17	45	400	530	160	300
				8.0	17	45	8	22	45	90	23	55	300	400	200	300
				12.5[e]	15	35	11	30	35	75	23	65	200	280	200	270
				18[e]	14	35	16	40	35	65	35	70	170	225	170	225
			Inverted[g] L	2.0	35	85	4	11	120	200	20	50	470	650	75	240
				4.5	27	65	6	16	80	150	20	50	400	550	180	330
SCR-506	20	80	15′ whip	2.0[h]	9	30	1	4	45	115	4	18	200	450	6	70
				4.5	10	35	2	8	35	100	8	28	270	450	65	225
SCR-694-C, AN/TRC-2	7	.20	15′ whip	2.0[h]	8	23	1	3	35	90	3	13	160	400	4	40
				3.8	8	27	2	5	30	85	6	20	240	430	30	150
				6.5	7	23	2	8	20	60	7	24	200	340	85	225

[a] Noise grade 4 assumed for tropical areas (figs. 6-90 and 6-91).

[b] Applies to flat or gently rolling country; for hilly country see paragraph 644c.

[c] Ranges for sea water assume that transmitter and receiver are at the water's edge; otherwise ranges may be materially shortened.

[d] Upper frequency limit of SCR-177 is 4.5 mc. Rated power of SCR-188-A is less than listed value at frequencies above 4.5 mc.

[e] Upper frequency limit of SCR-299 is 8.0 mc. Rated power of SCR-399 and SCR-499 is less than the listed value at frequencies above 8.0 mc.

[f] Lower frequency limit of SCR-694-C is 3.8 mc.

[g] Ranges assume 65′ total antenna length for 2 mc., 35′ for 4.5 mc., with 20′ vertical portion in each case.

[h] Set noise, rather than atmospheric noise, assumed to be controlling at receiver during midmorning in these cases.

Figure 6-74. Estimated ground-wave distance ranges for specific radio sets (continued).

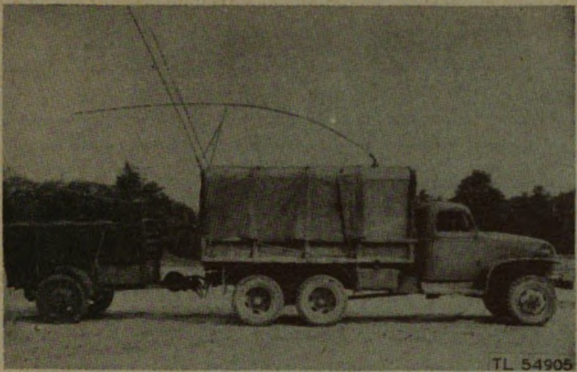


Figure 6-75. Radio Set SCR-399 installed in Truck, Cargo, 2½-ton, 6 x 6.

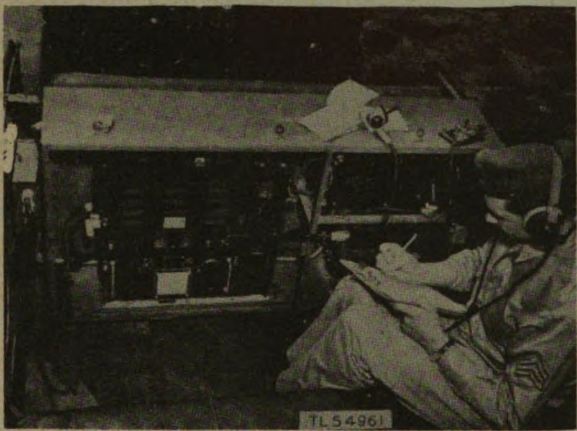


Figure 6-76. Vehicular Radio Set SCR-193 in Truck, Command, ¾-ton, 4 x 4.

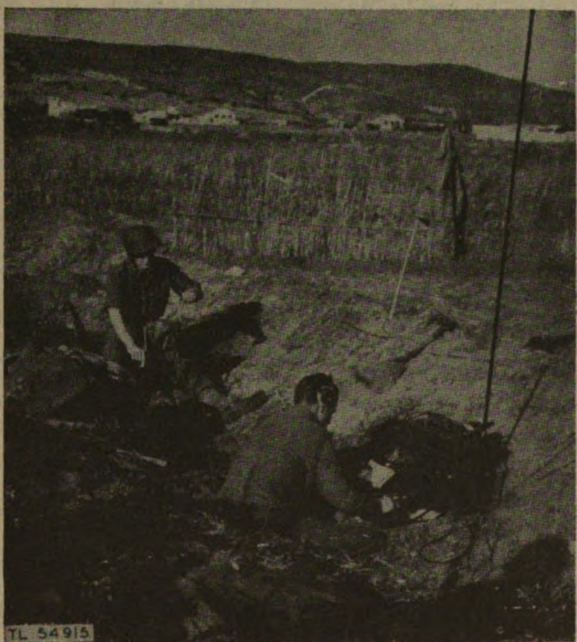


Figure 6-77. Field operation of Radio Set SCR-284,

Figure 6-78. H-f radio station consisting of transmitting and receiving components of Radio Set SCR-188.

Figure 6-79. Radio Set SCR-511 in operation.

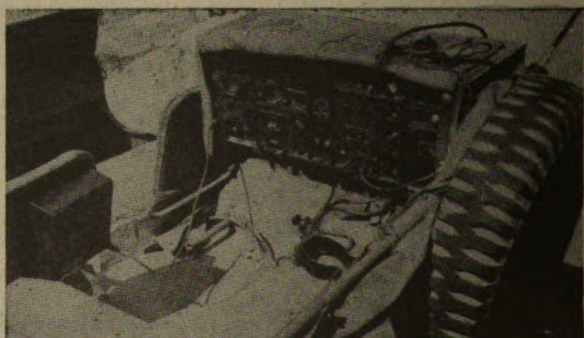


Figure 6-80. Radio Set SCR-506 installed in Truck, ¼-ton 4 x 4

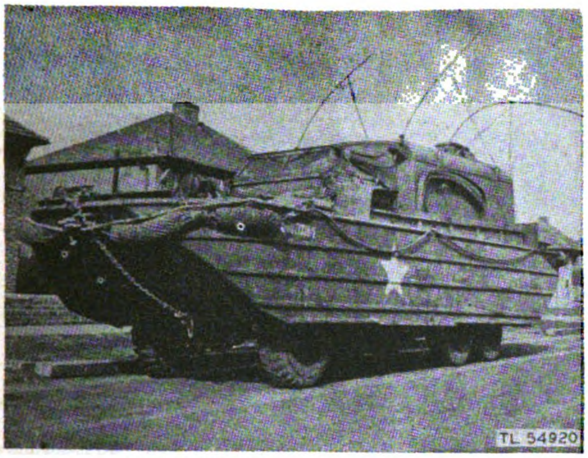


Figure 6-81. Radio Set SCR-399 installed in Truck, Amphibian, 2½-ton, 6 x 6.

Figure 6-82. Handie-talkie Radio Set SCR-536 in operation.

Figure 6-83. Radio Set SCR-543 and Switchboard BD-72 in operation.

Figure 6-84. Radio Set SCR-593 (receiver only) in use at an automatic gun site.

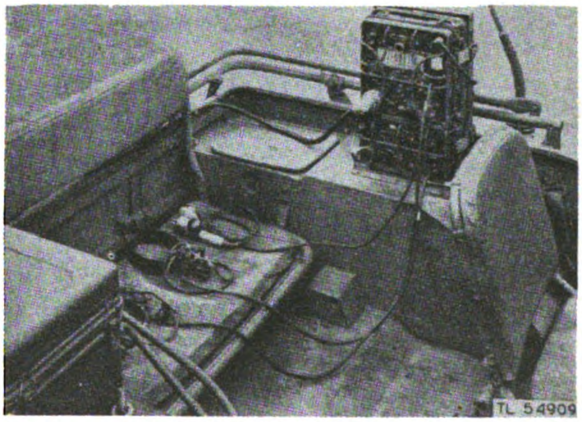


Figure 6-85. Radio Set SCR-694-C installed in Truck, ¼-ton, 4 x 4.

ward slope of a hill will tend to compensate for such losses.

d. Sample Estimated Sky-wave Performance.

(*1*) Figures 6-87, 6-88, and 6-89 give estimated sky-wave performance with half-wave horizontal or nearly horizontal antennas, for several tactical radio sets for distances in the 0- to 200-mile range. With such antennas, the received sky-wave signal is roughly the same at all distances up to about 200 miles. The figures show the frequencies at which reliable

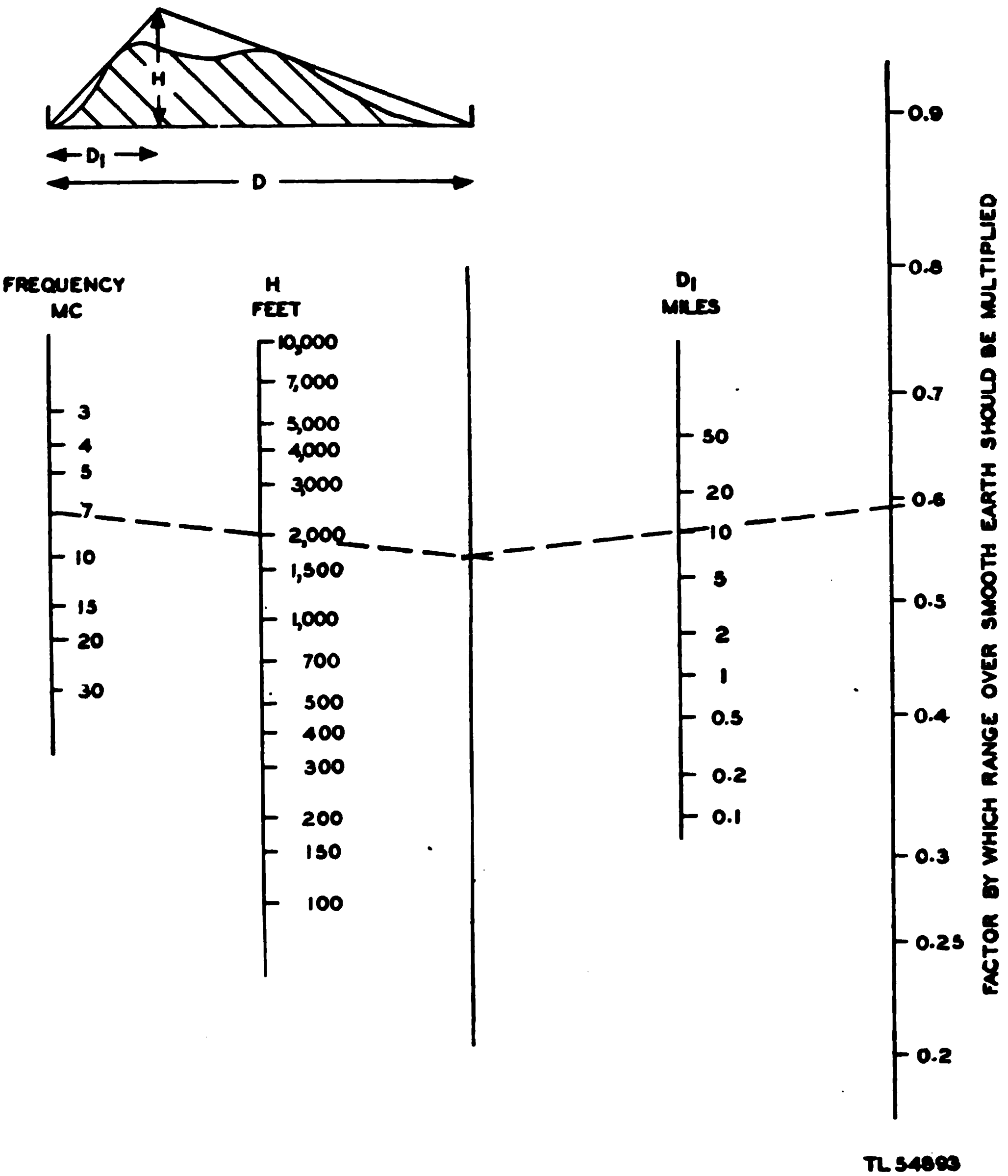
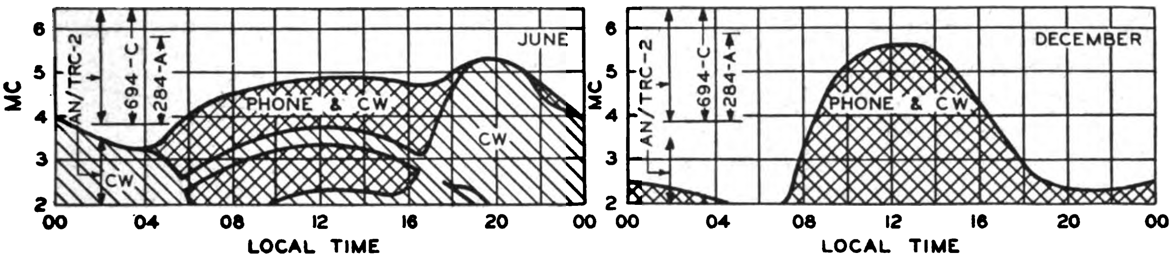


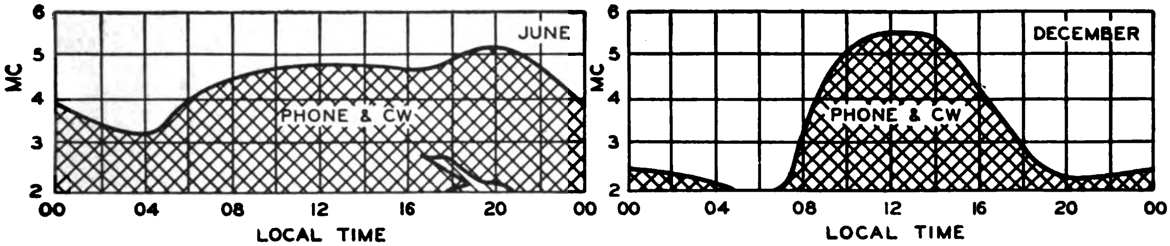
Figure 6-86. Nomogram for determining decrease in ground-wave range over land because of shadow effect.

point-to-point sky-wave transmission is expected at these distances at various hours of the day. The top curve on each graph is a plot of the optimum working frequency. Different kinds of cross-hatching indicate conditions which are good for phone and c-w transmission or for c-w transmission only. Areas below the owf but not cross-hatched indicate regions of poor signal-to-atmospheric-noise ratio. Each figure is for a separate locality, the upper and lower graphs in each case corresponding with two general types of radio sets rated at about 20 and 400 watts, cw, respectively. The performance is indicated for two times of the year 1944, June and December. In future years up to 1948 or 1949 the values of owf will tend to increase, as noted in paragraph 648e.

(2) It is assumed that both the transmitting and receiving antennas are horizontal. The use of horizontal receiving antennas is important for sky-wave transmission at these distances in order to favor reception of the high-angle signal and to discriminate against lower-angle atmospheric static.



RADIO SETS AN/TRC-2, SCR-284-A, SCR-694-C (NOTE FREQUENCY RANGE OF SETS)



RADIO SETS SCR-299, SCR-399, SCR-499

HALF-WAVE HORIZONTAL ANTENNAS, 30 FEET HIGH
DISTANCE: 100 MILES (TRANSMISSION APPROXIMATELY THE SAME, 0-200 MILES)

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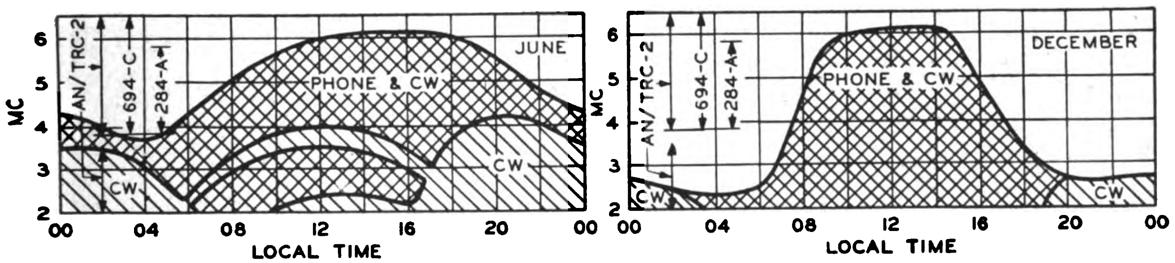
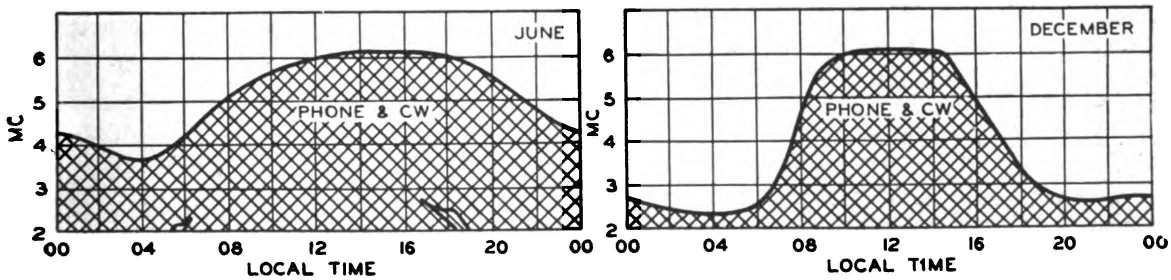
Figure 6-87. Sky-wave performance chart, location: Germany, 1944.



RADIO SETS AN/TRC-2, SCR-284-A, SCR-694-C (NOTE FREQUENCY RANGE OF SETS)



RADIO SETS SCR-299, SCR-399, SCR-499

HALF-WAVE HORIZONTAL ANTENNAS, 30 FEET HIGH
DISTANCE 100 MILES (TRANSMISSION APPROXIMATELY THE SAME, 0-200 MILES)

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Figure 6-88. Sky-wave performance chart, location: Japan, 1944.

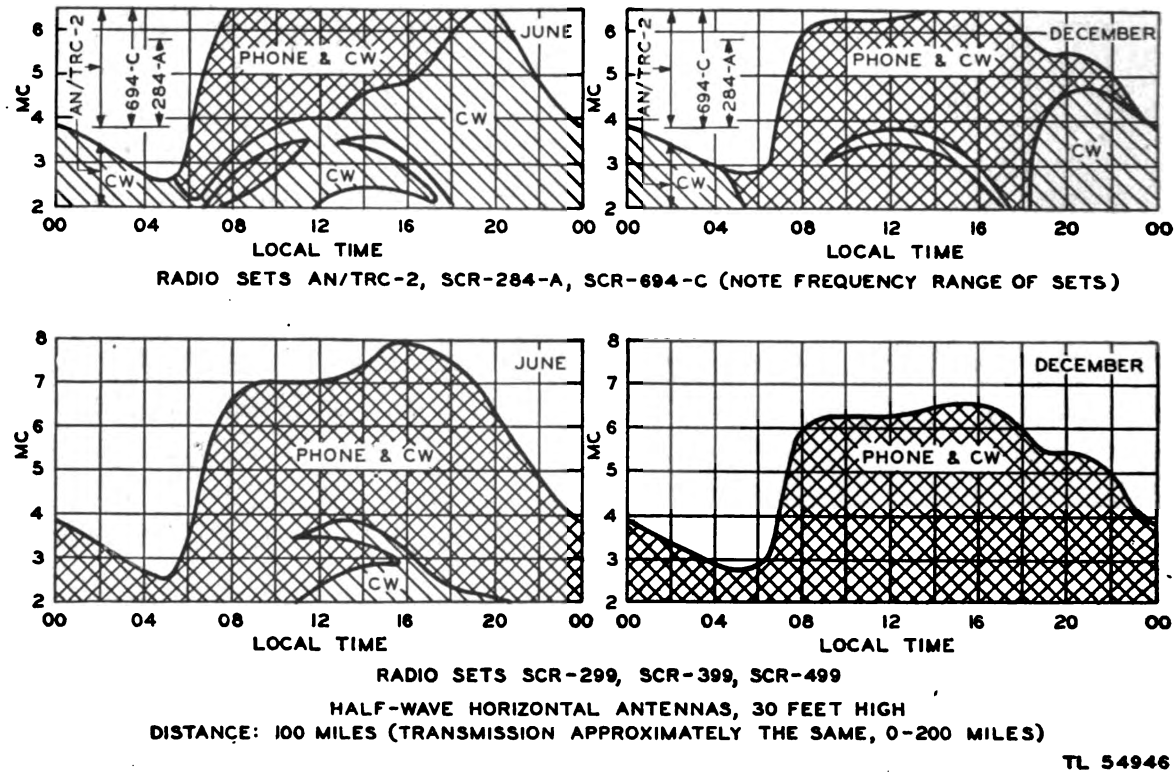

Figure 6-89. Sky-wave performance chart, location: Philippines, 1944.

e. Periodic Estimates of Transmission Range for Specific Radio Sets. Periodic estimates of ground-wave and sky-wave transmission for particular radio sets and antennas, and for specified theaters of operation, are given in special reports on *Ground and Sky-wave Distance Ranges of Selected Army Radio Sets for Tactical Use in the ——— Theater of Operations,* obtainable from the Office of the Chief Signal Officer, Plans and Operations Division, Communication Liaison Branch, Washington 25, D. C. The particular month and theater of operations for which information is desired should be specified. These predictions are based on current estimates of sky-wave conditions and upon current revisions of other data bearing on h-f transmission. They give ground-wave estimates over sea water and ground of types appropriate to the particular area, including jungle where applicable. The sky-wave estimates apply for distances up to about 200 miles. This information also contains estimates of ground conductivity (good, poor, or jungle) for particular areas. The sky-wave estimates are, at the time of writing this manual, based on the assumption that the receiving antenna is equally efficient for signal and noise. For transmission distances up to 200 miles, horizontal half-wave antennas favor the signal as against the noise and therefore will give better performance, while vertical whips favor the noise as against the signal and will therefore give poorer performance than the receiving antenna assumed in the special reports.

645. CALCULATION OF GROUND-WAVE AND SKY-WAVE TRANSMISSION PERFORMANCE.

a. General.

(*1*) Estimates of performance with either ground-wave or sky-wave transmission require the evaluation of a number of factors which are described in subsequent paragraphs. The information given below on these factors can be used to make transmission calculations in situations where the less detailed data described in paragraph 644 are unavailable or are insufficient or are not applicable to the case at hand. This information, moreover, provides a background for a general understanding of transmission characteristics and problems.

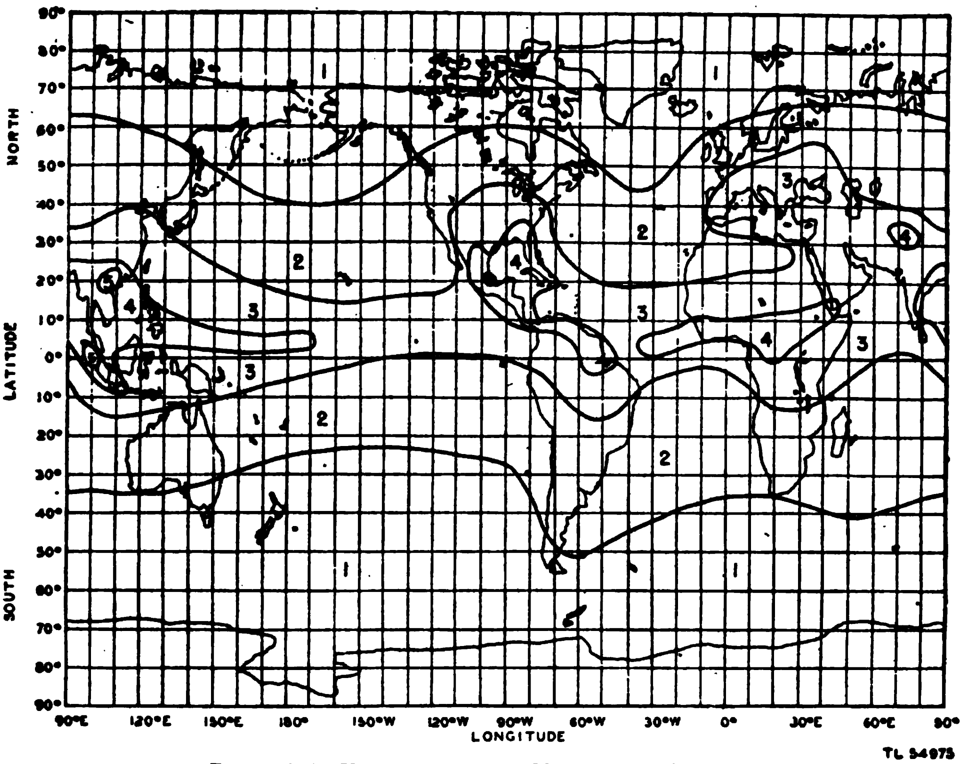

Figure 6-90. Noise grade areas, May through September.

(*2*) Basically, the question as to whether radio transmission in a given case is satisfactory can be answered by comparing two quantities, namely: the field intensity *actually recieved,* and the field intensity (at the radio receiver) *required* to over-ride atmospheric or other noise. Subparagraph b below, gives data relating to the *required* field intensities, assuming that certain conditions apply at the receiving end. Corrections to cover other conditions are given further on. The *actual* received field intensity is discussed in paragraph 646 for ground wave and in paragraph 648 for sky wave. A short-cut in ground-wave calculations can be taken in the case of certain particular noise conditions by using the information in paragraph 647, instead of that in paragraphs 645b and 646. Data given in paragraphs 649 to 652 relative to the characteristics of transmitting and receiving antennas must be used in conjunction with the other material. Examples of the use of all this material, in itemized step-by-step form, are given in paragraph 653.

b. Required Field Intensities for Various Noise Areas.

(*1*) Estimated values of signal required to override atmospheric noise can be obtained from figures 6-90, 6-91, and 6-92. These figures are based on available information regarding atmospheric static, and it is expected that they will be revised when additional information becomes available. These data refer to intensities which would over-ride static perhaps 95 percent of the time. With somewhat lower received field intensities, transmission would be practicable part of the time, insofar as atmospheric static is concerned.

(*2*) Figures 6-90 and 6-91 show the world as divided for convenience into five static noise areas. This is done separately for the periods from May through September and from November through March. The atmospheric noise level is low in area 1 and high in area 5.

(*3*) Estimated values of signal field intensity required to over-ride the atmospheric noise in each of these areas are shown in figure 6-92 for various frequencies at different times of the day. These values are for voice communication; for manual cw the required field intensities are taken to be about 17 db less. The difference of 17 db makes a small allowance for conditions under which the talker does not produce full modulation of the radio transmitter.

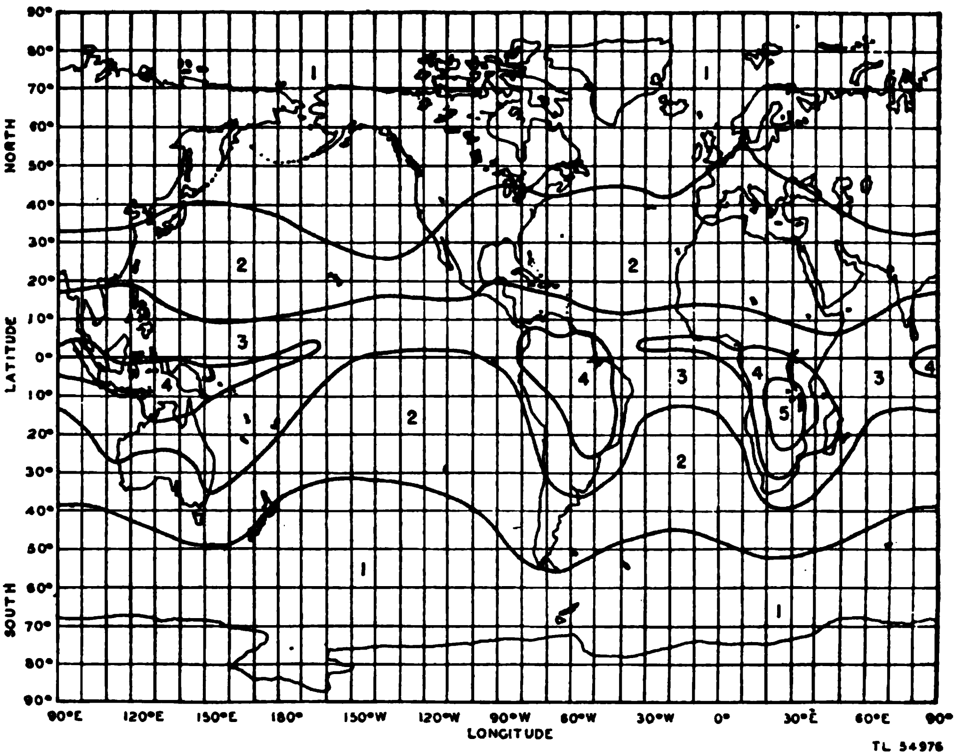

Figure 6-91. Noise grade areas, November through March.

(*4*) In the portions of these curves indicating low required field intensities, atmospheric static may be so low that limitations produced by other kinds of noise must be allowed for. The field intensity required to override set noise is not indicated on the curves, on account of the wide range of efficiencies of tactical antennas and receiving-set input coupling arrangements. The likelihood is that set noise will be limiting during part of the time in the lower noise grade areas, but not often in the higher noise grade areas.

(*5*) The data on which figure 6-92 is based were obtained by measurements of noise in short vertical receiving antennas. Receiving antenna corrections for use in sky-wave propagation computations are discussed in paragraph 652.

646. GROUND-WAVE SIGNAL FIELD INTENSITIES.

a. Transmission Over Land and Sea Water. Computed curves of ground-wave field intensity over smooth earth and sea water are given in figures 6-93, 6-94, and 6-95. Over land, the field decreases rapidly as the distance is increased. At moderate or great distances, loss due to the curvature of the earth becomes important, and the rate of attenuation over land or sea becomes increasingly large. The field intensity values given in these figures are expressed in terms of power radiated from a short vertical antenna and apply with sufficient accuracy also to a vertical antenna up to a half wave long. *They do not apply to the rated power of the radio set.* Corrections to relate rated power to radiated power are given for vertical whip and half-wave horizontal antennas in paragraphs 650 and 651, respectively. These corrections are particularly important in the case of the short whips frequently used for h-f transmission. In the lower end of the h-f band, the radiated power from such antennas is only a small fraction of the rated transmitter power. The qualifications noted in paragraph 644c should also be borne in mind when using figures 6-93 to 6-95. Estimates of ground conductivity for particular theaters of operations are given in the publications referred to in paragraph 644e.

b. Transmission Through Jungle. The attenuation of ground waves through heavy jungle

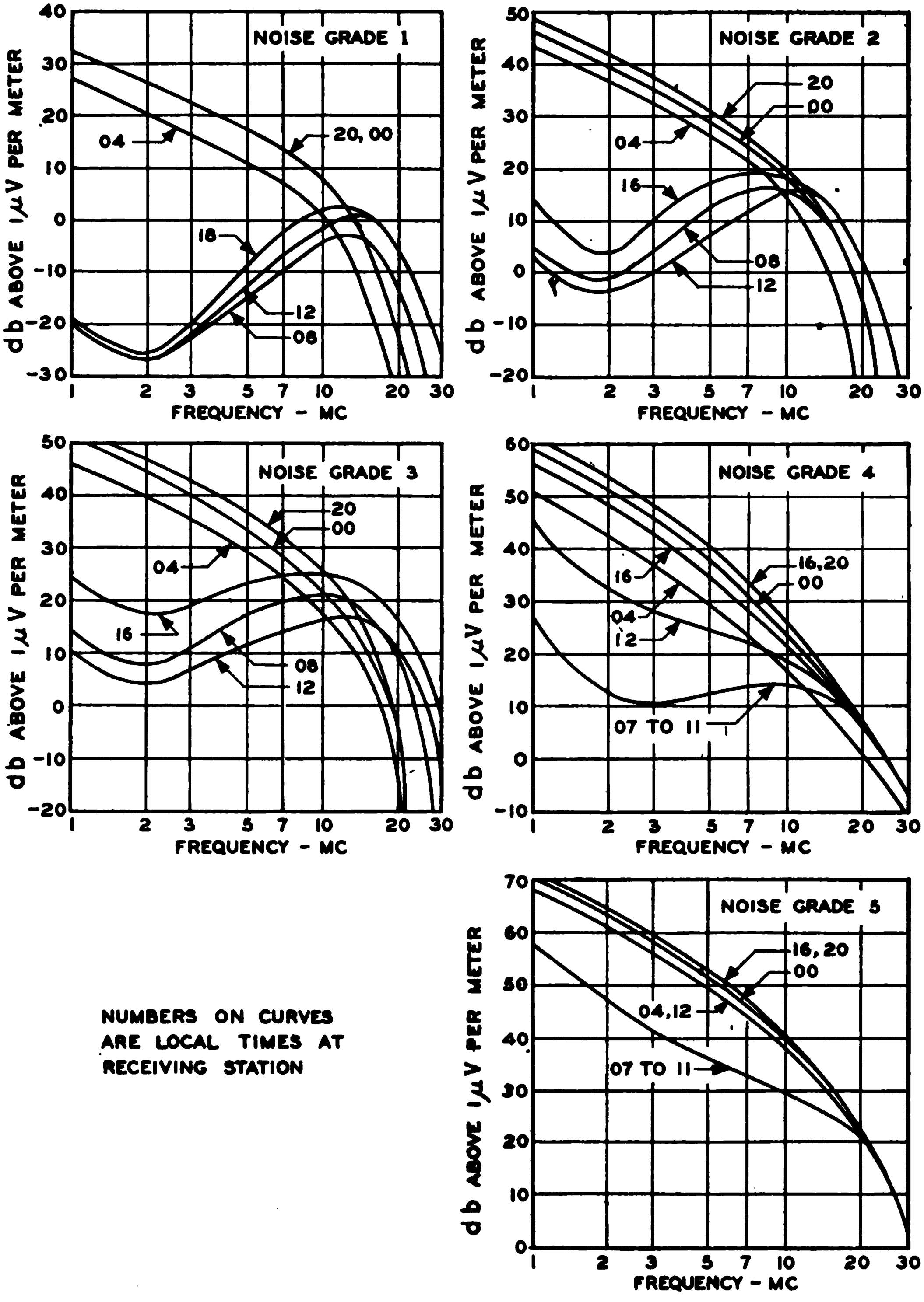

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Figure 6-92. Field intensity required to override atmospheric static in various noise grade areas, for voice transmission.

is extremely great. The effect of this high attenuation, combined with losses due to foliage in the immediate vicinity of the antennas and with the high atmospheric noise characteristic

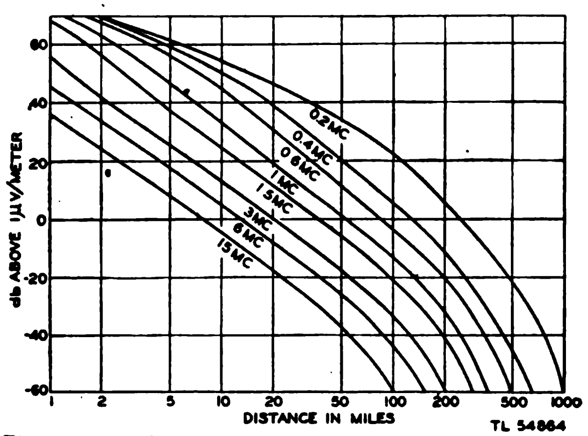

Figure 6-93. Ground-wave field intensity versus distance over poor soil, 1 watt radiated, short vertical antenna.

of such regions, has limited the h-f ground-wave distance ranges obtainable with tactical radio sets in heavy jungle in the stormy season to distances of the order of 1/8 to 5 miles. In light jungle somewhat greater ranges can be obtained, and if antennas can be located on hillsides providing a line-of-sight path, or in large clearings, the ground-wave range is materially increased. Approximately straight-line transmission over the surface of a river may

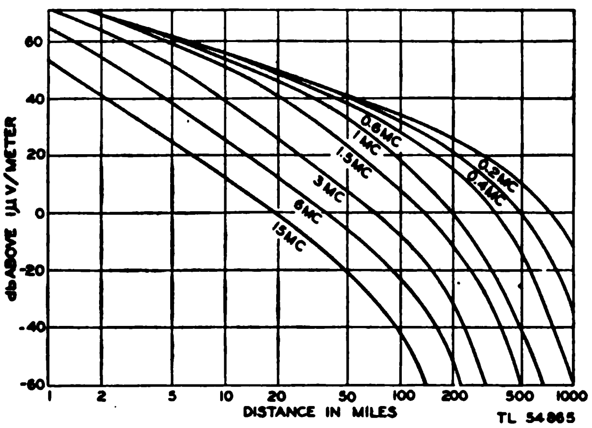

Figure 6-94. Ground-wave field intensity versus distance over good soil, 1 watt radiated, short vertical antenna.

also afford a suitable path. Another possibility is the use of long horizontal antennas, which may work even when lying on the ground (pars. 666 and 667). The use of sky-wave transmission is often the best solution. Estimates of jungle ground-wave ranges are given in some of the published information referred to in paragraph 644e.

c. Example of Use. As an example of the use of figures 6-93 to 6-95, suppose that a certain radio circuit is observed to give just tolerable voice transmission at 20 miles over level ground on a frequency of 3 mc, and that, moreover, it is observed that the signals are steady and therefore presumably ground waves. How far can the circuit be used for cw on ground-waves? Solution: The required field intensity for cw is about 17 db less than for voice transmission (par. 645b). On figure 6-93, the distance at which the 3-mc signal intensity is 17 db weaker than it is at 20 miles is found to be 50 miles for poor soil, and for good soil (fig. 6-94) the result is about the same. Hence cw could probably be used out to 50 miles.

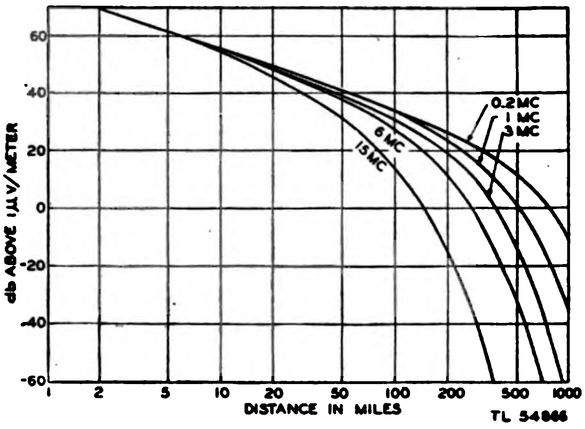

Figure 6-95. Ground-wave field intensity versus distance over sea water, 1 watt radiated, short vertical antenna.

d. Step-by-step Procedure. Detailed procedure is given in paragraph 653 for the use of figures 6-93 to 6-95 together with other information in this chapter, to obtain an estimate of ground-wave performance of a particular radio set.

647. GROUND-WAVE DISTANCE RANGE VERSUS RADIATED POWER FOR SPECIFIC NOISE CONDITIONS.

a. General.

(*1*) Figures 6-96 to 6-101 inclusive give estimated ground-wave ranges over poor soil, good soil, and sea water, for various values of *radiated* power, assuming that the transmitting and receiving antennas are vertical and not exceeding a half wave in length. The ranges shown assume that the earth is smooth, hence they are subject to the qualifications

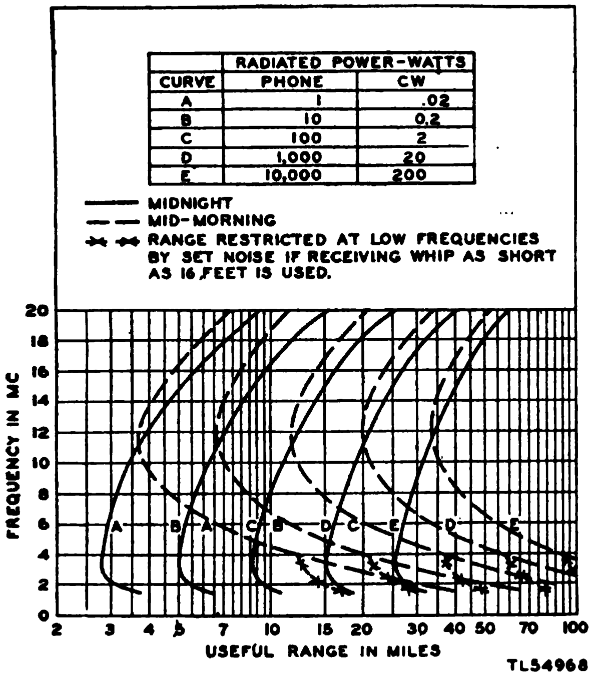

Figure 6-96. Ground-wave distance range over poor soil, noise grade 2, vertical antennas.

given in paragraph 644. The relation between radiated power and the rated output power of the radio transmitter is discussed in paragraphs 649 to 651. Separate curves are given for noise grades 2 and 4 (figs. 6-90 and 6-91); these correspond roughly to conditions in the middle latitudes and in tropical areas, respectively. These curves may be used directly for the specific conditions to which they apply. For other conditions, interpolation may be resorted to; or better, the method given in paragraph 646 may be used instead. The *mid-*

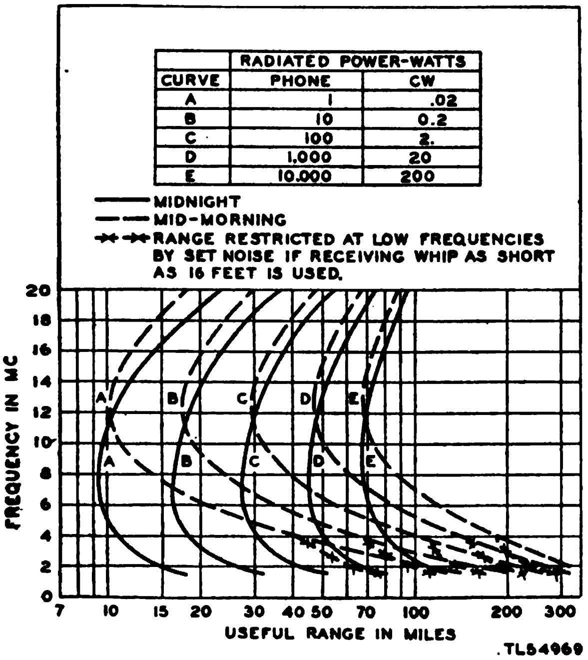

Figure 6-97. Ground-wave distance range over good soil, noise grade 2, vertical antennas.

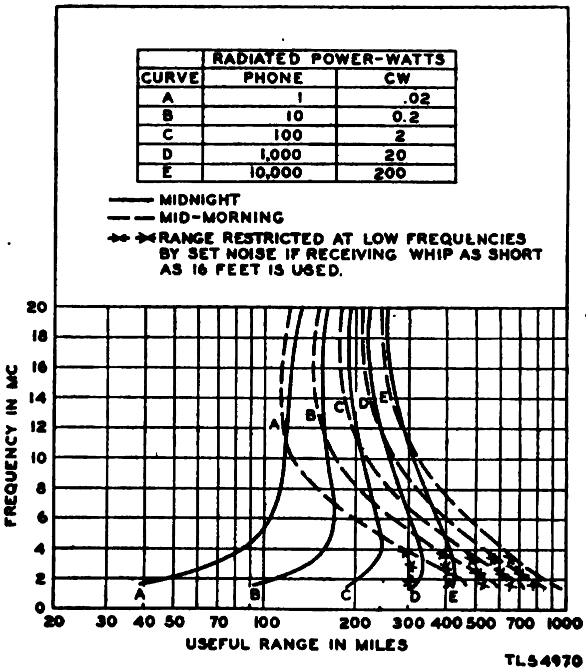

Figure 6-98. Ground-wave distance range over sea water, noise grade 2, vertical antennas.

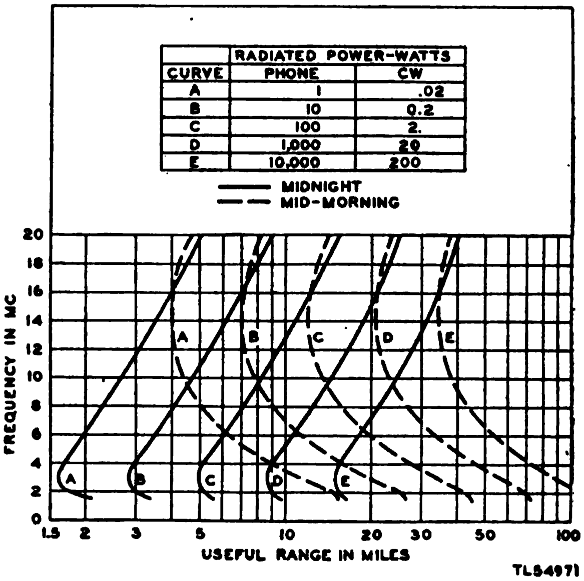

Figure 6-99. Ground-wave distance range over poor soil, noise grade 4, vertical antennas.

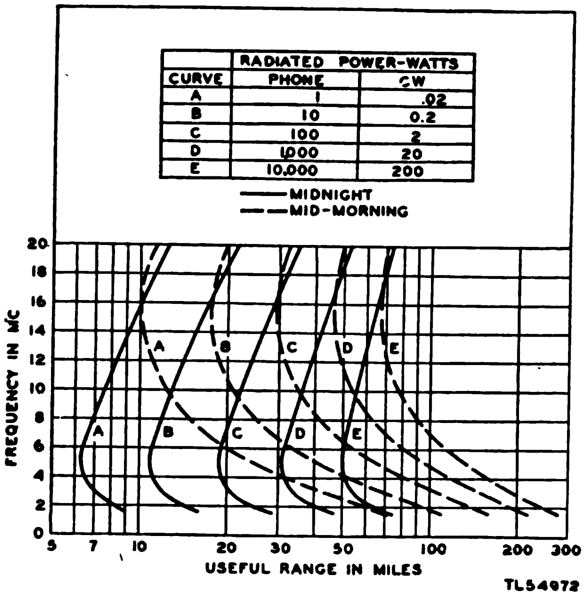

Figure 6-100. Ground-wave distance range over good soil, noise grade 4, vertical antennas.

night curves apply fairly well throughout the hours of darkness; the *midmorning* (not noon) curves represent conditions when atmospheric static is at its lowest intensity at frequencies in the lower part of the h-f band (fig. 6-92).

(*2*) When atmospheric static is of low intensity, and when only a small fraction of the voltage picked up in the receiving antenna is delivered to the radio receiver (as in the case of a short whip), the controlling noise at the radio receiver output is apt to be set noise rather than static. It is estimated that this will occur for noise grade 2, midmorning, for 16-foot whips at frequencies below 4 megacycles. This tends to reduce the range to distances less than would be predicted for static noise alone. Such reductions in range are shown by separate branches of the daytime curves on figures 6-96 to 6-98. The branches of these curves which do not show these reductions apply to longer antennas; for example, at 2 mc a length of about 35 feet would be required to avoid a reduction in range.

b. Step-by-step Procedure. Detailed procedure is given in paragraph 653 for the use of figures 6-96 to 6-101 together with other information in this chapter, to obtain an estimate of the ground-wave performance of a particular radio set.

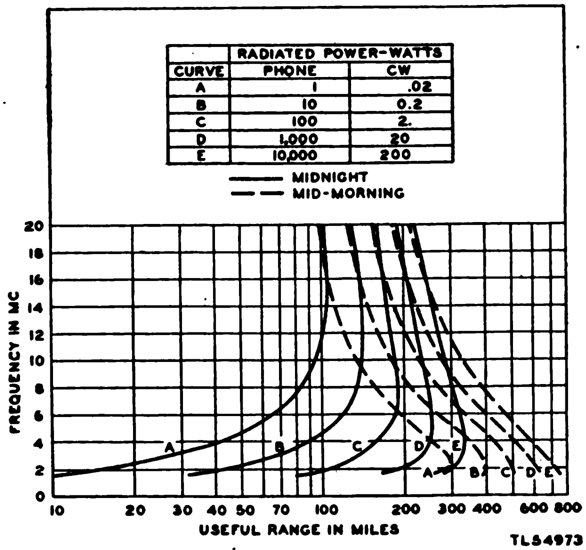

Figure 6-101. Ground-wave distance range over sea water, noise grade 4, vertical antennas.

648. SKY-WAVE SIGNAL FIELD INTENSITIES.

a. General. Sky waves are subject to fading, and to various kinds of other variations, as outlined above. Hence sky-wave field intensities are predictable only on an average basis. Estimates of sky-wave field intensities, based on information available at present, are given in this paragraph.

b. Estimated Values. Figure 6-102 shows estimates of sky-wave field intensity for various frequencies and distances, for maximum and minimum absorption in the ionosphere. At night the absorption is minimum (absorption constant $K = 0$), and a single curve serves for all the frequencies indicated. The other curves are for $K = 1$, which occurs when the

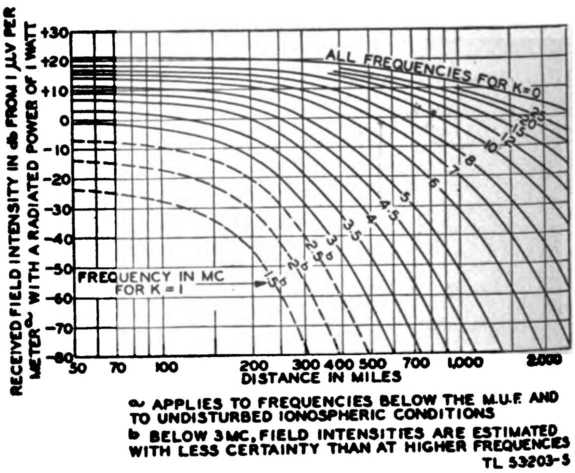

Figure 6-102. Sky-wave field intensity versus distance between ground stations for limiting values of K.

sun is at the zenith (directly overhead). For other cases the value of K varies as shown approximately in figure 6-103. (Monthly values of K are given in the TB 11–499 series reports.) To illustrate, figure 6-103 shows that at latitude 25° at noon in winter, K = 0.72. To estimate the received field intensity for this

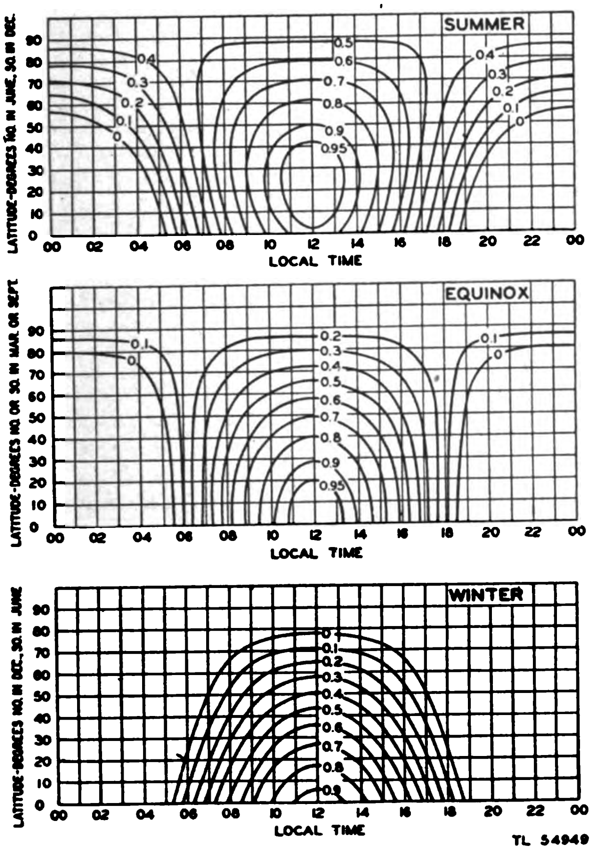

Figure 6-103. Typical values of K for use in conjunction with figure 6-102.

or any other fractional value of K, prorate the difference between the K = 0 and K = 1 curves on figure 6-102. For example, at 2 mc and 150 miles, the received field intensity (fig. 6-102) is about 21 db above 1 microvolt per meter for K = 0, and –23 db for K = 1; 0.72 times the difference between these values is 0.72 (21 + 23) = about 32 db, and the received field intensity for K = 0.72 is 21–32 = –11 db from 1 microvolt per meter.

c. Qualifications. The values of received field intensities in figure 6-102 are for 1 watt of ***radiated power,*** determined as described in paragraphs 650 to 652. The values apply to the incident, or arriving field intensities, and not necessarily to field intensities in line with a particular antenna; hence they are subject to the receiving antenna corrections described in paragraph 652. Figure 6-102 applies only when the frequency is below the muf for the conditions in question, and a separate check must be made to see whether this condition is satisfied before using the curves. Furthermore, figure 6-102 is based on normal absorption, not including auroral absorption near the magnetic poles, or effects of sporadic–E or other variant conditions. An additional absorption effect not included in figure 6-102 occurs when the frequency in question is very close to the muf. Absorption close to the E-layer muf produces the rainbow-shaped regions of relatively poor transmission shown in some parts of figures 6-87 to 6-89 (see particularly figs. 6-87 and 6-88, June, Radio Set AN/TRC–2).

d. Effect of Path Length on K. For distances up to 2,500 miles, the value of K should be determined for the midpoint of the transmission path. For greater distances the process is more complicated, and may be handled by use of TM 11–499 *Radio Propagation Handbook* and the TB 11–499–( ) series reports, or by referring the problem to Communication Liaison Branch, Plans and Operations Division, Office of the Chief Signal Officer, Washington 25, D. C. TM 11–499 contains a considerable fund of additional information on sky-wave propagation.

e. Step-by-step Procedure. Detailed procedure for the use of figure 6-102, together with other information in this chapter, to obtain an estimate of sky-wave performance of a particular radio set, is given in paragraph 653.

649. DETERMINATION OF *RADIATED* POWER.

a. The term ***radiated power*** has been used in the sense used in other Signal Corps publications on sky-wave transmission. This ***radiated power*** is a quantity proportional to the square of the *field radiated in the desired direction* by a transmitter.[12] If ground-wave transmission is being used, the direction in question is that along the ground toward the distant station. If sky-wave transmission is being used, the desired direction is upward

[12] In general, the ***radiated power*** as used in this and other Signal Corps publications is not the true total power radiated, but is a quantity convenient to use in transmission calculations. It includes a correction for radiation pattern of the transmitting antenna.

toward the ionosphere in such a direction that it will ultimately arrive at the distant receiver. In practice, the field intensity in the desired direction, for a given transmitter and antenna, may be considerably smaller than would be computed by assuming that the ***radiated power*** would be equal to the rated power of the transmitter. This is particularly true with short vertical antennas in the lower part of the h-f band. Antennas used with fixed plant h-f radio sets may be considerably more efficient, since they can be built with dimensions which are optimum for use between well defined points.

b. In order to convert rated power into ***radiated power*** it is necessary to apply a correction which is largely a function of the antenna type used. In the case of whip antennas it is convenient to consider this correction as consisting of three parts, namely; No. 1, the *transfer efficiency* of the combination of radio transmitter, coupling unit and antenna used, that is, the proportion of the rated transmitter power which reaches the antenna-ground circuit; No. 2, the *radiation efficiency* of the antenna, that is, the proportion of the power fed into the antenna-ground circuit which is actually radiated; and No. 3, the *pattern efficiency*, that is, a correction to take into account the fact that any antenna radiates better in some vertical directions than in others. For ground-wave transmission using short whips, correction No. 3 is 0 db when used in conjunction with figures 6-93 to 6-101. In the case of sky-wave transmission using a half-wave horizontal antenna, correction No. 1 is usually taken as negligible, and corrections Nos. 2 and 3 are combined for convenience.

650. POWER CORRECTIONS FOR WHIP ANTENNAS.

a. Transfer Efficiency. The transfer efficiency correction for a whip antenna used for transmitting varies with the radio transmitter used. For four types of tactical transmitters tested, the correction varied from –10 to –2 db at 2 to 3 megacycles, and improved with increasing frequency until it reached –4 to about 0 db at 6 to 8 megacycles. These values probably indicate the range in magnitude of correction No. 1 of paragraph 649 for tactical sets using whips. Since such information on specific sets is not generally available, this correction may be approximated by assuming –6 db at 2 mc, –2 db at 8 mc, and 0 db above 10 mc.

b. Radiation Efficiency. Figure 6-104 gives estimated radiation efficiency corrections for 16-foot and 4-foot whip antennas as a function of frequency. It is believed that the corrections for a 16-foot vertical whip will apply approximately when it is mounted on a vehicle or when used with a radio transmitter placed on the earth together with a good counterpoise, such as Counterpoises CP–12 and CP–13, or 8 radial wires about 25-feet long laid on the ground and connected together at

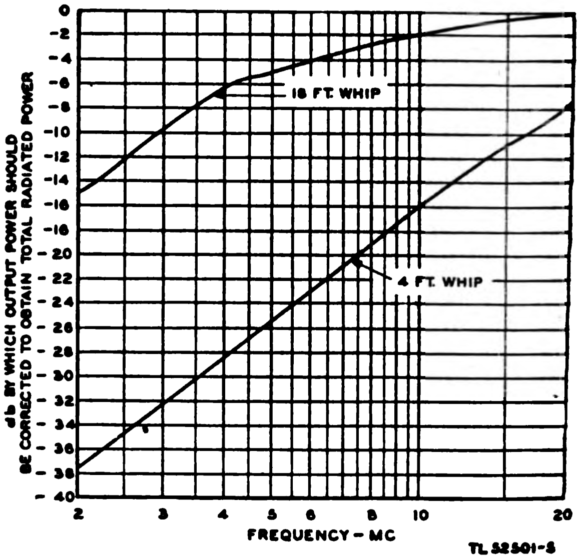

Figure 6-104. Radiation efficiency correction for vertical whip antennas.

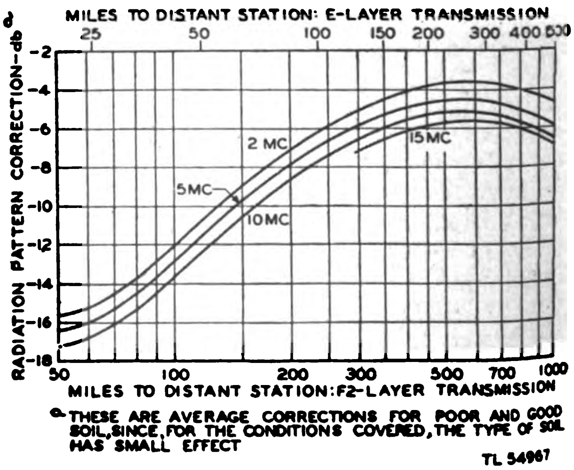

Figure 6-105. Sky-wave radiation pattern corrections for vertical whip transmitting antennas.

the ground terminal of the radio set. If the counterpoise or other good ground is not used, much greater losses may be experienced. The corrections shown in figure 6-104 correspond to correction No. 2 of paragraph 649.

c. **Pattern Efficiency.** Figure 6-105 gives estimated sky-wave pattern efficiency corrections for a vertical whip antenna, as a function of distance between transmitting and receiving sites. Two distance scales are given on this figure. The F2-layer distance scale is for use when sky-wave transmission occurs via the F2 layer, as will be true at night and also in the daytime unless the operating frequency is well below the maximum usable frequency.[19] These curves give values for correction No. 3 of paragraph 649. In practice, the pattern efficiency can probably be improved a little (possibly 3 or 4 db) for short distance sky-wave transmission by tilting the antenna somewhat from the vertical in a direction away from the distant station (fig. 6-106-A). Further improvement might be obtained by placing the antenna on a steep slope such as the side of a mountain and erecting it perpendicular to the slope (fig. 6-106-B). Another possibility of improvement arises when the antenna is in a valley, in such a position that waves radiated sideward from the antenna reflect from the side of the valley and up to the ionosphere at such an angle as to return to earth at the distant receiver (fig. 6-106-C). For such purposes the ionosphere can be imagined as an approximately horizontal mirror at a great height. Also, a whip antenna mounted on a large unsymmetrical metal object (such as a truck with trailer) which may serve as a horizontal radiating surface raised off the ground, may have a better pattern efficiency for short distances than shown by the figure.

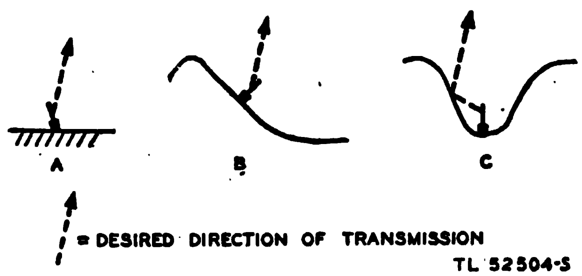

Figure 6-106. Use of whip for short distance sky-wave transmission.

d. **Use of Corrections.**

(*1*) As an example of the use of the above power corrections, assume that a transmitter rated at 75 watts output is to be used on a 100-mile sky-wave circuit at a frequency of 2 megacycles, with F2-layer transmission. Assume further that a 16-foot whip is to be used and that correction No. 1, the transfer efficiency correction, amounts to –6 db for the average combination of transmitter and antenna (par. 650a). From figure 6-104, the radiation efficiency correction, No. 2, is –15 db; and from figure 6-105, the pattern efficiency correction, No. 3, is –12 db. The total correction to be applied to the rated power is therefore $-6-15-12 = -33$db, corresponding to a power ratio of 0.0005. Hence, a transmitter rated at 75 watts would in this instance yield a ***radiated power*** of only $75 \times 0.0005 = 0.04$ watt. This is the power to be used in estimating received sky-wave field intensity from figure 6-102.

(*2*) For ground waves, correction No. 3 is 0 db and the total correction is –21 db, that is, the radiated power is $75 \times 0.008 = 0.6$ watt. This is the power to be used in estimating received ground-wave field intensity from figures 6-93 to 6-95, or ground-wave distance range from figures 6-96 to 6-101.

e. **Effect of Multiple-hop Transmission.** In computing figure 6-105 one-hop transmission was assumed, that is, a single reflection from the ionosphere. At the longer distances, multiple-hop transmission will often contribute materially to the received field. This is equivalent to improving the pattern efficiency; that is, equivalent to moving the long-distance values closer to 0 db (fig. 6-105).

651. POWER CORRECTIONS FOR A HALF-WAVE HORIZONTAL ANTENNA.

a. Limited data indicate that with properly fed half-wave horizontal antennas the transfer efficiency correction is negligible.

b. Computed values of radiation plus pattern efficiency correction for such antennas

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[19] Reports in the TB 11–499–( ) series give 2,000-km E-layer muf predictions; for other distances the E-layer muf can be obtained by multiplying the 2,000-km values by the following factors:

Distance (miles)	0	100	200	300	400	500	600	800	1000
Factor	0.21	0.24	0.31	0.41	0.51	0.61	0.70	0.84	0.95

If the E-layer muf for the distance in question is above the operating frequency, use the E-layer scale on figure 6-105; otherwise use the F2-layer scale.

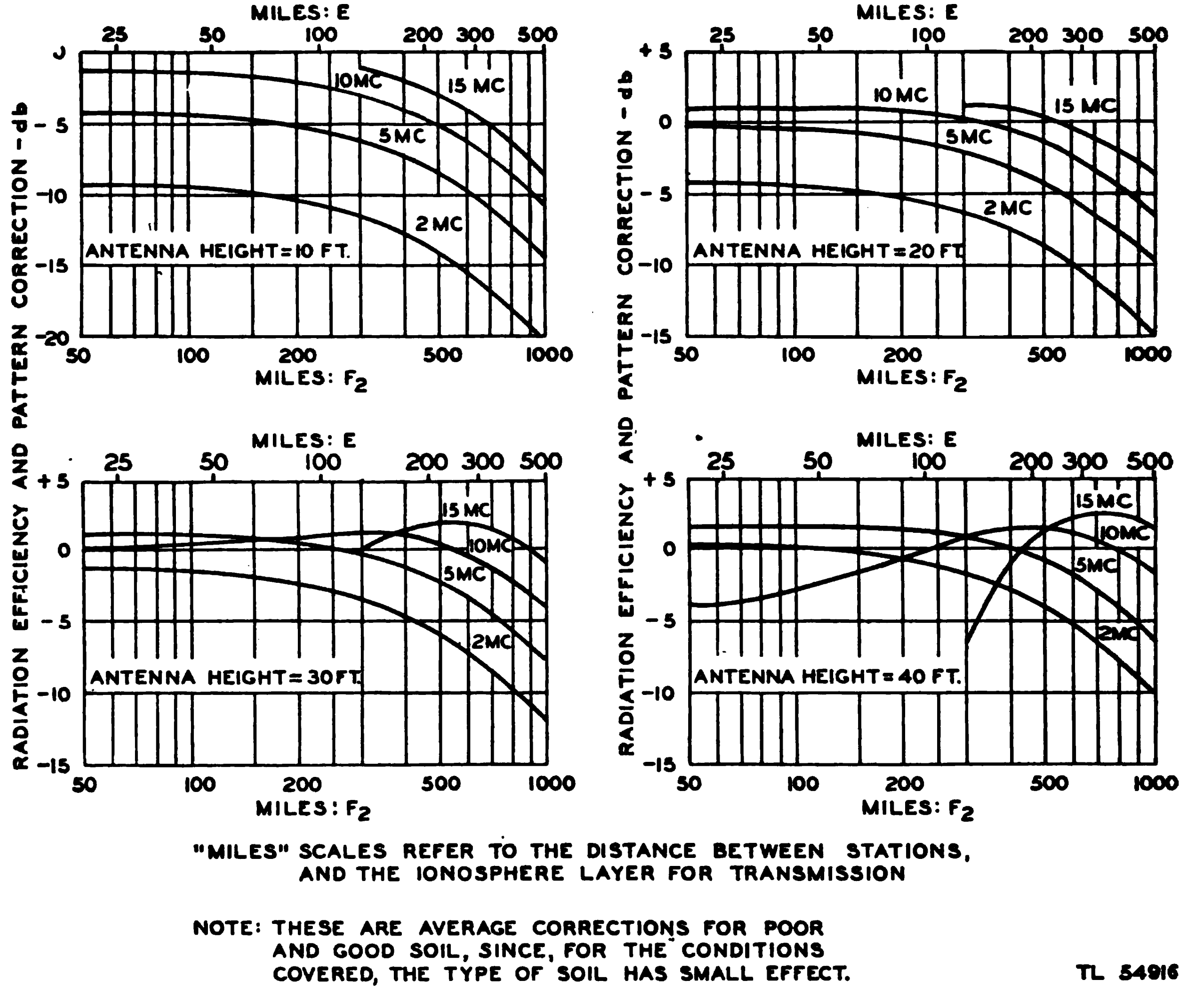


Figure 6-107. Sky-wave radiation efficiency and pattern corrections for half-wave horizontal transmitting antennas.

are given in figure 6-107. The values given are for the case when the sending and receiving antennas are broadside to each other, a condition advisable for long-distance transmission. At short distances, values for the case when the antennas are end-on to each other would be approximately the same as shown. The curves indicate the effects of changing the height of the transmitting antenna, for various frequencies and transmission distances. In general, for short- or medium-distance transmission between horizontal half-wave antennas, the antennas should be not greater than about one quarter wavelength above the ground; while for long-distance transmission, heights approaching half-wave will result in increased efficiency, since a greater part of the radiation in this case is at low vertical angles.

c. At long distances, in cases where poor efficiency is shown in figure 6-107, multiple-hop transmission will tend to improve the pattern efficiency.

652. RECEIVING ANTENNA PATTERN CORRECTIONS.

a. Sky-wave signals at the receiving site arrive at various vertical angles, depending on the distance between stations. The amount of signal picked up and delivered to the receiver therefore depends on the vertical pattern of the receiving antenna, that is, its response to a signal arriving at the vertical angle or angles involved. The amount of static interference delivered to the receiver is also a function of the vertical directional pattern of the receiving antenna and the angle of arrival of the static. The signal-to-noise ratio at the receiver input will therefore be independent of the antenna used if the signals and external noise arrive at the receiving antenna over the same sky-wave path. However, if the signal arrives at a high angle while the noise arrives at a low angle, or vice versa, the signal-to-noise ratio at the receiver input will depend on the relative response of the antenna at the two angles.

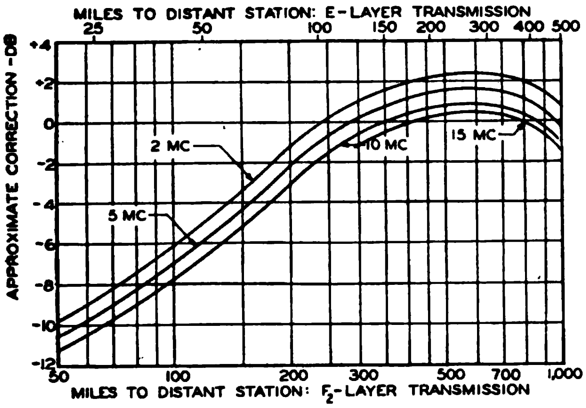


Figure 6-108. Sky-wave pattern corrections for vertical whip receiving antennas.

b. Approximate corrections to take into account the relative response of the receiving antenna to signal and to noise, for various distances of signal transmission by sky wave, are given in figure 6-108 for a short vertical antenna and in figure 6-109 for a half-wave horizontal antenna. These corrections are added to the estimated incoming signal field, and the result compared with the field required to override atmospheric static as given by figure 6-92. For example, at 2 mc, 100 miles, and F2-layer transmission, the receiving antenna pattern correction for a vertical whip is about —6 db and for a half-wave horizontal is about +9 db. (For information indicating when to use the F2-layer scale and when to use the E-layer scale, see paragraph 650c.)

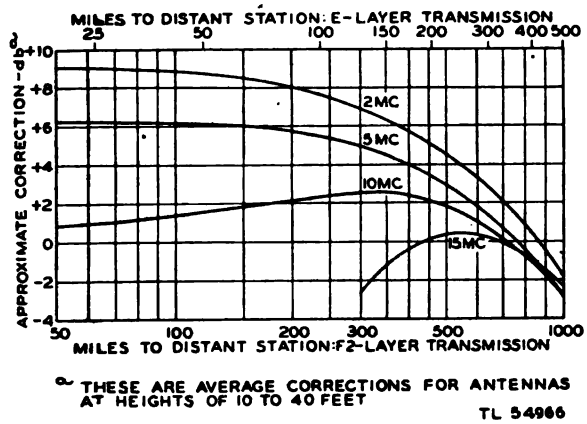


Figure 6-109. Sky-wave pattern corrections for half-wave horizontal receiving antennas.

c. With a directional receiving antenna, such as a horizontal rhombic on long-range circuits, considerable discrimination against noise is possible, especially when the direction of transmission is appreciably different from the direction of the controlling noise sources in the tropics.

653. PERFORMANCE ESTIMATES.

a. General.

(*1*) Step-by-step procedures for calculating ground-wave and sky-wave performance, and examples using the information in paragraphs 645 to 652, are given below.

(*2*) In considering whether a sky-wave calculation or a ground-wave calculation, or both, should be made in a particular problem, it may be clear from the nature of the problem which kind of transmission will predominate, and if so, only this kind need be calculated. For example, for 100-mile transmission in jungle, only sky waves need be considered; and for frequencies well above the muf, only ground waves need be considered. If there is doubt, both calculations can be made, and if either calculation indicates satisfactory transmission, the result can be considered satisfactory. A possible exception to the latter conclusion occurs when the estimated received ground-wave and sky-wave field intensities are practically equal, in which case there may be severe fading.

(*3*) In determining whether the ground-wave computation should be made with the aid of figures 6-93 to 6-95 (ground-wave field intensity versus distance), or of figures 6-96 to 6-101 (ground-wave range versus radiated power), use the information in paragraph 647a(1).

b. Step-by-step Procedure, Using Figures 6-93 to 6-95 (Ground Wave Field Versus Distance).

(*1*) Find required field intensity from figures 6-90, 6-91, and 6-92 (correcting for c-w versus voice transmission when appropriate) and from any additional data, gained from experience in the particular locality, on other sources of noise or interference.

(*2*) If the transmission path is over earth, estimate the type of ground; good, poor, or jungle. See the information referred to in paragraph 644e. In the absence of this information, loamy, clay, marshy, or alkali soil can be considered *good;* rocky, sandy, or gravelly soil and coral can be considered *poor.*

(*3*) Find the rated power of the transmitter, from section VIII of this chapter or otherwise. Express in db above 1 watt (fig. 6-110).

(*4*) Find from paragraphs 649 and 650, or otherwise, the relation between rated and radiated power. Hence find the radiated power in db above 1 watt.

(*5*) Find from figures 6-93, 6-94, or 6-95 the expected field intensity at a given distance, for the particular radiated power, as described in the above example, and compare with the required field; or find the distance at which the required field intensity is reached.

(*6*) If the country is hilly or mountainous, make the shadow correction described in paragraph 644c.

(*7*) If the transmission is through dense jungle, divide the expected range for poor earth by approximately 10.

c. Example of Use. Problem: Find the estimated ground-wave c-w distance range of Radio Set SCR-193 at 2 mc over sea water, using a 16-foot whip, for the month of December, in Formosa. The steps in the solution are numbered as in the preceding subparagraph.

(*1*) From figure 6-91 the noise grade is 2. From figure 6-92 night-time noise controls and midnight may be taken as representative, the required field at this time being 40 db above 1 microvolt per meter. This is for voice transmission; for cw, 40–17 = 23 db is required.

(*2*) Not involved in this problem.

(*3*) Rated power is 75 watts, or about 19 db above 1 watt (fig. 6-110).

(*4*) Transfer efficiency correction is –6 db (par. 650a).
Radiation efficiency correction is –15 db (par. 650b).
Total transmitting corrections are –6 –15 = –21 db.
Radiated power is 19 —21 = —2 db with respect to 1 watt.

(*5*) Figure 6-95 gives received field intensities over sea water at various distances with 1 watt radiated power. The required field is +23 db, from step (1), with a radiated power of 2 db below 1 watt, from step (4). This would correspond to a required field of +25 db. if 1 watt were radiated. Therefore, to find the range in the present example, note from figure 6-95 the distance at which the field intensity for 1 watt radiated falls to +25 db. This distance is about 150 miles. (As noted previously, the sea water curves of figure 6-95 are applicable only when antennas are close to the water's edge.)

Watts	*db above 1 watt*[a]
1	0
2	3
4	6
5	7
7	8.5
10	10
20	13
30	15
50	17
80	19
100	20
200	23
300	25
400	26
500	27
1,000	30
10,000	40
15,000	42

[a] Other values can be obtained from information in chapter 12.

Figure 6-110. Approximate relation between watts and db above 1 watt.

d. Step-by-step Procedure for Using Figures 6-96 to 6-101 (Ground-Wave Range Versus Radiated Power).

(*1*) If the transmission path is over earth, estimate the type of ground; good, poor, or jungle. See the information referred to in paragraph 644e; or in the absence of this information, loamy, marshy, or swampy soil can be considered *good;* rocky, sandy, or gravelly soil and coral can be considered *poor.*

(*2*) Find rated power of the transmitter, from section VIII of this chapter or otherwise.

(*3*) Find from paragraphs 649 and 650, or otherwise, the relation, in db, between rated and radiated power. Find the corresponding power ratio, less than unity, from chapter 12, and multiply by the rated power to obtain the estimated radiated power in watts.

(*4*) From the appropriate one of figures 6-96 to 6-101, find the estimated range (interpolating if necessary).

(*5*) If the country is hilly or mountainous, make the shadow correction described in paragraph 644c.

(*6*) If transmission is through dense jungle, divide the expected range for poor earth by approximately 10.

e. Example of Use. Take the problem of subparagraph c above, and use the numbered steps of subparagraph d.

(*1*) Not involved in this problem.

(*2*) Rated power is 75 watts.

(*3*) As in step (4) of subparagraph c: total transmitting corrections are –21 db. Hence the radiated power is 21 db below the rated power. From chapter 12, the corresponding power ratio is 0.008; hence, radiated power is $75 \times 0.008 = 0.6$ watts.

(*4*) The appropriate one of figures 6-96 to 6-101 is figure 6-98, which applies to sea water and noise grade 2. (The noise grade is determined by consulting figure 6-91 for the given conditions, namely Formosa in December.) On figure 6-98, at 2 mc, the range for 0.2-watt cw is about 110 miles, and for 2-watts cw it is about 200 miles; hence, by a rough interpolation process the range for 0.6-watt cw is about 150 miles. Steps (5) and (6) do not apply to this problem.

f. Step-by-step Procedure for Sky-wave Transmission.

(*1*) Determine whether the proposed frequency is above the muf (par. 643). If it is, do not make these computations since the magnitude of any signal which may be received is not obtainable from such computations. Instead, follow the instructions given in paragraph 643.

(*2*) Find the required field intensity from figures 6-90, 6-91, and 6-92 (correcting for cw versus voice when appropriate) and from any additional data, gained from experience in the particular locality, on other sources of noise or interference.

(*3*) Find the rated power of the transmitter, from section VIII of this chapter or otherwise. Express in db above 1 watt (fig. 6-110).

(*4*) Find from paragraphs 649 to 651, or otherwise, the relation between rated power and ***radiated power***. Hence, find the ***radiated power*** in db above 1 watt.

(*5*) Find from figure 6-102 the expected incident field intensity at the given distance, for the particular ***radiated power,*** as described in the above example.

(*6*) Find the receiving antenna pattern correction (par. 652) and add it to the expected incident field intensity.

(*7*) Compare the result of step (6) with the required field intensity of step (2).

g. Example of Use. Problem: Find whether Radio Set AN/TRC–2 with half-wave horizontal transmitting and receiving antennas 30 feet high, will give acceptable c-w sky-wave transmission under the conditions of the problem stated in subparagraph c: December, Formosa, 150-mile distance (land or sea in this case), 2 mc.

(*1*) The frequency is below the muf at all hours, from the information described in paragraph 643.

(*2*) The required field intensity at midnight is +23 db above 1 microvolt per meter, and at noon it is –21 db referred to 1 microvolt per meter (figs. 6-91 and 6-92 together with the correction for cw versus voice). The value for noon is quite low; its use would assume little or no man-made interference and interference from other radio stations. Sky-wave interference from distant stations would be small at noon on this frequency.

(*3*) The rated power is 20 watts, or 13 db above 1 watt (fig. 6-110).

(*4*) At night, with F2-layer transmission, the correction for rated versus ***radiated power*** at 150 miles is –2 db (fig. 6-107). Hence the ***radiated power*** is $13-2 = 11$ db above 1 watt. At noon, with E-layer transmission, the correction is –4 db and the ***radiated power*** is $13-4 = 9$ db above 1 watt.

(*5*) From figure 6-102 and step (4), the received incident field at night is $21+11=32$ db above 1 microvolt per meter. At noon, for Formosa (latitude about 25°) in December, the absorption coefficient $K = 0.72$; and as worked out in paragraph 648b, the received incident field for 1 watt radiated is –11 db with respect to 1 microvolt per meter. Hence for the ***radiated power*** determined in step (4), the received incident field is $-11 + 9 = -2$ db with respect to 1 microvolt per meter.

(*6*) The receiving antenna pattern correction (fig. 6-109) is +8 db at night (F2-layer transmission) and +6 db at noon (E-layer transmission). The sum of the incident field and the receiving antenna correction is $32+8=40$ db above 1 microvolt per meter at night, and $-2 + 6 = 4$ db above 1 microvolt per meter at noon.

(7) Night: required, +23 db; expected, +40 db; satisfactory. Noon: required, –21 db; expected, +4 db. Satisfactory. A check at other hours of the day would reach the same conclusion.

654. RADIO NOISE REDUCTION AT RECEIVING LOCATIONS.

a. General.

(1) Man-made noise of various types, and measures for reducing its effects on radio receivers at ground installations, are discussed briefly in this paragraph. Much of the information given is general, and suggests principles to be followed in the layout of installations where radio receivers must be located in close proximity to other electrical equipment. The applications of the principles will vary depending on the conditions found in particular cases. The measures discussed are for application on a trial basis in specific cases. If one alternative does not succeed, another may; in many cases large noise reductions can be achieved only by drastic changes.

(2) Common sources of noise are electric sparks such as those produced in commutator-type motors, the ignition systems of motor vehicles, gasoline-engine-driven generators, etc., and any equipment in which current flow is abruptly interrupted, thus generating r-f wave components. Examples of the latter are contacts in d-c circuits, a-c power switches, and radio telegraph transmitters (which produce key clicks). In some instances it may be necessary to first identify the disturbing noise source; simple means for doing this are described in subparagraph e below.

b. Noise Suppression at the Source.

(1) Reduction of noise at the source involves either circuit modification to prevent the formation of large r-f components, or the provision of filters or shielding to confine such waves to a restricted area. The former treatment is more direct and is to be preferred whenever practicable. Standard filters are available for some equipment, and these frequently constitute the most convenient remedy. It may be found that later models of some equipment (teletypewriters, for example) have filters incorporated, whereas earlier ones did not.

(2) For d-c telegraph or keying circuits, including those for operating remote control devices, and for other similar circuits, bridging a 1-mf capacitor in series with a 100-ohm resistor across the relay or key contacts will often be effective as a spark killer. The connecting leads must be short, otherwise they may act as radiators. The resistor is included in order to prevent pitting of contacts. For motors or generators, a small capacitor, on the order of 1,000 mmf (noninductive) bridged from each lead to the frame of the machine will act as a radio-frequency shunt if the connecting leads are made very short (less than 1 inch). *In applying any improvised arrangement, care must be taken to insure that its use does not impair the operation of the equipment to which it is attached,* and to see that its current and voltage ratings are consistent with the applied current and voltage. The numerical constants given above are first approximations for trial.

(3) In some instances it may be expedient to place a shield around the noise-producing equipment and to insert filters in all leads entering or leaving the equipment. A completely enclosing screen or mesh shield is more effective than a partly enclosing solid shield. Sometimes a considerable number of disturbing sources can be placed in a shielded room, with filters in all wires leaving the room.

(4) Where practicable, the influence of a source can be markedly decreased by forcing it to operate only in a metallic circuit which is balanced to ground at radio frequencies.

c. Reduction of Coupling Between Noise Source and Receiving Equipment.

(1) Noise may enter the receiving equipment either by coupling through space (by radiation or by magnetic or electric induction) or through a common impedance; that is, an impedance which forms a part both of the receiver circuit and of the noise-source circuit.

(2) Coupling through space may take place into the receiving antenna, the lead-in, the ground lead, or apparatus or wiring in the receiver itself. This may be reduced by increasing the physical separation between these circuits and the disturbing equipment and associated wiring. The practice of bunching together various wires and leads is a common source of unwanted coupling, particularly since unrelated wiring may act as a carrier of noise currents. For example, wiring which nominally carries only d-c or 60-cycle power may be coupled, at different points perhaps,

both to disturbing and disturbed circuits, and thereby serve as an intermediary. The presence of incidental resonance or standing-wave conditions in the wiring may increase this coupling.

(*3*) The ground connection of a radio receiver operating with one side of its input grounded is a common means of noise entering the receiver. Noise may result either by inductive coupling, as described above, or by conductive coupling arising from the common impedance of the noise source and radio receiver ground circuits. The best remedy is to provide short, direct, and independent ground connections from the receiver and from the noise source to a low-impedance ground. (Several good grounds are described in chapter 10.) At frequencies in the h-f or v-h-f band, any large metallic body on or close to the earth may be a satisfactory ground. To minimize inductive coupling between ground leads, avoid running the ground connection wire in the same form, that is, tied in the same group, with the ground connection wires of disturbing circuits, such as d-c telegraph circuits. If a low-impedance ground cannot be obtained, it may be necessary to use separate grounds for radio, and for other electrical equipment. In this case a protector should be connected between the two grounds in areas where thunderstorms occur, in order to reduce the chance of hazardous voltages between the grounds.

d. Remedial Measures Applicable to Receiver Equipment.

(*1*) Balanced horizontal antennas are apt to pick up less local man-made noise than other types, provided that the rest of the radio receiver input system is balanced to ground. Freedom from noise will not be insured when a coaxial lead-in from such an antenna to a grounded receiver is used. This is particularly true when the lead-in length is an odd multiple of a quarter-wave length in the circuit which is formed by the coaxial sheath and ground. A wavelength in this circuit is apt to be materially shorter than one in free space. Information on balanced lead-ins is given in paragraph 676. Many fixed plant radio sets have balanced inputs (sec. VIII). Radio Receiver BC–779, or its commercial counterpart the Hammarlund super pro, which may be available in some theaters, has a well-balanced input.

(*2*) Some radio receivers have power-supply filtering which fails to adequately block high r-f noise voltage on the power supply leads. With such a set, an external radio-noise filter of suitable voltage and current rating can be used, mounted at the set.

(*3*) Some radio receivers have insufficient shielding for use near sources of magnetic induction. It may be possible to orient such a receiver to minimize pick-up from a particular source, but not from the many sources which may exist in a large headquarters. Physical separation or room shielding can be considered.

e. Identification of Noise Sources.

(*1*) Oftentimes the source of a noise can be identified by listening to its character, or by observing when the noise starts and stops and correlating these times with the times when various possible disturbing sources are operating, or by deliberately starting and stopping various possible sources. Where these methods do not suffice, listening tests can be made with the simple exploring devices described in subparagraphs (2) and (3) below.

(*2*) As an exploring device to trace the source of local high magnetic fields, a small hand-made loop consisting of a few turns of wire an inch or so in diameter can be connected to a well shielded, battery-operated receiver with its automatic volume control (avc) disabled. The connection between loop and receiver should be shielded and connected to the receiver ground post. Listen at the receiver output as the loop is moved around. If only the magnetic field is wanted, the input system including loop should be shielded and balanced, and the shield of the loop should be split as in a direction finding loop, to prevent the flow of large circulating currents in the shield.

(*3*) An exploring device to trace the source of local high electrostatic field intensities can be constructed by baring an inch or so of the center conductor of a piece of coaxial cable, and connecting the other end of the center conductor to the antenna post, and the outer conductor of the coaxial cable to the ground post of the radio receiver mentioned above, operating the receiver with one side grounded. The bare portion of the center conductor serves as the electrostatic probe.

f. Precipitation Static. Noise arising from precipitation static (dust or snow static) can be reduced, but not eliminated, by providing a d-c path from antenna to ground external to the radio receiver. This may be accomplished by connecting a suitable r-f choke or high resistance from an unbalanced antenna to earth, or, if the antenna is balanced to ground, by bridging across it a balanced r-f drainage coil and grounding the midpoint of the coil.

655. LONG-DISTANCE RELIABILITY CURVE.

The *reliability* of a radio circuit is here taken to mean the percentage of usable circuit time, counting as unusable only that lost because of poor signal-to-noise ratio. The effect of changes in transmitter power on reliability of long-distance h-f radio circuits is indicated by figure 6-111, which is a generalized curve obtained from tests on commercial transoceanic circuits. As an example, assume that in a given situation, communication turns out to be only 40 percent reliable with the apparatus involved. It is desired to increase the reliability to 90 percent, that is, permit only 10 per cent lost circuit time. Under the 10 per cent point on the curve, the value on the bottom scale indicates a required improvement of 19 db. The corresponding db value for 40 percent reliability is –3 db. Hence to change from 40 to 90 percent reliability, the radiated power must be increased by 19– (–3) = 22 db (to about 160 times as much power) by using a set with higher output rating or a transmitting antenna having more efficiency, or a receiving antenna which discriminates against the noise source must be used, or a combination of the three. There is no other alternative except to review the procedure used in the choice of frequency in order to insure that the best choice has been made for each time of day.

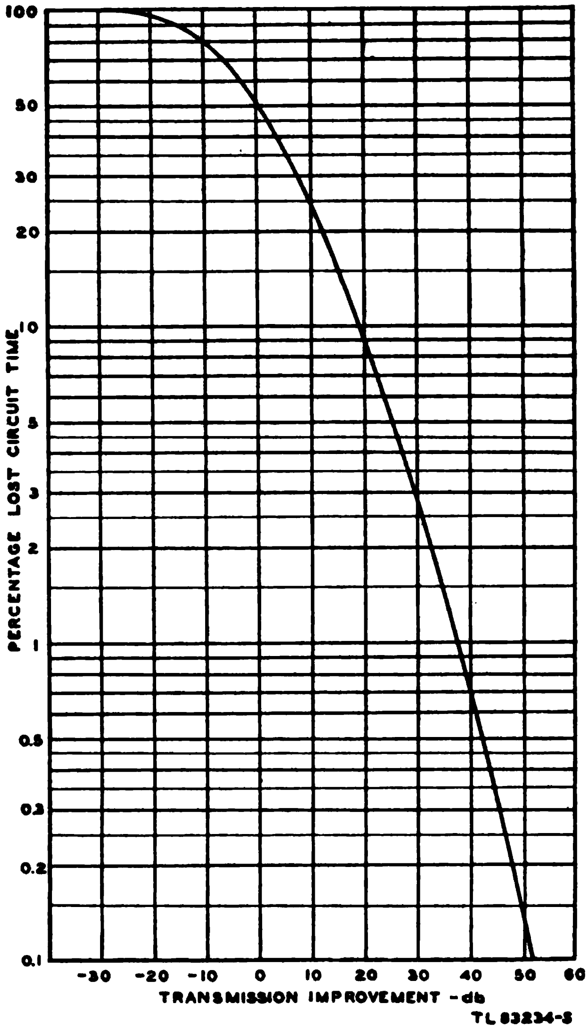


Figure 6-111. Long distance sky-wave reliability curve.

656. FIXED PLANT RADIO SETS.

In general, long transoceanic circuits are handled by fixed plant equipment, with transmitting powers ranging up to about 40 kilowatts. A few of the great variety of fixed plant transmitters and receivers are shown in figures 6-112 to 6-116 inclusive. Others are shown in TM 11–487.

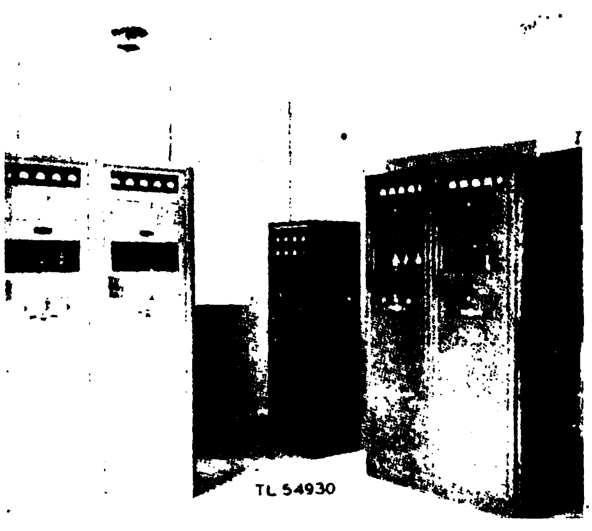


Figure 6-112. AACS transmitting station (showing two Radio Transmitters BC–401 and one Western Electric Company D–151249 or Pan American Airways 4WTFA transmitter).

Figure 6-113. Army Communications Service 10-kw transmitting equipment (showing Power Amplifier BC-340 and Radio Transmitter BC-339).

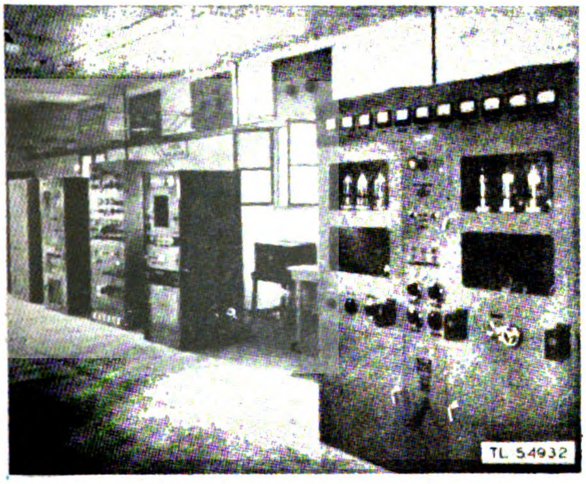


Figure 6-114. Transmitting station (showing Radio Transmitters BC-447, BC-339, and part of 15-kw transmitting equipment, Press Wireless PW-15).

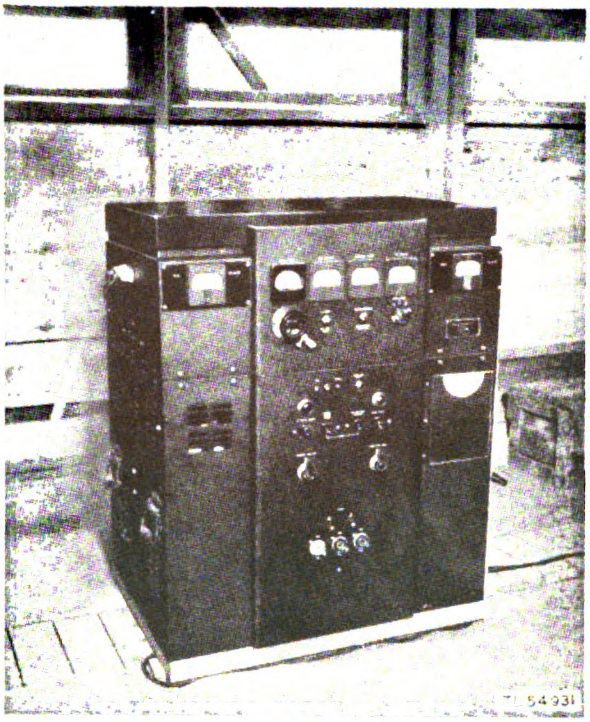


Figure 6-115. Radio Transmitter BC-610 in administrative communications network.

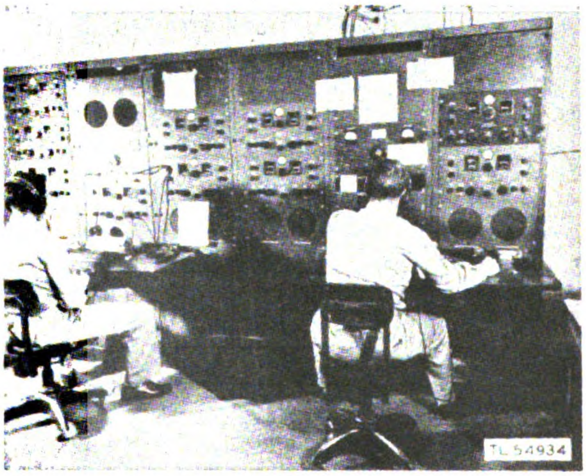


Figure 6-116. Receiving and operating position at AACS radio station (showing 10 Hammarlund super-pro receivers and two transmitter remote control panels).

Section V. H-F ANTENNAS

657. GENERAL.

a. From an operational standpoint, h-f antennas are primarily of two classifications, tactical and fixed plant. Tactical antennas are relatively simple and can be readily set up with a minimum of manpower. Fixed plant antennas are similar to commercial installations and require more time and effort to erect. Some antennas are of intermediate character and may be used for either fixed or tactical purposes.

b. Another general classification of h-f antennas relates to the type of transmission employed, namely, ground wave, short-distance sky wave, or long-distance sky wave. Any antenna will give some transmission of all three kinds, but particular antennas are primarily adapted for certain types of transmission, depending on their vertical and horizontal radiation patterns.

c. The short antennas often used on the tactical radio sets for reasons of size, mobility, and simplicity are inefficient radiators in the lower part of the h-f band. Fixed plant transmitting antennas can be made relatively efficient because they can be of larger size. For example, horizontal rhombic antennas may employ 70-foot masts with wires 300 to 400 feet long on the sides.

d. For best radiation efficiency, end-fed transmitting antennas of lengths up to a quarter wave, or odd multiples of a quarter wave at the operating frequency, should be placed in an area where low-impedance ground connections are available; or alternatively, a low-impedance counterpoise should be used such as described in paragraph 663a(1). This is especially true at the lower end of the h-f band, but is not so important above about 15 mc. With balanced center-fed antennas, and end-fed antennas of a total length of a half wave, grounding conditions are not important.

e. For receiving, losses in ground connections or losses which arise from mismatch between antenna and receiver input impedances generally are not of major importance in the lower part of the h-f band. This is because in most cases, except when the antenna transmission line loss is large, external interference rather than set noise controls the *percentage of reliability* of the circuit over a 24-hour period. Under these conditions, an improvement in receiving efficiency increases noise in about the same proportion as signal. However, a low-impedance ground connection is advisable in order to reduce the effects of local noise sources.

f. Directivity is important in both receiving and transmitting antennas. For receiving, the best antenna is one which favors reception of the signal and discriminates against other signals and atmospheric or other radio noise. The improvement in signal-to-noise ratio over that with a nondirectional antenna may be considerable if the major source of noise is in a direction corresponding to a minimum in the antenna pattern. For transmitting, a directional antenna results in the radiated power being concentrated in the desired direction. In fixed plant applications, antennas of relatively sharp horizontal directivity can often be used. In tactical work, horizontal directivity can be used on point-to-point circuits, but generally must be avoided in net operations involving a number of scattered stations operating on a common frequency.

g. Types of antennas in general use for tactical purposes, and other antennas which can be used to improve ground-wave or sky-wave transmission with tactical sets are described briefly in paragraphs 658 to 668, inclusive. When an antenna is used with a set not originally designed to work with it, proper coupling arrangements are important. Specific arrangements are given in appropriate places below. Additional information on antennas and coupling arrangements is given in TM 11–314.

h. Several antenna types for use in the more permanent radio installations are described briefly in paragraphs 669 to 672, inclusive. Additional types are shown in TM 11–487. Since h-f sky-wave operation requires the use of more than one frequency for optimum 24-hour reliability, antennas for use in large fixed plant installations are often of types suitable for operation over a fairly wide frequency band without changes in antenna dimensions. The more elaborate fixed plant receiving stations use a *diversity* antenna system to minimize the effects of sky-wave fading on telegraph reception (par. 674).

i. Information on antennas suitable for frequencies below 800 kc, which are used for transmission in high latitudes, is given in paragraph 673. Methods of grouping antennas at locations where a large number of radio circuits terminate, are described in paragraph 675. Data on radio frequency transmission lines, covering both hf and vhf, are given in paragraph 676. Information on h-f and v-h-f phantom antennas (dummy or artificial antennas) is given in paragraph 677.

658. WHIP ANTENNA.

a. Whip antennas, such as illustrated in figure 6-117, are used in the h-f band to a great extent where portable and mobile operation is required with equipment such as Radio Sets SCR–399, SCR–506, and SCR–193. This antenna type is suitable primarily for ground-wave use, although with a set having the transmitting power of the SCR–399, long-distance sky-wave transmission can often be obtained. Antenna Tuning Unit BC–939–A, which is used to couple a 15-foot whip to the output of the transmitter of Radio Set SCR–399, is shown in figure 6-118.

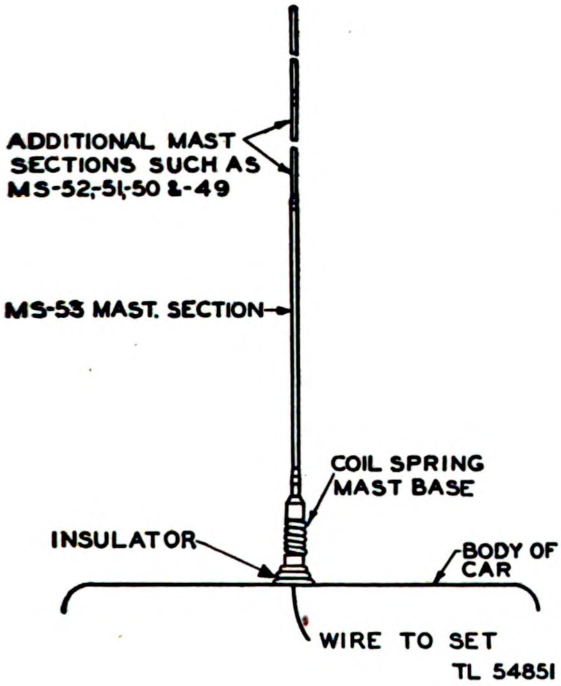


Figure 6-117. Whip antenna.

b. The whip antennas used in the h-f band are essentially of the same mechanical design as those used for v-h-f operation, although of somewhat longer physical length. Electrically, however, their length is only a small fraction of a wavelength at frequencies in the lower part of the h-f band, and consequently their radiation efficiency at these frequencies is low, as discussed in paragraph 650. To help increase the range of communication, the whip may be extended by adding sections or by connecting a wire between the end of the whip and any convenient tree or other support to increase the total height; this height should not exceed about one-half wave. If such an antenna is used, the transmitter output plate tuning and antenna tuning controls should be readjusted to obtain optimum results and to prevent overloading of the output tube. Some sets may be incapable of being tuned for an antenna as long as a half wave.

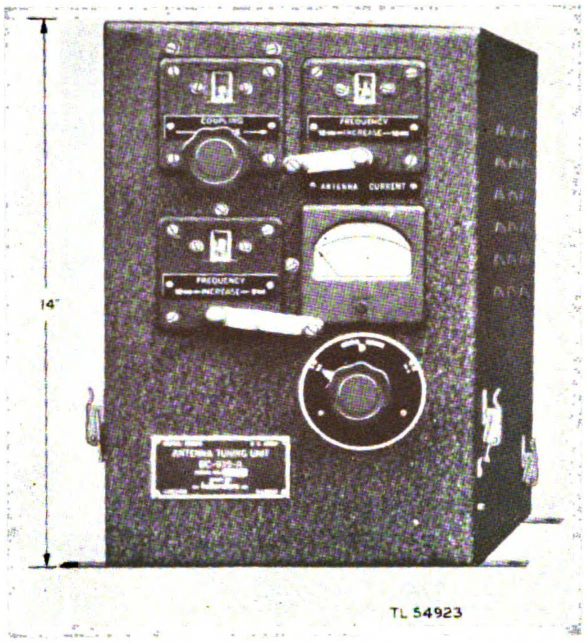
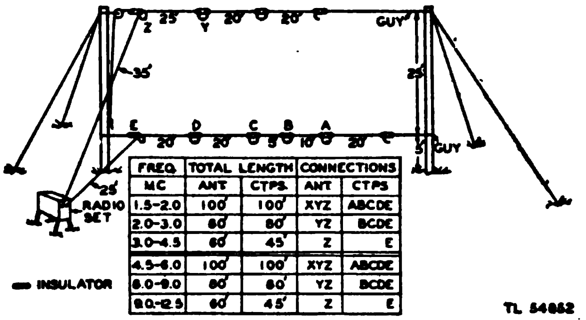


Figure 6-118. Antenna Tuning Unit BC-939-A.

659. INVERTED-L ANTENNA.

a. An inverted-L antenna with counterpoise, illustrated in figure 6-119 and used with equipment such as Radio Sets SCR–177 and SCR–188, is designed to operate with a total length of antenna plus down lead of roughly one-quarter wavelength or three-quarter wavelength. At frequencies in the lower part of the h-f band, this results in the horizontal portion of this antenna being only a small fraction of a wavelength. The counterpoise serves to establish a low-impedance ground for the antenna circuit. This antenna is best suited to ground-wave transmission, although it is a better sky-wave antenna than a short whip. With the dimensions shown in figure 6-119, it should be used with a transmitter capable of matching a low impedance load.

b. An inverted-L antenna with a horizontal portion approximately a half-wave long will be good for sky-wave transmission under suitable circumstances (par. 663).



FREQ.	TOTAL LENGTH		CONNECTIONS	
MC	ANT	CTPS.	ANT	CTPS
1.5–2.0	100'	100'	XYZ	ABCDE
2.0–3.0	80'	80'	YZ	BCDE
3.0–4.5	60'	45'	Z	E
4.5–6.0	100'	100'	XYZ	ABCDE
6.0–9.0	80'	80'	YZ	BCDE
9.0–12.5	60'	45'	Z	E

Figure 6-119. Inverted-L antenna for use with Radio Sets SCR–177 and SCR–188.

660. SLOPING-WIRE ANTENNA.

The sloping-wire antenna illustrated in figure 6-120 is an end-fed antenna which may be strung up hurriedly between two trees, or between one tree or other support and a post driven in the ground near the radio set. When used for short- or moderate-distance sky-wave

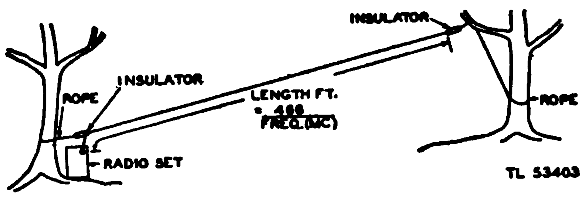


Figure 6-120. Sloping-wire antenna.

transmission, this antenna works best if made approximately a half wavelength at the operating frequency and sloped at a fairly low angle to the ground. The sky-wave signal transmission will be best when the sending and receiving antennas are broadside to each other, about 6 db poorer when they are end on with their high ends pointing toward each other, and intermediate when they are end on with low ends pointing toward each other. This type of antenna produces good short-distance sky-wave transmission; it produces fair ground-wave transmission, especially in directions approximately in line with the antenna. The efficiency for ground-wave transmission can be increased, and directional effects reduced, by making the antenna nearly vertical. Further information on this antenna is given in paragraphs 663 and 664.

661. HALF-WAVE HORIZONTAL ANTENNAS.

a. General. The most suitable type of tactical antenna for sky-wave transmission is the horizontal half-wave antenna. Such antennas may be either center-fed or end-fed. Center-fed antennas are used preferably with a low-impedance transmitter or receiver which is balanced to ground, and with a balanced down-lead or transmission line. End-fed antennas of a total length of a half wave are high impedance; however, this impedance may be lowered in various ways (par. 663) to permit proper loading of a transmitter.

b. Use for Short-distance Transmission. These antennas when erected at heights under a quarter wavelength, radiate and receive well at the steep vertical angles involved in sky-wave transmission over distances up to at least 200 miles between stations. As receiving antennas for such use, they tend to reject atmospheric noise and interference coming from distant sources via sky waves at low angles, thus improving the signal-to-noise ratio. Experiments indicate that these advantages are shared by both end-fed and center-fed antennas, provided a proper down lead is used with the end-fed type (par. 663). At distances up to 200 miles, the orientation of the antennas is relatively unimportant as regards reception of the desired signal; hence the antennas can sometimes be oriented so as to minimize interference from distant sources.

c. Use for Long-distance Transmission. If the antenna height is increased above about a quarter wavelength, the maximum of the antenna vertical directional pattern will no longer be vertically upward but will be at some lower angle. At heights approaching one-half wavelength above ground (which are practical for the upper part of the h-f band) the pattern maximum will be at angles suited for sky-wave transmission over a distance of several hundred miles. This is indicated on figure 6-107.

d. Length of Half-wave Antenna. The length in feet of a half-wave horizontal antenna, reasonably remote from the earth or from other structures, is approximately 468 divided by the frequency in megacycles. This is 95 percent of the free-space half wavelength. Figure 6-121 tabulates this length in feet versus operating frequency. The length of a half-wave antenna consisting of an insulated wire on or close to the ground will be from 55 to 80 percent of these values.

Frequency (megacycles)	*Antenna length (feet)*
2	234
3	156
4	117
5	94
6	78
7	67
8	59
9	22
10	47
F	468/F

Figure 6-121. Length of half-wave antenna versus frequency.

e. Standard Tactical Half-wave Antennas.

(*1*) *Center-fed.* A doublet antenna kit has been standardized for use as a *transmitting* antenna with Radio Sets SCR–299–( ), SCR–399–A, and SCR–499–A. This kit is described in TM 11–280 and TM 11–281 with changes thereto. It consists of the parts for the antenna, a coaxial transmission line, and coupling arrangements which are substituted for the regular tuning units and transmitter tank[14] coils. A sketch of the antenna is given in figure 6-122.

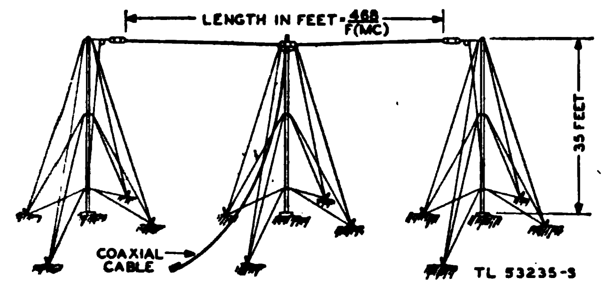


Figure 6-122. Doublet antenna for use with Radio Sets SCR–299, SCR–399, and SCR–499.

(*2*) *End-fed.* Certain tactical radio sets are arranged to end-feed an antenna of a total length of approximately a half wave. These include Radio Set SCR–694, the higher frequency unit of Radio Set AN/TRC–2, and Radio Transmitter BC–191–( ) used in Radio Sets SCR–177–( ), SCR–188–( ), SCR–193–( ), and AN/VRC–1. At frequencies above about 5 megacycles, somewhat better transmission can be obtained by using the arrangements described in paragraph 663 where applicable.

[14] This *tank* coil is the inductor in the tuned plate output circuit of the radio transmitter.

662. IMPROVISED CENTER-FED HALF-WAVE ANTENNAS.

a. For particular Radio Sets. In one theater, a doublet antenna, including a twisted pair down-lead, was improvised using available materials. The improvised method of connecting the antenna, and changes made in the transmitter output circuit, are shown in figure 6-123 for Radio Transmitter BC–191–( ), and in figure 6-124 for Radio Transmitter BC–610–B used in Radio Set SCR–299–( ). No change was made in the antenna circuit of the receiver used with this arrangement.

b. For Other Radio Sets. With other radio sets having transmitters capable of feeding a doublet through a transmission line of 50- to 100-ohm impedance, an improvised antenna such as described in subparagraph a above or one made from parts of the antenna kit described in paragraph 661e could be used, preferably making changes similar to those shown in figures 6-123 and 6-124 in the transmitter output and receiver input circuits to isolate them from ground. If the radio set cannot be isolated from ground, an isolating transformer can be used (par. 675c (1)).

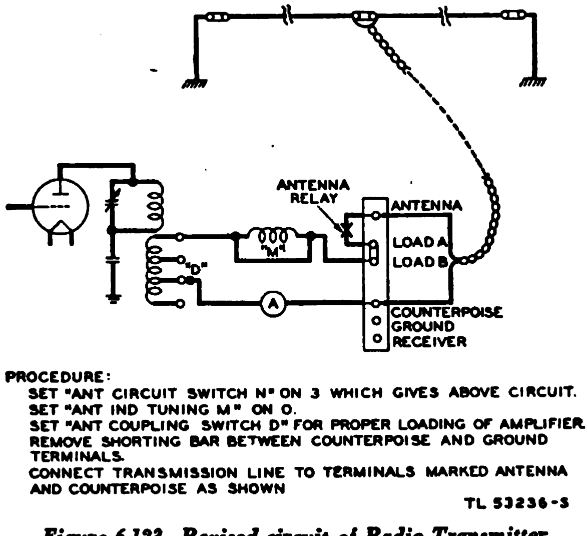


Figure 6-123. Revised circuit of Radio Transmitter BC–191–( ) for use with half-wave doublet antenna.

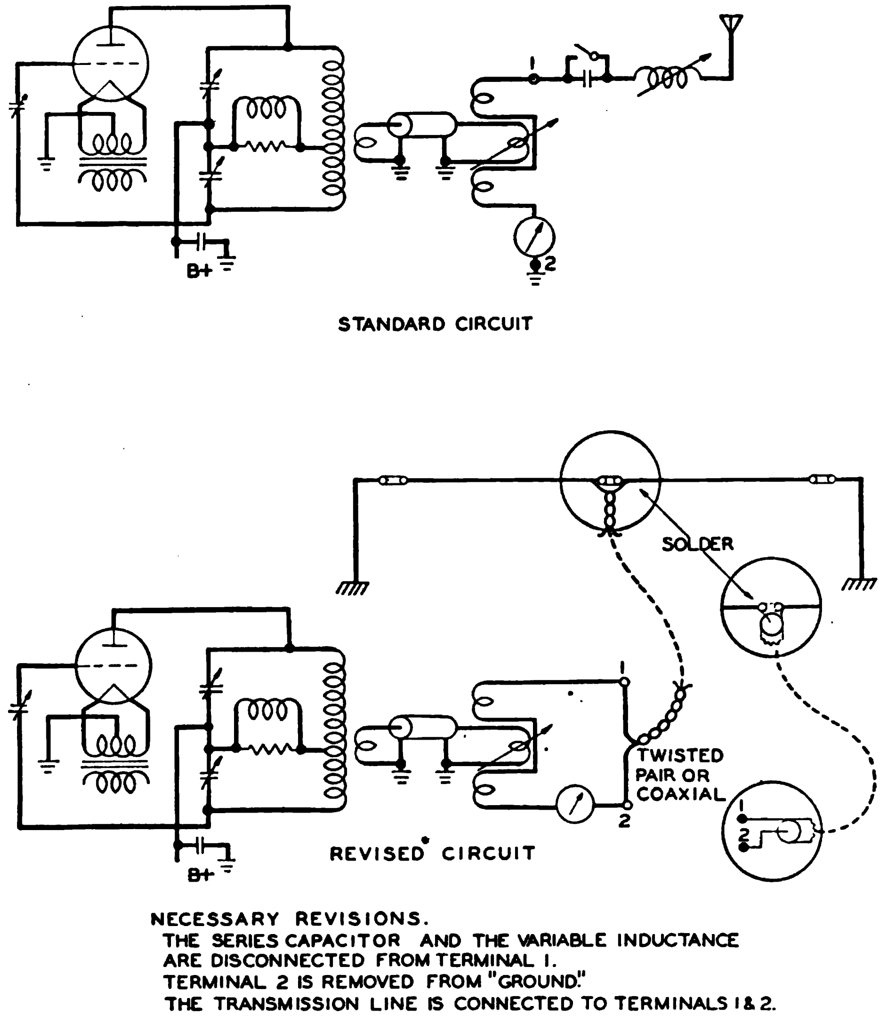


Figure 6-124. Revised circuit of Radio Transmitter BC-610-B for use with half-wave doublet antenna.

c. Transmission Lines. If the antenna is removed so far from the radio set that the loss in a twisted pair down-lead or transmission line would be objectionable, a spaced-pair transmission line may be used. Losses in twisted pair are given in paragraph 676, which also describes an improvised spaced-pair transmission line using Wire W–110–B. A better impedance match is obtained between antenna and spaced-pair transmission line if the improvised folded doublet described in subparagraph d below is used instead of a half-wave doublet.

d. Folded Doublet Antenna.

(*1*) A folded doublet may often be used to advantage with an open wire transmission line or 200-ohm transmission cable. The input impedance-frequency characteristic of such an antenna at frequencies near half wave is broader than for a single half-wave antenna near its resonant frequency; hence moderate changes in frequency should not require dimensional changes. The total length of a folded doublet is a multiple of a half wave, but since it is folded it requires the same space between supports as a half-wave antenna. Its directional pattern is approximately that of a center-fed half-wave antenna.

(*2*) Figure 6-125 shows a 2-wire folded doublet, having an impedance of about 300 ohms, used with a transmission line having a characteristic impedance of about 450 ohms.

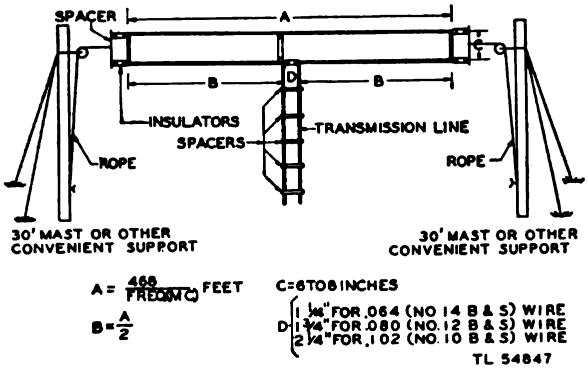


Figure 6-125. Center-fed horizontal 2-wire folded doublet antenna.

The transmission line impedance may be lowered by bringing the wires closer than indicated in the figure; or a 4-wire line or 200-ohm cable (par. 676) may be used for this purpose.

(*3*) Figure 6-126 shows a 3-wire folded doublet, having an impedance of about 600 ohms, used with a transmission line of about 600-ohm characteristic impedance. While it is preferable to keep the folded horizontal wires in a horizontal plane, they can be arranged one above the other, as illustrated.

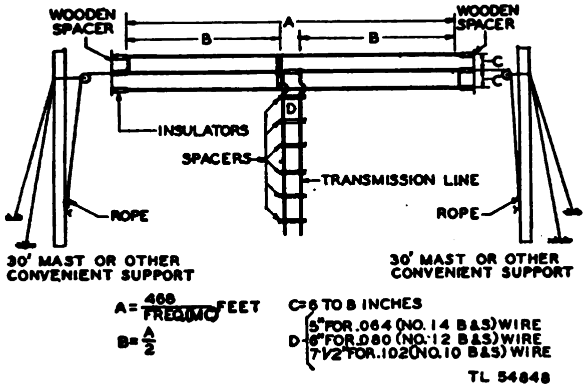


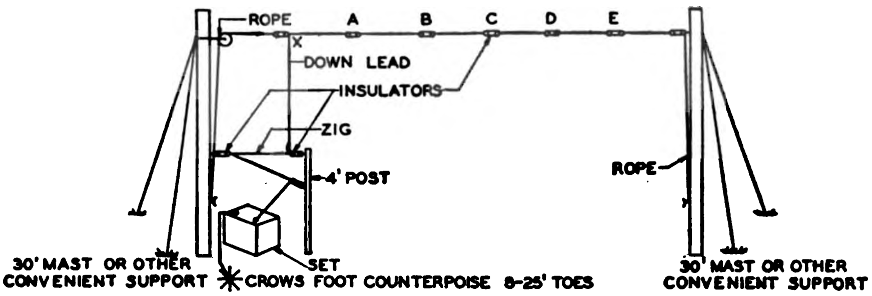
Figure 6-126. Center-fed horizontal 3-wire folded doublet antenna.

(*4*) These antennas are not furnished as standard antennas, but have been improvised successfully in the field using 080 copper or copper-steel wire. For optimum results, they should be used with balanced transmitter output and receiver input circuits.

663. IMPROVISED END-FED HALF-WAVE ANTENNAS.

a. General.

(*1*) Improvised end-fed half-wave horizontal and sloping antennas for use in the frequency band from 2 to 6.5 megacycles are shown in figures 6-127 and 6-128, respectively. As indicated, the wires are equipped with insulators which may be jumpered to give antennas which are half wavelength at 2.0, 2.5, 3.0, 4.0, 5.0, or 6.0 megacycles. The figures also indicate simple down-lead arrangements helpful in loading the transmitters when such antennas are used with radio sets on the ground. In general, a lead-in is used which is of such a length that the antenna-to-ground impedance as seen from the set is of a value which permits efficient feeding of the antenna by the transmitter. In the case illustrated, a lead-in ranging from 26 to 47 feet is used, the length depending on the transmitter used and the frequency of transmission, as explained below. With horizontal antennas, the excess of lead-in wire is taken up by a folded *zig* at the set, as indicated in figure 6-127. With a sloping-wire



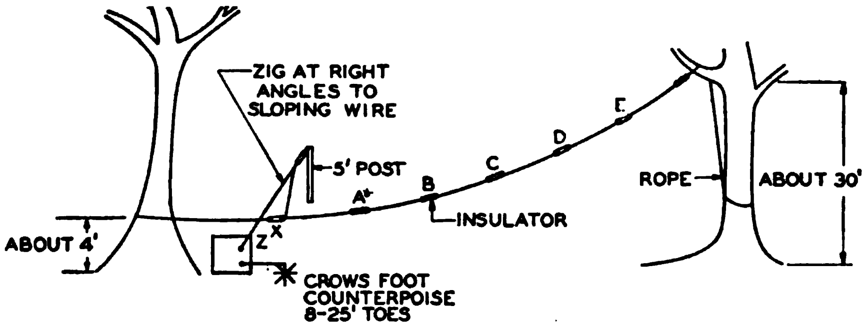
LENGTH OF HORIZONTAL WIRE

FREQUENCY [a] (MC)	EFFECTIVE LENGTH (FT)	JUMPER INSULATORS
2.0	234	ABCDE
2.5	187	ABCD
3.0	156	ABC
4.0	117	AB
5.0	93.5	A
6.0	78	—

[a] FREQUENCY AT WHICH WIRE IS HALF-WAVE LENGTH.

TL 52591-S

Figure 6-127. Horizontal half-wave antenna with impedance-transforming lead-in.



LENGTH OF HORIZONTAL WIRE

FREQUENCY [a] (MC)	EFFECTIVE LENGTH (FT.)	JUMPER INSULATORS
2.0	234	ABCDE
2.5	187	ABCD
3.0	156	ABC
4.0	117	AB
5.0	93.5	A
6.0	78	—

[a] FREQUENCY AT WHICH WIRE IS HALF-WAVE LENGTH.

TL 53237-S

Figure 6-128. Sloping-wave antenna with impedance-transforming lead-in.

antenna, practically all the lead-in is employed in a *zig*. For tactical sets operated on the ground, the set ground is provided by means of a crow-foot counterpoise consisting of eight 25-foot wires.

(*2*) A similar antenna and feeding arrangement may be used with vehicular mounted sets by connecting the lead-in wire to the terminal on the mast base (remainder of mast not used), or directly to the antenna

RADIO TRANSMITTER BC-653-A USED IN SCR-506-A.

Operating frequency (mc)	Antenna length (feet)		Approx. transmitter settings for maximum power [a]	
	Top	Lead-in [b]	PA coil	Antenna coupler
2.0	234	47	31	75
2.5	234	47	15	85
2.5	187	47	21	75
3.0	187	47	11	90
3.0	156	47	15	85
3.5	156	47	6	95
3.5	117	47	13	100
4.0	117	47	4	80
4.0	94	47	10	90
4.5	94	47	4	100

RADIO TRANSMITTER AND RECEIVER BC-654-A USED IN SCR-284-A.

Operating frequency (mc)	Antenna length (feet)		Approx. transmitter settings for maximum power [a]		
	Top	Lead-in [b]	Antenna selector	Antenna coupler	Antenna tuning
3.8	117	26	1	100	200
4.0	117	26	1	100	290
4.5	117	26	1	100	450
4.5	94	26	1	100	290
4.95	94	26	1	100	420
5.5	94	26	1	100	490
5.5	78	26	1	100	430
5.8	78	26	1	100	480

[a] For frequencies between those listed, approximate settings may be estimated by interpolating between values at successive tabulated frequencies which have the same tabulated length of antenna top and lead-in.

[b] For horizontal antennas, lead-in length is length of down-lead plus *zig*; for sloping antennas, lead-in length is *zig* length.

Figure 6-129. Approximate settings for use in loading transmitters when used on the ground with end-fed half-wave horizontal or sloping antennas with lead-ins (*continued on opposite page*).

RADIO TRANSMITTER BC-191-E USED IN SCR-177-( ), SCR-188-( ), SCR-193-( ), AND AN/VRC-1.

Operating frequency (mc)	*Antenna length (feet)*		*Tuning unit*[c]	*Approx. transmitter settings for maximum power*[a] *(Antenna circuit switch "N" on position 1)*		
	Top	*Lead-in*[b]		*Antenna coupler "D"*	*Antenna inductance tuning "M"*	*Antenna capacitance tuning "O"*
2.0	234	47	TU-5-A	5	36	35
2.5	234	47	TU-5-A	5	13	100
2.5	187	47	TU-5-A	5	23	100
3.0	187	47	TU-5-A	5	11	80
3.0	156	47	TU-5-A or-6-A	5	21	35
3.5	156	47	TU-6-A	5	8	50
3.5	117	47	TU-6-A	5	23	0
4.0	117	47	TU-6-A	5	9	100
4.0	117	26	TU-6-A	6	11	100
4.5	117	26	TU-6-A	6	12	0
4.5	94	26	TU-6-A or-7-A	5	17	0
4.95	94	26	TU-7-A	6	13	0
5.5	94	26	TU-7-A	5	5	100
5.5	78	26	TU-7-A	5	9	50
6.0	78	26	TU-7-A	5	6	50
6.5	78	26	TU-8-A	6	0	0

[a] For frequencies between those listed, approximate settings may be estimated by interpolating between values at successive tabulated frequencies which have the same tabulated length of antenna top and lead-in.

[b] For horizontal antennas, lead-in length is length of down-lead plus *zig;* for sloping antennas, lead-in length is *zig* length.

[c] Or equivalent (TM 11-800).

Figure 6-129. Approximate settings for use in loading transmitters when used on the ground with end-fed half-wave horizontal or sloping antennas with lead-ins (continued).

post of the set if a relatively large opening in the vehicle is available. In this case, the ground terminal of the set is connected to the vehicular chassis which serves as a counterpoise.

(*3*) For *end-fed* receiving horizontal half-wave antennas in the band from about 3 to 6 mc, a mast height of about 30 feet is favorable for good signal-to-noise ratios.

b. Transmitter Settings. Approximate transmitter settings and recommended antenna dimensions for certain tactical radio transmitters are given in figure 6-129. These apply when the sets are used on the ground. The transmitter settings for a given set would be different with the set mounted in a vehicle. Final adjustments should be made for maximum current in antenna meter or indicator, with a plate meter reading within limits specified for the particular transmitter.

c. Use With Radio Sets SCR-299 and SCR-399. In one theater, end-fed inverted-L antennas of a total length in the general vicinity of a half wave were used satisfactorily for transmitting and receiving antennas with Radio Sets SCR-299 and SCR-399. For frequencies of 2 to 3 mc, a capacitor was bridged across the antenna and ground posts, and the antenna network switch was placed in the 2- to 10-mc position. Capacitor values in the neighborhood of 100 to 200 mmf were used, the proper value for each frequency being determined by trial. Fixed capacitors of suitable voltage rating were obtained from spare parts equipment for this purpose. Because of the relatively high resistance of this type of antenna at its feed-point, the r-f ammeter reads relatively low, even when the rated power is being fed into the antenna.

Type of antenna	*Approximate relative received powers for equal sending powers*[a]			*Approximate relative transmitting power required for equal S/N*
	Signal (db)	*Noise (db)*	*S/N (db)*	
Horizontal half-wave, end-fed, 7′ high	0	0	0	1
Horizontal half-wave, end-fed, 30′ high[b]	+21	+12	+9	0.13
Horizontal half-wave, balanced center-fed, 30′ high	+21	+12	+9	0.13
Sloping half-wave, 5 to 30′ high (broadside)	+12	+4	+8[c]	0.16
Sloping quarter-wave, 5 to 20′ high, counterpoise 2′ high (broadside)	+1	+6	−5	3.2
SCR-188-A antenna: 45′ top, 35′ down-lead, 80-foot counterpoise 5′ high	−2	+14	−16	40
15′ tuned whip, crowfoot counterpoise	−38	−3	−35	3200

[a] Compare only figures within any vertical column. The figures in the first horizontal row are merely reference values. Observed signals and noise were corrected to values which would have been obtained if receiver resistance had been matched to antenna resistance with the reactance tuned out.

[b] 150-mile distance.

[c] This figure may be somewhat high to be representative, since noise received from this type of antenna depends more on the azimuth of the noise than in the case of the reference antenna.

Figure 6-130. Sky-wave transmission between like antennas, 75 miles, 3 megacycles, F2-layer.

664. SAMPLE VALUES OF RELATIVE ANTENNA EFFICIENCY.

Figure 6-130 gives some quantitative comparisons for several different types of antennas tested over a 75-mile course in southern Florida using sky-wave transmission at 3 mc. Data for this table were obtained by comparisons of pairs of antennas on different nights, together with cross comparisons made in order to reduce the data on all the antennas to a common basis.

665. WAVE ANTENNA (BEVERAGE ANTENNA).

a. In the form suggested for tactical use, the wave antenna consists of a single wire two or more wavelengths long, supported on poles at a height of 12 to 20 feet above ground. At the distant end the wire is connected to ground through a resistance of about 500 ohms, which is approximately the characteristic impedance of the ground-return circuit. A reasonably good ground arrangement such as a crowfoot counterpoise should be used. Sometimes two or more antenna wires are used in parallel instead of the single wire, with a resulting decrease in the characteristic impedance of the ground-return circuit and therefore of the required value of terminating resistance. The input impedance is reasonably constant with frequency and the antenna may be used over a considerable frequency range without changing dimensions.

b. This antenna is directional and is used primarily for either transmitting or receiving *vertically* polarized ground waves. Maximum response or radiation is in line with the wire and off the terminated end, with little response or radiation in the opposite direction or broadside, if correctly terminated. The forward lobe may be made narrower and the gain increased by using several wavelengths of wire.

c. The operation of the wave antenna is based on *wave tilt*. When a vertically-polarized radio wave passes over the ground, a component of the electric field appears which is parallel to the earth and in the direction in which the wave is propagated, that is, the wave may be pictured as *tilted* in the direction of propagation. A receiving antenna oriented in this direction will therefore have a voltage induced in it. Similarly, by wave-tilt action a horizontal transmitting antenna will generate a vertically polarized wave which is strongest along the direction of the antenna. The finite conductivity of the earth is the cause of the wave tilt, that is, the appearance of the horizontal component in the receiving case and the vertical component in the transmitting case. The component due to wave tilt is larger over poor earth than over good earth; over sea water it is very small. The wave antenna, because of these properties and because of its fairly high impedance, can be used to advantage over rocky or sandy soil, where difficulty in obtaining a low-resistance ground connection decreases the efficiency of low-resistance antennas such as short whips or quarter-wave antennas. With two wavelengths of wire, an efficiency equalling that of a quarter-wave vertical can be expected in the h-f band over poor or medium soil. This antenna should not be used over salt marsh or sea water.

d. The terminating resistor of about 500 ohms must be able to dissipate about 1/3 of the power fed into the antenna when transmitting. This resistor and the transmitter should be connected to earth through a relatively low-impedance ground, such as the h-f crowfoot counterpoise described in paragraph 663a(1).

666. ON-GROUND ANTENNAS.

Insulated wires of sufficient length laid on the ground, or better on vegetation just above the ground, will provide ground-wave transmission with vertical polarization in line with the direction of the wire, that is, off either end of the wire, and for moderate horizontal angles from this direction. Such low antennas have the advantage of being easily concealed. A length of about 600/F feet (where F is the operating frequency in megacycles), or somewhat longer, is suitable, if the length is adjusted by trial to permit good transmitter loading. A 100-foot on-ground antenna attached to Radio Set SCR–536 (handie-talkie) gives at least as good transmission in such directions as the whip supplied with the set, and can be more easily concealed. Half-wave on-ground antennas (see par. 661d for length) can sometimes be used for short-distance sky-wave reception or transmission.

667. FULL-WAVE HORIZONTAL WIRE.

An unterminated end-fed horizontal wire one wavelength long and a few feet off the ground will produce a *vertically* polarized ground wave, in line with the wire, which has materially higher intensity than that from a short whip. This assumes that the wire is fed as described for end-fed half-wave horizontal antennas (par. 663). The horizontal radiation pattern for ground waves is like a figure 8, the two maxima being in the forward and backward directions of the wire, with the field at 30° from these directions only slightly reduced. This antenna can be used satisfactorily over ground of high or average resistivity, but not over sea water or salt marsh.

668. BALLOON-SUPPORTED HALF-RHOMBIC (INVERTED VEE).

a. Antenna Assembly AS–51/MRQ–2 (TM 11–2610) includes two half-rhombic antennas, a balloon, hydrogen cylinders, a kite, and auxiliary apparatus. One antenna, designed for frequencies of about 1 to 8 mc, has a length (projection on the ground) of 1,600 feet and an apex height of 560 feet. The other, designed for frequencies of about 3 to 18 mc, has a projection length of 625 feet and an apex height of 225 feet. The balloon is used to support the apex in winds under 20 miles per hour; the kite, in winds over 20 miles per hour.

b. The antenna is directional, radiating largest field intensities in the direction of the terminated end and responding best to incoming signals from that direction. The pattern is broader at the lower than at the higher end of the operating frequency band. The antenna has a fairly constant impedance over its operating frequency band. It is primarily suited to ground-wave use, and provides a large gain over a short whip.

c. A balloon-supported single vertical wire, not exceeding about a half wavelength, would be an efficient nondirectional ground wave antenna.

669. H-F FIXED PLANT ANTENNAS, GENERAL.

Several antenna types for use in the more permanent radio installations are described briefly in the following paragraphs. These are apt to be higher, and often require more ground space, than representative tactical antennas. An example to illustrate these points is given in figure 6-131. Since h-f sky-wave operation requires the use of more than one frequency for optimum 24-hour reliability, antennas for use in large fixed plant installations are often of types suitable for operation

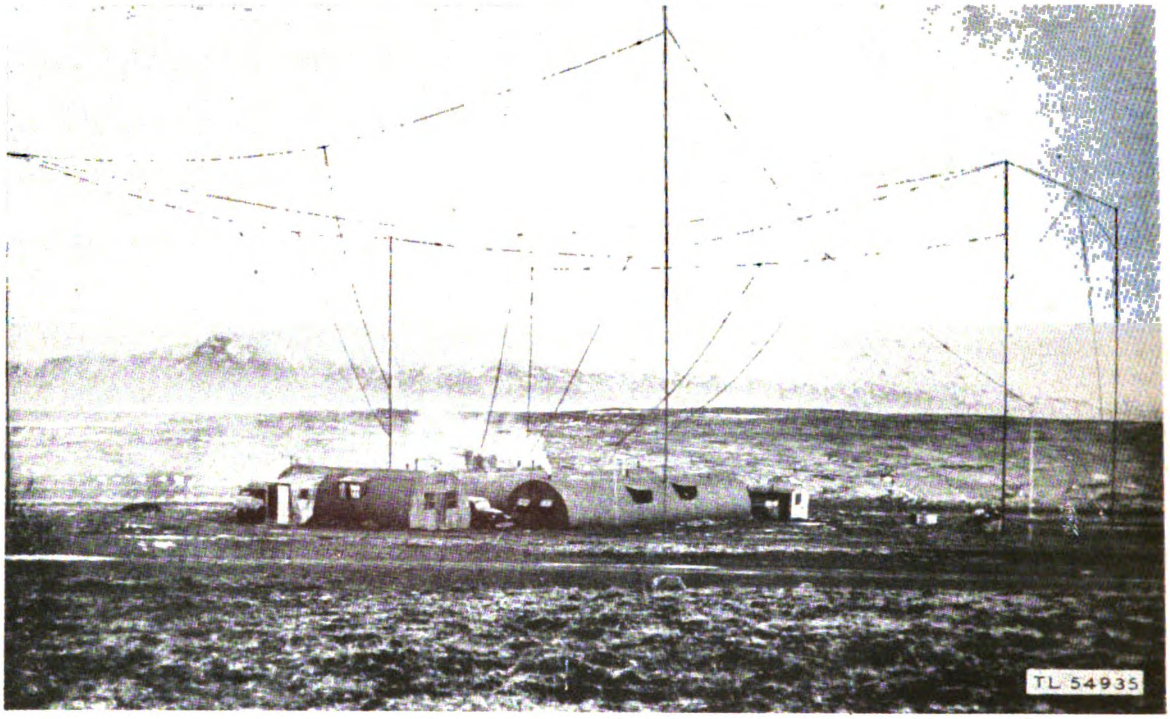


Figure 6-131. Net control station for an island radio net.

over a fairly wide frequency band without changes in antenna dimensions.

670. HORIZONTAL RHOMBIC ANTENNAS.

a. General. Horizontal rhombic antennas are commonly used for long-distance sky-wave transmission. This antenna type is a 4-sided diamond-shaped antenna mounted parallel to the ground and, as furnished by the Army Communications Service, supported on four large wooden telephone poles, or on specially designed steel towers (TM 11–2614 and TM 11–2615). This antenna is balanced to ground. A balanced radio transmitter or receiver is connected at one end of the diamond; a terminating resistance is connected at the other end, which points toward the distant station. Radiation from or response of a properly designed and constructed rhombic will be greatly reduced in all directions materially separated from the desired direction. The dimensions of the antenna, as compared to the wavelength at the operating frequency, control the directional pattern. A properly designed and terminated rhombic will have an input impedance which approximates the terminating resistance over a fairly wide frequency range. If the antenna is left unterminated it will be bidirectional, that is, will radiate and respond nearly as well in the opposite direction as in the desired direction; the configuration of the field pattern will be changed, and the input impedance of the antenna will vary quite widely with frequency.

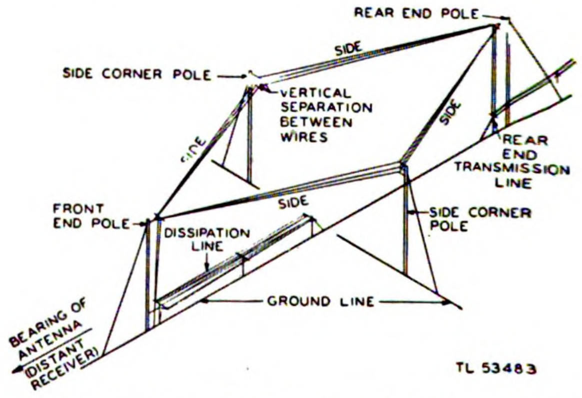


Figure 6-132. Transmitting horizontal rhombic antenna.

b. Transmitting Horizontal Rhombic Antenna.

(*1*) The transmitting rhombic illustrated in figure 6-132 differs from a receiving rhombic by the addition of one or more conductors on each side. The conductors are brought together at the front and rear apexes and are separated by several feet at the side poles. Such a multiwire arrangement reduces the antenna input impedance, reduces the required value of terminating impedance, and provides a more uniform impedance over the frequency band. A number of designs have been standardized by the Army Communications Service, as indicated in figure 6-133 (TM 11–2617, when published). These antennas are intended to operate in the frequency band from 4 to 22 megacycles at frequencies which are appropriate to the sky-wave transmission conditions for the transmission distance and the time of day involved in a particular application.

Antenna type	*Range (miles)*	*Side length (feet)*	*Tilt[a] angle (degrees)*	*Height (feet)*	*Length, end pole to end pole (feet)*	*Width, side pole to side pole (feet)*
A	Over 3,000	375	70	65	723	268
B	2,000 to 3,000	350	70	60	676	251
C	1,500 to 2,000	315	70	57	611	228
D	1,000 to 1,500	290	67.5	55	553	234
E	600 to 1,000	270	65	53	506	240
F	400 to 600	245	62.5	51	453	238
G	200 to 400	225	60	50	407	237

[a] The *tilt angle* is half the horizontal angle at the side corner pole (fig. 6-134). This has no relation to *wave-tilt* described in paragraph 665c.

Figure 6-133. Horizontal rhombic antenna dimensions.

(*2*) From 30 to 50 percent of the power fed into the rhombic antenna appears at the far end and must be dissipated in the resistance termination. This lost power is more than compensated for by the gain resulting from the directional properties of the antenna. The power loss in the termination reaches such large magnitudes when a transmitter of 10- to 40-kw output is used that available nonreactive resistors will not dissipate the power. The problem is overcome by the use of a long transmission line or *dissipation line*, composed of iron or stainless steel conductors. The spacing of the line is so chosen with respect to the diameter of the resistance wire that the characteristic impedance of the line is equal to the proper impedance for terminating the rhombic. If the line is sufficiently long electrically, the far end may be shorted and the input impedance will still be practically a pure resistance equal to the characteristic impedance of the line. One type of dissipation line supplied by Army Communications Service is only about 300 feet in length and is composed of four stainless steel conductors; other longer lines have been supplied. In one theater an improvised dissipation line was constructed by using iron baling wire for the conductors.

c. Receiving Horizontal Rhombic Antenna.

(*1*) The rhombic is also extremely useful as a receiving antenna, particularly on long haul point-to-point circuits. The dimensions and height above ground of receiving rhombics are similar to those of equivalent transmitting rhombics, but the construction is generally much simpler, as illustrated in figure 6-134, since the power involved is negligible. Single wires are generally employed for the sides of this rhombic. Receiving rhombics also require a terminating resistor, but since the power dissipated in the resistor is very small,

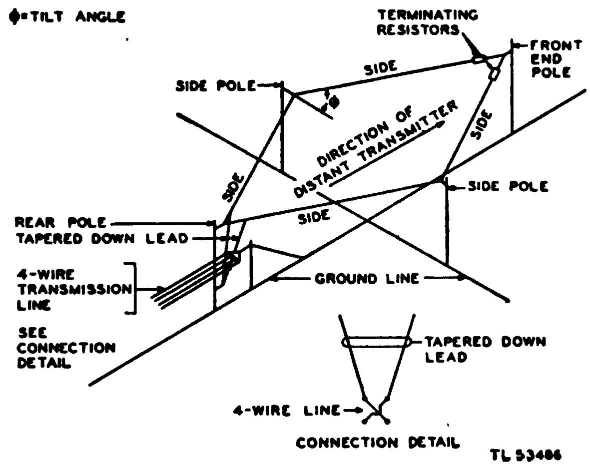


Figure 6-134. Receiving horizontal rhombic antenna.

nonreactive resistors of a few watts rated dissipation are used. The directional pattern of a receiving rhombic is similar to that of an equivalent size transmitting rhombic. For receiving rhombics, reference may be made to TM 11–2611.

(2) The broad-band properties of the rhombic have permitted as many as four to six receivers, each tuned to a different frequency, to be multipled on a single antenna. The direction of each distant station should in general be close to the optimum direction of transmission for the particular rhombic. Each radio receiver should be balanced to ground. To prevent interaction between receivers, it may be necessary to use arrangements such as described in paragraph 675c.

d. Choice of Site for Rhombic Antennas.

(1) Bearings for proper alignment of rhombics, and engineering details, are furnished to the field for each specific installation by Army Communications Service. However, the actual choice of an antenna site is the responsibility of the officer in the theater. Proper choice of an antenna site to take fullest advantage of existing terrain is always of importance, and especially so in the case of rhombic antennas.

(2) The best location for a rhombic is over flat, level terrain with no obstructions beneath or surrounding the antenna. It is very seldom that this ideal condition can be found in practice.

(3) The following points should be considered in the choice of a site:

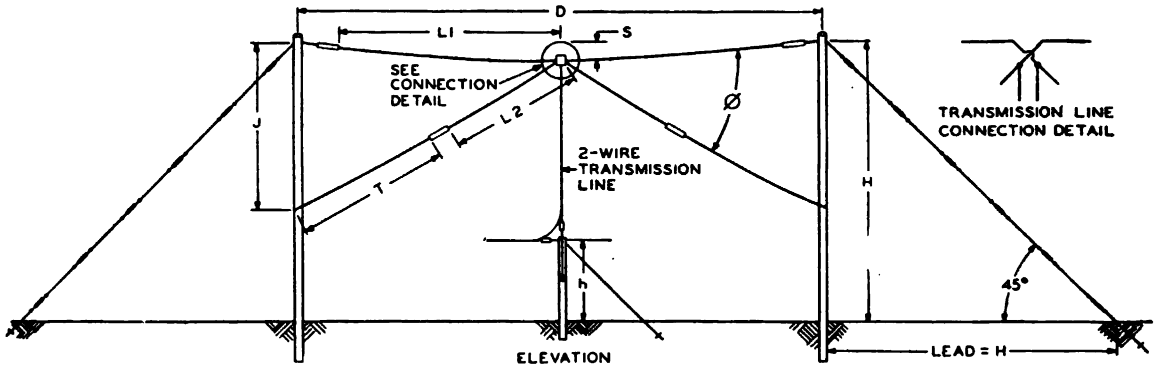
(a) The antenna should be erected over flat terrain with no hill, building, or other large object within the area of the rhombic.

(b) The terrain immediately in front of the termination end of the antenna should preferably be level and of approximately the same slope as the ground beneath the antenna, for a distance of at least ½ mile. In this case the rhombic may be mounted parallel to the ground.

(c) Where the rhombic must be located over ground where there are differences in elevation at the various pole sites, but where the terrain ahead of the antenna is level, it should be erected with the antenna wires level. Their elevation should be the average of the elevation of the four pole sites plus the recommended height above ground.

(d) Hills or large buildings (particularly metal frame structures) immediately in front of the proposed antenna site should be avoided.

(e) Isolated trees within the rhombic area will have negligible effect on the performance of the antenna. However, the antenna should not be erected over a heavily wooded area where the trees are an appreciable height compared to the rhombic. Choice of such a site is likely to result in absorption loss and in a change of directional characteristics. Data are not available on the exact magnitude of the changes in rhombic antenna characteristics over heavily wooded areas.



LEGEND			
D	POLE SPACING BETWEEN CENTERS	J	ATTACHMENT SPACING
L1	ONE HALF UPPER ELEMENT	T	TIE WIRE (APPROX 45 FT)
L2	ONE HALF LOWER ELEMENT	Ø	30° APPROX
S	INITIAL DEFLECTION (DOWN LEAD	H	75 FT. PREFERRED
	& LOWER ELEMENTS HANGING FREE)	h	12 FT. PREFERRED

TABLE I
DOUBLE DOUBLET REC. ANTENNA DATA

TYPE	BAND RANGE (NOMINAL) (IN MEGACYCLES)	D	J	L1	L2	S
		(IN FEET)				
A	2.5 - 20	130	37	60	30	3

TL 53487

Figure 6-135. Double doublet receiving antenna.

671. DOUBLE DOUBLET RECEIVING ANTENNA.

a. A receiving antenna used rather widely in fixed plant is the double doublet illustrated in figure 6-135 (TM 11–2629, when published). This consists of two doublets of different lengths connected criss-cross at their center, as shown in the detail, and attached to the end of a 2-wire transmission line, preferably of about 200 ohms impedance (par. 676). One doublet is cut to a half wavelength for the lower of two operating frequencies and the other is made a half wavelength for the higher frequency. The impedance curve of such an antenna will not change as rapidly in the neighborhood of the half wavelength frequencies as does the curve for a single doublet. The antenna is therefore more of a broad band antenna than would be the case if two separate half-wave doublets were used. However, the antenna impedance has an antiresonance point intermediate between the two half-wave frequencies. The signal-to-noise ratio is, in general, not as good as if at each operating frequency a half-wave horizontal cut to that frequency were used. Maximum response in the directional pattern is broadside to the antenna.

b. Recent tests indicate that a general purpose double doublet may be constructed for use from about 2.5 to 20 mc. This antenna consists of a top horizontal 4-mc half-wave element and a lower 8-mc half-wave element, both erected on poles 50 to 75 feet high. The higher poles are suitable for longer-distance transmission. Such an antenna collects signals (long-distance sky-wave) better over a wide range of frequencies than any single half-wave dipole, but not as well as a set of dipoles, each cut to half wavelength at its own operating frequency.

672. TRANSMITTING DOUBLET ANTENNA (DELTA-MATCHED).

The doublet antenna illustrated in figure 6-136 is often used with moderate powered (0.3 to 2.5 kw) transmitters over distances of 500 miles or less for point-to-point fixed station communication (TM 11–2656). For this application its use is often justified in place of the more elaborate rhombic, and it has advantages by virtue of its high-angle radiation properties. For transmission up to about 200 miles, the height of the antenna above ground should not exceed approximately a quarter wavelength for the operating frequency used; for long distances the height expressed as a fraction of a wavelength may with advantage be increased, but not above approximately a half wave. The transmitting doublet furnished for fixed stations consists of a single horizontal wire of approximately one-half wavelength, the exact length of which must be properly adjusted by a trial and error procedure. The power is transferred from a balanced 600-ohm transmission line to the antenna by a so-called *delta-matching* system. The ends of the wires of the transmission line are fanned out and attached to the antenna at equal distances from the center. The dimensions of the delta and the length of the antenna must be such as to match the line to the antenna so that standing waves on the line are minimized. The proper length of the antenna and the width of the delta at the antenna end are dependent upon height above ground, ground conditions, frequency, and the effect of metallic structures (towers, guys, etc.) in the vicinity of the antenna. In practice, it has been found possible to specify the dimensions of the delta for a given frequency and height above ground so that only the

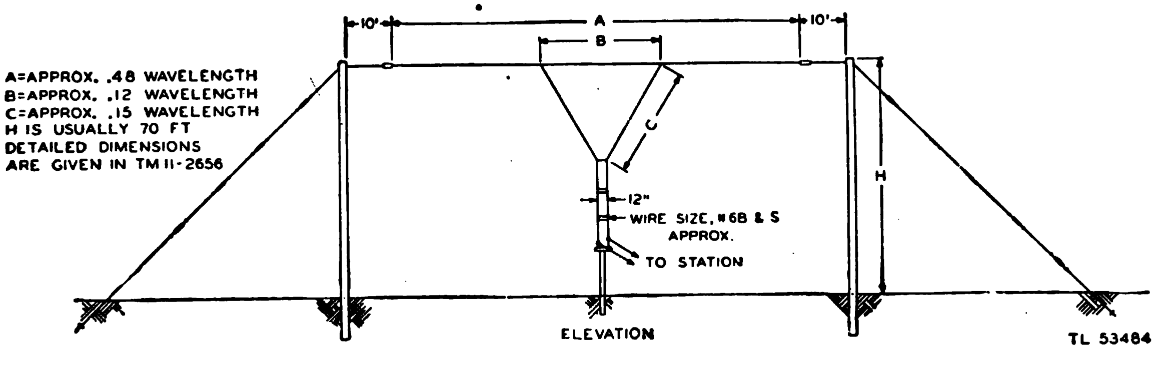


Figure 6-136. Delta-matched doublet antenna.

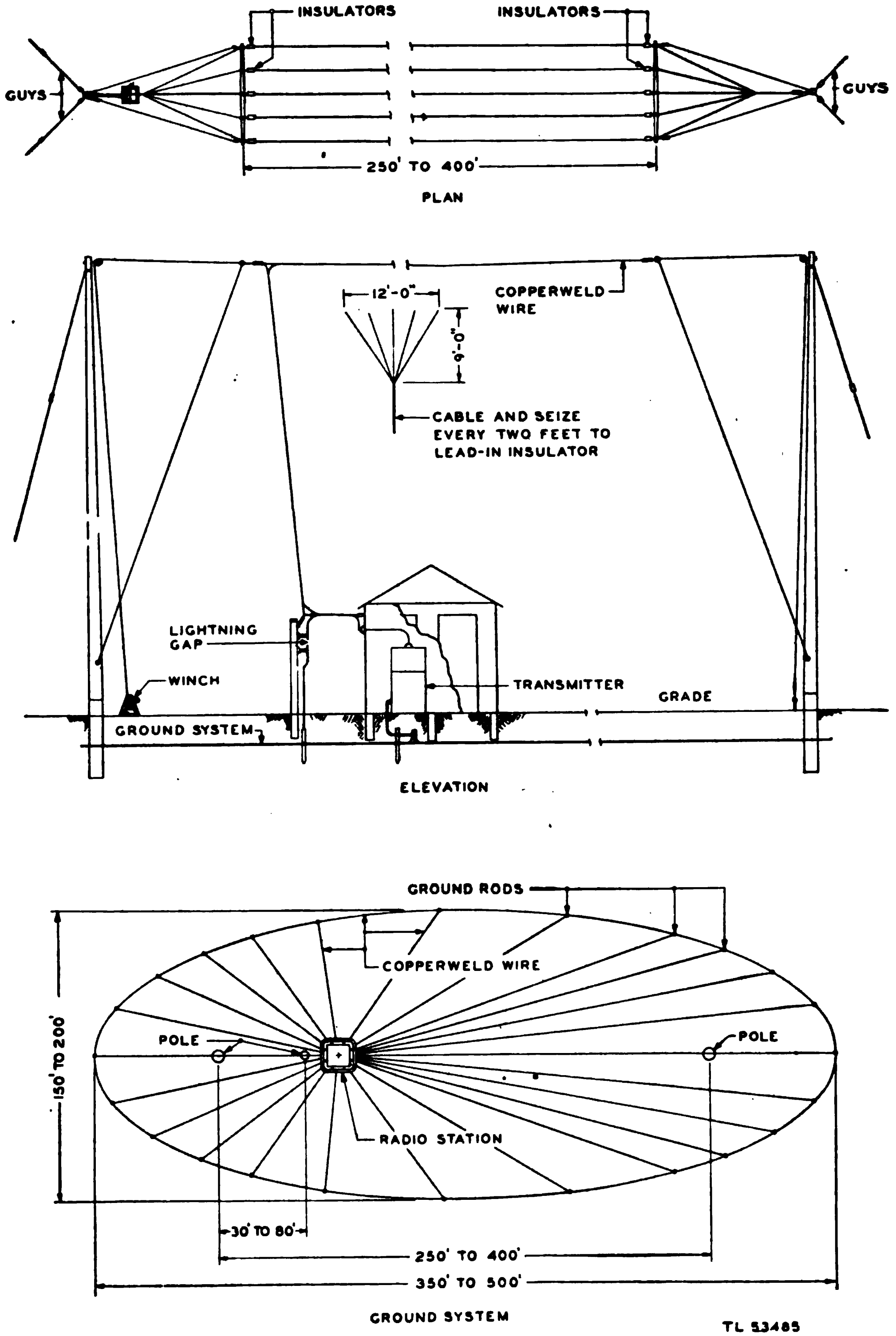


Figure 6-137. Intermediate-frequency flat-top antenna.

length of the antenna need be adjusted by the trial and error procedure to give a practical match (TM 11–2656). A separate antenna is usually required for each assigned operating frequency. Maximum radiation from the delta-matched doublet is broadside to the axis of the antenna.

673. ANTENNAS FOR FREQUENCIES BELOW 800 KC.

a. General. Frequencies below 800 kc (the lower the better down to about 100 kc) are used for ground-wave transmission over rocky or mountainous areas since at the lower frequencies the waves bend more readily over mountains and hills. The following types of antennas are in general use at frequencies in this range. Frequencies below 500 kilocycles are used in the higher latitudes when it is necessary to provide communication during magnetic disturbances which blackout h-f sky-wave transmission.

b. The Marconi or Flat-top Antenna. The flat-top is a grounded vertical antenna, with a horizontal top to increase the capacitance of the antenna. Flat-top antennas supplied by Army Communications Service consist of one or more horizontal parallel conductors supported by two masts with a vertical down-lead in the center or at one end. Thus, the antenna takes the form of a T or an inverted L (fig. 6-137). Most of the useful radiation occurs in the vertical portion, or down-lead. The horizontal section acts to increase the effective height of the antenna, and gives practically the same efficiency that would be obtained by a much higher vertical antenna without the flat top. The flat-top antenna is always worked against ground, and the vertical down-lead is connected through a tuning network directly to ground, or to a counterpoise system a few feet above the ground. A tuning network must be used at the base of a flat-top antenna to tune the antenna to resonance and to match it to a balanced or an unbalanced type transmission line, when used.

c. Crowfoot Antenna. The antenna shown in figure 6-138, which is similar to a Marconi antenna, is used at frequencies from 400 to 500 kc with Radio Set SCR–177–B (TM 11–232).

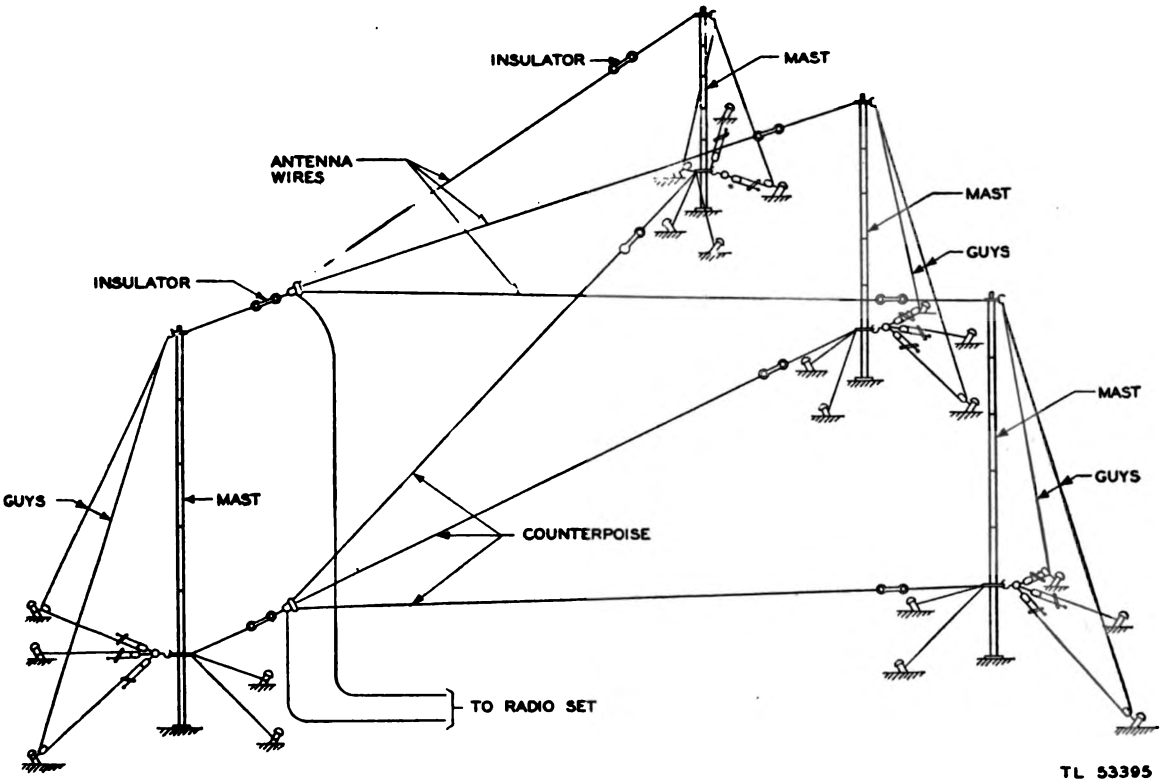


Figure 6-138. Crowfoot antenna.

d. Wave or Beverage Antenna.

(*1*) A general description of this antenna is given in paragraph 665. At the lower frequencies being considered here, it becomes more important to install the antenna over high-resistivity (rocky or sandy) earth, since the wave-tilt effect which is responsible for its operation is approximately proportional to the square root of the product of frequency and soil resistivity at these frequencies. The wave antenna may be used for long-distance transmission and reception. The construction of the standard transmitting wave antenna differs from that of the receiving wave antenna, though both operate on the same basic principle of wave tilt. The receiving wave antenna generally consists of two spaced wires erected about 15 feet above ground on short telephone poles and is often made several wavelengths long, perhaps a mile or two, although for best efficiency it should not exceed about 2½ wavelengths. In the reception of signals on the antenna, the two wires operate in parallel with ground return. The antenna may be connected directly to the receiver or through coupling transformers and a transmission line. When operated in this fashion, the terminating resistor is placed at the end remote from the receiver and nearest the origin of the desired signal (fig. 6-139-A). It may often be necessary to locate the near end of the receiving antenna 200 feet or more from the receiving station to avoid the man-made noise which would be picked up if the end of the antenna were located at the receiver building.

(*2*) The receiving wave antenna is often arranged in a somewhat different manner (fig. 6-139-B). The antenna is run from the receiving site in a direction opposite to the origin of the desired signal. The received signal is built up between the wires and ground as it travels along the antenna away from the receiving site. At the far end of the antenna, a special transformer takes the signal existing between the pair and ground, converts it to a balanced-to-ground signal and feeds this signal to the pair of wires which now act as a balanced 600-ohm transmission line back to the receiver. Thus, the antenna serves as both antenna and transmission line. At the receiver end of the line, the balanced-to-ground signal is fed through a transformer and transmission line to the receiver. The terminating resistor

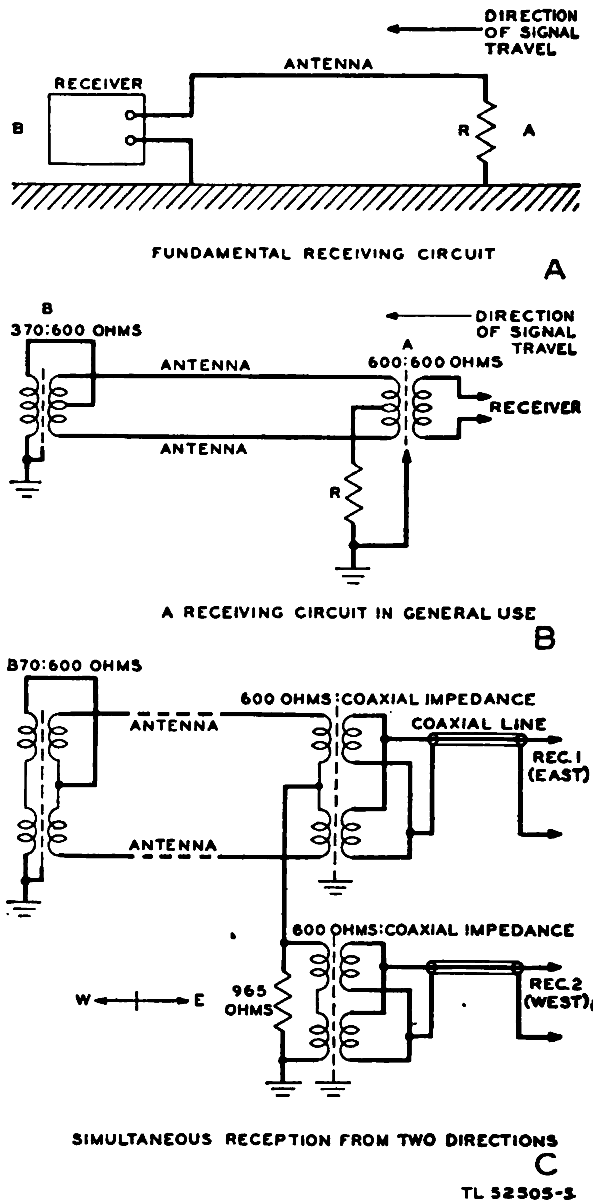


Figure 6-139. Receiving wave antenna.

R is located at this coupling transformer and serves to dissipate any signal arriving from the direction opposite the desired signal. With this system, optional reception in either direction or simultaneous reception in two directions with two receivers is possible (fig. 6-139-C).

(*3*) At frequencies below 800 kc a properly located transmitting wave antenna should give results equivalent to a vertical antenna several hundred feet high. The transmitting wave antenna as furnished by Army Communications Service consists of three conductors arranged in the configuration of an equilateral triangle (5 feet on a side) and erected approximately 15 feet above ground on short telephone poles. The antenna length is generally made between one and two wavelengths. For lengths greater than about 2½ wavelengths, the gain of the antenna generally decreases. Because of limitations of ground space, it is sometimes necessary to make the antenna less than one wavelength long, in which case the full gain of the antenna is not realized. The antenna is terminated at the far end (to ground) through noninductive resistors capable of dissipating approximately one-third of the transmitter power. The near end of the wave antenna may be connected to the transmitter directly or by means of a transmission line of the same impedance as the antenna. The antenna may then be operated over a wide frequency range without adjustment.

674. SPACE DIVERSITY ANTENNA SYSTEMS.

a. For long-distance sky-wave transmission, the use of a *space diversity* antenna system together with specially designed radio receiving equipment will provide an advantage of the order of 10 to 15 db as compared with use of a single antenna in combatting the effects of fading on teletypewriter operation. A similar but perhaps smaller advantage may be obtained for sky-wave transmission at short distances. In this system, two (or sometimes three) separate receiving antennas are connected to separate radio receivers, the outputs of which are suitably combined. Each individual antenna should be adapted to the type of transmission in question. The antennas should be separated approximately 3 wavelengths or more at the operating frequency; where space is available, 10 wavelength separation is worth while. The reason for the advantage is that under these circumstances the signals received in each antenna usually fade independently of each other.

b. When space limitations do not permit obtaining the separation referred to above, a lesser diversity advantage may be obtained by utilizing *polarization diversity*. This is based on the observation that the vertical and horizontal polarization components of a received sky-wave signal usually do not fade simultaneously. Thus, diversity can be obtained from two antennas, one responsive to horizontally polarized waves and the other to vertically polarized waves; for example, a horizontal doublet and a vertical doublet. It has been observed also that on two horizontal half-wave antennas, placed at right angles to each other, signals do not usually fade simultaneously. Such antennas may be used to obtain diversity and low noise on short-distance sky-wave transmission. Polarization diversity can also be obtained from a single horizontal half-wave doublet used together with a suitable balanced transformer with midtap (fig. 6-140).

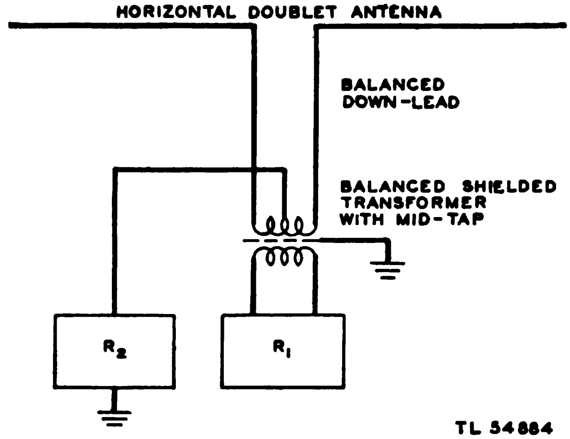


Figure 6-140. Schematic of means of obtaining polarization diversity from horizontal doublet.

The horizontal component is picked up in receiver R_1 and the vertical component in receiver R_2. A similar scheme can be used to obtain polarization diversity from a single rhombic antenna. The directional patterns of the antenna circuits connected to R_1 and R_2 will differ, whether the antenna is a doublet or a rhombic. This limits the effectiveness of these arrangements.

c. One form of radio equipment for diversity reception is illustrated in figure 6-141.

675. ANTENNA PARKS.

a. General.

(*1*) At locations where a large number of radio circuits terminate, such as a higher headquarters, careful layout of the numerous antennas is needed. A general plan for signal center radio equipment is discussed in chapter 11, which includes a figure (fig. 11-59) showing relative locations of a signal center and associated radio transmitters and receivers. Some general technical principles for laying out antenna parks are given below.

(*2*) The use of separate sites for the

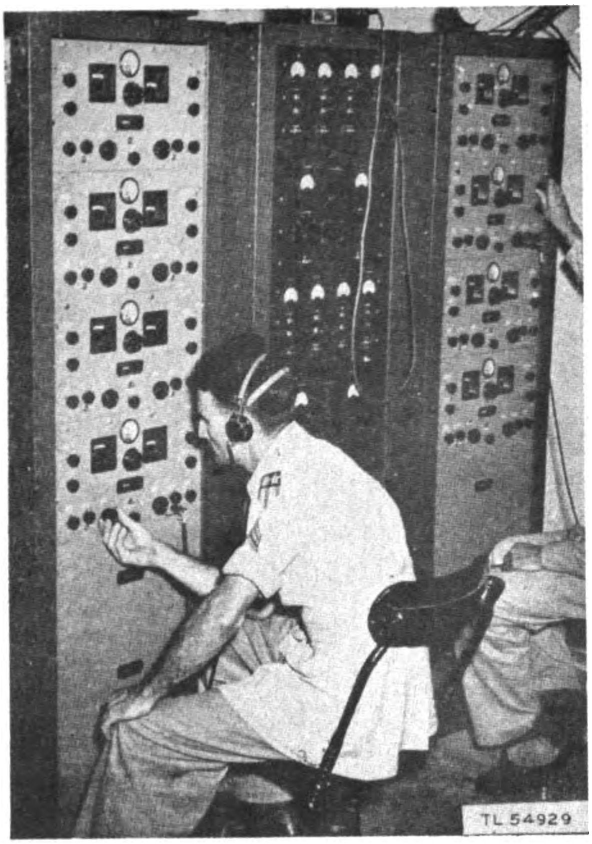


Figure 6-141. Radio receiving station using diversity reception equipment (showing two Schuttig diversity mixing units and eight Radio Receivers BC-779).

transmitting antennas, the receiving antennas, and the signal center, together with suitable remote control arrangements, helps to prevent interference between transmitters and receivers (sec. VI), and reduces interference into receiving antennas from man-made radio noise arising from unsuppressed teletypewriter and ciphering equipment, d-c motors, etc. at the signal center.

(*3*) A reasonable rule to follow when greater separations would be impractical, is to separate transmitting and receiving antenna parks by at least one mile when the transmitter power is less than 10 kw. For higher transmitter powers the spacing should be greater. In many cases, the separation is much greater than indicated above because of local considerations (ch. 11).

(*4*) When it is necessary to place the receiving antennas close to the signal center in which the radio receivers are located, higher minimum received field intensities are generally required, because of radio noise from the signal center itself and also from industrial sources when the signal center is in a city. Furthermore, the small space available in a city location may force the use of antennas which do not discriminate very well against such kinds of interference.

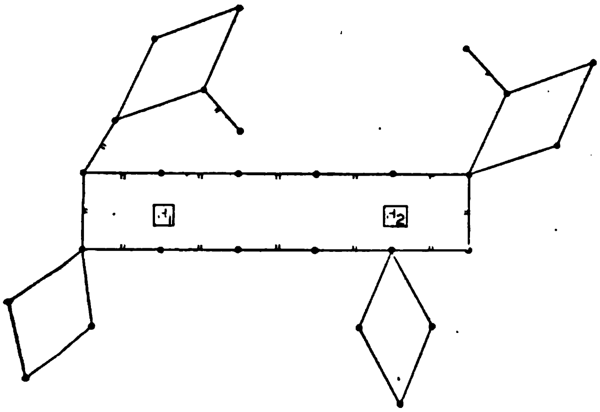
b. Transmitting Antenna Parks.

(*1*) Large transmitting antenna parks should be planned in advance to use the available space to the best advantage, provide for efficient operation, allow space for growth, reduce hazard from bombing, economize on the total number of tall poles which must be erected, and obtain reasonably short antenna r-f transmission lines.

(*2*) When a transmitting antenna is closely coupled to others in the vicinity, the currents induced in these antennas may be large enough to distort the radiation pattern of the transmitting antenna. Furthermore, cross modulation between transmitters may cause the radiation of spurious frequencies (par. 686). Separations of a half wavelength or more are desirable when convenient. Theater experience indicates that a separation of about a quarter wavelength between parallel half-wave transmitting antennas is reasonably adequate, provided that the antennas are tuned to materially different frequencies, that the length of one antenna is not an integral multiple of another, and that the transmitters have about the same output power ratings.

(*3*) The use of single-wire ground return transmission lines bunched closely together to feed several antennas will introduce coupling which will nullify any benefits obtained by proper separation of the antennas. Low-impedance end-fed ground-wave antennas may be fed by coaxial transmission lines, with the center conductor attached to the antenna down-lead and with the outer conductor connected to a crowfoot counterpoise. Balanced antennas, fed through balanced open wire lines or low-loss balanced cable pairs, are to be preferred for skywaves. For low coupling between balanced open wire r-f transmission lines, a rough rule to follow is that the minimum separation between pairs should be about eight times the spacing of the wires of a pair.

(*4*) One arrangement of balanced antennas which typifies layouts which have been used in the theaters is shown in figure 6-142. An arrangement which was found workable in



NOTES:
◇ RHOMBIC ANTENNA. WHERE SPACE IS AVAILABLE, GREATER SEPARATION BETWEEN RHOMBICS AND OTHER ANTENNAS IS DESIRABLE
— DOUBLET OR FOLDED DOUBLET; INSERT INSULATORS TO OBTAIN PROPER LENGTH
▣ TRANSMITTER HOUSE
• SUPPORTING POLE OR MAST
TRANSMISSION LINES, ETC., NOT SHOWN TL 54927

Figure 6-142. Sample transmitting antenna park.

one case for end-feeding half-wave sloping antennas from a number of Radio Transmitters BC–610 (used in Radio Set SCR–399) is shown in figure 6-143. To adjust each sloping-wire antenna to approximately half wavelength at its operating frequency, an insulator is inserted at the proper point. In some cases it may be necessary to carefully select operating frequencies for antennas separated by only 75 feet (fig. 6-143) in order to avoid excessive coupling between transmitters. Some of the

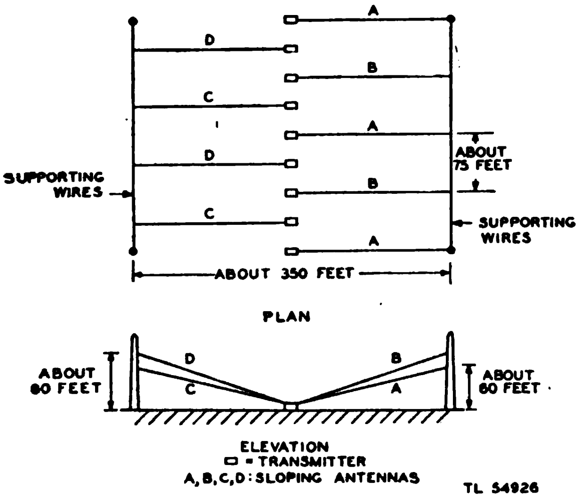


Figure 6-143. Antenna park for a number of Radio Transmitters BC–610.

transmitter tuning units used (Radio Set SCR–399) were modified to use parallel resonance instead of series resonance to permit proper feeding of the antenna. For alternative methods see paragraph 663.

c. Receiving Antenna Parks.

(*1*) The antennas in a large receiving park can be arranged along the general lines discussed above. In a park close to a large headquarters, balanced antennas, balanced r-f transmission lines, and balanced receivers are desirable for sky-wave reception in order to minimize the effects of man-made noise. Unbalanced antennas required for ground-wave reception may be connected to their receivers through coaxial cable; a better method may be to use an isolating transformer at the base of the antenna, with its balanced winding connected to a balanced transmission line working into a balanced receiver. One such transformer (stock No. 2C471) is listed in TM 11–487.

(*2*) For optimum performance, individual antennas tuned to the operating frequency should be used with each receiver. However, where space is limited, several receivers may be multipled on a single antenna. With this arrangement, the antenna should have suitable directional and impedance characteristics over the required band of frequencies. One antenna may not be able to meet all requirements, in which case the receivers should be divided into groups with a separate antenna for each group. For example, a horizontal doublet antenna may be used for sky-wave circuits over distances up to 200 or 300 miles, while a tall vertical antenna will give better results on ground-wave reception from nearby stations. The doublet antenna may be cut to about 1.25 wavelengths for the highest frequency to be used and will work reasonably well down to frequencies at which the length is somewhat below a half wave. The vertical antenna for ground waves should not exceed about 0.65 wavelength at the highest frequency, and is relatively efficient down to frequencies at which the length is somewhat below quarter wave.

(*3*) When space permits and where their directional characteristics are suitable for the transmission paths involved, wave antennas and rhombic antennas are also suitable for use over a relatively wide frequency band with multiple receivers. Double doublet antennas may also be used. In addition, the antenna illustrated in figure 6-144 is suggested as an improvised sky-wave antenna (not supplied as standard) which has a better impedance characteristic over the 2- to 10-mc band than a single-wire doublet antenna such as described

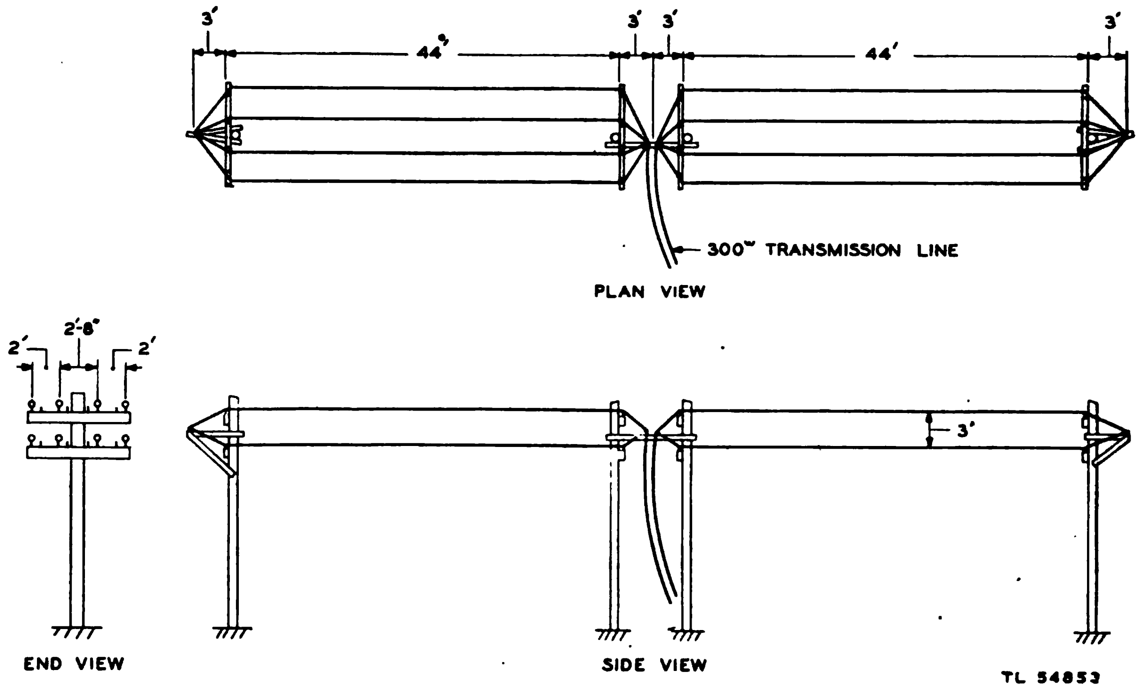


Figure 6-144. Eight-wire broad-band doublet receiving antenna for 2- to 8-mc band, improvised from tactical open wire pole line materials.

in subparagraph (2) above. However, such refinement in doublet antenna construction is not warranted unless external noise is low enough for set noise to become controlling with a simple doublet.

(*4*) When several receivers operating on different frequencies are connected to the same antenna, some reduction in the signal voltage delivered to each receiver must be expected. When receivers having balanced inputs are available, less loss will ordinarily result if these are located close together and connected in series, rather than connected in parallel. Up to four or five receivers may be connected in series in this manner before the losses exceed 10 to 15 db with respect to an individually tuned half-wave horizontal antenna per receiver. Unbalanced receivers must be operated in parallel, and the use of more than two or three will probably cause substantial transmission losses. These losses in signal caused by the use of several receivers on a common antenna do not necessarily degrade the audio signal-to-noise ratio; where atmospheric static or man-made noise is high, considerable loss can be tolerated before the set noise of a good receiver becomes an important factor.

(*5*) When several receivers are on the same antenna, interference in a receiver may be caused by radiation from the high-frequency oscillators of the other receivers. One arrangement for reducing this effect is to use a distributing amplifier system which affords some isolation between the various receivers. A small 10-channel device of this sort, available in limited quantity through Army Communications Service, is the RCA multicoupler, model S-8853-1. It has a 200- or 600-ohm balanced input and also a 75-ohm unbalanced input. The input circuit is untuned, but with selected vacuum tubes the modulation products caused by strong undesired signals are kept to about 2 microvolts for unwanted signals up to 10 millivolts. The requirement of restricting unwanted signals to 10 millivolts may necessitate considerable separation from any transmitting antenna, especially in the case of vertical antennas and transmission over good soil.

(*6*) Another method, which avoids interference from modulation products, is to parallel all receivers across the common antenna after first inserting in one of the leads to each receiver a series-connected fixed inductor and variable capacitor. The reactance of the whole series circuit formed by the inductor, capacitor, receiver, and impedance toward the antenna is tuned out at the operating frequency of the particular receiver. This method reduces the loss caused by multipling, and also produces a maximum of signal voltage across the receiver. By this method, 5 to 10 receivers may be multipled without excessive loss. Standard equipment for using this method is not available, and construction of this type of equipment in the theaters should be undertaken only by skilled radio design personnel. The capacitor should be variable with a maximum capacitance of the order of 100mmf. The tuning adjustments of the individual series circuits are not entirely independent of each other when bridged across a common antenna. Hence, after initial adjustments, or when an operating frequency is changed, the tuning should be checked over two or three times to insure optimum adjustments of all networks for the particular set of operating frequencies.

676. RADIO-FREQUENCY TRANSMISSION LINES.

a. General. When a radio set cannot be located very close to its antenna, connection is made by means of a transmission line which may be either open wire or cable. In tactical applications such a line is usually short, consisting merely of a down lead. In fixed locations where numerous sets are operated, the antenna separations are such that transmission lines back to receiver or transmitter centers may be as much as several hundred feet long.

b. Types of Lines.

(*1*) An *open wire line* consists of two or more parallel wires of the same size maintained at a fixed separation by insulating spacers at suitable intervals. An open wire line commonly used in fixed plant transmitting installations consists of a pair of 162-mil (No. 6 B&S or AWG) copper wires spaced 12 inches apart to give a characteristic impedance of 600 ohms. Another type of open wire line, frequently used in fixed plant receiving installations, is composed of four 64-mil (No. 14 B&S or AWG) copper wires arranged in the form of a 1.3-inch square, with diagonally opposite wires connected together. The characteristic impedance of this arrangement is about 200 ohms.

(*2*) Transmission *cables* are available in various forms. One variety consists of two insulated wires twisted together or paralleled and held together wth a weatherproof material such as impregnated braid or vinyl insulation. Another type of balanced cable consists of two parallel conductors imbedded in a common insulating medium, with or without a metallic sheath. *Coaxial cable,* consisting of a center conductor mounted inside of and coaxial with an outer metallic tubing or metallic braid conductor and separated from it by spaced insulators or solid insulation, is also in general use.

(*3*) An unbalanced *open wire cage* is used in broadcast and low-frequency service. The construction resembles a coaxial line and, as supplied by Army Communications Service, consists of four outer conductors in the configuration of a 15-inch square connected together at each line support, and an inner conductor mounted coaxially with and insulated from the cage formed by the outer conductors. Two parallel conductors connected together are sometimes used in place of the single center wire when a lower characteristic impedance is desired.

(*4*) Improvised lines using field wire are discussed in subparagraph f below.

c. Transmission Line Balance. Two-wire or 4-wire open wire lines, and twisted-pair or parallel-pair cables, are known as *balanced* transmission lines, because the impedance to ground of each side of the line is about the same as a result of symmetry. Coaxial cables and the open wire cage are called *unbalanced* lines, since the two sides of the circuit have entirely different impedances to ground because of the asymmetrical construction. For minimum transmission line radiation and attenuation while transmitting, and for minimum attenuation and noise pick-up while receiving, balanced transmission lines should operate between antennas and apparatus which are balanced to ground. The 4-wire line with diagonally opposite wires shorted together has a high degree of balance to ground if installed properly. Coaxial type lines are for use mainly between antennas and apparatus which are unbalanced to ground. (See also paragraph 624c(2) and 654d(1).

d. Characteristic Impedance and Attenuation.

(*1*) Open wire lines having practicable wire spacings generally range from about 200 to 800 ohms in characteristic impedance, and have low transmission loss (attenuation). The impedance depends on the center-to-center spacing between conductors, and on the number and size of the conductors used. In figure 6-145 the characteristic impedances of 2-wire and 4-wire open wire lines are plotted for several sizes of wire and spacings, together with the formulas from which they were derived.

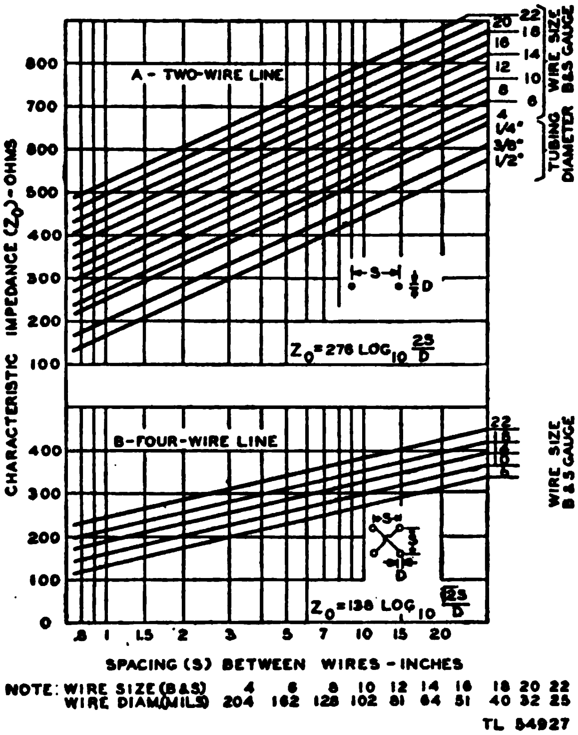


Figure 6-145. Characteristic impedance of open wire balanced transmission line.

(*2*) For all practical purposes the loss of an open wire transmission line whose length is 100 feet or less may be neglected at frequencies in the h-f band. The r-f loss of a 2-conductor open wire line may be estimated from the following formula for copper or copper-steel wires and dry weather:

$$a = 0.00314 \frac{\sqrt{F}}{d \log_{10} \frac{2S}{d}}$$

where

a = loss in db per 100 feet
F = frequency in megacycles
d = diameter of conductor in inches
S = spacing of conductors in inches

The loss of a 4-conductor line may correspondingly be estimated from:

$$a = 0.00314 \frac{\sqrt{F}}{d \log_{10} \frac{\sqrt{2}\,S}{d}}$$

where S is the side of the square and the other symbols are as above. Sample values of loss, computed from the above formulas, are included among the curves plotted on figure 6-146.

(*3*) Cables, either balanced pair or coaxial, generally have characteristic impedances ranging from about 50 to 200 ohms, and the transmission loss is usually relatively high. Some data on coaxial cables, twin conductor balanced shielded cables, and a balanced unshielded cable are given in figure 6-147. Infor-

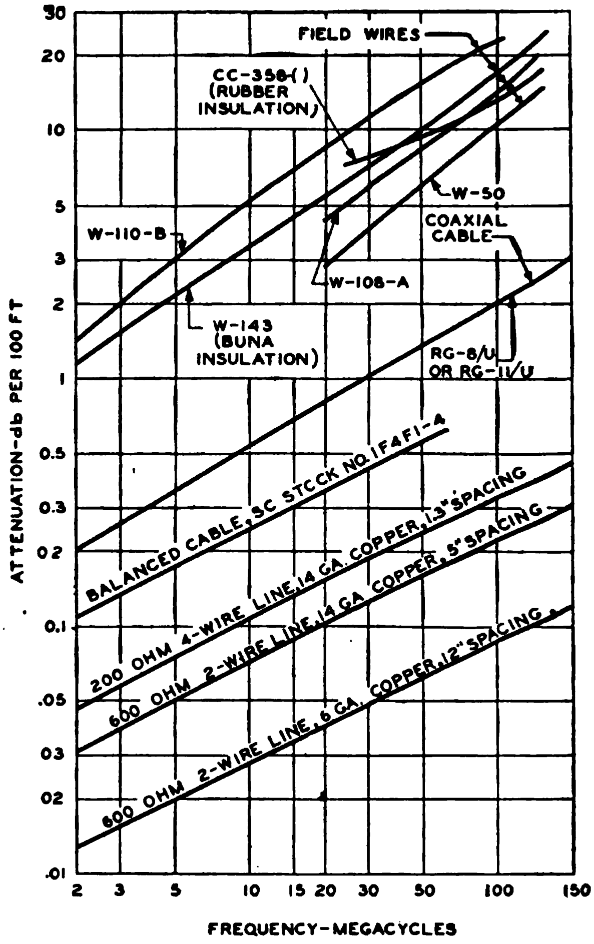


Figure 6-146. Attenuation of coaxial cable, balanced polyethylene cable, dry field wire, field cable, and open wire.

mation on most of these, and on other standard types of coaxial cables, is given in TM 11-487. A curve showing loss at various frequencies for two types of coaxial cable is included in figure 6-146. For balanced operation, a dual coaxial can be improvised by lash-ing together two single coaxials and using the inner conductors for a transmission line and the outer conductors for a shield. This pair has the same loss as the single coaxial, but twice its impedance.

Type	*Description*	*Characteristic impedance (ohms)*	*Approximate loss at 20 mc (db per 100 ft)*	*Over-all dimensions (inches)*
RG-8/U	Single coaxial	52	0.8	0.4
RG-11/U	Single coaxial	75	0.8	0.4
RG-22/U	Twin conductor	95[a]	1.3	0.4
RG-57/U	Twin conductor	95[a]	1.1	0.62
RG-23/U	Dual coaxial	125[a]	0.6	0.7 x 0.9
Stock No. 1F4F1-4	Balanced unshielded polyethylene cable	200[a]	0.35	0.6 x 0.3

[a] Impedance of balanced circuit.

Figure 6-147. Characteristics of radio-frequency cables.

e. Velocity and Electrical Length. The velocity of propagation of waves along a well-insulated open wire line is nearly that of a wave in free space. In paired and coaxial cables the velocity is materially reduced. Because of these deviations from free-space velocity, the physical length corresponding to a full-wave electrical length is less than it would be in free space and may be calculated from the formula

$$\text{Physical length (feet)} = \frac{984\ V/V_0}{F}.$$

In this formula F is the frequency in megacycles and V/V_0 represents the ratio of actual velocity to free-space velocity; V/V_0 is about 0.98 for open wire lines, and has values ranging from about 0.5 to 0.7 for various types of twisted pairs. For solid dielectric coaxial cable, the value of V/V_0 is approximately 0.65, and for bead-insulated cable the value is about 0.85. All of these values are approximate, and are given to indicate that impedance matching sections, etc., may vary appreciably in physical length, depending on the type of line used.

f. Improvised R-f Transmission Lines.

(*1*) Field wire of the types ordinarily used for telephone purposes may be used as twisted pair r-f transmission cable in emergencies. The transmission loss in these wires is high, even when dry, as indicated by the curves for various field wire types in figure 6-146. At receivers, such losses between antenna and set may be tolerated in cases where external noise, rather than set noise, controls the audio signal-to-noise ratio. At transmitters, however, the losses cause equivalent decreases in radiated power, and should be avoided except in emergencies or on circuits having plenty of transmission margin. When moist, the losses of these wires may be several db greater per 100 feet than shown for dry wire. The characteristic impedances of Wire W-110-B and Wire W-143 are about 150 and 70 ohms, respectively, in either the h-f or v-h-f bands. The impedances of most other field wires are probably within that range.

(*2*) These field wires may be used as spaced twin pairs to form a relatively low-loss, high-impedance open wire pair, such as the 2-inch spaced portion of the line illustrated in figures 6-66 and 6-67. Lines of this type will have characteristic impedances comparable with similarly spaced open wire lines of the same general dimensions (fig. 6-145), but the losses will ordinarily be greater. However, the losses should be materially lower than shown for field wire in figure 6-146, where the field wires are used as twisted pairs. Hence spaced twin pairs are advantageous when fairly long radio-frequency transmission lines must be constructed of field wire. Impedance relations must be such as to permit satisfactory transmitter loading.

g. Impedance Relations. When a radio set is connected to an antenna through a transmission line, the impedance looking into the line at the radio set terminals (here called the *load impedance* for brevity) will in general not be equal to the antenna impedance, but will be modified by propagation down the line. In the special case when the antenna impedance equals the characteristic impedance of the line, the load impedance will also be equal to the antenna impedance. With low-loss lines of any impedance, the following are good approximations for the impedance relationships. If the line is a half wave in length (or a whole multiple of a half wavelength), the load impedance will equal the antenna impedance. If the line is an odd multiple of a quarter wave in length, it will act as an impedance transformer, thus: let the antenna impedance be A and the characteristic impedance of the line be Z; then the load impedance equals Z^2/A. (In this expression, both the magnitude and the phase of Z and A must be considered. Z is nearly a pure resistance. Thus if A has negative reactance, Z^2/A will generally have positive reactance, and vice versa.) The length of a transmission line can sometimes be chosen so as to utilize these properties. For example, if a transmitter is designed to work directly into a given antenna, but if in a particular case the antenna must be located some distance from the transmitter, it may be practicable to arrange matters so that the length of the transmission line between transmitter and antenna is a half wave, or a multiple thereof, at the operating frequency. By this means the impedance facing the transmitter is made about the same as if the transmitter were directly connected to the antenna.

677. PHANTOM ANTENNAS.

a. General. Phantom antennas (dummy or artificial antennas) are used in place of the actual antennas for routine testing of radio transmitters under normal load conditions, or when retuning a transmitter to a new operating frequency. Their use is essential in combat areas in order to avoid putting r-f carrier on the air when not sending a message.

b. Standardized Phantom Antennas.

(*1*) Phantom antennas have been standardized for use with several radio sets, as follows:

(*a*) Antenna A–27 (Phantom); for use with Radio Set SCR–506. (TM 11–630).

(*b*) Antenna A–28 (Phantom); for use with Radio Set SCR–300. (TM 11–242).

(*c*) Antenna A–29 (Phantom); for use with Radio Set SCR–624.

(*d*) Antenna A–62 (Phantom); for use with Radio Sets SCR–508 and SCR–528. (TM 11–600).

(*e*) Antenna A–82 (Artificial); for use with Radio Set SCR–536. (TM 11–311).

(*f*) Antenna A–83 (Phantom); for use with Radio Sets SCR–608 and SCR–628 (TM 11–620).

(*2*) Two of the above phantom antennas are illustrated in figures 6-148 and 6-149. Antennas A–27, A–62, A–82, and A–83 are adjustable and can be made to quite accurately represent the actual impedance of the antenna as installed, so that little or no retuning is required when the transmitter is switched to the operating antenna. Antennas A–28 and A–29 contain fixed elements representing average antenna impedances, and some additional adjustments may be required when the transmitter is switched to the operating antenna.

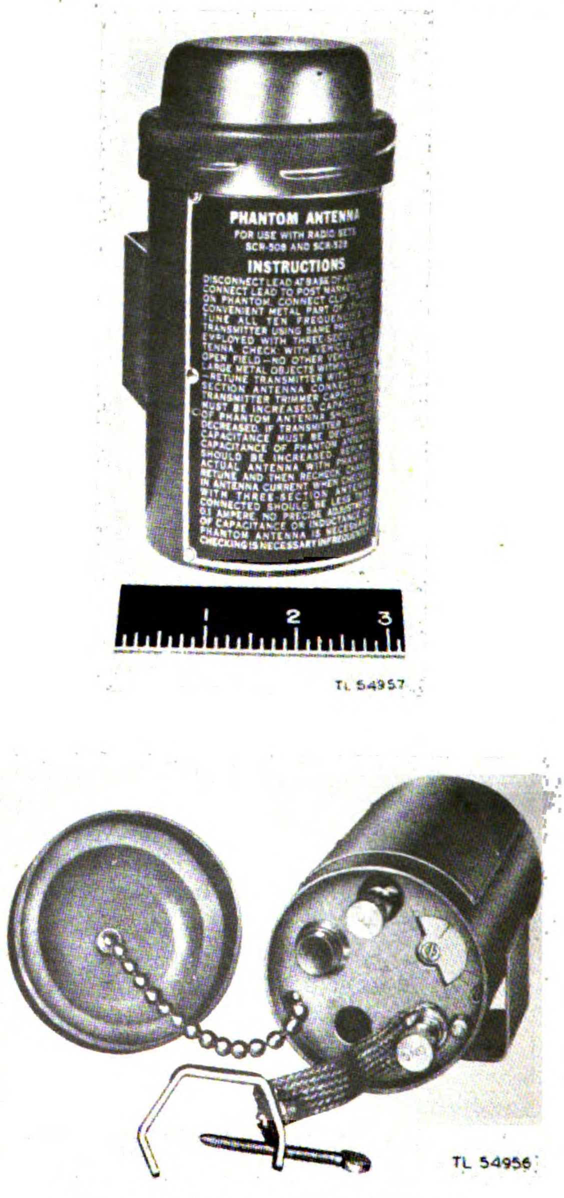


Figure 6-148. Antenna A–62 (Phantom).

The use of these phantom antennas is described in the technical manuals for the respective radio sets and in TM 11–314.

c. Improvised Phantom Antennas.

(*1*) Phantom antennas for the h-f band can be improvised by using electric light bulbs

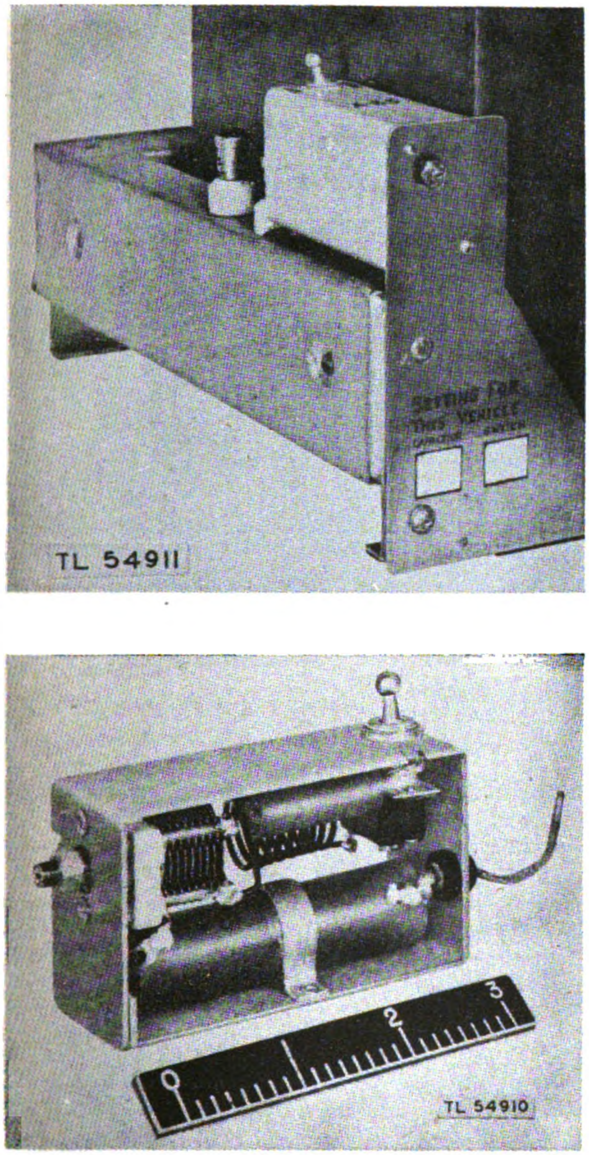


Figure 6-149. Antenna A–83 (Phantom).

of appropriate voltage ratings to produce various desired *resistance* loads. This type of dummy antenna is particularly useful as a substitute for a resonant antenna since such an antenna is resistive only. However, lamp loads can also be used to provide the resistance component of nonresonant antennas, on the assumption that the reactive component of the actual antenna can be tuned out.

(*2*) Connections to the lamps should be made by short heavy leads soldered to the base, in order to minimize reactance which, as the frequency is increased, may otherwise cause the total impedance to differ appreciably from the calculated hot d-c resistance value. If it is necessary to use more than one lamp to produce the desired load resistance, the lamps should be arranged symmetrically and the connecting wiring should be balanced, that is, the leads to each lamp should have the same length. In the v-h-f band, lamp loads may have appreciable reactance and consequently may not produce satisfactory loading of some transmitters.

(*3*) Antenna resistance varies considerably with the type, ranging from 5 ohms or less for the resistive component of short whips to at least 1,500 ohms for end-fed half-wave antennas. Figure 6-150 suggests lamp combinations for various resistance loads. In each case the lamps should light to about normal brilliance; otherwise the resistance values may depart appreciably from those shown in the figure. For example, when an 80-ohm load is desired for a 50-watt transmitter, figure 6-150 indicates that two Lamps LM–28 connected in series will be suitable. If a 600-ohm load is desired for a 25-watt transmitter the nearest available lamp load is obtained from one lamp having Stock No. 6Z6815–9.

(*4*) Carbon resistors of the ½-to 5-watt size may be used as phantom antennas in low power transmitters. If an r-f milliammeter is not available for current readings (power = I^2R), a pilot light of appropriate current rating, inserted in series with the resistor, may be used for making a rough estimate of current by observations of its brilliance as compared to normal.

Xmtr output (watts)	*Characteristics and resistance* [a] *of lamp combinations suitable for loading various transmitters*					
0.1	No. of lamps	1, LM-74	1, LM-71			
	Characteristics	1.3v, 0.1a	2.0v, 0.06a			
	Resistance	13 ohms	33 ohms			
	Stock No.	6Z6756	2Z5971			
0.5	No. of lamps	1, LM-50		2, par.		
	Characteristics	2v, 0.25a		6v, 0.04a		
	Resistance	8 ohms		75 ohms		
	Stock No.	2Z5950		2Z5877-11		
2	No. of lamps	2, ser.	1, LM-27	1, LM-53		
	Characteristics	3.2v, 0.35a	6-8v, 0.25a	12-16v, 0.2a		
	Resistance	18 ohms	25 ohms	70 ohms		
	Stock No.	2Z5882-1	2Z5927	2Z5953		
5	No. of lamps	1	1, LM-37	1	2, LM-49, ser.	1, LM-41
	Characteristics	6.3v, 0.8a	13v, 0.33a	18v, 0.25a	28v, 0.1a	110v, 6w
	Resistance	8 ohms	39 ohms	72 ohms	560 ohms	2020 ohms
	Stock No.	2Z5878-9	2Z5937	2Z5878-6	2Z5949	2Z5941
10	No. of lamps	2, ser.	2, LM-37, par.	2, LM-38, par.		2, LM-41, par.
	Characteristics	6.3v, 0.8a	13v, 0.33a	28v, 0.17a		110v, 6w
	Resistance	16 ohms	20 ohms	82 ohms		1010 ohms
	Stock No.	2Z5878-9	2Z5937	2Z5938		2Z5941
25	No. of lamps	1	1, LM-28		1	1
	Characteristics	12v, 25w	32v, 25w		115v, 25w	230v, 25w
	Resistance	6 ohms	40 ohms		528 ohms	2090 ohms
	Stock No.	6Z6812-6	6Z6832-1		6Z6815-9	6Z6830-25

[a] The resistance values indicated in the body of the table are those calculated for normal brilliance, with either a single lamp or combination of lamps. The abbreviations *ser.* and *par.* indicate that the lamps are in series or parallel, respectively.

Figure 6-150. Incandescent lamps suitable for dummy loads ***(continued on opposite page).***

Xmtr output (watts)	Characteristics and resistance* of lamp combinations suitable for loading various transmitters					
50	No. of lamps		2, LM-28, par.	2, LM-28, ser.	1	1
	Characteristics		32v, 25w	32v, 25w	115v, 50w	240v, 50w
	Resistance		20 ohms	80 ohms	264 ohms	1150 ohms
	Stock No.		6Z6832-1	6Z6832-1	6Z6815-2.1	6Z6840
100	No. of lamps	2, ser.		2, par.	1	2, ser.
	Characteristics	12v, 50w		115v, 100w	250v, 100w	240v, 50w
	Resistance	6 ohms		66 ohms	625 ohms	2300 ohms
	Stock No.	6Z6812-7		6Z6815-17	6Z6850-100	6Z6840
300	No. of lamps	6, ser.	3, par.	1	3, ser.	3, ser.
	Characteristics	12v, 50w	115v, 100w	115v, 250w	115v, 100w	250v, 100w
	Resistance	17 ohms	44 ohms	53 ohms	396 ohms	1875 ohms
	Stock No.	6Z6812-7	6Z6815-17	6Z6815-4	6Z6815-17	6Z6850-100

* The resistance values indicated in the body of the table are those calculated for normal brilliance, with either a single lamp or combination of lamps. The abbreviations *ser.* and *par.* indicate that the lamps are in series or parallel, respectively.

Figure 6-150. Incandescent lamps suitable for dummy loads (continued).

Section VI. MUTUAL INTERFERENCE BETWEEN RADIO SETS

678. GENERAL.

a. At key points in a military radio communications system numerous circuits terminate, necessitating the use of many transmitters and receivers in the same general locality. The selection of frequency assignments to avoid mutual interference between neighboring radio sets therefore becomes considerably more complicated than when only two or three units are involved. This is especially true when only a restricted number of frequencies are available in a given area, thus preventing free selection of frequencies.

b. The major type of interference which must be guarded against is interference in receivers from nearby transmitters. Interference in receivers caused by spurious radiations from other nearby receivers is usually not serious, but must sometimes be considered in situations where receiving antennas are closely grouped or when several receivers are connected to a common antenna. Proper tuning of transmitters and proper lining up of receivers, as described in the technical manuals for particular radio sets, will reduce the likelihood of mutual interference. The information in this section will aid in locating the sources of such mutual interference as may occur.

c. A description of the way in which transmitter-to-receiver interference arises is given first, and broad measures which may be taken to reduce it are suggested (par. 679). The factors responsible for interference, including spurious transmitter outputs, spurious receiver outputs, and spurious receiver responses are discussed next (pars. 680, 681, and 682). The location of spurious responses in simple superheterodyne receivers and in superheterodyne receivers having two mixers are then considered in some detail (pars. 683 and 684). A discussion of additional spurious receiver responses caused by the heterodyning of two interfering signals, and additional spurious transmitter outputs caused by cross-modulation between two transmitters concludes the section (pars. 685 and 686).

d. Present information on the magnitudes of some factors affecting the interference-producing properties of various radio sets is very limited. Therefore, while it is possible to estimate reasonably well the frequencies at which interference is likely, and to draw general conclusions as to the degree of interference, it is impractical to predict accurately the seriousness of interference at specific frequencies. Wherever possible, therefore, it is wise to rehearse communication set-ups, using proposed physical layouts and frequency assignments. By this procedure, necessary changes in the initial assignments can be made before the actual operation. Experience gained in this manner should be made available to others so that frequency assignment combinations which have been found to work satisfactorily can be among the first to be tried in similar situations elsewhere. An example of this procedure is TB SIG 78 and TM 11–2601 which recommend certain frequency combinations for use with Radio Terminal Set AN/TRC–3 and Radio Relay Set AN/TRC–4.

679. TRANSMITTER-TO-RECEIVER INTERFERENCE.

a. Transmitter-to-receiver interference is difficult to avoid in a congested area because the desired signals arriving at the receivers from distant transmitters are usually weak, and can be interfered with easily by the relatively strong signals radiated by nearby transmitters.

b. Each transmitter radiates small amounts of energy at many frequencies other than its carrier frequency; and each receiver is responsive, although very inefficiently, to signals of many frequencies other than the one to which it is tuned. In addition, signals from two transmitters of different frequencies may heterodyne in a receiver mixer tube to produce interference. These spurious radiations and responses greatly increase the number of frequencies at which interference can occur. For example, when transmitting and receiving antennas are close together, interference may result not only in receivers tuned to frequencies near the strong transmitter carrier, but also in receivers tuned to frequencies corresponding with weaker spurious transmitter radiations. In addition, interference may result when the strong transmitter carrier frequency corresponds with one of the many weak spurious responses of the receiver. It is also possible for interference to occur when a spurious transmitter radiation corresponds with one of the receiver spurious responses, but serious interference of this type is not normally experienced.

c. Many of the interferences which occur with antennas closely spaced disappear when the intensities of interfering signals are reduced by separating the transmitting and receiving antennas. Such separation pays larger dividends than might be expected, because at many of the spurious response frequencies the receiver sensitivity has been found to depend on the intensity of the interfering signal. For these cases, a decrease of 20 db in the field intensity, caused by antenna separation, simultaneously reduces the receiver sensitivity to spurious response by another 20 db or more, thus rapidly eliminating many interferences.

d. Because of the advantages brought about by antenna separation, it should be emphasized that *a headquarters location should be so chosen as to provide ample opportunity for separating transmitting and receiving antenna parks as much as is feasible.* Such separations have been found desirable even in commercial installations which operate on fixed frequencies. Antenna separations of as much as 5 miles are not uncommon in military use for h-f sets using powers of 400 watts and above, and a spacing of 1 or 2 miles should permit reasonable flexibility in frequency assignments.[15] For 50-watt sets in the v-h-f band, numerous workable assignments should be available with ½-mile antenna separation,[16] provided that the transmitters and receivers operate near opposite ends of their available frequency band, thus taking full advantage of antenna tuning and r-f tuning. In most cases, a frequency dif-

[15] Separation of transmitters and receivers generally requires the use of remote control equipment, such as is discussed in section VII of this chapter.

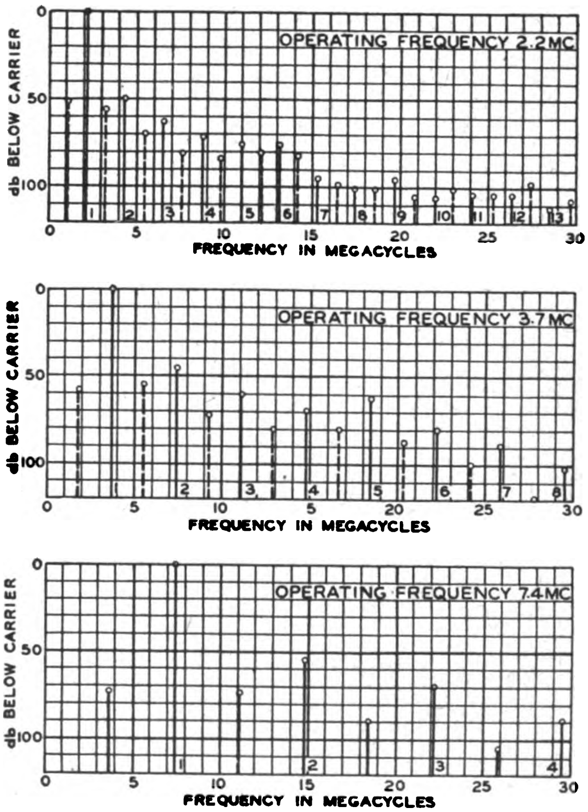
[16] As noted in paragraph 678, this applies when several transmitters are involved. With a single radio relay set, it is not difficult to find combinations of frequencies permitting close proximity of transmitting and receiving antennas.

ference greater than 10 percent should prove adequate. With greater antenna spacing, the number of workable channels increases. Mutual interference can exist between sets operating in widely separated frequency bands if they are physically near each other. For example, h-f transmitters emit spurious radiations at many times the operating frequency, and these radiations may cause interference in v-h-f receivers. Also, h-f receivers frequently have spurious responses in the v-h-f band, which may permit a nearby v-h-f transmitter to cause interference.

e. When space is not provided to establish the separations between transmitting and receiving antenna parks noted in subparagraph d above, types of interference normally neglected become important. With numerous transmitting and receiving antennas separated only a few hundred feet or located very close together on a building or tower, the number of interference possibilities increases to such an extent that a solution of the frequency assignment problem becomes very difficult, if not impracticable, with the information on sets which is generally available in the field. If such a difficult situation cannot possibly be avoided, it is essential to understand the set characteristics responsible for interference in order to select initial frequency assignments which will have some prospect of proving reasonably satisfactory when operations begin. Also, when interference does occur, a knowledge of the various possible interference factors will permit a more rapid determination of the type of interference involved, thus leading to a rational rather than a trial and error solution of frequency rearrangement. The remainder of this section therefore deals with spurious set characteristics, and indicates at what frequencies spurious radiations and responses are apt to occur, including illustrations based on measurements made on several sets.

680. SPURIOUS TRANSMITTER OUTPUTS.

a. Most of the power in the r-f output of a transmitter is at the operating carrier frequency and its relatively narrow sidebands. However, a small amount of power is always present at all of the harmonics of the master-oscillator frequency. In h-f transmitters, the operating frequency is the same as this oscillator frequency or double, triple, and in some cases, four times the oscillator frequency. In crystal controlled v-h-f equipment, the operating frequency is often many times (for example, 18, 24, or 96 times) the master-oscillator frequency, particularly in f-m transmitters where frequency modulation is derived from phase modulation. In the latter case the spurious components are spaced fairly closely and those falling near the transmission frequency tend to have the greatest magnitudes. For example, in a transmitter having a multiplication of 96, as in Radio Set AN/TRC-1, which uses frequency modulation, spurious outputs occur at intervals of $\frac{f_{opr}}{96}$ above and below the operating frequency, f_{opr}. Figures 6-151, 6-152, and 6-153 show magnitudes, as measured in a 70-ohm load, for Radio Transmitters BC-610, BC-191-E, and T-14/TRC-1.



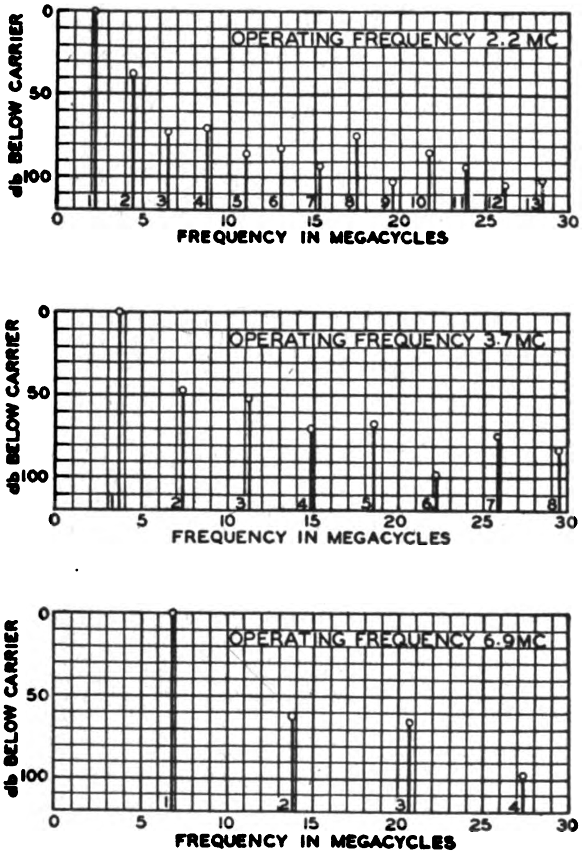
NOTES: THE NUMBER AT PLOTTED LINES EQUALS THE FREQUENCY DIVIDED BY THE OPERATING FREQUENCY.

THE OUTPUTS SHOWN DOTTED ARE NOT PRESENT WHEN A CRYSTAL IS USED.

TL 54982

Figure 6-151. Spurious outputs of Radio Transmitter BC-610 arranged to feed a 70-ohm load. (BC-610 is a component of Radio Sets SCR-299 and SCR-399.)

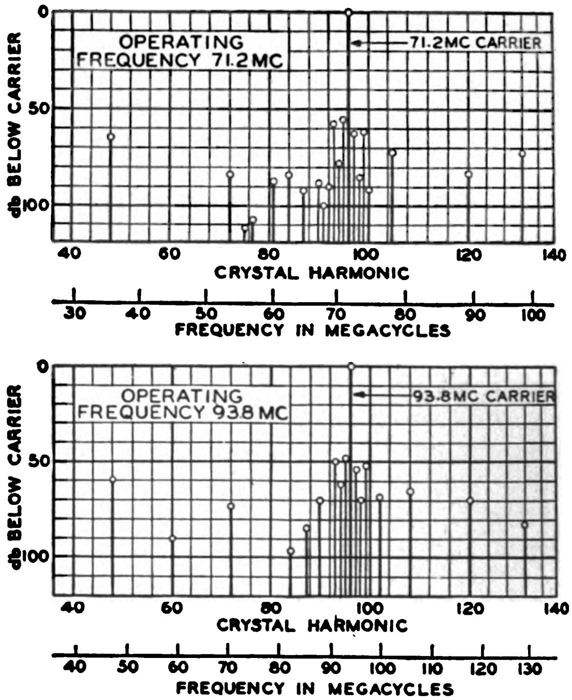
b. Since the frequencies of these spurious outputs are different for different operating frequencies, it is apparent that the number of receiving channels which may be interfered with increases rapidly with the number of transmitters in operation, because each transmitting frequency will be accompanied by a series of spurious outputs, displaced in frequency from any other series.



NOTE: THE NUMBER AT EACH PLOTTED LINE IS THE HARMONIC OF THE CARRIER.

TL 54878

Figure 6-152. Spurious outputs from Radio Transmitter BC–191–E measured in a 70–ohm resistive load. (BC–191–( ) is a component of Radio Sets SCR–177–B, SCR–188–A, SCR–193–( ), and AN/VRC–1.)



TL 54877

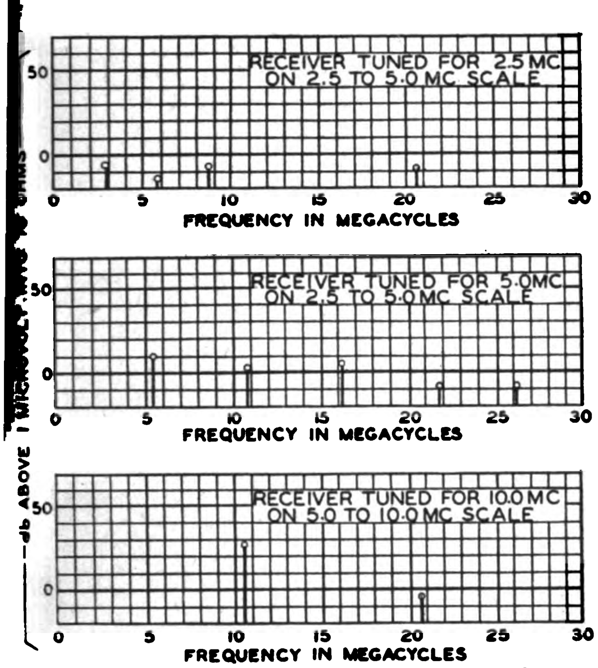
Figure 6-153. Spurious outputs of Radio Transmitter T–14/TRC–1 measured in a 70–ohm resistive load. (T–14/TRC–1 is a component of Radio Sets AN/TRC–1, –3, and –4.)

681. SPURIOUS RECEIVER OUTPUTS.

Almost without exception, military receivers are of the superheterodyne type. The fundamental or harmonics of the local oscillator in one receiver may reach a nearby receiver through various paths, the most important probably being by coupling between the antennas connected to the two receivers. Examples of the magnitudes and frequencies of these spurious receiver outputs in a 70-ohm dummy antenna for the Hammarlund superpro and the Hallicrafters SX–28 h-f receivers, and for Radio Receivers BC–312 and BC–342, are shown in figures 6-154, 6-155, and 6-156. Figure 6-157 shows spurious receiver outputs for a v-h-f receiver, Receiver R–19/TRC–1 of radio sets AN/TRC–1, –3, and –4. In a simple superheterodyne receiver the local oscillator frequency is related to the operating frequency by expressions given in paragraph 683b.

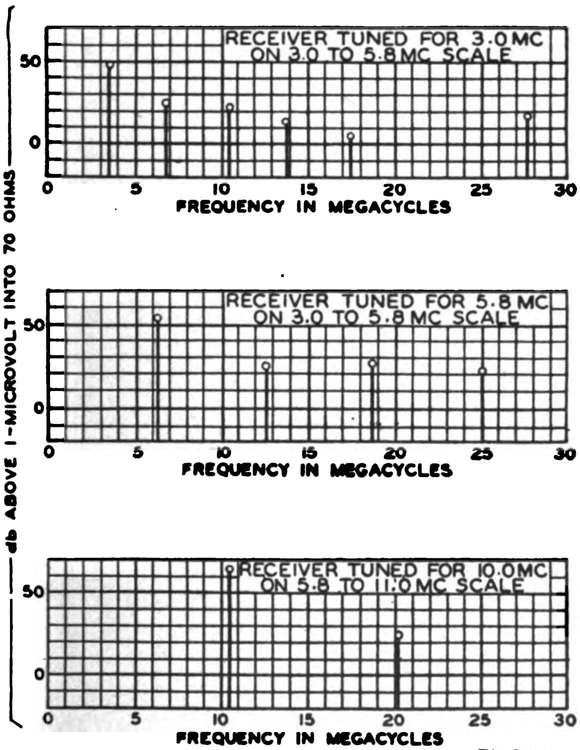
682. SPURIOUS RECEIVER RESPONSES.

a. A superheterodyne receiver which is tuned to receive an r-f signal of a certain frequency will respond at that frequency better than at any other. However, it will also respond inefficiently to signals at numerous other frequencies scattered over a wide band extending above and below the normal operating range of the set. The exact location of the spurious response frequencies is a function of receiver design, and the relative efficiency or sensitivity oi the receiver at these freqencies depends on



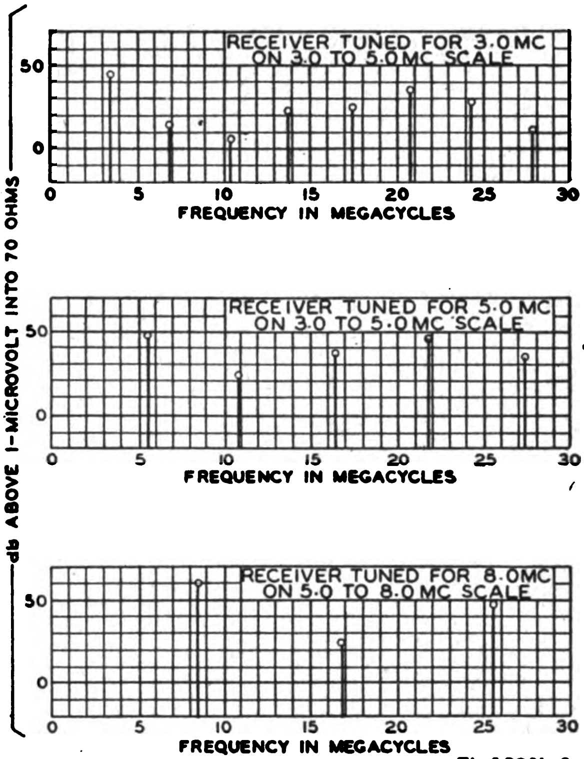
TL 54874

Figure 6-154. Spurious r-f outputs from a Hammarlund super-pro receiver (equivalent to BC-779) measured across 70-ohm resistance connected across the antenna terminals.



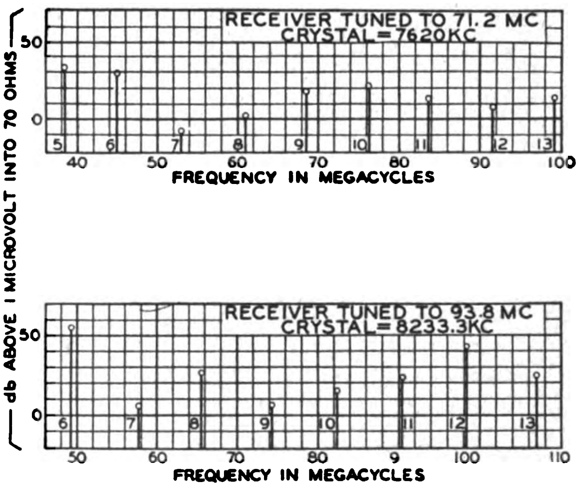
TL 54875

Figure 6-155. Spurious r-f outputs from a Hallicrafters SX-28 receiver measured across 70-ohm resistance connected across the antenna terminals.



TL 53201-S

Figure 6-156. Spurious r-f outputs from Radio Receivers BC-312 and BC-342 measured across 70-ohm resistance connected across the antenna terminals. (One or both of these receivers are components of Radio Sets SCR-177-B, SCR-188-A, SCR-193-( ), SCR-209, SCR-210, SCR-245, SCR-299, SCR-399, SCR-499, and AN/VRC-1.)



NOTE: NUMBER AT EACH PLOTTED LINE INDICATE THE CRYSTAL HARMONIC

TL 54876

Figure 6-157. Spurious r-f outputs from Receiver R-19/TRC-1 measured across 70-ohm resistance connected across the antenna terminals. (R-19/TRC-1 is a component of radio sets AN/TRC-1, -3, and -4.)

such factors as the antenna selectivity, the r-f selectivity, the degree of filtering in the heterodyning oscillator output circuit, and, in numerous cases, on the intensity of the interfering signal at the spurious response frequency.

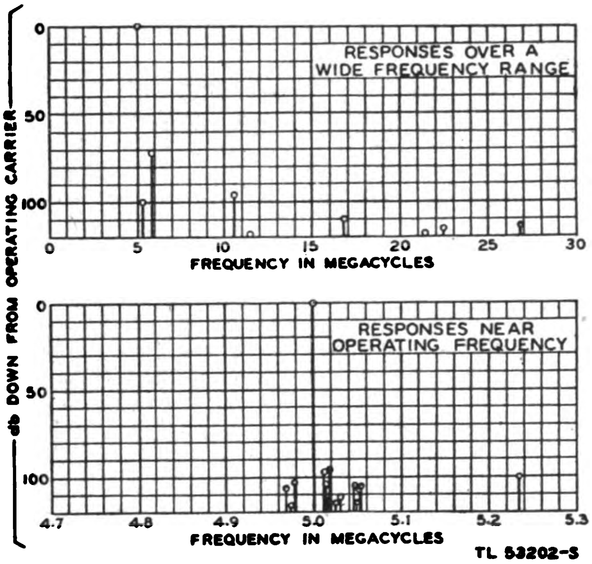


Figure 6-158. Responses of Radio Receivers BC–312 and BC–342, tuned to 5.0 mc on the 3.0- to 5.0-mc scale. (One or both of these receivers are components of Radio Sets SCR–177–B, SCR–188–A, SCR–193–( ), SCR–209, SCR–210, SCR–245, SCR–299, SCR–399, SCR–499, and AN/VRC–1.)

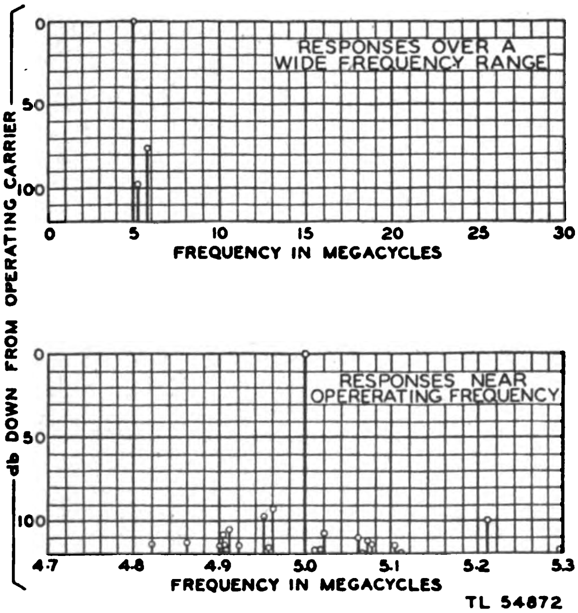


Figure 6-159. Response of a Hammarlund super-pro receiver, tuned to 5.0 mc on the 2.5- to 5.0-mc scale.

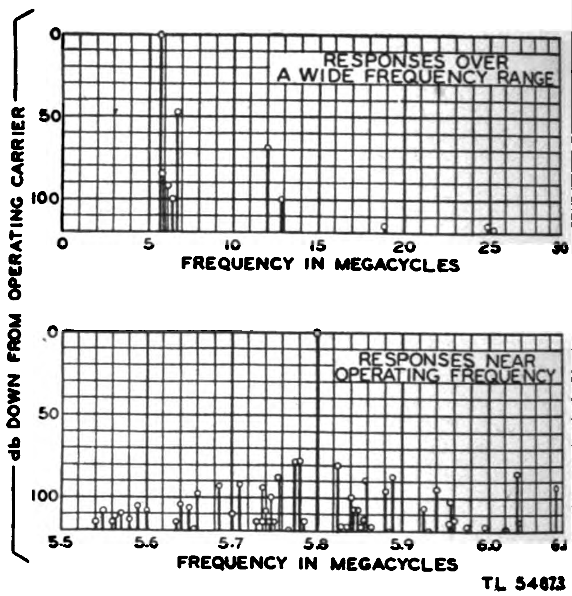


Figure 6-160. Responses of a Hallicrafters SX–28 receiver, tuned to 5.8 mc on the 3.0- to 5.8-mc scale.

b. When the receiver is properly lined up, the sensitivity of the receiver at spurious response frequencies is always much less than at the operating frequency, but it may easily be sufficient to permit interference from a local transmitter which radiates a relatively strong signal at a spurious response frequency. Figures 6-158, 6-159, 6-160, and 6-161 show typical response locations and corresponding receiver sensitivities for Radio Receivers BC–312 and BC–342, for a Hammarlund super-pro receiver, a Hallicrafters SX–28 receiver, and for Receiver R–19/TRC–1 of Radio Set AN/TRC–1, respectively.

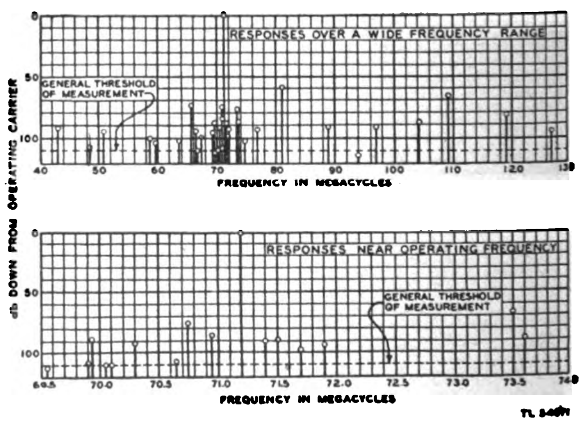


Figure 6-161. Responses of Receiver R–19/TRC–1 tuned for 71.2 mc (crystal frequency = 7.620 mc). (R–19/TRC–1 is a component of radio sets AN/TRC–1, -3, and -4.)

683. LOCATION OF SPURIOUS RESPONSE FREQUENCIES IN A SIMPLE SUPERHETERODYNE RECEIVER.

a. General. The following steps first review the normal operation of a simple superheterodyne receiver, and then indicate the various manners in which the set may respond to frequencies other than the desired signal frequency. Formulas and rules are given for locating the more important spurious response frequencies in each case. The same principles can be extended to apply to double conversion superheterodyne receivers, as outlined in paragraph 684.

b. Normal Response. For normal response, the incoming signal at the operating frequency, f_{opr}, is selected by antenna tuning, amplified in the tuned r-f stages and then combined with a heterodyning frequency f_{het} in the mixer stage. The value of f_{het} is adjusted so that the difference frequency (beat frequency) from the mixer tube is equal to f_{if}, the frequency to which the i-f (intermediate-frequency) amplifier stages are tuned. In some sets $f_{opr}-f_{het}=f_{if}$, and in others $f_{het}-f_{opr}=f_{if}$. After passing through the i-f amplifier, f_{if} is applied to the final detector of an a-m receiver or to the first limiter grid of an f-m receiver, as the case may be.

c. Spurious Responses, General. The receiver, although tuned to f_{opr}, will also respond to frequencies other than f_{opr} when, by some combination of circumstances, a frequency of f_{if} is produced in sufficient magnitude at the output of the mixer stage, or in the i-f stages. Any radio frequency at which such a *spurious* receiver response occurs is referred to in what follows by the symbol f_{resp}. The symbol f_{if} refers to any frequency falling in the i-f pass band. If such a spurious signal reaches the limiter grid in an f-m receiver or final detector in an a-m receiver with an amplitude comparable with the desired signal, serious interference to voice or teletypewriter transmission will generally result. However, in c-w reception by ear, substantially more interference can be tolerated by skilled operators.

d. I-f Response. Signals within the i-f pass band may be picked up directly in receivers having insufficient shielding or insufficient r-f selectivity. The latter is an important factor when the operating frequency is within 20 percent of the intermediate frequency, which is generally possible in sets designed for use in the l-f or m-f band. In such cases it is ordinarily specified that the receiver should be at least 80 db less sensitive to an interference at f_{if} applied to the receiver input terminals than to a signal at its operating frequency.

e. Image Response. The most commonly recognized spurious receiver response is at the so-called *image frequency.* It is caused by the fact that there are two values of incoming frequency which will beat with f_{het} to produce f_{if}; one of these frequencies is above f_{het} by f_{if} and the other is below f_{het} by f_{if}. For sets designed such that $f_{opr}-f_{het}=f_{if}$, the image response frequency is

$$f_{resp}=f_{opr}-2f_{if}$$

and for sets where $f_{het}-f_{opr}=f_{if}$,
it is

$$f_{resp}=f_{opr}+2f_{if}$$

As noted above, *the symbol* f_{resp} *is used here and throughout to designate any of the response frequencies, of which the image is but one example.* The antenna and r-f amplifier circuits are tuned to amplify f_{opr}. Such circuits are therefore detuned with respect to the image frequency, so that a signal at this frequency is considerably reduced in magnitude before reaching the mixer grid, thus reducing the receiver sensitivity at this image frequency. The amount of such reduction depends on set design.

f. Response at Submultiples of the Operating Frequency, f_{opr}. A series of spurious receiver responses can also occur at frequencies of $\frac{f_{opr}}{2}$, $\frac{f_{opr}}{3}$, $\frac{f_{opr}}{4}$, ... $\frac{f_{opr}}{n_{rf}}$, where $n_{rf}=1, 2, 3,$.........etc.

When such frequencies are applied to the r-f stages, the r-f amplifier output will include small amounts of energy at their harmonics, because of nonlinear characteristics in the r-f stages. One of these harmonics will equal f_{opr}, which will mix with f_{het} to produce f_{if} in the receiver output, and this signal will proceed through the i-f and other stages in the same manner as the desired signal. The frequencies, f_{resp} at which such spurious responses can occur are as follows:

$$f_{resp}=\frac{f_{opr}}{n_{rf}}$$

Ordinarily, when f_{rf} exceeds 5, the magnitude of the response at the corresponding value of f_{resp} is so weak that it can be neglected. This is because such frequencies are sufficiently removed from the operating frequency to be well attenuated by antenna and r-f tuning, and also because higher harmonics produced in the r-f stages by nonlinear action are weaker. Also, responses involving values of n_{rf} equal to 2 or more are of the type noted in paragraph 679c which are rapidly eliminated by increased separation between transmitting and receiving antennas.

g. Responses Due to Harmonics of the Heterodyning Frequency, f_{het}. Another receiver characteristic which is responsible for numerous responses at frequencies other than f_{opr} is that the heterodyning frequency is not usually a pure frequency, f_{het}, but includes harmonics of f_{het} such as $2f_{het}$, $3f_{het}$ .... n_{het}, f_{het} where $n_{het} = 1, 2, 3$, etc. Such harmonics will beat with certain incoming frequencies, f_{resp}, to produce f_{if} in the output of the mixer. This occurs when

$$n_{het}\, f_{het} - f_{resp} = f_{if}, \text{ or } f_{resp} - n_{het}\, f_{het} = f_{if},$$

that is, when

$$f_{resp} = n_{het}\, f_{het} \pm f_{if}$$

The sensitivity of the receiver at the spurious frequencies caused by harmonics of f_{het} is less than the sensitivity at the operating frequency because the voltage applied to the grid of the mixer at the desired heterodyning frequency, f_{het}, is large compared to that of its harmonics, $n_{het}f_{het}$. The magnitudes of these harmonics become progressively smaller for greater values of n_{het}. Values of n_{het} above about 4 therefore usually need not be considered.

h. Response Due to Harmonics of Base Frequency, f_{osc}. When the desired heterodyning frequency, f_{het}, is obtained by using a particular harmonic of a lower base frequency, f_{osc}, (for example, the frequency of the crystal oscillator), as is common in v-h-f sets, f_{het} may be defined as $N_{osc}f_{osc}$, where N_{osc} is the *particular* harmonic of f_{osc} chosen for amplification before application to the mixer grid. Other harmonics of f_{osc} also get through to the mixer grid in varying degrees. Any harmonic of f_{osc} is here designated n_{osc}, whereas the capital letter N_{osc} refers to the one used in the normal response. These harmonics will beat with certain incoming frequencies in the mixer to produce f_{if}. The frequencies at which such spurious responses can occur are as follows:

$$f_{resp} = n_{osc}\, f_{osc} \pm f_{if}$$

The more important values of f_{resp} are: those which result from values of n_{osc} corresponding to multiples N_{osc} up to about 4; and those values of f_{resp} which have a frequency between about one-half the operating frequency and twice the operating frequency, resulting from other values of n_{osc}.

i. Responses Due to R-f Harmonics in Combination with Harmonics of the Heterodyning Frequency or of the Base Frequency. As mentioned in subparagraph f above, harmonics of any incoming signal are produced in the r-f amplifier stages. These harmonics of an incoming signal, combined with values of $n_{het}f_{het}$ or $n_{osc}f_{osc}$, produce numerous responses, the most important of which are those for which f_{resp} is within ± 5 or ± 10 percent of f_{opr}. The frequencies at which these responses occur are

$$f_{resp} = \frac{n_{het}f_{het}}{n_{rf}} \pm \frac{f_{if}}{n_{rf}}$$

$$\text{or } f_{resp} = \frac{n_{osc}}{n_{rf}N_{osc}}\,(N_{osc}f_{osc}) \pm \frac{f_{if}}{n_{rf}}$$

These expressions are the same as those in subparagraphs g and h above except for the n_{rf} in the denominator. This type of action in the receiver is responsible for a large number of spurious responses which occur near the operating frequency, f_{opr} (figs. 6-158, 6-159, and 6-160). Such responses occur when $\frac{n_{het}}{n_{rf}}$ or $\frac{n_{osc}}{n_{rf}N_{osc}}$ takes on values equal to $\frac{2}{2}$ and $\frac{3}{3}$; also values near unity, such as $\frac{2}{3}, \frac{3}{4}, \frac{4}{5}$, up to, say $\frac{19}{20}$, where f_{het} is higher than f_{opr}, or values $\frac{3}{2}, \frac{4}{3}, \frac{5}{4}$, up to, say, $\frac{20}{19}$, where f_{het} is lower than f_{opr}. These responses are usually so dense within a range near f_{opr} and extending as much as ± 10 percent from f_{opr}, that it is very difficult to operate nearby transmitters in that range without causing interference. The likelihood of interference at these frequencies disappears very rapidly as the transmitting antennas are moved further away.

684. LOCATION OF RESPONSES IN A SUPERHETERODYNE RECEIVER HAVING TWO MIXERS.

a. The location of spurious response frequencies in a receiver which has two heterodyning stages (as in the v-h-f Radio Receiver R-19/TRC-1 of Radio Set AN/TRC-1) can be obtained by applying the methods given in paragraph 683 in two steps.

b. In step 1, the portion of the receiver following the input to the first i-f amplifier is assumed to contribute no spurious responses, and computations of response frequencies for the first half of the set are made as in paragraph 683. The intermediate frequency used for this computation is the actual first or *high* intermediate frequency, and its heterodyning frequency is the first heterodyning frequency, f_{het1} (or, if derived from a base frequency, $n_{osc1} f_{osc1}$).

c. In step 2, the chief additional responses resulting from the second half of the set can be computed using the first form of the equation of paragraph 683i and including the case where $n_{rf}=1$. The intermediate frequency used for this computation is the second or *low* intermediate frequency of the receiver. The heterodyning frequency to use is $f_{het1}+f_{het2}$ for receivers where f_{het1} is less than the operating frequency, f_{opr}, and is $f_{het1}-f_{het2}$ in the case where f_{het1} is greater than f_{opr}; where f_{het1} and f_{het2} are the first and second heterodyning frequencies in the actual receiver. These responses, together with those computed in step 1, give an essentially complete picture of the more important spurious responses of the actual receiver.

d. While the process of producing spurious responses in a receiver with two heterodyning stages is more complicated than in the simple superheterodyne, experience has indicated that the number of *important* responses may be no greater. As in the simple superheterodyne, it is impractical to determine accurately the relative importance of specific spurious response frequencies without complete knowledge of the circuit characteristics of the particular receiver involved.

685. SPURIOUS RECEIVER RESPONSES DUE TO HETERODYNING OF TWO R-F FREQUENCIES.

a. When signals of different frequencies arrive at a receiver input from two local transmitters, one of the frequencies will act as a heterodyning frequency for the other in the mixer stage. If the two frequencies, or their harmonics produced in the r-f stages and in the mixer, differ by f_{if}, interference will be possible. As a further example, interference may also arise if the sum or difference of two r-f frequencies, or of a combination of their harmonics, corresponds with the operating frequency or an important spurious response frequency. Nonlinearity of the first r-f tube is usually the cause of this latter type of effect.

b. These effects can be serious especially when one or both of the two interfering frequencies are near the operating frequency, f_{opr}. For frequencies substantially different from f_{opr}, the attenuation due to r-f selectivity will reduce the magnitudes arriving at the mixer grid or at the first amplifier grid. This considerably reduces the interfering effect, since the magnitude of the interfering signal at frequency f_{if} at the mixer output has been found proportional to the product of the r-f input values, so that a reduction of 10 db in magnitude at both frequencies, for example, reduces the interference by 20 db. Separation of transmitting and receiving antennas or taking advantage of minima in directional patterns, is therefore an effective way of reducing this type of interference.

686. SPURIOUS TRANSMITTER OUTPUT CAUSED BY CROSS-MODULATION BETWEEN TWO TRANSMITTERS.

a. When the antennas (or r-f feed lines) of two transmitters are located near each other, an appreciable r-f voltage from one transmitter may be impressed across the output tank circuit of the other. Because of nonlinear phenomena in the final amplifier circuit, this induced r-f voltage causes the generation and radiation of spurious signals at other than the operating frequency at either transmitter. For example, if one transmitter operating at 100 mc has impressed across its output tank circuit a voltage at 90 mc from a nearby transmitter, a signal at 110 mc will be formed in the output circuit of the first transmitter which will be radiated after being attenuated by the tank, antenna coupling, and antenna tuning. Other spurious signals will be generated similarly at 80, 120, 70, 130 mc etc., in the order of their strengths, but these will be of importance only in extreme cases. A difference frequency of $100-90=10$ mc will also be generated. In this example, interference with a nearby h-f receiver operating at 10 mc may be caused, as well as interference with v-h-f receivers at several frequencies.

b. Interference of this type should not prove serious if receiving antennas are well separated from transmitting antennas. In the event they are not, the interference may be reduced by: increasing separation between transmitting antennas; reorienting the antennas of transmitters which are reacting upon each other so as to take advantage of minima in the directional patterns; and avoiding or removing any condition where two adjacent transmitting antennas are tuned for the same or nearly the same operating frequency.

Section VII. REMOTE CONTROL OF TACTICAL RADIO SETS

687. GENERAL DESCRIPTION OF REMOTE CONTROL EQUIPMENTS.

a. Introduction.

(*1*) Remote control equipments are devices for providing means whereby a radio set can be used for voice transmission or for c-w telegraph by an operator located at a point remote from the set. The principal purposes of such equipments are to provide push-to-talk control of a radio set over wire lines connected between the set and the remote operator, and to provide means for satisfactory voice transmission over these wire lines, particularly from the remote point to the radio transmitter. The push-to-talk control feature inherently provides the necessary c-w control of the transmitter for hand telegraph speeds.

(*2*) The components of some of these equipments include one unit which is located at the radio set and another unit which is located at the remote point. Some equipments contain arrangements for ringing and for intercommunicating over the wire lines between the remote operator and personnel at the radio set. The lengths of the connecting wire lines over which remote control and voice transmission are satisfactory vary from 1 to 10 miles, depending on the types of control units, wire, and radio sets.

(*3*) This section outlines the advantages of remote control equipments, discusses the principal operating features, and indicates the factors which limit the distances over which remote control and satisfactory voice transmission are feasible (pars. 687 to 690 inclusive). Remote control equipments are included as components of some radio sets. Others may be procured as separate units and can be used with a number of different radio sets. Some of the more common remote control equipments are described briefly in paragraph 691. Arrangements for improvising remote controls are discussed in paragraph 692.

b. Operating Advantages. The principal advantages which can be realized from the use of remote control equipments are:

(*1*) In combat areas, a radio operator can be in a foxhole, dugout, or other location sheltered from enemy action, while his radio set and antenna are at a more exposed site suitable for satisfactory radio transmission.

(*2*) A speaker can be at a telephone in quarters while talking on a radio net over a field wire extension from the radio station.

(*3*) The locating of radio sets by an enemy radio direction finder or by aerial observation does not disclose the location of the headquarters.

(*4*) Time consumed by messengers traveling between headquarters and radio sets at widely dispersed points can be eliminated by locating the operators in a radio control central adjacent to the headquarters, thus expediting the handling of messages.

(*5*) Radio transmitters can be separated from radio receivers by distances of ½ mile or more to reduce mutual interference (sec. VI).

(*6*) In hilly country, radio sets can be located at high points from which the best radio transmission is obtained, particularly with radio sets operating in the v-h-f band, while the radio operators are at more convenient and sheltered points.

(*7*) A group of radio operators can be located together in a remote control central adjacent to a message center, thus minimizing personnel requirements and improving efficiency by adequate supervision.

(*8*) Air warning operation centers can be established reasonably remote from associated radio sets, with numerous radio channels to observers, airplanes, and other points involved in the control of operations.

c. Technical Functions.

(*1*) Push-to-talk control is the chief technical function of most remote control equipment. This consists principally of causing the radio transmitter to radiate only while the push-to-talk switch is pressed; but under many conditions it includes simultaneous disabling of the associated receiver. When the push-to-talk switch is released, the control equipment will cause the radio set to revert to receiving. Another push-to-talk function of some remote control equipments is to connect a 2-wire line from a remote telephone to the radio transmitter while the push-to-talk switch is pressed, and to transfer this line back to the receiver when this switch is released.

(2) Various other operating features in addition to those associated with the push-to-talk switch are provided in some types of remote control equipment, among which are the following:

(a) C-w telegraph, by means of a key at a remote point.

(b) Intercommunication and ringing between a radio operator at a remote point and an attendant at the radio set.

(c) Audio amplification to provide adequate modulation of radio transmitters over long lengths of wire.

(d) On-off control of the radio set power supply.

(e) Remote selection of any one of several predetemined radio carrier frequencies.

688. RADIO SYSTEMS WITH REMOTE CONTROL EQUIPMENT.

a. The most common radio systems in which remote control equipments offer advantages are single-frequency radio nets which operate on a push-to-talk basis. Each of these nets contains at least two radio sets but may contain as many as a dozen or more. The principal reasons for push-to-talk control in such a net are:

(1) To reduce power consumption in the radio transmitters during idle periods, particularly with battery-operated sets.

(2) To permit the use of only one frequency per net and thus minimize the number of different radio frequencies required, particularly in areas with large numbers of different nets.

(3) To enable communication from the transmitter of any set in a net, to the receiver of every other set in the same net.

(4) To reduce the probability of detection by the enemy by radiating only during the transmission of a message.

b. Radio nets for observers associated with air warning operations centers are sometimes arranged with an individual frequency for the radio transmitter of each observer while a separate common frequency is used for transmitting from the operations center to the receivers of all observers. This enables an officer in the operations center to broadcast to all observers and yet permits each observer to report individually. It also enables an observer to receive a radio message even while his push-to-talk switch is pressed for transmitting.

c. The push-to-talk feature of remote control equipment is not applicable to multichannel radio systems in which the transmitters radiate continuously.

689. PUSH-TO-TALK OPERATIONS.

a. Local Control with Remote Talking. Some remote control equipments such as RM–29–( ) require an attendant at the radio set to control its push-to-talk operation. The talker at the remote point announces a word such as *transmit* at the beginning of each message and the word *over* at the end of each message. The local attendant at the radio set listens for these words and operates the push-to-talk switch accordingly. Remote control equipments are described in paragraph 691.

b. Remote Control.

(1) With remote control equipment such as RC–261 the radio set is controlled by the pressing of the push-to-talk switch at the remote point. This control is accomplished by the operation of an electromagnetic relay in the control unit at the radio set, which in turn controls the radio set.

(2) Some radio sets can be controlled without remote control equipment over only a few feet such as the length of the cord between the radio set and the local microphone. However, the over-all distance for push-to-talk control of such a set may be increased up to several miles by providing a control unit at the radio set. This increase is made possible by making the relay in the control unit more sensitive than the relay in the radio set. The sensitive relay operates over the longer distance, and it controls the less sensitive relay through a local circuit over the cord to the microphone jack.

(3) The range of remote control, that is, the distance permissible between the push-to-talk switch and the control unit at the radio set, may be at least one mile with most remote control equipments and Wire W–110–B. One of the equipments provides ranges up to 10 miles under favorable conditions. The ranges obtainable with various types of equipment are listed in figure 6-162. These ranges are determined principally by the following factors:

(a) The current required to operate the relay in the control unit.

(b) The resistance of the wire between this relay and the push-to-talk switch, the resistance of the relay itself, and any other resistance in the relay operating circuit.

(*c*) The d-c voltage operating in the relay circuit.

(*d*) The voice transmission features discussed in paragraph 690.

(*4*) The equipment provided at a remote point to permit remote control may be a Telephone EE–8–( ) and a telegraph key, a remote control unit with a microphone and headset, or the type of local battery telephone used in Operations Center AN/TTQ–1. With a Telephone EE–8–( ) and telegraph key, the operator has to press the telegraph key to control the radio set while talking, in addition to pressing the switch in the handset for battery supply to its microphone. With other types of equipment, such as RC–261 the push-to-talk switch of the remote microphone controls the radio set.

(*5*) The current for push-to-talk control is supplied from dry batteries in some remote control equipment such as RC–261 and RC–289. Dry batteries are also used for microphone battery supply with these equipments. With Remote Control Equipment AN/TRA–2, the push-to-talk control current is supplied from a rectifier associated with the 60-cycle power supply at the radio transmitter. The same current serves as battery supply to the microphone of the remote handset.

690. VOICE TRANSMISSION OVER WIRE LINES BETWEEN REMOTE POINTS AND RADIO SETS.

a. The length of wire line which may be used between the remote point and the radio set may be limited by transmission and noise rather than by the capabilities of the d-c push-to-talk control. Among the transmission factors to be considered are the following:

(*1*) The audio volume output from the remote control unit or telephone at the remote point.

(*2*) The audio volume required for proper modulation of the radio transmitter.

(*3*) The transmission losses in the wire line and in the control equipment.

(*4*) Reflection losses caused by connecting a line having one impedance to an equipment having a different impedance.

(*5*) Impedance unbalances to ground from opposite wires of the line pair, resulting in crosstalk and noise.

(*6*) Control of the volume output from the radio receiver to provide adequate volume at the remote point without producing crosstalk into adjacent circuits.

b. The most difficult problems are those related to providing adequate input to the radio transmitter from a talker at the remote point. Ordinarily, there will be no particular problem associated with the listening condition, because most radio receivers have capacity for a volume output which is more than adequate for any length of wire permitted by the remote talking conditions. For the listening condition, it will generally be necessary only to set the audio volume control on the radio receiver so that a comfortable volume is heard in the remote telephone receiver when it is on the listener's ear. If the volume is set higher than this, objectionable crosstalk is apt to be produced in adjacent circuits. Some remote control equipments use automatic volume limiters which prevent this.

c. The volume output from a telephone depends principally on the microphone and its battery supply current (ch. 2). For example, an increase in the battery supply current from 0.030 ampere to 0.100 ampere will increase the volume output about 5 db. For the efficient transmission of speech from a microphone over a telephone line, an induction coil is generally associated with the microphone, as in the Telephone EE–8–( ). This reduces reflection losses which otherwise would exist because the impedance of the microphone is lower than that of the line to which it is connected. The induction coil in Telephone EE–8–( ) also reduces sidetone (ch. 12).

d. The volume output from a Telephone EE–8–( ) produced by a person talking with average loudness, and with the batteries in good condition, is probably about −5 vu. Although this volume may vary widely in individual cases, the large majority of talkers will probably produce something in the range from −13 vu to +3 vu. The volume required for proper modulation of a radio transmitter depends on the particular transmitter. In general, a transmission loss of about 5 db can be tolerated between a Telephone EE–8–( ) and a radio transmitter. This permits at least one mile of Wire W–110–B between the telephone and the radio set, assuming about 2-db loss in the control unit at the radio set. Some radio transmitters are equipped with audio preamplifiers which permit relatively low input volumes and therefore greater transmission losses between the talker and the radio set.

e. When figuring transmission losses, it is important to consider the impedances of the audio circuits to which the lines and equipments are connected. For example, if a Telephone EE–8–( ) having an impedance of about 600 ohms is connected directly to the microphone jack of a radio transmitter having an input impedance of about 50 ohms, a reflection loss amounting to about 6 db will result because of the mismatch in impedances (ch. 12). However, a Remote Control Unit such as RM–29–( ), RM–39–( ), or RM–53, includes a transformer which matches these impedances and nearly eliminates the reflection loss although it produces an insertion loss of about 2 db (ch. 12).

f. The over-all losses (line loss plus reflection losses, but excluding battery supply loss) produced by various lengths of Wire W–110–B connected between a microphone and a radio transmitter are indicated in the following table:

Length of line with Wire W-110-B between microphone and radio transmitter	*Typical over-all transmission losses between 40-ohm microphone and radio transmitter (db)*		
	40-ohm radio transmitter input impedance	*100-ohm radio transmitter input impedance*	*Impedance matching transformers at both ends of the line*
1,000 feet	3.0	2.0	2.0
2,500 feet	5.0	3.5	3.0
1 mile	7.0	5.5	4.0
2 miles	14.0	11.0	6.5

The data in the above table may be helpful when considering the improvised remote control arrangements discussed in paragraph 692.

g. For more than a mile or two of Wire W–110–B between a remote point and a radio transmitter, the volume at the radio transmitter can be increased to compensate for the transmission losses in the field wire by providing an audio amplifier at the remote point, such as that in remote Control Unit RM–13–( ) or in the Operations Center AN/TTQ–1. Losses in field wire can also be compensated for by an audio preamplifier at the radio set such as that used in Radio Set SCR–399–A. However, the usefulness of such a preamplifier will be controlled by the noise in the field wire because this preamplifier will amplify the noise as well as the speech.

h. Unbalanced circuits which produce susceptibility to crosstalk and noise are commonly encountered; for example, such unbalanced circuits occur on connections to the sleeves of microphone jacks and headphone jacks which are connected to metal frames which in turn are grounded. Such unbalances can be overcome by connecting a repeating coil or transformer between the line and the radio set, such as in Remote Control Units RM–29–( ), RM–39–( ), and RM–53. If such a coil or transformer should be applied without a remote control unit, the continuity of the push-to-talk control circuit should be suitably maintained. Crosstalk to other lines resulting from unbalanced line wires can sometimes be reduced to practical limits by separating the unbalanced wires about 6 inches from wires used on circuits which are balanced, or by considerably more separation from the wires of other unbalanced circuits. It is important to separate such unbalanced circuits from teletypewriters and from d-c telegraph circuits operating on a ground return basis, because the telegraph signals might be radiated from the transmitter as a result of being impressed on the wire line via the crosstalk path. This possibility of undesired radiations is greatest with radio sets having audio preamplifiers adjusted for low input volumes.

691. TYPICAL REMOTE CONTROL EQUIPMENTS

a. General.

(*1*) The remote control equipments commonly used with radio sets for ground use are summarized in figure 6-162. This summary does not include the various types of equipments used in v-h-f air-ground fighter control systems.

(*2*) Although TM 11–487 describes in some detail the remote control equipment summarized in figure 6-162, certain of the more commonly used remote control equipments are briefly described in the subparagraphs below. Paragraph 692 briefly describes some improvised remote control arrangements. Where more detailed information is required on any particular remote control equipment, reference should be made to the technical manual associated with that equipment.

Type[a]	Control equipment		Associated radio sets	Field wire between radio transmitter and remote location		Remarks
	At radio transmitter	At remote location		Number of pairs	Maximum length of each pair (miles of Wire W110-B)[b]	
AN/TRA-2	C-113/TRA-2	C-112/TRA-2	AN/TRC-1 or AN/TRC-8	1 or 2	2	Two pairs of wire are provided if receiver is remote from transmitter at radio terminal or if simultaneous 2-way voice service is provided with two different radio frequencies.
	C-113/TRA-2	AN/TTQ-1[c]	AN/TRC-1 or AN/TRC-8	1 or 2	7½	
RC-47-( )[d]	RM-12-( )	RM-13-( )	SCR-177-A, SCR-177-B, SCR-188, SCR-188-A, or SCR-193	2	6 (wet) 10 (dry)	
RC-261	RM-53	RM-52	SCR-300, SCR-509, SCR-510, SCR-608, SCR-609, SCR-610, SCR-619, SCR-628, or AN/TRC-7	1	2	
RC-289	RM-39-( )	Telephone EE-8-( ) and Key J-47	SCR-178, SCR-284, SCR-299-D, SCR-399-A, SCR-499-A, SCR-608, SCR-609, SCR-610, SCR-628, or SCR-694	1	5	
RC-290	RM-29-( )	Telephone EE-8-( )	SCR-178, SCR-284, SCR-608, SCR-609, SCR-610, or SCR-628	1	2	
None[e]	None	Push-to-talk handset[f]	RC-256 or RC-257	2	2	

[a] All have push-to-talk control from the remote point except RC-290 which must be controlled at the transmitter and Radio Sets SCR-299-D, SCR-399-A, and SCR-499-A (last item in figure) which are controlled at the transmitter except where RM-39-( ) units are provided.

[b] Greater lengths permissible with other wire having lower resistance and lower transmission losses.

[c] Not a component of this remote control equipment.

[d] Part of Radio Set SCR-188-A.

[e] No separate control unit, part of radio set and cannot be procured separately.

[f] Not a component of the radio sets.

Figure 6-162. Remote control equipments for tactical radio sets *(continued on opposite page).*

Type[a]	Control equipment		Associated radio sets	Field wire between radio transmitter and remote location		Remarks
	At radio transmitter	At remote location		Number of pairs	Maximum length of each pair (miles of Wire W110-B)[b]	
RM-7-( )[g]	RM-7-( )	RM-7-( )	SCR-197	2	7½	Two RM-7-( ) units are provided with radio set. One of these is with transmitter equipment and the other with receiver equipment.
RM-14	RM-14	Telephone EE-8-( ),[c] Switch SW-158-A, and Ground Rod GP-30	SCR-194 or SCR-195	1	2	
RM-21[g]		RM-21	SCR-543	7 conductors	18 feet	7-conductor cord, 18 feet long provided with remote control equipment.
None[e]	None	Unit similar to C-112/TRA-2	AN/CRC-3 or AN/CRC-3A	1	1	
None[e]	None	AN/TTQ-1[f]	AN/CRC-3 or AN/CRC-3A	1 or 2	1	Two pairs of wire are provided if receiver is remote from transmitter at radio terminal or if simultaneous 2-way voice service is provided with two different radio frequencies.
None[e]	None	Telephone EE-8-( ),[c] Junction Box JB-60,[c] and Key J-47[c]	SCR-299-D, SCR-399-A, or SCR-499-A	1	1	

[a] All have push-to-talk control from the remote point except RC-290 which must be controlled at the transmitter and Radio Sets SCR-299-D, SCR-399-A, and SCR-499-A (last item in figure) which are controlled at the transmitter except where RM-39-( ) units are provided.

[b] Greater lengths permissible with other wire having lower resistance and lower transmission losses.

[c] Not a component of this remote control equipment.

[d] Part of Radio Set SCR-188-A.

[e] No separate control unit, part of radio set and cannot be procured separately.

[f] Not a component of the radio sets.

[g] Part of radio set.

Figure 6-162. Remote control equipments for tactical radio sets (continued).

b. Remote Control Equipment AN/TRA–2. This equipment (TM 11–2621) is shown in figure 6-163 with connections to Radio Set AN/TRC–1. All power for this equipment is derived from the 60-cycle source at the radio set. The remote control unit can be connected to a loud speaker and to as many as three head and chest sets.

c. Remote Control Equipment RC–47–( ). This equipment (TM 11–312) is shown in figure 6-164. The principal components of this equipment are Control Unit RM–12–( ) which is located at the radio transmitter, and Control Unit RM–13–( ) which is located at the radio receiver, remote from the transmitter. Power for this equipment is derived from

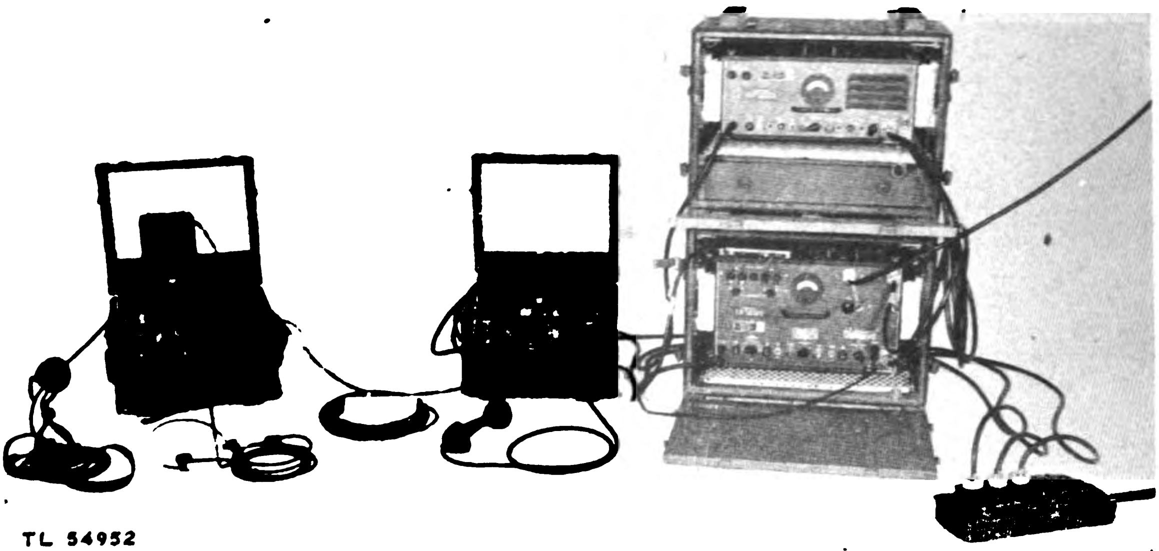


Figure 6-163. Remote Control Equipment AN/TRA-2 with Radio Set AN/TRC-1.

the 60-cycle source at the receiver. Two pairs of wire are provided between the two units. Under favorable conditions, the distance between units could be as great as 10 miles of Wire W–110–B. One pair is used for the voice circuit to the transmitter and the other for intercommunicating. The push-to-talk control or c-w telegraph operation is by means of direct current on the phantom circuit derived from these two pairs of wires. An audio amplifier is included in Control Unit RM–13–( ). This unit includes facilities to control the disabling of the receiver when the push-to-talk switch is pressed or the c-w telegraph key is operated.

d. Remote Control Equipment RC–261. This equipment (TM 11–2632) is shown in figure 6-165 with connections to Radio Set SCR–619.

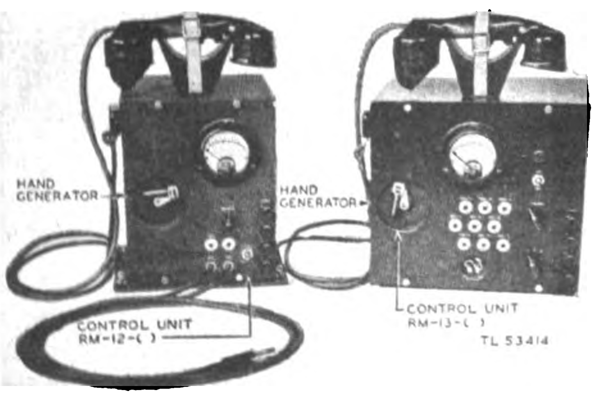


Figure 6-164. Remote Control Equipment RC–47–( ).

It can be used with various other radio sets listed in figure 6-162. The principal components of this equipment are Control Unit RM–53

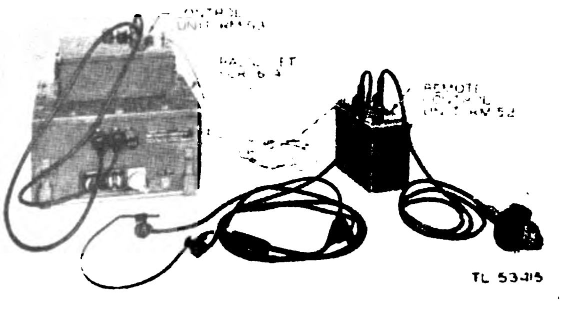


Figure 6-165. Remote Control Equipment RC–261.

which is located at the transmitter and Remote Control Unit RM–52 which is located at a remote point. These units are interconnected by a single pair of field wire which can have a length up to about 2 miles if Wire W–110–B is used. Dry batteries are employed for microphone battery supply and push-to-talk control.

e. Remote Control Unit RM–39–( ). This equipment (TM 11–2667) which is part of Remote Control Equipment RC–289 is shown in figure 6-166. It provides push-to-talk control or c-w telegraph operation over a 2-wire line from a remote telephone to a radio set in combination with intercommunicating and ringing features like those of Remote Control Unit RM–29–( ) (subpar. f below). Dry bat-

Figure 6-166. Remote Control Unit RM–39–( ), part of Remote Control Equipment RC–289.

teries are used for the operation of this equipment. The remote telephone is equipped with a telegraph key which is used for push-to-talk control or c-w telegraph operation (par. 689b(4)).

f. Remote Control Unit RM–29–( ). This equipment (TM 11–308) which is part of Remote Control Equipment RC–290 is shown in figure 6-167. This unit is located at the radio set and a Telephone EE–8–( ) is located at a remote point. Only local push-to-talk control at the radio set is possible with this unit (par. 689a). It includes facilities for intercommunicating and ringing over a 2-wire line between the telephone at the remote point and an attendant at the control unit.

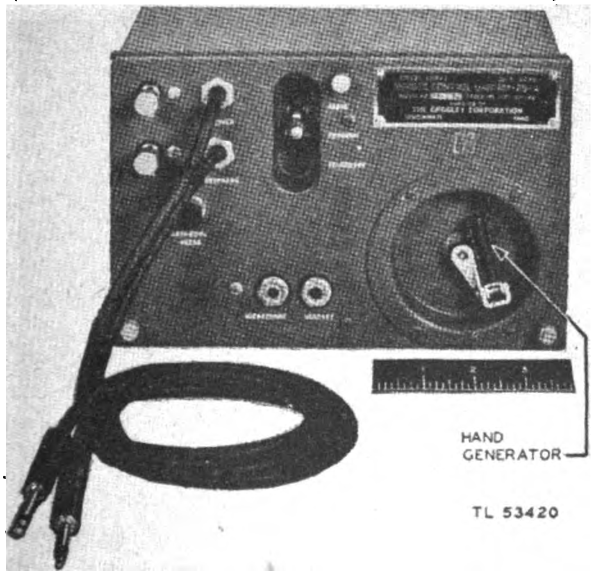


Figure 6-167. Remote Control Unit RM–29–A, part of Remote Control Equipment RC–290.

g. Operations Center AN/TTQ–1. The uses of the radio channel control circuits of the Operations Center AN/TTQ–1 on connections to a variety of different types or radio sets are described in a Supplement to TM 11–438 dated 3 October 1944.

692. IMPROVISED REMOTE CONTROL ARRANGEMENTS.

a. Improvised remote control arrangements can sometimes be assembled for use where regular remote control equipment is not available. Some radio sets can be remotely controlled merely by extending the circuits from the microphone and head phone jacks over field wires to handset or head and chest set at the remote point. For such an extension, special adapters assembled from spare cords, plugs, jacks, binding posts, etc., may be desirable as shown in figure 6-168-A. The operations over such simple remote control facilities will not be satisfactory unless the push-to-talk control range of the radio set (par. 689b(3)) will accommodate the resistance in the field wire, and the audio transmission conditions discussed in paragraph 690 are satisfactory. The transmission loss with these facilities is derived from the sum of the three following losses:

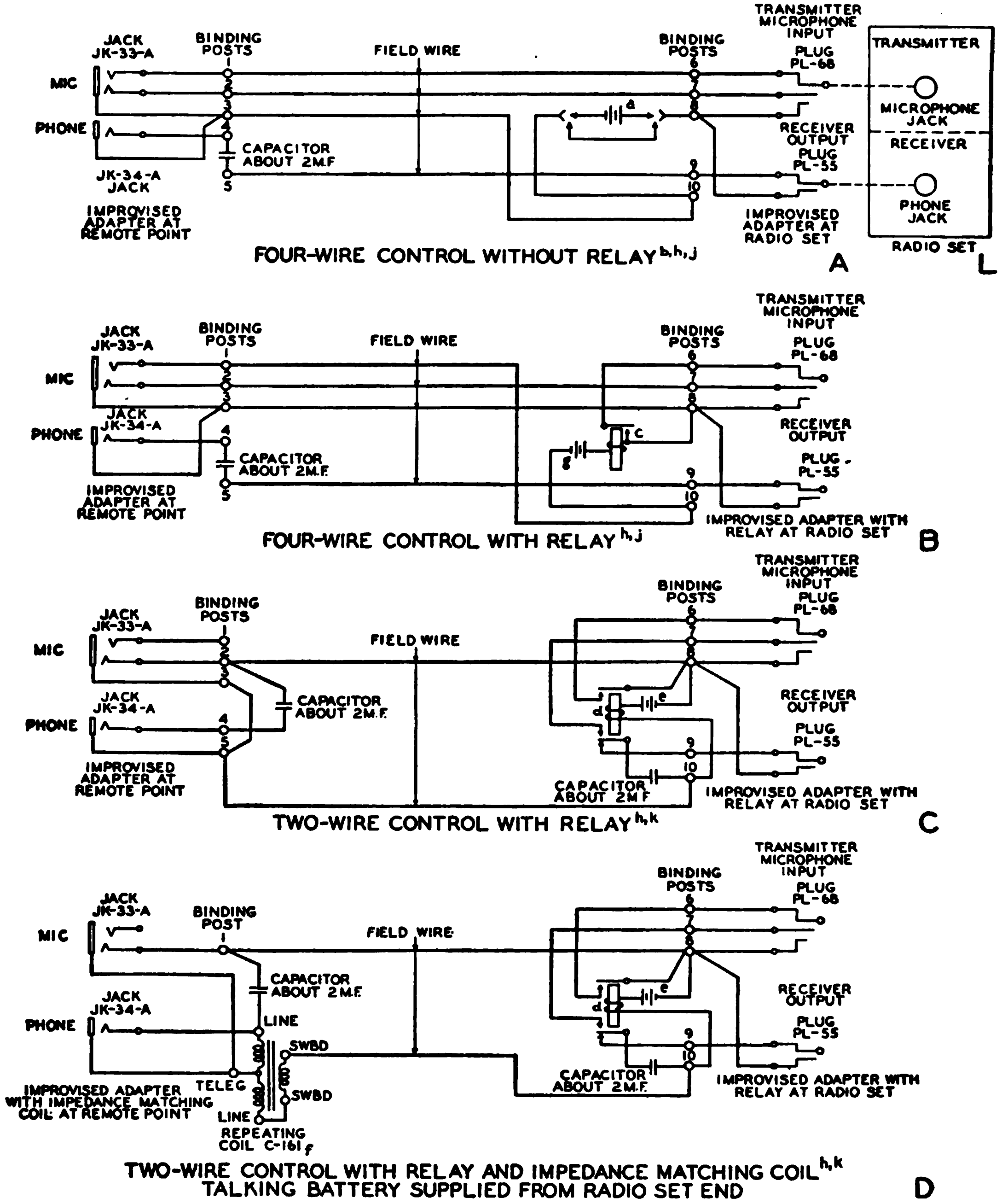
(*1*) Attenuation loss in the field wire.

(*2*) Loss in microphone output caused by the reduction in battery supply current through the microphone.

(*3*) Reflection losses at each end of the field wire.

b. If the d-c push-to-talk control range is exceeded by the simple arrangements described in subparagraph a above, using the required length of Wire W–110–B, one or more of the following steps may be considered to provide satisfactory push-to-talk operation.

(*1*) Reduce the resistance in the push-to-talk control circuit by connecting two or more pairs of Wire W–110–B in multiple or by providing wire of larger gauge such as Wire W–143. If the control wires are also to be used for voice transmission from the remote point, connect the extra wires as described in subparagraph c(1) below.



[a] PROVIDE BATTERY IF NEEDED TO INCREASE CURRENT TO REMOTE MICROPHONE AND INCREASE OPERATING RANGE OF PUSH-TO-TALK RELAY IN RADIO SET. POLE BATTERY SO THAT IT WILL NOT OPPOSE THE BATTERY IN THE RADIO SET.

[b] THIS ARRANGEMENT SHOULD NOT BE USED IF THE POWER SUPPLY TO THE CONTROL RELAY IN THE RADIO SET IS NOISY. SEE PAR. 692

[c] THIS RELAY SHOULD BE OF A TYPE WHICH OPERATES ON LESS THAN 0.5 AMPERE AND LESS THAN 50 VOLTS AND HAS A RESISTANCE OF LESS THAN 500 OHMS.

[d] THE RESISTANCE OF THE RELAY WINDING IN C OR D SHOULD BE MORE THAN 200 OHMS AND IN F MORE THAN 500 OHMS IN ORDER THAT THE TRANSMISSION LOSS CAUSED BY IT WILL NOT BE EXCESSIVE. DO NOT USE RELAY WITH NON-INDUCTIVE SHUNT.

[e] THE VOLTAGE OF THE BATTERY REQUIRED SHOULD BE APPROXIMATELY 0.06 TIMES THE SUM OF THE RESISTANCE OF THE RELAY WINDING, PLUS THE LOOP RESISTANCE OF A PAIR OF FIELD WIRE, PLUS 100 OHMS.

[f] REPEATING COIL C-161 SHOULD BE CONNECTED SERIES AIDING BY STRAPPING THE TWO BINDING POSTS ADJACENT TO ONE OF THE LONG SIDES OF THE BASE.

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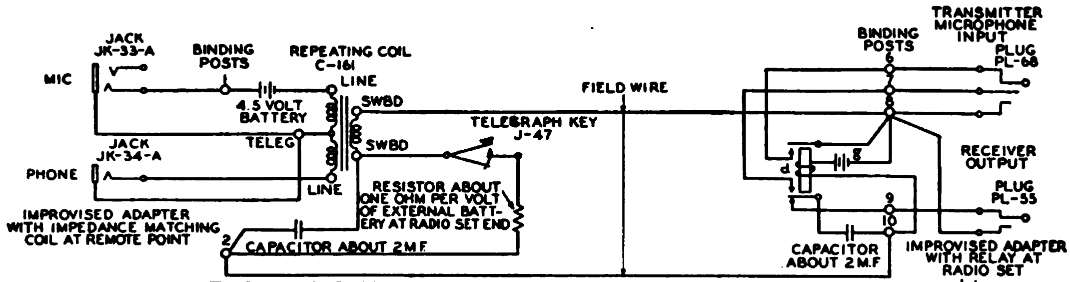
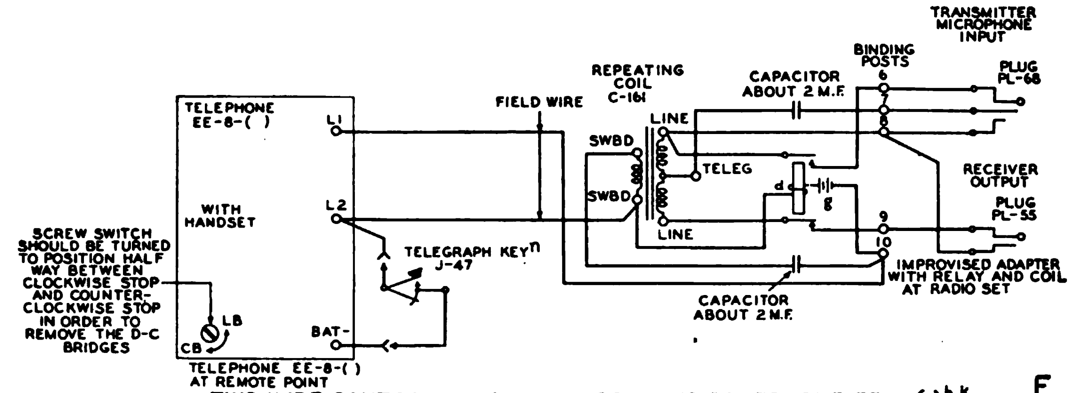
Figure 6-168. Improvised



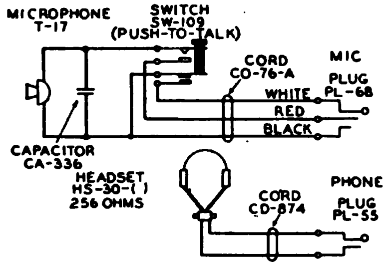
TWO-WIRE CONTROL WITH RELAY AND IMPEDANCE MATCHING COIL[h,k]
TALKING BATTERY SUPPLIED LOCALLY

E



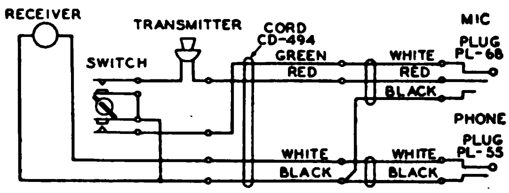
TWO-WIRE CONTROL WITH RELAY, COIL, AND TELEPHONE EE-8-( )[h,k]
TALKING BATTERY SUPPLIED LOCALLY

F



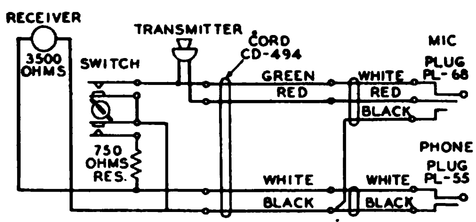
MICROPHONE AND HEADSET

G



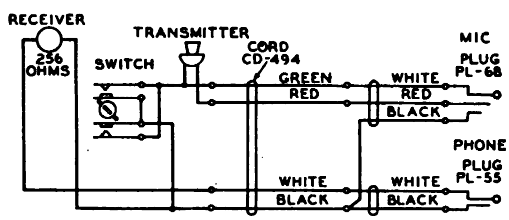
HANDSET H-22/U AND HANDSET H-23/U[j,m]

H



HANDSET TS-13-( )[j]

J



HANDSET TS-15-( )[j]

K

g THE VOLTAGE OF THIS BATTERY SHOULD BE ONLY SUFFICIENT TO OPERATE THE RELAY.

h WHERE APPARATUS SHOWN IS NOT AVAILABLE USE EQUIVALENT APPARATUS.

j MODIFY HANDSETS J AND K IN ACCORDANCE WITH H WHEN REQUIRED TO OPERATE WITH B. SAME MODIFICATION IS REQUIRED WITH A EXCEPT WHERE A OPERATES WITH RADIO SETS WHICH OPERATE NORMALLY WITH HANDSETS J AND K. HANDSET TS-15-B CANNOT BE MODIFIED.

k WHEN INTERFERENCE FROM OTHER LINES (POWER OR COMMUNICATION) IS EXPECTED, USE F. THIS ARRANGEMENT CAN ALSO BE OPERATED WITH THE IMPROVISED ADAPTER SHOWN AT THE REMOTE POINT IN C, D, AND E, INSTEAD OF THE TELEPHONE EE-8-( ) SHOWN IN F. IF THIS IS DONE APPLY NOTE e TO THE BATTERY IN F, INSTEAD OF NOTE g, WHEN OPERATING WITH C OR D.

m HANDSET H-22/U (RECEIVER IMPEDANCE - 3500 OHMS) MODIFICATION OF TS-13-( ). HANDSET H-23/U (RECEIVER IMPEDANCE - 256 OHMS) MODIFICATION OF TS-15-A AND TS-15-C. SEE MWO SIG-24 AND MWO SIG-25.

n IF THIS KEY IS NOT PROVIDED, PUSH-TO-TALK CONTROL CAN BE ACCOMPLISHED BY PUSHING IN ON THE CRANK OF THE HAND GENERATOR IN THE TELEPHONE. THIS ADDS ABOUT 400 OHMS TO THE SIGNALING CIRCUIT, AND MAY REQUIRE ADDITIONAL VOLTAGE AT g.

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arrangements for remote control of radio sets.

(*2*) Connect a battery in series with the push-to-talk control circuit to increase the current as shown optional in figure 6-168-A.

(*3*) Provide a more sensitive electromagnetic relay at the radio set as shown in figures 6-168-B and -C.

c. If adequate modulating volume at the radio transmitter is not obtained with the simple arrangement described in subparagraph a above, consider one or more of the following steps:

(*1*) Reduce the transmission loss in the voice circuit to the transmitter by providing wire of lower loss per mile, such as Wire W–143, or by providing two pairs of field wire instead of only one pair, short the wires of each pair at the ends and space the pairs about 8 inches apart on insulators, as described for open wire lines with twin pairs in chapter 5. Such a voice circuit with Wire W–110–B will have a loss of about 0.5 db per mile which is about 1/5 that of a single pair. If it is not practical to place the wires on insulators, keep them off the ground by tying them to trees, because the loss with two pairs on the ground in wet conditions would probably be no less than that of a single pair. If tied to trees, the pairs should retain a separation of 8 inches or more, and should not be in frequent contact with wet foliage.

(*2*) Increase the battery supply current through the microphone by one of the following procedures: connect a battery in series with the microphone as shown in figure 6-168-A; increase the potential of the battery shown in figures 6-168-C and 6-168-D; or provide the local talking battery arrangement shown in figure 6-168-E or figure 6-168-F.

(*3*) Reduce the reflection loss between the microphone and the field wire (par. 690f) by matching impedances through a repeating coil. A circuit for this purpose with an external battery at the radio set end is shown in figure 6-168-D. A local battery circuit is shown in figure 6-168-E. The Telephone EE–8–( ) connected as shown in figure 6-168-F can also be used.

d. Figures 6-168-A and 6-168-B cover 4-wire remote control arrangements. The arrangement in figure 6-168-A is merely an extension circuit which can provide additional battery for the microphone and the operation of the control relay in the radio set if required. With this 4-wire control arrangement, noise from the signaling power supply will be introduced in the microphone circuit because of the resistance of the wire which is common to the push-to-talk, microphone, and receiver circuits. The amount of noise introduced in the radio transmitter will depend upon the noise in the signaling power supply and the resistance of the common wire. The arrangement in figure 6-168-B is an extension circuit with a sensitive relay, and is mainly used with radio sets which have control relays which operate on high current or which control the radio transmitter and receiver by means of the vacuum tube filament circuit. It does not, however, provide for increasing the current through the microphone. The noise difficulties mentioned above are not experienced with this arrangement.

e. Noise or crosstalk may be encountered in the use of figures 6-168-A to 6-168-E inclusive, if the wire line is close to a power line or another communication circuit. This is because one side of the wire line is grounded at the radio set. Figure 6-168-F greatly reduces the noise and crosstalk by using a coil at the radio set end which insulates the grounded radio set from the wire line. Other nongrounded arrangements can be improvised by using the improvised adapter at the radio set end in figure 6-168-F, with the improvised adapter at the remote point in figures 6-168-C to 6-168-E inclusive.

Section VIII. RADIO SET TECHNICAL AND DESCRIPTIVE INFORMATION

693. RADIO SETS.

a. General. Figures 6-169 to 6-175, inclusive, list a number of U. S. Army, U. S. Navy, and British radio sets with pertinent data on electrical characteristics. Pictures of some of these radio sets are shown in sections II and IV. For more complete information on tactical sets for ground use, and on fixed plant radio equipment, reference should be made to TM 11–487 or to technical manuals indicated for the specific sets. (The text of this paragraph is continued on page 379.)

Type	Frequency range (mc)	Rated xmtr output (watts)	Type emission	Type mod	Frequency control	Remarks
SCR-177-A	xmtr, 0.4 to 0.8 & 1.5 to 4.5 rcvr, 0.4 to 1.0 & 1.5 to 4.5	75	cw tone voice	am	mo	Limited Standard; ground, transportable; for tactical field units; crowfoot antenna (0.4 to 0.8 mc) and ¼-wave inverted L antenna with counterpoise (1.5 to 4.5 mc). Replaced by SCR-177-B.
SCR-177-B	xmtr, 0.4 to 0.8 & 1.5 to 4.5 rcvrs, 0.15 to 1.5 & 1.5 to 18.0	75	cw tone voice	am	mo	Ground, transportable; for tactical field units and ground-to-air communication; two receivers. Crowfoot antenna (0.4 to 0.8 mc) and ¼-wave inverted L antenna with counterpoise (1.5 to 4.5 mc). Transported by vehicle or cargo aircraft. TM 11-232.
SCR-188	xmtr, 1.5 to 12.5 rcvr, 0.4 to 13.0	75	cw tone voice	am	mo	Limited Standard; ground, transportable; for ground-to-ground or ground-to-air communication. ¼- or ¾-wave inverted L antenna with counterpoise. TM 11-233. Replaced by SCR-188-A.
SCR-188-A	xmtr, 1.5 to 12.5 rcvr, 1.5 to 18.0	75	cw tone voice	am	mo	Ground, transportable; for semifixed use; arranged for remote control; ¼- or ¾-wave inverted L antenna with counterpoise. Transported by vehicle or cargo plane. TM 11-233.
SCR-193-( )	xmtr, 1.5 to 6.2 rcvr, 1.5 to 18.0	75	cw tone voice	am	mo	Vehicular; for communication between stationary or moving vehicles equipped with 50-amp. generator and 12-volt 180 amp. hr. battery. 15-ft. whip. TM 11-273.
SCR-197	xmtr, 1.5 to 18.0 3 rcvrs, 1.5 to 18.0 1 rcvr, 0.54 to 44.0	400 100 100	cw tone voice	am	mo or xtal	Limited Standard; ground, mobile; high power radio station installed in truck and trailer for operation from stationary position. 45-ft. vertical antenna for transmitting and 15-ft. whip for receiving. TM 11-241. Replaced by SCR-399.
SCR-203	xmtr, 2.2 to 3.06 rcvr, 2.1 to 3.1	7.5	cw tone voice	am	mo	Limited Standard; pack; mounts on Phillips pack saddle for animal pack transportation and operation. 25-ft. whip. TM 11-239. Replaced by SCR-245.
SCR-209	xmtr, 2.2 to 2.6 rcvr, 1.5 to 18.0	8.5 7.5 7.5	cw tone voice	am	mo	Limited Standard; vehicular; used in combat and scout cars. 15-ft. whip. Replaced by SCR-508 and SCR-528.
SCR-210	rcvr, 1.5 to 18.0	—	cw tone voice	am	Manual tuning	Limited Standard; vehicular; receiver only of SCR-245, 15-ft. whip. TM 11-272. Replaced by SCR-538.

Figure 6-169. Tactical radio sets for ground use (continued on following page).

Type	Frequency range (mc)	Rated xmtr output[a] (watts)	Type emission	Type mod	Frequency control	Remarks
SCR-245	xmtr, 2.0 to 5.25 rcvr, 1.5 to 18.0	10	cw tone voice	am	mo or xtal	Limited Standard; vehicular; for communicating between stationary or moving vehicles. 15-ft. whip. TM 11-272. Replaced in Armored Force by SCR-508 and SCR-528. Radio Sets SCR-245-A, -B, -C, -E, -F, -H, -K, -L, -M, -MX, -N, and -NX are obsolete.
SCR-284-A	3.8 to 5.8	20/6.5 8/2	cw voice	am	mo (xtal cal.)	Limited Standard; ground, transportable; vehicular or pack; arranged for remote control. 25-ft. whip with counterpoise for field operation or 15-ft. whip for vehicular operation. TM 11-275. Replaced by SCR-694.
SCR-288-A	xmtr, 3.5 to 6.3 rcvr, 2.3 to 6.5	4	cw voice	am	mo	Limited Standard; ground; transportable or pack; temporary replacement for SCR-131, SCR-161, and SCR-171. 35-ft. horizontal end-fed wire and counterpoise. TM 11-250. Replaced by SCR-284-A.
SCR-293	20.0 to 27.9	25 or 0.5	voice	fm	xtal	Limited Standard; vehicular; installed in tanks and scout cars. High or low power by switch control. 9-ft. whip. Replaced by SCR-508 and SCR-528.
SCR-294	rcvr, 20.0 to 27.9	—	voice	fm	xtal	Limited Standard; vehicular; receiver only of SCR-293. 9-ft. whip. Replaced by SCR-538.
SCR-298-C	30 to 40	35	voice	fm	xtal	Vehicular; commercial police set, used by umpire personnel. 6-ft. whip.
SCR-299	xmtr, 2.0 to 8.0 (299-F 2.0 to 12.0) 2 rcvrs, 1.5 to 18.0	400 300	cw voice	am	mo or xtal	Limited Standard; ground, mobile; high power radio station for operation from stationary or moving position. Frequency Conversion Kit MC-509 gives transmitter coverage down to 1 mc. MC-516 gives coverage to 12 mc; MC-517 to 18 mc. 15-ft. whip or half-wave doublet antenna. TM 11-280. Replaced by SCR-399.
SCR-300	40 to 48	0.5	voice	fm	mo (xtal. cal.)	Pack; walkie-talkie for *back-pack* or *on-ground* operation for short range communication. Half-wave whip or 3-ft. end-loaded whip. TM 11-242.
SCR-399	xmtr, 2.0 to 18.0 2 rcvrs, 1.5 to 18.0	400 300	cw voice	am	mo or xtal	Ground, mobile; high power radio station installed in Shelter HO-17 which may be mounted on a 2½ ton 6 x 6 truck; for operation from stationary or moving position. Frequency Conversion Kit MC-509 gives transmitter coverage down to 1 mc. (Conversion Kit MC-543 is available for use with Radio Transmitter BC-610 to provide high-power, high-speed telegraph operation. Kit includes a 2 kw. power amplifier, with power supply, for use in frequency range of 1.0 to 18.0 mc.) 15-ft. whip or half-wave doublet antenna. TM 11-281.
SCR-499	xmtr, 2.0 to 18.0 2 rcvrs, 1.5 to 18.0	400 300	cw voice	am	mo or xtal	Air transportable; high power radio station similar to SCR-399 except arranged for transportation by air. Frequency Conversion Kit MC-509 gives transmitter coverage down to 1 mc. 15-ft. whip or half-wave doublet antenna. TM 11-281.

[a] When two values of power are shown separated by a slant bar (/), the higher value in general applies to ground, transportable, and vehicular operation; the lower value to pack operation.

Figure 6-169. Tactical radio sets for ground use (continued on opposite page).

Type	Frequency range (mc)	Rated xmtr output (watts)	Type emission	Type mod	Frequency control	Remarks
SCR-506	xmtr, 2.0 to 4.5 rcvr, 2.0 to 6.0	80 20	cw voice	am	mo (xtal cal.)	Vehicular; installed in tanks, amphibian cars and personnel carriers for communication to airplanes or base stations. Five preset channels. 15-ft. whip. TM 11-630.
SCR-508	20.0 to 27.9	30	voice	fm	xtal	Vehicular; installed in tanks, armored cars, scout cars, and trucks. Two receivers; interphone amplifier; ten preset channels; 9-ft. whip. TM 11-600.
SCR-509	20.0 to 27.9	1.8	voice	fm	xtal	Pack; operates on dry batteries from stationary position, two preset channels. 8-ft. whip. TM 11-605.
SCR-510	20.0 to 27.9	1.8	voice	fm	xtal	Pack and vehicular; same as SCR-509 with vibrator plate supply and components for vehicular use. 6- or 8-ft. whip. TM 11-605.
SCR-511	2.0 to 6.0	0.75	voice	am	xtal	Pack and vehicular; installed in vehicle or carried as guidon by man on horseback or as one-man load. 11-ft. whip. TM 11-245.
SCR-528	20.0 to 27.9	30	voice	fm	xtal	Vehicular; same as SCR-508 less one receiver. 9-ft whip. TM 11-600.
SCR-536	3.5 to 6.0	0.02	voice	am	xtal	Pack; light-weight, self-contained very short range *Handie-talkie*. 3-ft. whip. TM 11-235.
SCR-538	rcvr, 20.0 to 27.9	—	voice	fm	xtal	Vehicular; receiver only of SCR-528 plus interphone amplifier. Ten preset channels. 9-ft. whip. TM 11-600.
SCR-543	1.68 to 4.45	45	voice cw	am	xtal	Ground, transportable and vehicular. Six preset channels. 15-ft. whip. TM 11-625. SCR-543-A, -B, and -C (voice only) are Limited Standard.
SCR-578	xmtr, 0.5 only	5	tone	am	mo	Substitute Standard; air transportable; hand powered sea rescue transmitter. May be dropped from aircraft. 300-ft. sloping wire antenna. See AAF Technical Order AN 08-10-94.
SCR-593	rcvr, 2.0 to 6.0	—	voice	am	mo	Pack and vehicular; receiver only; for alert or warning messages. Four preset channels. 7-ft. whip. TM 11-859.
SCR-608	27.0 to 38.9	30	voice	fm	xtal	Vehicular; has two receivers; similar to SCR-508 except frequency; used in armored cars, half-tracks and trucks. Ten preset channels. 9-ft. whip. TM 11-620.
SCR-609	27.0 to 38.9	2	voice	fm	xtal	Substitute Standard; pack; dry battery set similar to SCR-509 except frequency. Two preset channels. 13-ft. whip. TM 11-615.
SCR-610	27.0 to 38.9	2	voice	fm	xtal	Substitute Standard; pack and vehicular; same as SCR-609 plus vibrator plate supply and components for vehicular use. 9 or 13-ft. whip. TM 11-615.

Figure 6-169. Tactical radio sets for ground use (continued on following page).

Type	Frequency range (mc)	Rated xmtr output* (watts)	Type emission	Type mod	Frequency control	Remarks
SCR-619	27.0 to 38.9	1.5	voice	fm	xtal	Pack and vehicular; light weight, similar in function to SCR-609 and SCR-610. Two preset channels. 4½, 9- or 12-ft. whip. TM 11-619.
SCR-624	100 to 156	8	voice	am	xtal	Air transportable; similar to SCR-522 and SCR-542 air-borne sets except arranged for ground use. Four preset channels. Vertical half-wave J antenna on 50-ft. mast. See AAF Technical Order AN 08-10-185.
SCR-628	27.0 to 38.9	30	voice	fm	xtal	Vehicular; same as SCR-608 less one receiver. Ten preset channels. 9-ft. whip. TM 11-620.
SCR-694-AW	3.8 to 6.0	25/15	cw	am	mo or xtal	Pack; ground, transportable and vehicular. Limited production. 15-ft. whip or half-wave sloping wire antenna. Lower values of power than those indicated may be obtained by switch control.
		7/5	voice			
SCR-694-C	3.8 to 6.5	20/10	cw	am	mo or xtal	Pack; ground, transportable and vehicular. Used by parachute, airborne, and mountain troops and in amphibious operations. Repla ement for SCR-284-A. 15-ft. whip and counterpoise or half-wave sloping wire antenna. Lower values of power than those indicated may be obtained by switch control. TM 11-230C.
		7/5	tone			
		7/5	voice			
SCR-808	27.0 to 38.9	35 or 2	voice	fm	mo (xtal cal.)	Vehicular; has two receivers; equipped with interphone amplifier. Four preset channels. High or low power by switch control. 6- or 9-ft. whip. TM 11-601.
SCR-828	27.0 to 38.9	35 or 2	voice	fm	mo (xtal cal.)	Vehicular; same as SCR-808 less one receiver. Four preset channels. High or low power by switch control. 6- or 9-ft. whip. TM 11-601.
AN/CRC-3	30 to 40	50	voice	fm	xtal	Limited Standard; air transportable; commercial police set modified for air warning service. Transmitter employs a frequency multiplication of 32 times crystal frequency. (AN/CRC-3A is similar except employs an 8 times frequency multiplication). Vertical half-rhombic or coaxial half-wave dipole on 50-ft. mast.
AN/MRC-1	xmtr, (incl. ampl.) 2.0 to 13.0	2,000	cw	am	mo or xtal	Ground, mobile; provides facilities for high power, high-speed automatic c-w transmission and reception employing Boehme equipment in addition to the normal functions of Radio Set SCR-399. The radio transmitter power amplifier and one radio receiver are housed in the transmitting Shelter HO-17, with three radio receivers and the Boehme equipment housed in the operating Shelter HO-17 or HO-27. Requires three 2½-ton, 6 x 6, cargo trucks for transportation. 15-ft. whip or half-wave doublet antenna. TM 11-602 and TM 11-281. Also see Chapter 3.
	xmtr, (less ampl.) 2.0 to 18.0	400	cw			
		300	voice			
	rcvrs, 1.5 to 18.0					

* When two values of power are shown separated by a slant bar (/), the higher value in general applies to ground, transportable, and vehicular operation; the lower value to pack operation.

Figure 6-169. Tactical radio sets for ground use (continued on opposite page).

Type	Frequency range (mc)	Rated xmtr output* (watts)	Type emission	Type mod	Frequency control	Remarks
AN/MRC-2	xmtr, 2.0 to 18.0 rcvrs, 1.5 to 18.0	2,000 (incl. ampl.)	cw & special	am	mo or xtal	Ground, mobile; under development; to provide a high-power, single-channel radio-teletype system using carrier-shift keying and dual space-diversity reception in addition to the normal facilities of Radio Set SCR-399. Equipment to be housed in three Shelters HO-17 or HO-27. Frequency range of 2 kw power amplifier is 1.0 to 18.0 mc. Frequency Conversion Kit MC-509 gives transmitter coverage down to 1.0 mc. Half-wave doublet antenna. Also see chapter 3.
		400 (less (ampl.)	cw			
		300 (less ampl.)	voice			
AN/TRA-1	70 to 100	250	—	—	—	Ground, transportable; amplifier equipment for use with AN/TRC-1, -3 or -4. Three element directional array on 40-ft. mast. TM 11-2601.
AN/TRC-1	70 to 100	50 or 10	voice	fm	xtal	Ground, transportable; for single channel, or multichannel operation with spiral-four carrier terminal equipment. High or low power by switch control. Three element directional array on 40-ft. mast. TM 11-2601.
AN/TRC-2	2.0 to 3.4 and 3.8 to 6.5	20/10	cw	am	mo or xtal	Ground, transportable and pack; two receiver-transmitters for use by isolated units. Quarter-wave inverted L antenna with counterpoise or half-wave antenna without counterpoise. Lower values of power than those indicated may be obtained by switch control. TM 11-2603.
		7/5	tone			
		7/5	voice			
AN/TRC-3	70 to 100	50 or 10	voice	fm	xtal	Ground, transportable; radio terminal set similar to AN/TRC-1 except has sufficient equipment to insure continuous service. High or low power by switch control. Three element directional array on 40-ft. mast. TM 11-2601.
AN/TRC-4	70 to 100	50 or 10	voice	fm	xtal	Ground, transportable; radio relay set similar to AN/TRC-1 except has sufficient equipment to insure continuous service as a repeater station. High or low power by switch control. Three element directional array on 40-ft. mast. TM 11-2601.
AN/TRC-7	100 to 156	0.5	voice	am	xtal	Pack and ground, transportable; light-weight v-h-f communication set, transportable by a 4-man team. Two preset channels. Quarter-wave whip, or vertical broad-band antenna on 30-ft. mast. TM 11-617.
AN/TRC-8	230 to 250	12	voice	fm	mo (temp. compensated)	Ground, transportable; for single channel, or multichannel operation with spiral-four carrier terminal equipment. Half-wave dipole and 90° corner reflector on 40-ft. mast. TM 11-618.
AN/TRC-11	230 to 250	12	voice	fm	mo (temp. compensated)	Ground, transportable; radio terminal set similar to AN/TRC-8 except has sufficient equipment to insure continuous service. Half-wave dipole and 90° corner reflector on 40-ft. mast. TM 11-618.

* When two values of power are shown separated by a slant bar (/), the higher value in general applies to ground, transportable, and vehicular operation; the lower value to pack operation.

Figure 6-169. Tactical radio sets for ground use (continued on following page).

Type	Frequency range (mc)	Rated xmtr output (watts)	Type emission	Type mod	Frequency control	Remarks
AN/TRC-12	230 to 250	12	voice	fm	mo (temp. compensated)	Ground, transportable; radio relay set similar to AN/TRC-8 except has sufficient equipment to insure continuous service as a repeater station. Half-wave dipole and 90° corner reflector on 40-ft. mast. TM 11-618.
AN/VRC-1	*h-f units* xmtr, 3.0 to 6.2 rcvr, 1.5 to 18.0	75	cw / tone / voice	am	mo	Ground, mobile; combines SCR-542 airborne set, with SCR-193; mounted in a ¼-ton 4 x 4 truck; for ground-to-air and ground-to-ground h-f and v-h-f communication. V-h-f set has four preset channels. 15-ft. whip as h-f antenna. 3-ft. whip as v-h-f antenna. TM 11-277.
	v-h-f units 100 to 156	6	voice	am	xtal	
AN/VRC-3	40 to 48	0.5	voice	fm	mo (xtal cal.)	Substitute Standard; vehicular; similar to SCR-300 except arranged for installation in light and medium tanks. 3- or 6-ft. whip. TM 11-637.
AN/VRC-5	20.0 to 27.9	30	voice	fm	xtal	Vehicular; same as SCR-528 except for mounting arrangement. Transmitter and receiver are in separate mountings. For use in twin 40 mm. gun carriage. Ten preset channels.
RC-256	rcvr, 100 to 156	—	cw / tone / voice	am	manual tuning (xtal cal.)	Ground, transportable; receiving equipment RC-256 and transmitting equipment RC-257 are used together as a single channel radio link terminal station in conjunction with other v-h-f equipment. A waterproof shelter is required to house the combined equipment. Balanced vertical half-wave dipole on 90-ft. mast. See AAF Technical Order AN 08-10-227.
RC-257	xmtr, 100 to 156	50	tone / voice	am	xtal	

Figure 6-169. Tactical radio sets for ground use (continued).

Type[a]	Frequency range (mc)	Rated xmtr output (watts)	Type emission	Frequency control	Preset channels	Power source	Remarks
SCR-183	xmtr, 2.5 to 7.7 rcvr, 0.2 to 0.4 & 2.5 to 7.7	3.5	cw / tone / voice	mo	none	14v, dc	Limited Standard; command set for 2-way plane-to-plane and plane-to-ground communication. Receiver is not arranged for c-w reception. Same as SCR-283 except for operating voltage. TM 11-200.
SCR-187	xmtr, 0.4 to 12.5 rcvr, 1.5 to 18.0	75	cw / tone / voice	mo	none	14v, dc	Limited Standard; liaison set for 2-way plane-to-plane and plane-to-ground communication. Same as SCR-287 except for operating voltage and transmitter tuning units supplied.

[a] All sets are amplitude modulated.

Figure 6-170. Airborne radio equipment (continued on opposite page).

Type[a]	Frequency range (mc)	Rated xmtr output (watts)	Type emission	Frequency control	Preset channels	Power source	Remarks
SCR-274-N	xmtrs, 3.0 to 9.1 rcvrs, 0.19 to 0.55 & 3.0 to 9.1	36 12	cw tone voice	mo (xtal cal.)	1 (per xmtr.)	28v, dc	Command set for 2-way plane-to-plane and plane-to-control tower communication. Frequency range shown is covered by four transmitters and three receivers, not necessarily all used in one installation.
SCR-283	xmtr, 2.5 to 7.7 rcvr, 0.2 to 0.4 & 2.5 to 7.7	3.5	cw tone voice	mo	none	28v, dc	Limited Standard; command set for 2-way plane-to-plane and plane-to-ground communication. Receiver is not arranged for c-w reception. Same as SCR-183 except for operating voltage. TM 11-200.
SCR-287	xmtr, 0.35 to 0.65 & 1.5 to 12.5 rcvr, 0.2 to 0.5 & 1.5 to 18.0	75	cw tone voice	mo	none	28v, dc	Limited Standard; liaison set for 2-way plane-to-plane and plane-to-ground communication. Same as SCR-187 except for operating voltage and transmitter tuning units supplied.
SCR-522	100 to 156	6	voice	xtal	4	28v, dc	For 2-way plane-to-plane and plane-to-ground communication. Same as SCR-542 except for operating voltage. TM 11-509.
SCR-542	100 to 156	6	voice	xtal	4	14v, dc	For 2-way plane-to-plane and plane-to-ground communication. Same as SCR-522 except for operating voltage. TM 11-509.
AN/ARC-3	100 to 156	6	voice	xtal	8	28v, dc	For 2-way plane-to-plane and plane-to-ground communication. Automatic tuning of transmitter and receiver upon insertion of crystal.
AN/ARC-9 (Bendix RTA-1B)	2.5 to 13.0	50	voice	xtal	10	28v, dc or 14v, dc	For 2-way plane-to-plane and plane-to-ground communication.
AN/ARR-11	0.2 to 0.5 & 1.5 to 18.0	—	cw tone voice	—	none	28v, dc	Receiver only. Manual tuning, six bands. Used with AN/ART-13 as a replacement for SCR-287.
AN/ART-13	0.2 to 1.5 & 2.0 to 18.1	100/50	cw tone voice	mo (xtal cal.)	11	28v, dc	Transmitter only. Same as Navy Model ATC. One preset channel is between 0.2 to 1.5 mc and ten are between 2.0 to 18.1 mc. Half power is automatically obtained upon reaching an elevation of approx. 25,000 feet. Used with AN/ARR-11 as a replacement for SCR-287.

[a] All sets are amplitude modulated.

Figure 6-170. Airborne radio equipment (continued).

Type [a]	Radio components [b]	Rated xmtr output (watts)	Aux power supply [c]	Approx total weight [d] (lbs.)	Remarks
SCR-561	none	—	1 PE-99	10,500	Control set used as an operations block of Control Net System SCS-2; provides the necessary control equipment for simultaneous operational control of up to four aircraft squadrons, for ground control of interceptor pursuit operations.
SCR-562	6 xmtrs, BC-640 (1 spare)	50	2 K-63	40,000	Mobile transmitting station for ground control of interceptor pursuit operations. Part of Control Net System SCS-2; provides five independent channels. Uses half-wave dipoles on 90-foot steel mast.
SCR-563	6 rcvrs, BC-639 (1 spare)	—	1 K-63	27,000	Mobile receiving station for ground control of interceptor pursuit operations. Part of Control Net System SCS-2. Provides five independent channels. Uses half-wave dipoles on 90-foot steel mast.
SCR-564	2 rcvrs, BC-639 (1 spare)	—	1 PE-99	25,000	Sector homing D/F station for ground control of interceptor pursuit operations. Part of Control Net System SCS-2. By utilizing a sector transmitter the D/F operator homes the aircraft by the *talk down method.* Uses Adcock D/F antenna with sensing facilities.
SCR-565	2 rcvrs, BC-639 (1 spare)	—	1 PE-99	25,000	Fixed D/F fixer station for ground control of interceptor pursuit operations. Part of Control Net System SCS-2. Two or more of these sets are used for determining azimuth bearing of aircraft equipped with transmitters in the 100-to 156-mc band. Uses Adcock D/F antenna with sensing facilities.
SCR-566	rcvr, (1 ea.) BC-639 BC-624 1 xmtr, BC-625	— — 8	1 K-63	13,500	Mobile D/F station for ground control of interceptor pursuit operations. Part of Control Net System SCS-2. Used as a homing and D/F Station for planes having 100- to 156-mc. radio equipment. Uses Adcock D/F antenna with sensing facilities.

[a] All radio sets operate with amplitude modulation in the 100- to 156-mc. band.
[b] The following table gives the characteristics of the component parts of these radio sets.

Component	Characteristics of components		
	Type emission	Frequency control	Preset channels
xmtr, BC-625	voice	xtal	4
xmtr, BC-640	voice, tone	xtal	1
rcvr, BC-624	voice, tone	xtal	4
rcvr, BC-639	cw, tone, voice	Manual tuning (xtal cal, with assoc. Frequency Meter BC-638).	none

[c] K-63 is a one-ton cargo trailer containing 1 Power Unit PE-99 which provides up to 7.5 kw. of three plase 120-v., 60-cycle ac. The Power Unit PE-99 has recently been replaced on new equipments by Power Unit PE-197 which provides up to 5 kw. of single phase 120-v., 60-cycle ac.
[d] Total weight includes vehicles, antennas, masts, and shelters.

Figure 6-171. V-h-f fighter control equipment *(continued on opposite page).*

Type [a]	Radio components [b]	Rated xmtr output (watts)	Aux power supply [c]	Approx total weight [d] (lbs.)	Remarks
SCR-567	2 xmtrs, BC-640	50	1 K-63	17,000	Mobile forward relay station for ground control of interceptor pursuit operations. Part of Control Net System, SCS-2. Provides two independent transmitting and receiving channels for extending the range of SCR-562 and SCR-563. Uses half-wave dipoles on 50-foot steel mast.
	2 rcvrs, BC-639	—	1 K-63	16,500	
SCR-572	none	—	1 K-63	20,000	Mobile control set used as an operations block of Control Net System SCS-3. Provides the necessary control equipment for simultaneous operational control of up to two aircraft squadrons, for ground control of interceptor pursuit operations.
SCR-573	2 xmtrs, BC-640	50	1 K-63	15,000	Mobile two channel transmitting station for ground control of interceptor pursuit operations. Part of Control Net System SCS-3. Uses half-wave dipoles on 75-foot plywood mast.
SCR-574	2 rcvrs, BC-639	—	1 K-63	14,500	Mobile two channel receiving station for ground control of interceptor pursuit operations. Part of Control Net System SCS-3. Uses half-wave dipoles on 75-foot plywood mast.
SCR-575	rcvrs, 2 BC-639 (1 spare)	—	1 K-63	14,000	Mobile D/F station used either as a fixer or homer station for ground control of interceptor pursuit operations. Part of Control Net System SCS-3. For obtaining bearings on aircraft having 100 to 156 mc radio equipment. Uses Adcock D/F antenna with sensing facilities.
	1 BC-624	—			
	xmtr, 1 BC-625	8			
SCR-632	6 xmtrs, BC-640 (1 spare)	50	2 PE-99	22,600	Fixed transmitting station for ground control of interceptor pursuit operations. Part of Control Net System SCS-2. Provides five independent channels. Uses half-wave dipoles on 90-foot steel mast.
SCR-633	6 rcvrs, BC-639 (1 spare)	—	1 PE-99	18,300	Fixed receiving station for ground control of interceptor pursuit operations. Part of Control Net System SCS-2. Provides five independent channels. Uses half-wave dipoles on 90-foot steel mast.

[a] All radio sets operate with amplitude modulation in the 100- to 156-mc. band.
[b] The following table gives the characteristics of the component parts of these radio sets.

Component	Characteristics of components		
	Type emission	Frequency control	Preset channels
xmtr, BC-625	voice	xtal	4
xmtr, BC-640	voice, tone	xtal	1
rcvr, BC-624	voice, tone	xtal	4
rcvr, BC-639	cw, tone, voice	Manual tuning (xtal cal, with assoc. Frequency Meter BC-638).	none

[c] K-63 is a one-ton cargo trailer containing 1 Power Unit PE-99 which provides up to 7.5 kw. of three plase 120-v., 60-cycle ac. The Power Unit PE-99 has recently been replaced on new equipments by Power Unit PE-197 which provides up to 5 kw. of single phase 120-v., 60-cycle ac.
[d] Total weight includes vehicles, antennas, masts, and shelters.

Figure 6-171. V-h-f fighter control equipment (continued on following page).

Type [a]	Radio components [b]	Rated xmtr output (watts)	Aux power supply [c]	Approx total weight [d] (lbs.)	Remarks
SCR-634	1 rcvr, BC-639	—	1 PE-214	1,035	Air transportable, field operated D/F station used primarily with similar units as a fixer D/F station or, with the addition of Radio Set SCR-624, as a homer D/F station. Uses Adcock D/F antenna with sensing facilities.
SCR-637	2 xmtrs, BC-640	50	1 PE-99	5,830	Fixed forward relay station for ground control of interceptor pursuit operations. Part of Control Net System SCS-2. Provides two independent transmitting and receiving channels for extending the range of SCR-562 and SCR-563. Uses half-wave dipoles on 50-foot steel mast.
	2 rcvrs, BC-639	—	1 PE-99	5,330	
SCR-642	none	—	1 PE-99	4,000	Fixed control set used as an operations block of Control Net System SCS-3. Provides the necessary control equipment for simultaneous operational control of up to two aircraft squadrons for ground control of interceptor pursuit operations.
SCR-643	2 xmtrs, BC-640	50	1 PE-99	5,800	Fixed two channel transmitting station for ground control of interceptor pursuit operations. Part of Control Net System SCS-3. Uses half-wave dipoles on 90-foot steel mast.
SCR-644	2 rcvrs, BC-639	—	1 PE-99	5,300	Fixed 2-channel receiving station for ground control of interceptor pursuit operations. Part of Control Net System SCS-3. Uses half-wave dipoles on 90-foot steel mast.
SCR-645	rcvrs, 2 BC-639 (1 spare)	—	1 PE-99	25,000	Fixed D/F station used either as a fixer or homer station for ground control of interceptor pursuit operations. Part of Control Net System SCS-3. For obtaining bearings on aircraft having 100- to 156-mc. radio equipment. Uses Adcock D/F antenna with sensing facilities.
	1 BC-624	—			
	xmtr, 1 BC-625	8			
AN/CRC-2	rcvrs, 6 BC-639	—	4 PE-214	2,670	Air transportable airdrome fighter control system.
	1 BC-624	—			
	xmtr, 1 BC-625	8			

[a] All radio sets operate with amplitude modulation in the 100- to 156-mc. band.

[b] The following table gives the characteristics of the component parts of these radio sets.

Component	Characteristics of components		
	Type emission	Frequency control	Preset channels
xmtr, BC-625	voice	xtal	4
xmtr, BC-640	voice, tone	xtal	1
rcvr, BC-624	voice, tone	xtal	4
rcvr, BC-639	cw, tone, voice	Manual tuning (xtal cal, with assoc. Frequency Meter BC-638).	none

[c] K-63 is a one-ton cargo trailer containing 1 Power Unit PE-99 which provides up to 7.5 kw. of three plase 120-v., 60-cycle ac. The Power Unit PE-99 has recently been replaced on new equipments by Power Unit PE-197 which provides up to 5 kw. of single phase 120-v., 60-cycle ac.

[d] Total weight includes vehicles, antennas, masts, and shelters.

Figure 6-171. V-h-f fighter control equipment (continued).

Type	*Frequency range (mc)*	*Rated xmtr output (kw)*	*Type emission*	*Frequency control*	*Remarks*
BC-339-( )	4.0 to 26.5	1	A1 and Special	mo or xtal	For telegraph or teletype operation. Switch selection of master oscillator or any one of six crystal frequencies. TM 11-836.
BC-365-( )	0.15 to 0.55	0.35	A1	mo	Includes remote control unit; manual frequency change. Also used as exciter for Bunnell 6 kw amplifier. TM 11-828.
BC-447-( )	2.0 to 8.0 and 4.0 to 13.4	0.3	A1	mo or xtal	Includes remote control unit. Two preset channels. May be modified for teletype operation using external exciter. TM 11-827.
SCR-281	1.7 to 2.75	0.025	A3	xtal	Transmitter and receiver for use, primarily on coastal and harbor vessels. Four preset channels. TM 11-244.
10-KW Transmitting Equipment	4.0 to 26.5	10	A1 and Special	mo or xtal	Includes Power Amplifier BC-340, Transmitter BC-339 (exciter), Rectifier RA-22, Water Cooling Unit RU-2 and expansion tank. TM 11-801.
Bunnell 6 KW (amplifier)	0.15 to 0.55	6	A1	—	Includes power amplifier, rectifier and antenna tuning house. Used as amplifier for Transmitter BC-365. TM 11-1055.
Press Wireless PW-15-( )	4.0 to 21.0	15	A1 and Special	xtal	For telegraph or teletype operation. Manual selection of any one of six crystals. TM 11-821 (when published).
Press Wireless PW-40-( )	4.0 to 21.0	40	A1 and Special	mo or xtal	For telegraph or teletype operation. Frequently used as a linear amplifier for single side-band transmitter D-156000. TM 11-835 (when published).
Press Wireless PW-981-( )	2.5 to 26.0	2.5	A1 and Special	mo or xtal	For telegraph or teletype operation. Manual frequency selection of master oscillator, one of five crystals or teletype exciter. TM 11-834.
Western Electric Company D-156000	4.5 to 22.0	2	Special	xtal	Part of entire terminal for single-sideband radio telephone system which includes receiver D-99945 and v-f carrier telegraph equipment. TM 11-832 (when published).

Figure 6-172. Equipment commonly used by command radio, Army Communications Service ***(continued on following page).***

RECEIVING EQUIPMENT

Type	Frequency range (mc)	Type output	Type emission received	Frequency control	Remarks
AN/FRR-3A	2.4 to 23.0	dual bal. 600 ohm	Special	xtal	Used as radio-teletype receiving station. Balanced input. Five preset channels. Tuning range may be extended to 26 mc if desired. Requires one Radio Teletype Terminal Equipment AN/FGC-1. See chapter 3. TM 11-872A.
BC-779-( )	0.1 to 0.4 and 2.5 to 20.0	8w. 600 or 8,000 ohm grounded	A1, A2 and A3	manual tuning	Three of these receivers used with each Schuttig Diversity equipment. Also used as manual receiving station. Balanced input. Similar to Hammarlund super-pro receiver. TM 11-866.
BC-794-( )	1.25 to 40.0	8w. 600 or 8,000 ohm grounded	A1, A2 and A3	manual tuning	Same as BC-779 except for frequency coverage. Balanced input. Similar to Hammarlund super-pro receiver. TM 11-866.
Schuttig Diversity (Mixing unit only)	—	6mw. bal. 600 ohm	A1	manual (af only)	Used as receiving station for high speed tape circuit. Requires three BC-779 or three BC-794 receivers and power supplies. TM 11-2515.
Western Electric Company D-99945	4.5 to 22.0	60mw bal. 600 ohm	Special	xtal	Single-sideband triple detection receiver. Unbalanced input. Used with transmitter D-156000 and v-f carrier telegraph equipment. TM 11-884 (when published).

Figure 6-172. Equipment commonly used by Command Radio, Army Communications Service (continued).

TRANSMITTING EQUIPMENT

Type	Frequency range (mc)	Xmtr output (watts)	Type emission	Frequency control	Remarks
BC-315	2.0 to 18.1	400	A1, A2 and A3	xtal	Point-to-point and ground-to-air. Dial selection of ten preset channel frequencies. No longer procured.
BC-325-( )	1.5 to 18.0	400	A1	mo or xtal	Point-to-point and ground-to-air. Switch selection of master oscillator or any one of five crystal frequencies. No longer procured.
		100	A2, A3		
BC-339-( )	4.0 to 26.5	1,000	A1	mo or xtal	Point-to-point. Switch selection of master oscillator or any one of six crystal frequencies. Also used as exciter for Power Amplifier BC-340. TM 11-836.
BC-340-( ) (amplifier)	4.0 to 26.5	10,000	A1	—	Point-to-point. Provides approx. 10 db increase in power output when used with Transmitter BC-339. TM 11-801.
BC-365-( )	0.15 to 0.55	350	A1	mo	Point-to-point. Manual frequency change. TM 11-828.
BC-401-( )	2.0 to 18.1	400	A1, A2 and A3	xtal	Point-to-point and ground-to-air. Dial selection of ten preset channel frequencies. No longer procured.

Figure 6-173. Equipment commonly used by Airways Section, Army Communications Service.
(continued on opposite page).

Type	Frequency range (mc)	Xmtr output (watts)	Type emission	Frequency control	Remarks
BC-460-( )	2.0 to 18.0	250	A1	mo or xtal	Point-to-point and ground-to-air. Dial selection of ten preset channel frequencies. Late models are the same as Navy TDO transmitter and are master oscillator controlled only. TM 11-812.
		200	A2, A3		
BC-610	2.0 to 18.0	400	A1	mo or xtal	Point-to-point and ground-to-air. Also used as transmitter of SCR-299, SCR-399, and SCR-499. TM 11-813.
		300	A3		
BC-642	4.0 to 20.0	3,000	A1, A3	xtal	Point-to-point. Dial selection of ten preset channel frequencies. No longer procured.
BC-1100-( )	1.5 to 10.0	75	A1	xtal	Point-to-point and ground-to-air. May be remotely controlled. Four preset channels. Part of Radio Transmitter Equipment RC-263. TM 11-816.
		50	A3		
RC-52-( )	1.5 to 7.0	300	A1, A2 and A3	xtal	Point-to-point and air warning. May be remotely controlled. Two preset channels.
T-4/FRC	2.0 to 18.0	400	A1, A2 and A3	mo or xtal	Point-to-point and ground-to-air. May be used in conjunction with Transmitter T-5/FRC for extended frequency coverage. TM 11-820.
T-5/FRC	0.15 to 0.55	600	A1, A2 and A3	mo or xtal	Point-to-point and homing. May be used in conjunction with Transmitter T-4/FRC for extended frequency coverage. TM 11-820.
Aircraft Accessories Corp. 500B	0.275 to 0.4 and 1.6 to 10.0	1,000	A1, A2 and A3	xtal	Point-to-point, ground-to-air and airport control. Includes RF unit, modulator and power supply in one cabinet. Two preset channels.
Federal FT-300	2.0 to 20.0	3,000	A1, A3	xtal	Point-to-point. Eight transmitters are normally used per rectifier and modulator. Dial selection of desired channel.
Pan Amer. Airways 12-ACX-2	1.6 to 24.0	1,200	A1, A3	xtal	Point-to-point. Push button selection of either of two preset channel frequencies.
Pan Amer. Airways 12-GLX-2	0.26 to 1.75	1,200	A1	xtal	Point-to-point and homing. Dial selection of either of two preset channel frequencies.
		750	A2, A3		
Pan Amer. Airways RFA-50	5.0 to 24.0	5,000	A1, A2 and A3	—	Point-to-point. Used as amplifier for Pan American Airways 12-ACX-2 transmitter. No longer procured.
Press Wireless PW-10LF	0.11 to 0.14	10,000	A1	mo	Point-to-point and radio teletype.
Temco 250-GSC	2.0 to 16.0	200	A1, A2 and A3	mo or xtal	Point-to-point and ground-to-air. Switch selection of master-oscillator or any one of four crystal frequencies.
Temco 1000-AG-CW	2.0 to 16.0	1,000	A1	xtal	Point-to-point and ground-to-air. Six preset channels. No longer procured.

Figure 6-173. Equipment commonly used by Airways Section, Army Communications Service (continued on following page):

TRANSMITTING EQUIPMENT

Type	*Frequency range (mc)*	*Xmtr output (watts)*	*Type emission*	*Frequency control*	*Remarks*
Western Electric Company D-151249 (Pan Amer. Airways 4WTFA)	1.6 to 13.2	350	A1	xtal	Point-to-point and ground-to-air. Relay selection of either of two preset channel frequencies. No longer procured.
		100	A3		
Wilcox 96A	2.0 to 12.0	2,500	A1, A3	xtal	Point-to-point and radio-teletype. Eight transmitters are normally used per rectifier. No longer procured. TM 11-2671 (when published).
Wilcox 96C and 96C-3	2.0 to 20.0	3,000	A1, A2 and A3	xtal	Point-to-point and radio-teletype. Four transmitters are normally used per rectifier. TM 11-803 (TM 11-2671 when published).
Wilcox 96-200A or B	0.195 to 0.525	2,000	A1, A2 and A3	mo or xtal	Point-to-point and homing. Wilcox 96-200A no longer procured. TM 11-802.

COMBINED TRANSMITTING AND RECEIVING EQUIPMENT

Type	*Frequency range (mc)*	*Rated xmtr output (watts)*	*Type emission*	*Type mod.*	*Frequency control*	*Remarks*
Collins 18-Q	1.5 to 12.0	25	cw	am	mo or xtal	Transmitter and receiver. Point-to-point and ground-to-air. Switch selection of five crystal frequencies. Same as Navy Model TCS.
		10	voice			
Jefferson Travis 350A	1.5 to 12.0	50	cw	am	mo or xtal	Transmitter-receiver equipment for fixed mobile communication. Switch selection of four crystal frequencies.
		40	voice			
Link 25-FMTR	30 to 40	25	voice	fm	xtal	Commercial police car equipment for providing 2-way mobile communication. Similar to SCR-298.
Link 35-FMTR	30 to 40	35	voice	fm	xtal	Commercial police car equipment for providing 2-way mobile communication. Similar to SCR-298-C.
Link 50 UFS	30 to 40	50	voice	fm	xtal	Self contained transmitter, receiver and power supply. For fixed control station in mobile net.
Link 1498	70 to 100	50	voice	fm	xtal	Self contained transmitter, receiver and power supply. For providing radio telephone communication when essentially line-of-sight operation is possible.
Link 1505	70 to 100	250	voice	fm	xtal	Self contained transmitter, receiver and power supply. Similar to Link 1498 except provides approx. 7-db greater power output.

Figure 6-173. Equipment commonly used by Airways Section, Army Communications Service *(continued on opposite page).*

COMBINED TRANSMITTING AND RECEIVING EQUIPMENT

Type	*Frequency range (mc)*	*Rated xmtr output (watts)*	*Type emission*	*Type mod*	*Frequency control*	*Remarks*
AN/TRC-13 (Motorola FMTR-50 BW.)	30 to 40	50	voice	fm	xtal	Commercial police type of transmitting and receiving equipment for fixed control station in mobile net. Transmitter and receiver each have built-in power supply.
AN/VRC-2 (Motorola FMTR-25 VM or FMTR-30 DW)	30 to 40	25	voice	fm	xtal	Commercial police car type of equipment for providing 2-way mobile communication. Separate transmitter and receiver, each with built-in power supply. TM 11-607 (when published).
AN/VRC-4	xmtr, 1.7 to 8.7 rcvr, 0.19 to 0.51 & 1.7 to 8.7	25	cw / voice	am	mo or xtal	Transmitting and receiving equipment for crash truck use. Switch selection of master-oscillator (4.0 to 7.0 mc) or any one of four crystal frequencies. In addition, receiver is tuneable from 0.19 to 0.51 mc. TM 11-829.

RECEIVING EQUIPMENT

Type	*Frequency range (mc)*	*Type output*	*Type emission received*	*Frequency control*	*Remarks*
AN/FRR-3A (Press Wireless diversity)	2.4 to 23.0	into AN/FGC-1	A1, A2, A3 & Special	xtal	Point-to-point and radio-teletype. Balanced input. Five preset channels. Tuning range may be extended to 26 mc if desired. Used with Radio Teletype Terminal Unit AN/FGC-1. TM 11-872A.
AN/GRR-2 (Hallicrafters SX-28)	0.55 to 42	speaker or headset, 500 or 5,000 ohms	A1, A2 & A3	manual tuning	Point-to-point and ground-to-air. Balanced input. Table model. Built-in power supply. Separate loud speaker. TM 11-874.
AN/GRR-3 (National NC-100-ASC)	0.2 to 0.4 & 1.5 to 30	speaker or headset	A1, A2 & A3	manual tuning	Point-to-point and ground-to-air. Balanced input. Table model. Built-in power supply. Separate loud speaker.
Federal 128-AY	0.015 to 0.65	speaker or headset	A1, A2 & A3	manual tuning	Marine or fixed station service. Unbalanced input. Table model. Built-in power supply. TM 11-858.
Hallicrafters S-22-R	0.11 to 1.5 & 1.7 to 18.0	built-in speaker, or headset	A1, A2 & A3	manual tuning	Marine or fixed station service. Unbalanced input. Table model. Built-in power supply.
Hallicrafters S-27	27 to 145	speaker or headset, 500 or 5,000 ohms	A1, A2, A3 & FM	manual tuning	Airport control and air warning. Balanced input. Table model. Built-in power supply.
Hallicrafters S-29	0.54 to 30.5	built-in speaker, or headset	A1, A2 & 43	manual tuning	Highly portable for miscellaneous monitoring. Uses built-in telescoping whip antenna.

Figure 6-173. Equipment commonly used by Airways Section, Army Communications Service *(continued on following page).*

Type	*Frequency range (mc)*	*Type output*	*Type emission received*	*Frequency control*	*Remarks*
Hallicrafters S-36	27.8 to 143	speaker or headset, 500 or 5,000 ohms	A1, A2, A3 & FM	manual tuning	Airport control and air warning. Similar to Hallicrafters S-27 receiver except treated for tropical use. Balanced input. Table model. Built-in power supply.
Hammarlund SP-110-LX (super pro) (BC-779-( ))	0.1 to 0.4 & 2.5 to 20	speaker or headset, 600 or 8,000 ohms	A1, A2 & A3	manual tuning	Airport control, point-to-point and ground-to-air. Balanced input. Modified table model. Separate power supply. Operates on 25-cycle supply or batteries. TM 11-866.
Hammerlund SP-210-LX (super pro) (BC-779-( ))	0.1 to 0.4 & 2.5 to 20	speaker or headset, 600 or 8,000 ohms	A1, A2 & A3	manual tuning	Airport control, point-to-point and ground-to-air. Balanced input. Rack mounting. Separate power supply. Operates on 60-cycle supply or batteries. TM 11-866.
National HRO	1.7 to 30	speaker or headset	A1, A2 & A3	manual tuning	Point-to-point and ground-to-air. Balanced input. Table mounting. Separate power supply. Uses plug-in coils which are inserted as a unit.
Wilcox CW3	1.15 to 25.5	speaker or headset	A1	xtal	Point-to-point and ground-to-air. Balanced input. Rack mounting. Uses plug-in coils. Eight CW3 receivers in a prewired rack, are available as Wilcox 113A Receiver Bay. TM 11-853 (when published).
Wilcox 4 CW3-D	2.0 to 26	into AN/FGC-1	Special, A1	xtal	For radio-teletype service. Balanced input. Used with Radio Teletype Terminal Unit AN/FGC-1 (see chapter 3). Four preset channels. The 4 CW3-D is an assembly of four CW3-D units in a single cabinet. TM 11-2204.
Wilcox F3	1.9 to 16.5	speaker or headset	A2, A3	xtal	Point-to-point and ground-to-air. Airport control. Balanced input. Rack mounting. TM 11-853 (when published).

Figure 6-173. Equipment commonly used by Airways Section, Army Communications Service. (continued).

Type[a], [b]	Frequency range (mc)	Rated xmtr output (watts)	Type emission	Frequency control	Remarks
MM	2 xmtrs, 0.35 to 1.0 & 3.0 to 18.1 2 rcvrs, 0.2 to 2.0 & 2.0 to 20.0	100 25 25	cw tone voice	mo	Portable transmitting and receiving equipment composed of model TBW transmitting equipment and model RBM receiving equipment. Intended, primarily, for use in establishing an advance base radio station.
MU MV MW MX MAB	2.3 to 2.8 2. 8 to 3.3 3.3 to 3.9 3.9 to 4.6 2.3 to 4.6	0.2	voice	xtal	Light weight battery operated, two-way communication set for use by paratroopers. This series was originally designated MP but was later redesignated MU, MV, MW, and MX according to the frequency range. The MAB covers the frequency range of the series.
RBM, −1 to −3	0.20 to 2.0 & 2.0 to 20.0	—	cw tone voice	manual tuning	Semiportable receiving equipment intended for use where transportation over wet and rough country is to be expected. Includes two superheterodyne receivers; normally used with semiportable transmitting equipment model TBW.
RBQ	132 to 156	—	voice tone	xtal	Single frequency, superheterodyne shore receiver used with model TDG transmitter and 42A1 carrier telegraph system as a receiving terminal of a point-to-point v-h-f link.
RBZ	2.0 to 5.8	—	tone	manual tuning	Light weight, battery operated personal receiver for shore use. Superheterodyne receiver carried on operator's chest in canvas holder; uses steel helmet as an antenna.
RCK	115 to 156	—	voice	xtal	Receiver for use on aircraft carriers and at shore stations for communication between aircraft and ship and shore stations. Selection of four operating frequencies by means of switch plus ganged tuning of r-f circuits. Designed to reduce radiation from oscillator.
TBS-3	60 to 80	50 50	voice tone		Transmitting and receiving equipment for installation on surface craft or submarine for intercommunication between task forces, convoy vessels and others.
TBW, −1	0.35 to 1.0 & 3.0 to 18.1	100 25 25	cw tone voice	mo	Portable transmitting equipment; two transmitters; intended, primarily, for use in establishing an advance base station. Commonly used with receiving equipment model RBM and when so used is known as Navy model MM portable transmitting and receiving equipment.
TBX, −1 to −3	xmtr, 2.0 to 4.525 rcvr, 2.0 to 8.0	9 3	cw voice	mo or xtal	For ship and shore communication. Major units are supplied with canvas pack carrying cases. Transmitter operates from hand-driven generator and receiver from battery pack.
TBY, −1, −2	28 to 80	0.5	voice tone	mo (xtal cal.)	Pack transmitting and receiving equipment intended primarily for use by Marines. May be operated by one man either in the field or while being transported.

[a] All sets are amplitude modulated.
[b] Many of these radio sets may be used as substitutes for the tactical radio sets for ground use in figure 6-169.

Figure 6-174. U. S. Navy radio equipment
(continued on following page).

TACTICAL EQUIPMENT

Type[a, b]	*Frequency range (mc)*	*Rated xmtr output (watts)*	*Type emission*	*Frequency control*	*Remarks*
TCS, −1 to −5	1.5 to 12.0	25	cw	mo or xtal	Semiportable equipment designed according to commercial standards. Used extensively on patrol and landing craft, reconnaissance vehicles, and for similar purposes. Switch selection of any one of four crystal controlled frequencies in each of the three bands.
		15	voice		
TCY	0.5 only	5	tone	mo	Portable emergency lifeboat transmitter for use, primarily, by inexperienced personnel.
TDG	132 to 156	12	voice	xtal	Transmitting equipment used with model RBQ receiver and 42A1 carrier telegraph system as a transmitting terminal of a point-to-point v-h-f circuit.

AIRBORNE EQUIPMENT

Type[a]	*Frequency range (mc)*	*Rated xmtr output (watts)*	*Type emission*	*Frequency control*	*Preset channels*	*Power source*	*Remarks*
AN/ARC-1	100 to 156	6	voice	xtal	10	28v, dc	For 2-way plane-to-plane and plane-to-ground communication. Nine main channels are provided plus one guard channel which may be simultaneously monitored.
AN/ARC-4	140 to 144	6	voice	xtal	4	28v, dc	For 2-way plane-to-plane and plane-to-ground communication. Three main channels are provided plus one guard channel on 140.58 mc which may be simultaneously monitored.
AN/ARC-4X (Western Electric Company 233A)	140 to 144	6	voice	xtal	4	28v, dc or 14v, dc	Same as AN/ARC-4 except may be operated on 14 or 28v, dc.
AN/ARC-5 (ATA/ARA)	*l-f, m-f, & h-f units* xmtrs, 0.5 to 9.1 rcvrs, 0.19 to 9.1	36	cw	mo (xtal cal.)	1 (per xmtr.)	28v, dc	For 2-way m-f, h-f, and v-h-f communication. The frequency range shown for the l-f, m-f, and h-f components is covered by eight transmitters and five receivers and the v-h-f range by one transmitter and one receiver which mount in the same rack with the l-f, m-f, and h-f components. Transmitters and receivers are usually installed in groups of two or three. (The ATA/ARA is similar but does not include v-h-f units and covers only the transmitting range of 2.1 to 9.1 mc, using five transmitters similar to those used with SCR-274-N. ATA/ARA—VHF consists of the v-h-f transmitting and receiving components only.)
			tone				
		12	voice				
	v-h-f units 100 to 156	6	voice	xtal	4	28v, dc	

[a] All sets are amplitude modulated.
[b] Many of these radio sets may be used as substitutes for the tactical radio sets for ground use in figure 6-169.

Figure 6-174. U. S. Navy radio equipment
(continued on opposite page).

AIRBORNE EQUIPMENT

Type[a]	*Frequency range (mc)*	*Rated xmtr output (watts)*	*Type emission*	*Frequency control*	*Preset channels*	*Power source*	*Remarks*
AR-10A (Harvey Wells)	0.195 to 10.0	—	cw tone voice	manual tuning & xtal	12	14v, dc	Commercial receiving equipment. Has dual audio output and may be remotely controlled. Manual tuning range 0.195 to 8.0 mc.
ATB/ARB	xmtr, 2.3 to 9.05 rcvr, 0.195 to 9.05	55 35	cw tone voice	mo	2	28v, dc	This equipment includes a single transmitter and a 4-band receiver. Installed in a wide variety of aircraft.
ATC (AN/ART-13)	0.20 to 1.5 & 2.0 to 18.1	90	cw tone voice	mo	11	28v, dc	Transmitting equipment for aircraft use; selection of one manual tuning channel between 0.2 and 1.5 mc and selection of ten preset channels between 2.0 and 18.1 mc. Used with model ARA, ARB, and RAX-1 receivers. (Superseded by in improved version, that is, transmitter AN/ART-13, used by the AAF with Receiver AN/ARR-11 as a replacement for SCR-287.)
AVR-7H (Radio Corp. of America)	0.195 to 0.42 0.495 to 1.4 & 2.3 to 6. 7	—	cw tone voice	manual tuning & xtal	2	14v, dc	Commercial receiving equipment which provides two crystal controlled channels or continuous tuning over the entire range.
AVT-12B (Radio Corp. of America)	2.6 to 6.5	30	cw voice	xtal	4	14v, dc	Commercial transmitting equipment for aircraft use. Used with Receiver AVR-7H.
AVT-23 (Radio Corp. of America)	3.0 to 12.5	15	cw voice	xtal	4	28v, dc or 14v, dc	Commercial transmitting equipment for aircraft use. Used with Receiver AVR-7H.
GF/RU	xmtr, 3.0 to 4.525 & 6.0 to 9.05 rcvr, 0.195 to 13.575	15	cw tone voice	mo	none	28v, dc or 14v, dc	This equipment consists of one transmitter and one receiver each using plug-in coils. Similar to Radio Sets SCR-183 and SCR-283. Transmitter GF-11 and Receiver RU-16 operate on 14v, dc; GF-12 and RU-17 operate on 28v, dc.
GO-9	0.30 to 0.60 & 3.0 to 18.1	100 70	cw tone	mo	none	120v. 600/800 cycle ac & 28v. or 14v, dc	Intended for installation in Navy patrol, land or seaplanes. Consists of a l-f transmitter and a h-f transmitter either of which may be operated from the common rectifier unit. Commonly used with receiving equipment model RAX-1.

[a] All sets are amplitude modulated.

Figure 6-174. U. S. Navy radio equipment
(continued on following page).

Type[a]	*Frequency range (mc)*	*Rated xmtr output (watts)*	*Type emission*	*Frequency control*	*Preset channels*	*Power source*	*Remarks*
RA-1 (Bendix)	0.15 to 1.5 & 1.8 to 15.0	—	cw tone voice	manual tuning	none	28v, dc or 14v, dc	Commercial multiband receiving equipment. May be locally or remotely operated.
RA-10 (Bendix)	0.15 to 1.1 & 2.0 to 10.0	—	cw tone voice	manual tuning	—	28v, dc or 14v, dc	Commercial multiband receiving equipment. Remotely controlled only.
RAX-1	0.20 to 27.0	—	cw tone voice	manual tuning	1 (per rcvr)	28v, dc	Receiving equipment used in the larger airplanes. The frequency range shown is covered by three multiband receivers.
RTA-1B (Bendix)	0.25 to 13.0	50	voice	xtal	10	14v, dc	Commercial transmitting and receiving equipment. May be remotely or locally operated.
TA-2 (Bendix)	0.3 to 0.6 &	30 20	cw tone voice	xtal	8	28v, dc	Remotely operated commercial transmitting equipment. (Model TA-2G covers only 2.9 to 15.0 mc; model TA-2J covers both frequency ranges shown.)
	2.9 to 15.0	100 75	cw tone voice				
TA-6 (Bendix)	2.8 to 12.0	4	cw voice	xtal	2	28v, dc or 14v, dc	Commercial transmitting equipment. May be remotely or locally operated.
TA-12 (Bendix)	0.3 to 0.6 & 3.0 to 1.20	35	cw tone voice	mo	4	28v, dc	Commercial transmitting equipment. May be remotely or locally controlled. (Frequency range shown is that covered by model TA-12C. Other models may cover different frequency ranges.)
29A (Western Electric Company)	0.2 to 15.0	—	cw tone voice	xtal	10	14v, dc	Commercial receiving equipment. Provides dual audio outputs.

[a] All sets are amplitude modulated.

Figure 6-174. U. S. Navy radio equipment (continued).

BRITISH ARMY COMBINED TRANSMITTER AND RECEIVER

Type	Frequency range (mc)	Xmtr output (watts)	Type emission	Remarks
1	4.2 to 6.8	0.5	cw, voice	Infantry Brigade and Royal Artillery set.
5 L.P.	2.4 to 20	500	cw, tone, voice	Medium to long range transmitter for fixed stations. Mo or crystal control.
5 H.P.	0.2 to 0.6 & 3.0 to 20	2,000	cw, tone, voice	Long range transmitter for fixed stations. Mo or crystal control.
9	1.875 to 9.0	10	cw, tone, voice	Medium range set for Armored Fighting Vehicle use and Divisional communication. Mo control.
11 L.P.	4.2 to 7.5	1.5	cw, voice	Infantry, mobile Brigade and Royal Artillery Regiment set. Mo control.
11 H.P.	4.2 to 7.5	7	cw, voice	Same use as 11 L.P. and for mechanized cavalry, some Armored Fighting Vehicles and Divisional communication.
12 L.P.	1.2 to 17.5	25	cw	Transportable Division-Corps set. Mo or crystal control.
		6	tone, voice	
12 H.P.	1.2 to 17.5	300	cw, tone, voice	Division and Corps high power set. Mo or crystal control.
17 (MK II)	44.0 to 61.0	0.5	voice	Searchlight control transceiver for use between searchlight section headquarters and details.
18 (MK I, II & III)	6.0 to 9.0	0.5	cw, voice	Infantry Battalion to Company man-pack set.
18 M.	2.0 to 5.0	0.5	cw, voice	Same as 18 set except lower frequency. For special uses and Naval Forward Observation Officer parties.
Collins 18 M.	2.0 to 16.0	15	cw	Special; not in general use. Mo or crystal control.
		5	voice	
19 (MK I)	2.5 to 6.25 & 230 to 255	10	cw, tone, voice	Armored Fighting Vehicle set for communication between tanks.
19 (MK II & III)	2.0 to 8.0 & 230 to 255	10	cw, tone, voice	Same as 19 MK I except frequency range. Mo control.
21	4.2 to 7.5 & 19.0 to 31.0	2	cw, tone, voice	Royal Artillery Regiment set to replace 11 L.P. set. Mo control.
22	2.0 to 8.0	3	cw, tone, voice	Divisional and Regimental set. May be used as vehicular, man-pack (3-man load), or as ground set.
23	1.2 to 15.0	250	cw, tone, voice	Long range mobile set.
26	85.0 to 95.0	65	voice	Multichannel point-to-point transmitter. Six duplex channels using group modulation of transmitter.

Figure 6-175. Principal British radio sets
(continued on following page).

Type	*Frequency range (mc)*	*Xmtr output (watts)*	*Type emission*	*Remarks*
33	1.2 to 17.5	250	cw	Long range line of communication set. Normally carried in 3-ton 4 x 4 vehicle but can be set up as a ground station. Mo or crystal control.
		60	tone, voice	
34	157 & 230 to 255		voice	Tentative characteristics; dual channel, crystal controlled FM set for local use at headquarters.
36	10 to 60	25	cw, tone, voice	AA gun control set. Capable of modulation at carrier frequencies required by Apparatus Carrier Telephone 1+1.
37	370 to 380	0.5	voice, tone	Special; set is in a telephone handset, batteries in a belt.
38 (MK I, II & III)	7.3 to 8.8	0.5	voice	Light infantry man-pack set. Mo control.
0-43	2 to 12	300	cw, voice	Canadian version of the 33 set.
46	3.6 to 4.3 5.0 to 6.0 6.4 to 7.6 7.9 to 9.1	1	voice, tone	Commando and paratroop set for combined operations and jungle warfare. Crystal controlled and has three preset channels (in same band).
48	5.9 to 9.1	0.5	cw, voice	Infantry Battalion and R.A. Regiment short range communication man-pack set. Has built-in crystal calibrator.
53	1.2 to 17.5	250	cw, tone, voice	Provisional data; long range set for Division and Corps communication. An improvement of the 12 H.P. set.
57	85 to 95	7	voice	V-h-f point-to-point set for duplex telephony using crystal control of transmitter and receiver.
68P	1.7 to 3.0	0.75	cw, voice	Used by Airborne troops and combined operations. Is modified form of 18 set. Transmitter can be crystal controlled.
68Q, 68R	3.0 to 5.2	0.75	cw, voice	68Q is similar to 68P set except has no provision for crystal control. 68R is similar to 68Q set except has provision for crystal control.
76A	2.0 to 12.0	4	cw	Provisional data; for airborne troops and jungle warfare. Modified Naval type 5G set. Crystal control only.
76P, 76Q	2.0 to 12.0	20	cw	Provisional data; for airborne troops, jungle warfare and combined operations. Crystal control only. 76P operates on 12 v, dc. 76Q operates on 100 to 250 volts, 50-cycle ac power pack.
Golden Arrow	2.5 to 17.5	1,000		Transportable, for point-to-point communication.
AD67	0.272, 0.545 1.5 to 20	75		Transportable, for point-to-point communication.

Figure 6-175. Principal British radio sets

(continued on opposite page).

R.A.F. COMBINED TRANSMITTER AND RECEIVER

Type	Frequency range (mc)	Xmtr output (watts)	Type emission	Remarks
TR-9B	4.3 to 6.0		voice	For 2-way fighter aircraft communication.
TR-9D	4.3 to 6.6	3		For single-seater aircraft or ground communication.
TR-9F	4.3 to 6.6		voice	For multi-seater aircraft.
TR 1091	1.222 to 1.539 & 2.0 to 3.409		cw, tone, voice	Airborne transmitter-receiver.
TR 1133B	100 to 120	2	voice, tone	Airborne v-h-f voice transmitter-receiver with facility for tone operation for special circumstances.
TR 1143	100 to 124	5	voice, tone	Airborne voice communication with tone operation on special frequency.
TR 1150	60	0.4	voice	Portable 2-way Balloon Command communication.
TR 1304	3.0 to 10.0	3	voice	Remote controlled aircraft transmitter.
5	2.3 to 2.8 & 4.0 to 7.0	15	voice	Portable ground station transmitter-receiver.
19 (MK II)	2.0 to 8.0	10	cw, tone, voice	Airborne transmitter-receiver used in fighter reconnaissance.

R.A.F. TRANSMITTING EQUIPMENT

Type	Frequency range (mc)	Xmtr output (watts)	Type emission	Remarks
T1083	0.136 to 0.50 & 3.0 to 15.0	30	cw, tone, voice	Airborne transmitter; used in conjunction with receiver R1082.
T1087	1.5 to 20.0	400	cw	Ground station.
		100	tone, voice	
T1090	0.545 to 0.857 & 1.222 to 6.667	40	cw, tone, voice	Mobile ground station.
T1115	0.142 to 20.0		cw, tone, voice	General purpose aircraft transmitter; used in conjunction with receiver R1116.
T1131	99 to 126	50	voice, tone	V-h-f ground station transmitter.
T1154	0.20 to 0.50 & 3.0 to 10.0	40	cw, voice	Aircraft or ground station transmitter; used in conjunction with receiver R1155.
T1190	1.5 to 15.0	350	cw, voice	Ground station transmitter.
T1204	2.5 to 5.7		cw	Point-to-point ground station.
T1223	2.5 to 5.7		cw	Same as transmitter T1204 except operates on 12V battery.

Figure 6-175. Principal British radio sets

(continued on following page).

R.A.F. TRANSMITTING EQUIPMENT

Type	Frequency range (mc)	Xmtr output (watts)	Type emission	Remarks
TA-2J	0.30 to 0.60 &	30	cw	Remote controlled aircraft transmitter. Provides eight crystal controlled channels. (Bendix.)
		20	tone, voice	
	2.9 to 15.0	100	cw	
		75	tone, voice	
TA-12B	0.30 to 0.60 & 3.0 to 7.0	35	cw, tone, voice	Aircraft transmitter with four preset channels which may be remotely or locally controlled. (Bendix.)
TA-12C	0.30 to 0.60 & 3.0 to 12.0	35	cw, tone, voice	Aircraft transmitter with four preset channels which may be remotely or locally controlled. (Bendix.)
SWB 8	4 to 23 or 3 to 22.2	3,500	cw	Fixed service ground transmitter. Also used by the Royal Navy. Mo control.

R.A.F. RECEIVING EQUIPMENT

Type	Frequency range (mc)	Type emission received	Remarks
R1082	0.111 to 15.0	cw, tone, voice	Airborne receiver.
R1084	0.12 to 20.0	cw, tone, voice	Ground station receiver. Normally used in conjunction with transmitter T1087.
R1100	1.2 to 1.5 & 2.0 to 3.0	cw, tone, voice	Portable field receiver for operation under tropical conditions.
R1129	2.0 to 30.0	cw	Ground station receiver working into tape recording device.
R1132A	100 to 124	voice	Ground station receiver for v-h-f or for direction finding. Unmodulated carrier used for D/F.
R1155B	0.075 to 1.5	cw, tone, voice	Airborne for communication and direction finding.
R1224	1.5 to 7.0	cw	Used with transmitters T1204 and T1223.
RA-1B	0.15 to 1.5 & 1.8 to 15.0	cw, tone, voice	Manual tuning, multi-band aircraft receiver which may be remotely or locally operated. (Bendix.)
RA-1J	0.15 to 1.5 & 2.5 to 20.0	cw, tone, voice	Airborne communication and direction finding receiver similar to RA-1B except for frequency. (Bendix.)
RA-10DA	0.15 to 1.1 & 2.0 to 10.0	cw, tone, voice	Remote controlled, manual tuning, multiband aircraft receiver. Operates on 14v, dc. (Bendix.)
RA-10DB	0.15 to 1.1 & 2.0 to 10.0	cw, tone, voice	Remote controlled, manual tuning, multiband receiver for airborne and mobile service. Operates on 28v, dc. (Bendix.)

Figure 6-175. Principal British radio sets

(continued on opposite page).

ROYAL NAVY SHORE EQUIPMENT

Type	*Frequency range (mc)*	*Xmtr output (watts)*	*Type emission*	*Remarks*
65	3.0 to 20.0	15		Fixed service in assault stages.
T1190	1.5 to 15.0	800		Transmitter for fixed service.
52 ERT	0.90 to 13.5	15		Port wave.
G.P. Sets (R.A.F.)	1.5 to 15.0	15		Port wave.
SWB 8	4 to 23 or 3 to 22.2	3,500	cw	Fixed service ground transmitter. Also used by the R.A.F. Mo control.

Figure 6-175. Principal British radio sets (continued).

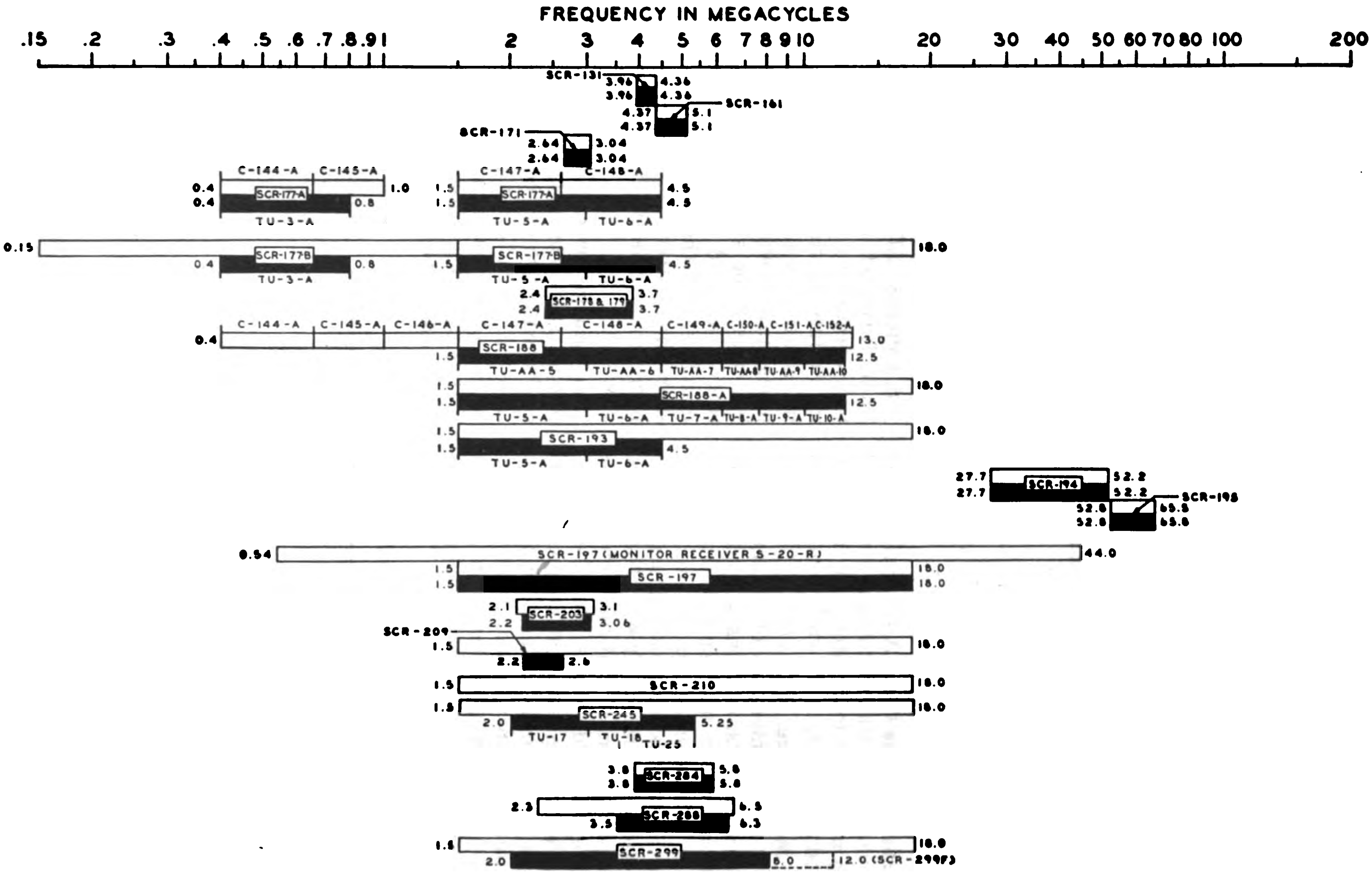
b. Frequency Range Chart. A frequency range chart covering tactical radio sets for ground use, both amplitude modulated and frequency modulated radio sets, is shown in figure 6-176.

c. Set Maintenance. TM 11-310 Schematic Diagrams for Maintenance of Ground Radio Communication Sets, contains a condensation of information for maintenance. It is presented as a supplement to the information given in the various technical manuals of the TM 11- series for particular sets. The manual is in loose-leaf form, so that additional sheets or reissues of old sheets can be added. Changes, which are issued at frequent intervals, include additional listings. This publication contains reference data on radio symbols, electrical units, special abbreviations, resistor and capacitor color codes and includes a vacuum tube cross-reference guide.

d. Batteries. SB 11-6 Dry Battery Supply Data, furnishes information on the dry batteries required for operation of all equipment maintained by the Signal Corps. This type of information is needed for a variety of purposes, among which are the determination of batteries to be shipped with initial issues of equipments and to be requisitioned by commanders, and the calculation of over-all and short-time battery requirements for planning purposes, both in the field and at procurement levels.

e. Vacuum Tubes. SB 11-17 Electron Tube Supply Data, contains in part I a listing of equipments which contain electron tubes, showing the tube complement and the spare tube factors for each. Part II consists of a listing of tubes, showing the equipments in which each tube is used.

FREQUENCY COVERAGE OF AMPLITUDE MODULATED TACTICAL RADIO SETS FOR GROUND USE



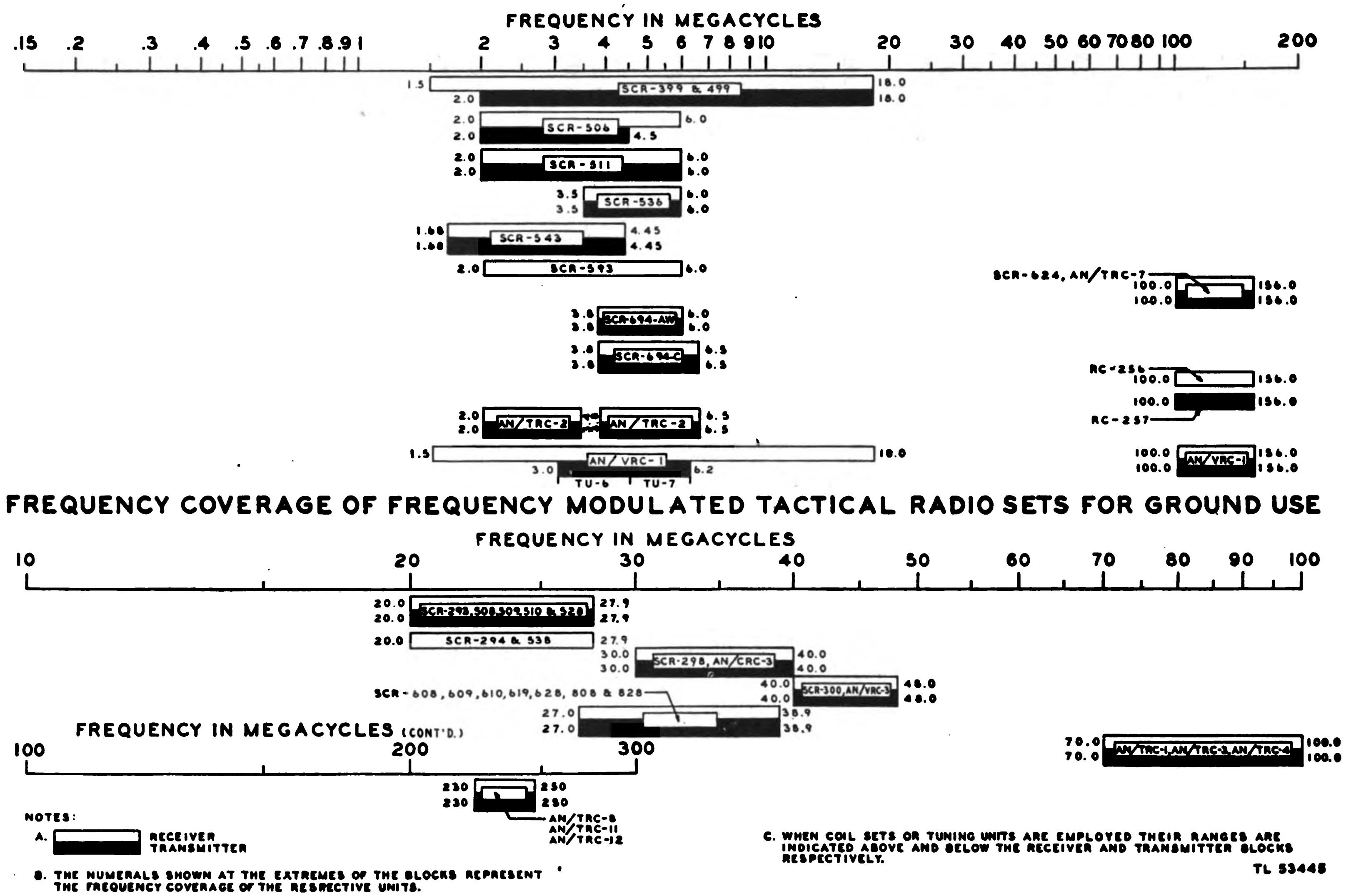


Figure 6-176. Frequency coverage chart.

CHAPTER 7

POWER

Section I. POWER SUPPLIES

701. GENERAL.

Among the several sources of power supply which can be considered are commercial power, dry batteries, storage batteries, engine-driven generators, rectifiers, etc. Each type has certain advantages and certain limitations. Depending upon the application involved, they may be used individually or in combinations.

702. COMMERCIAL POWER.

a. Types. Commercial power throughout the world consists of both a-c and d-c supplies, either or both of which may be found in some localities. A wide range of frequencies and voltages will be encountered. From recent surveys made, frequencies anywhere from 20 to 76 cycles are known to exist, and a-c voltages from 100 to 260 nominal, will accompany them. To design communication equipment which could be universally operated on such widely differing commercial power supplies is obviously not economical. In view of this, most a-c operated signal equipment has been designed to operate on power services of 50-60 cycles with nominal voltages of 115 and 230 having variations of plus or minus 10 percent. Where commercial frequencies fall outside of these limits it is usually easiest to use one or more engine-alternator sets of the types discussed in paragraph 710. Where the frequency is 50-60 cycles but the service voltage is outside the limits of 115 or 230 plus or minus 10 percent, transformers with multitap primary windings should be used (par. 705). Commercial power is often subject to unforeseen interruptions beyond immediate control. In view of this, it should be augmented by the use of one or more engine generators for standby purposes at important installations. D-c commercial power is not so readily adaptable to communication equipment except possibly in the case of some telegraph equipment such as motors of teletypewriters, etc., which have been arranged to operate from either dc or ac. The reliability of d-c commercial power is usually no better than that of a-c commercial power.

b. Power Services Throughout World. Information concerning the prevailing electrical frequencies, voltages, etc. of commercial power supplies of cities and countries throughout the world may be obtained from TM 11–487.

Section II. BATTERIES

703. DRY BATTERIES.

a. General. Dry batteries are especially adapted for use where small amounts of power are needed and portability is required. They are capable of furnishing high output per unit of weight or volume under suitable conditions of use and they will continue to provide service under many adverse conditions. However, serious impairment or failure may result under various conditions that may be encountered.

b. Aging. Dry batteries, whether on open circuit or under discharge, deteriorate in serviceability because of internal losses. The rate of deterioration varies with the size and type of cell and with temperature and humidity. In general, the smaller the size of cell the shorter will be its shelf life. High temperatures greatly decrease shelf life and low tem peratures increase it.

c. Refrigeration. Since the keeping qualities of batteries are aided by low temperatures, refrigeration should be used wherever possible during storage and shipment, and until the batteries are issued for service. Number 6 dry cells such as Battery BA–23 kept in cold storage for 12 months at 34° F have shown full capacity on subsequent test. Small size cells will be benefited, also, but not to the same extent. Storing batteries under these favorable conditions reduces the frequency of replacements, thus conserving shipping space.

d. Effect of Temperature on Capacity. The output obtainable from a dry battery is greater at a high temperature than at normal (70° F) temperature, provided the time of use does not extend over such a long period that the shelf loss is greater than the gain due to the increased chemical activity of the cell. At low temperatures the activity of the cell is decreased and a point may be reached where the cell is unable to deliver any current. The temperature at which this condition occurs depends on the size and type of cell and the load resistance. Except for grid service or very light current drains, dry batteries should be considered inoperative when frozen (—10° F or below). Batteries subjected to low temperatures are not permanently affected even though frozen, but are restored to full capability if their internal temperature is brought back to normal.

e. Excessive Severity of Service. High current drains reduce the battery voltage rapidly, and relatively short life and small output are obtained. The situation is improved by reducing the current drain, by providing more time for recuperation, and by operating to a low cut-off voltage per cell. Thus, for a load requiring a minimum of 4.5 volts, five cells in series will have a cut-off of 0.9 volt per cell as against 1.125 volt for four cells in series and the output will be considerably increased. If the drain is heavy, using two sets of cells in parallel will more than double the output and using two batteries alternately in place of a single battery continuously will also result in increased energy output per cell.

f. Voltage Regulation.

(*1*) The initial voltage of new dry cells is dependent upon the load and for ordinary loads is approximately 1.5 volts. Dry cells reaching the theaters will have lost some of their useful life, and their initial voltage under normal load may be approximately 1.4 volts.

(*2*) For grid service (practically no load) or very light drain services the initial voltage may be as high as 1.55 to 1.60 volts and a high cut-off voltage, 1.3 to 1.4 volts per cell, should be used to insure reliability of operation and to guard against sudden failure of the battery. In such cases the service life will approach the shelf life of the battery.

(*3*) As the severity of the load is increased the initial voltage will be reduced and a progressively lower cut-off voltage is required in order to avoid sacrificing battery output. For ordinary loads, it is desirable to be able to use the battery to a cut-off voltage of 0.9 to 1.1 volts per cell, in which case the average voltage will be about 1.2 to 1.25 volts per cell. Close voltage regulation (where required) can sometimes be accomplished by using a rheostat or by adding extra cells in series as the battery voltage drops off in service.

g. High Humidity. High humidity conditions such as are encountered in the tropics may have a very serious effect upon dry batteries by subjecting them to low continuous drains because of current leakage from cell to cell or across battery terminals. This may be caused by the condensation of moisture upon, or the absorption of moisture by, the battery jackets or assembly materials or the wetting of the packing materials in contact with the batteries. In order to reduce trouble of this nature, special precautions are taken in the manufacture and packing of batteries to be shipped, stored, or used in tropical countries.

h. References. Detailed information concerning dry batteries, their size and terminal arrangements, may be obtained from TM 11–487. Information on their construction, properties, performance, care, and testing will be found in Changes No. 1 to TM 11–430 and TB 11–430–1. Information concerning the quantities of dry batteries required for the operation of equipment is given in SB 11–6. Shelf life and similar information is given in SB 11–30.

704. LEAD STORAGE BATTERIES.

a. General. Storage batteries covered by this manual are largely used as portable sources of moderate amounts of power for the operation of electrical signal communication equipment, and for gasoline and diesel engine starting. They are generally of the automotive or aircraft types, having a compact rugged construction well suited to combat service. The high specific gravity (1,300 to 1,350) electrolyte serves to give maximum capacity in minimum space and good low temperature characteristics.

b. General Properties. Storage batteries are usually contained in moulded hard-rubber cases of three or six cells, or in separate hard rubber or plastic jars assembled into wooden trays, three or six cells per tray. The aircraft types, such as Battery BB–53, have a nonspill construction. Storage batteries are usually shipped in a dry condition, with the electrolyte in separate containers. Premature deterioration from self-discharge and sulphation are prevented by this means. Normally, they are filled with 1.285 (at 80° F) specific gravity electrolyte and charged as required. After discharge from use or long standing, they can be recharged from a source of d-c power such as a rectifier or d-c generator. The discharge and recharge cycle can be repeated; the number of times the cycle can be repeated depending upon such factors as temperature, thickness of plates, type of separators, rate of discharge, and rate of charge.

c. Factors Affecting Capacity and Life. The ampere-hour capacity of a storage battery is affected by temperature, being greater for high temperatures and less for low temperatures. Battery capacities at different temperatures are also affected to some extent by the battery construction used, but will usually come within the following limits:

Temp. °F	*Percent of capacity at 80°F and 20-hour rate*
100	105-110
80	100
0	50-65
—40	20-25

The rate at which current is drawn from a battery on discharge influences the output obtainable at any given temperature. At high currents the voltage will fall at a more rapid rate, and at low currents at a less rapid rate, with the result that less ampere-hours will be obtained from a battery at the higher rate. The life of a battery is shortened if operated for considerable periods at cell temperatures over 110° F. The life of a battery is also shortened if other than distilled water is added to the cells, or charging is prolonged for too long a time and at high rates which cause high cell temperatures and excessive gassing. Permitting a battery to stand in a partially or completely discharged condition for a long period (over one week at 80° F.) of time also tends to shorten its life.

d. Discharge While Idle. A storage battery loses capacity while standing idle and, if it is not used sufficiently to completely discharge it within two months, it should be given a freshening charge. The rate of discharge of batteries while standing idle is negligible at low temperatures but increases rapidly as the temperature increases, and if exposed to tropical conditions it may result in a complete discharge in less than one month.

e. Voltage Regulation. The voltage characteristic of a storage battery is relatively flat, that is, the voltage falls off at a slow rate throughout discharge. For example, the voltage of a fully charged battery at normal load is about 2 volts per cell and averages about 1.95 volts per cell for most of the discharge period. At the end of discharge the voltage falls rapidly, and no advantage is gained by allowing the voltage to fall below the cut-off voltage of 1.75 volts per cell. After discharge the battery should be charged at current rates designated for the particular battery used (TM 11–487). An example of the approximate voltages at which the battery should be recharged (cut-off voltage), is given in percentages of the 20-hour discharge rate, in the following table.

Percent of 20-hour discharge rate	*Cut-off voltage (80°F)*
200	1.70
100	1.75
50	1.77
5	1.81

f. References. Details of storage battery construction and other pertinent data are given in TM 11–430, and descriptive matter on the various types which are available is given in TM 11–487.

Section III. POWER EQUIPMENT

705. TRANSFORMERS.

a. Rectifiers and other a-c operated devices for communication systems are generally designed to operate from a source of alternating current of 115/230 volts ±10 percent at 50-60 cycles. Numerous power services have other operating voltages and it will be necessary to transform these operating voltages to the above mentioned values. For this purpose a line of single-phase air-cooled transformers is available.

b. The multitap transformers used in fixed plant and listed below are *single-phase transformers* designed for operation on 50-60 cycle current. These transformers may be connected to step up or to step down single-phase voltages or they may be banked to handle 3-phase voltages.

c. In general, the primary or input winding of all TF type transformers consists of four separate coils. In some cases each of these coils are tapped to carry 120 volts, 120 volts plus 10 percent and 120 volts minus 10 percent. By connecting these four windings in series, parallel, and series-parallel, voltages from 108 to 528 can be transformed to 120 volts, 240 volts, or 120/240 volts. The secondary or output of all these transformers have two windings. These windings may be connected in series for 240 volts, 2- or 3-wire, and in parallel for 120 volts, 2-wire. TF type transformers are equipped with solderless lugs on both the primary and secondary terminals. These transformers are air cooled and should be installed in a location that will allow ventilation and protection from the weather. An example of the terminal arrangements of Transformers TF–5–A, TF–7–A, TF–9–A, and TF–10–A is shown in figure 7-1.

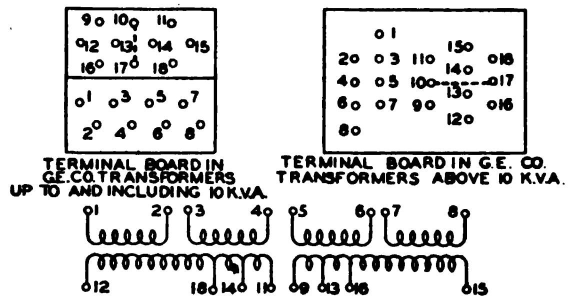


DIAGRAM OF WINDING
TERMINALS 10 AND 17 ARE NOT CONNECTED TO THE TRANSFORMER WINDING. THEY ARE CONNECTED TOGETHER UNDER THE TERMINAL BOARD AND ARE USED WHEN TERMINALS 9-11 OR 16 & 18 ARE TO BE CONNECTED WITH LINKS

PRIMARY INPUT CONNECTIONS		SECONDARY CONNECTIONS	
LINES ON 1 & 8		120 V- 2 WIRE LINES ON 12 & 15	240/120 V-3 WIRE LINES-ON 12-17-15
V.	CONNECT	CONNECT	CONNECT
108	1 TO 3 TO 5 TO 7	9 TO 12 & 11 TO 15	9 TO 10 TO 11
120	AND	12 TO 13 & 14 TO 15	10 TO 13 TO 14
132	2 TO 4 TO 6 TO 8	12 TO 16 & 15 TO 18	16 TO 17 TO 18
216	1 TO 3	9 TO 12 & 11 TO 15	9 TO 10 TO 11
240	2 TO 4 TO 5 TO 7	12 TO 13 & 14 TO 15	10 TO 13 TO 14
264	& 6 TO 8	12 TO 16 & 15 TO 18	16 TO 17 TO 18
432	2 TO 3	9 TO 12 & 11 TO 15	9 TO 10 TO 11
480	4 TO 5	12 TO 13 & 14 TO 15	10 TO 13 TO 14
528	6 TO 7	12 TO 18 & 15 TO 18	16 TO 17 TO 18

CONNECTION INFORMATION FOR GENERAL ELECTRIC COMPANY TYPES:
TF-5-A
TF-7-A
TF-9-A
TF-10-A

TL 54982

Figure 7-1. Terminal arrangements for Transformers TF–5–A, TF–7–A, TF–9–A, and TF–10–A (General Electric Company).

d. When TF type transformers are used to supply single-phase loads from 3-phase circuits, care should be exercised to avoid overloading one or more of the phase legs of the circuit or appreciable unbalancing the phase loads.

e. The capacity of these transformers is as follows:

Type transformer	*Capacity kva*
TF- 5-( )	1.5
TF- 6-( )	3.0
TF- 7-( )	7.5
TF- 8-( )	15.0
TF- 9-( )	37.5
TF-10-( )	75.0

f. Figure 7-2 shows diagrams of various connections of a load to a primary source of 3-phase power through single or banks of TF type transformers.

706. RECTIFIERS.

a. General Types. Rectifiers, as well as power packs which primarily include some form of rectifier, may be classified in three types, namely: tube, dry disc, and vibrator. Available equipments of these types are given in TM 11–487.

b. Application. Examples of applications of rectifiers are: the charging of lead-storage batteries while connected to a telephone load; the routine charging of lead-storage batteries in series or in series-parallel groups where no telephone load is involved; and the direct supply of power to a specific type of equipment, no lead-storage batteries being involved. In connection with the use of such rectifiers for telephone loads, it is necessary to insure that the rectifier output is satisfactory for use on a talking circuit. Filter coils for this purpose are furnished with the rectifiers and mounted within them or furnished separately for external mounting. Where a quiet supply is not required, the use of the filter coil may be dispensed with, especially in the case of separately furnished coils where this can readily be done.

c. Tube Type. Tube type rectifiers are supplied in half-wave and full-wave designs. Some are arranged for operation on 115 volts ac, some for 230 volts, while others are arranged for both 115 and 230 volts, 50 and 60 cycles. Tube type rectifiers of the tungar type are available for d-c loads between 2 and 12 amperes, and up to 75 volts. They may be operated in parallel as required to supply larger loads. When used for a telephone load, care should be taken to see that the proper filtering coil is furnished, either as a part of the particular rectifier chosen for the application or separately. Regulated types such as Rectifier RA–43–( ) are available to obtain higher d-c voltages than can be obtained from the tungar type. Regulated tube rectifiers are also used to provide the very-high voltages required for radio transmitters.

d. Dry Disc Type. Dry disc type rectifiers are either of the copper oxide or selenium disc type. They consist essentially of a transformer and varistor unit (copper oxide or selenium) with associated fuses, resistors, filter coils, etc., mounted as a completely assembled unit for mounting on a wall, table, relay rack, shelf, etc. They are usually designed for more or less specific applications and are primarily for smaller outputs than the tube type rectifiers. Like the tube type rectifiers, they are also arranged for operation on a-c supply voltages of 115 and/or 230, 50-60 cycles. In selecting a dry disc type of rectifier for a particular application, the characteristics of the selenium type are such that it has a decided advantage over the copper oxide type where high temperatures are to be encountered, and therefore should be used in preference to the copper oxide type in such instances.

e. Vibrator Type. Most of the vibrator type rectifiers fall in the class known as power packs. Their design is practically always specific to a particular application. Their outputs are necessarily small because of the nature of and limitations inherent in the vibrator elements. High currents through vibrator contacts tend to shorten their life, making frequent replacements necessary. Usually the vibrator type of rectifier is associated directly with a particular radio set or similar equipment. Consequently, their outputs have to meet such specific conditions of voltage and currents that they are rarely adaptable to other applications.

707. POWER PANELS.

a. General. Generally, for the smaller equipments at least, power panels associated with the control of generators, ringing units, rectifiers, small engine sets, etc., are an integral part of the particular equipment, so that no separate power panel for mounting their control equipment is ordinarily required. However, there are a few power panels furnished as separate units such as those for: telephone central office sets, larger engine-alternator sets, automatic engine power transfer, and synchronizing two or more alternators.

b. Telephone Central Office Power Panels. In the case of the large commercial type telephone central office sets, such as for dial equipments, the power panel mounts as a separate piece of equipment, with the apparatus mounted thereon for the control of generators, rectifiers, batteries, and ringing machines. In the case of the larger tactical telephone central office sets, such as the TC–1, a power panel having similar control functions is provided; in these cases the ringing equipment is mounted on the same panel. Panel BD–90 is a typical example of this.

c. Engine-alternator Power Panels. In the case of power panels for standard engine alternator sets (PE–( ) types) the control equipment for the smaller sets is usually mounted on a power panel directly on the set itself as an integral part of it. In the case of the larger sets, a separate power control panel is furnished.

d. Power Transfer Panel CN–22/F.

(*1*) *General Description.* Power Transfer Panel CN–22/F, obtainable with special engineering through Army Communications Service, is an automatic switching arrangement designed to maintain an uninterrupted a-c power supply for the operation of Signal Corps communication equipment. It requires

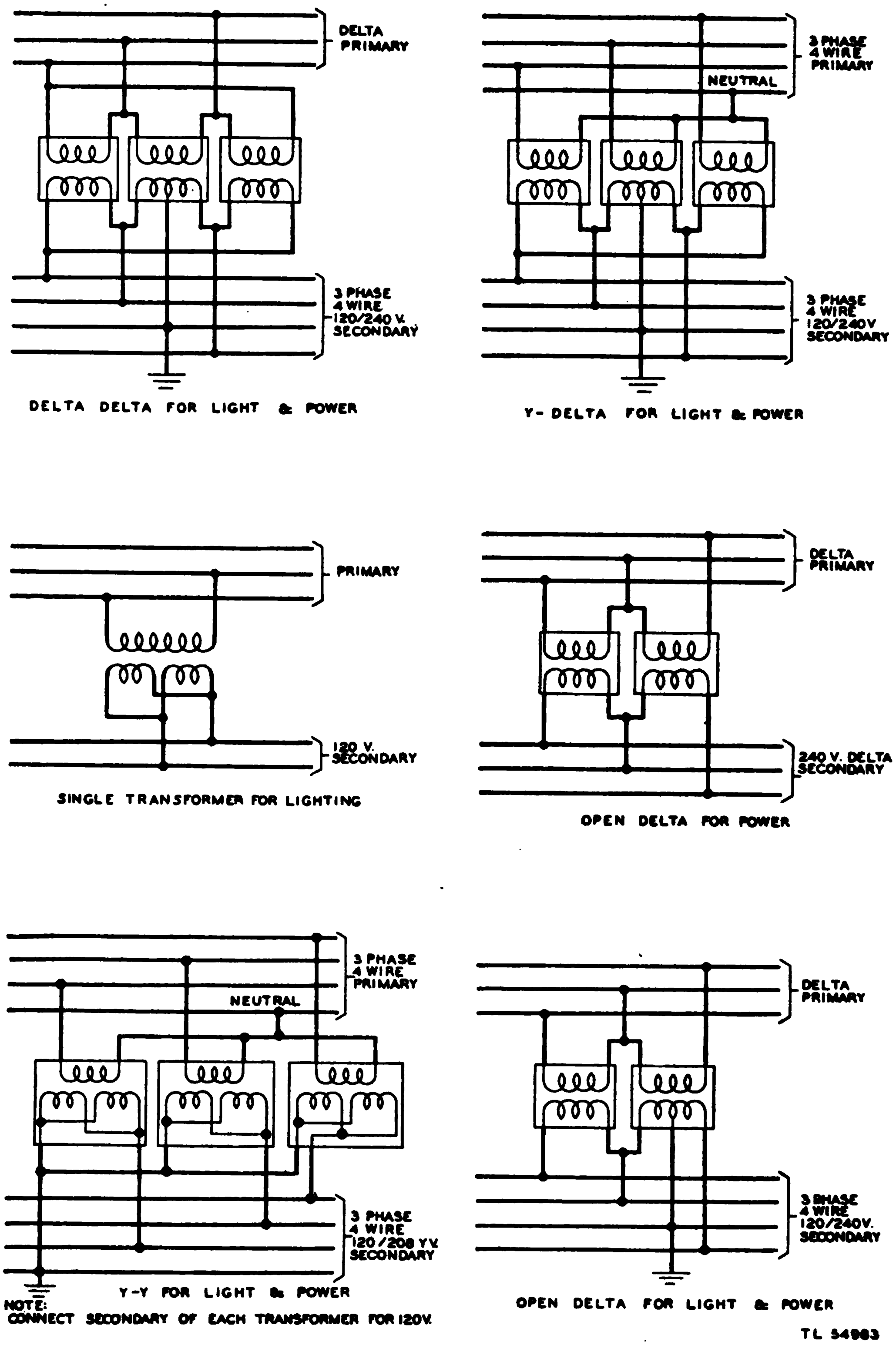
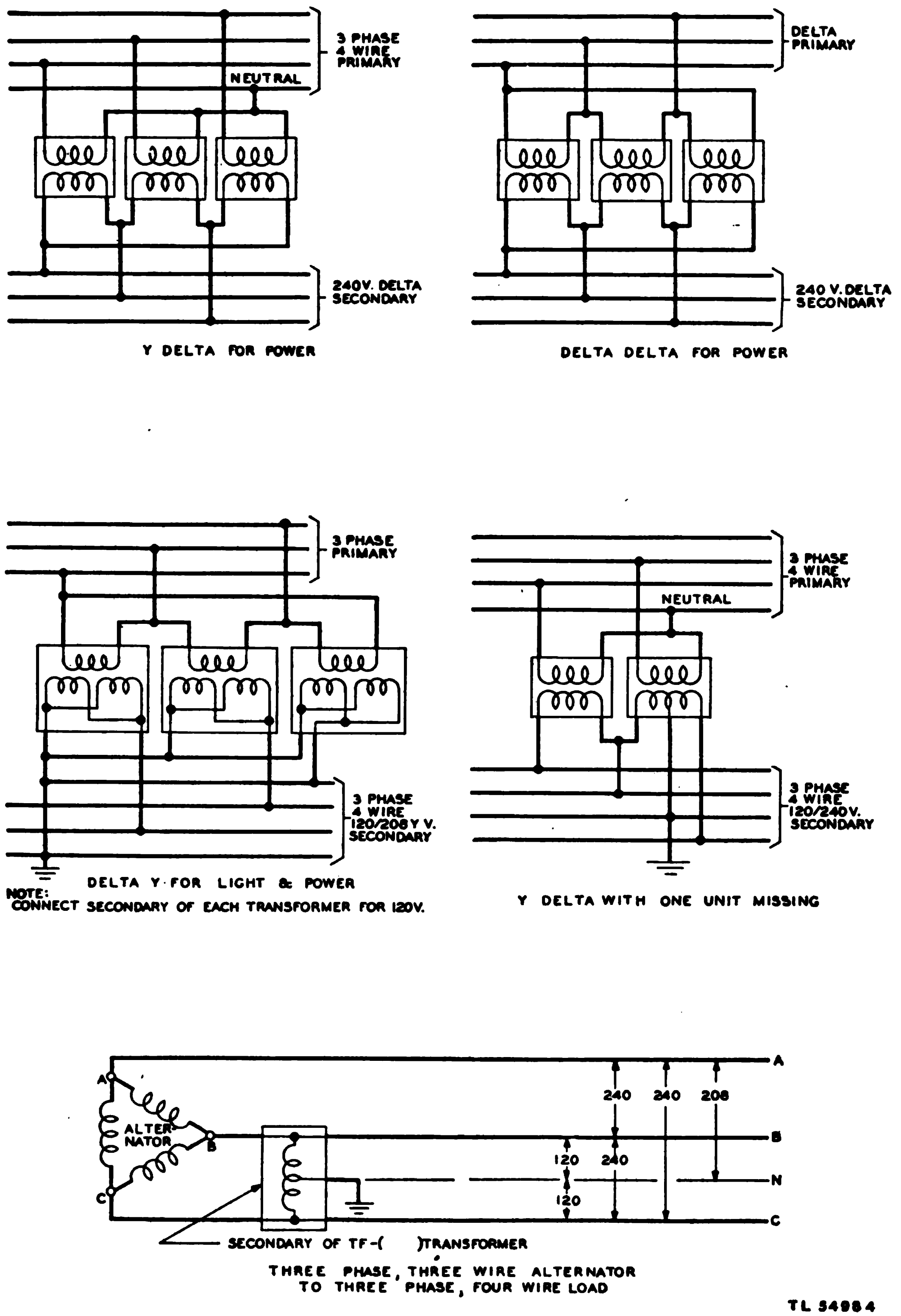


Figure 7–2. Power line



transformer connections.

three sources of ac, two continuous and one standby. These sources of power supply may be from a commercial a-c supply, supplemented by engine-driven generators, or engine-driven generators alone. This is accomplished by dividing the load and using independent sources of power for normal operation, with instantaneous switching to the alternate source of power in case of failure of one or the other source. Coincident with the failure of either

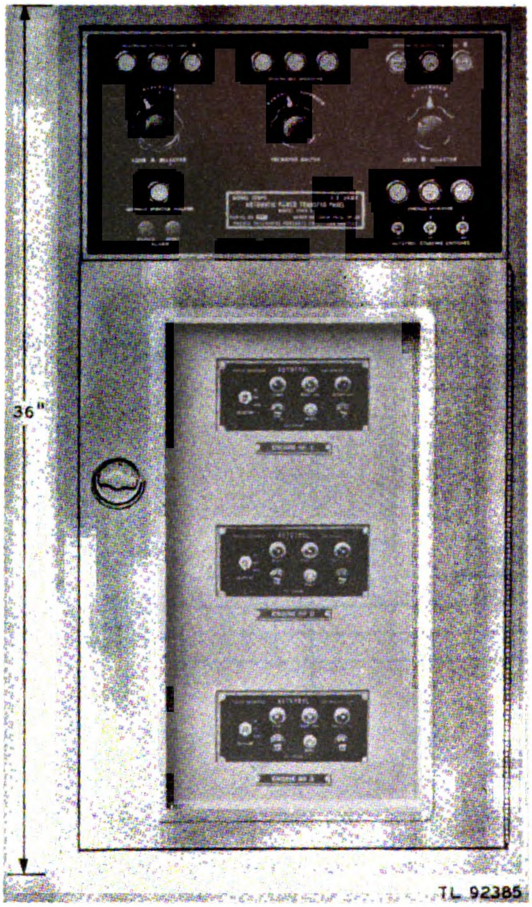


Figure 7-3. Power Transfer Panel CN-22/F.

of the two regularly used sources of power the standby generator is automatically started, and after a short warm-up period, supplies power to the load originally supplied from the source that failed. During the warm-up interval the full load is carried by one power source. If the power source that failed is restored, it again supplies power to its load and the emergency generator is disconnected and then stopped. An illustration of the panel is shown in figure 7-3.

(*2*) *Operating Features.* Complete control of power supply is maintained within the transfer panel. Any power source may be selected for either load, permitting rotation of generators in service. Any generator may be removed from service for repair. The system may be switched from automatic to manual operation at will. An audible alarm is provided. Signal lights indicate operating conditions, that is, generators supplying loads, switch positions, engine control operation, etc. An interlocking control prevents the interconnection of two generators on either automatic or manual operation. A time delay (thermal type) relay delays switching a load to a generator until its engine has had sufficient time to reach a satisfactory operating temperature. In case of a gradual decrease in the a-c voltage, voltage-controlled relays switch the load to an alternate source of power before the voltage has decreased below the minimum operating limit. Engine control panels are plug connected and may be removed from the cabinet for maintenance or repair.

(*3*) *Power Plan Of Operation.* Figure 7-4 shows typical power plans for using Power Transfer Panel CN-22/F with three power sources and two loads.

e. Synchronizing Power Panel.

(*1*) For the purpose of synchronizing two or more alternators which are to be operated in parallel, it is necessary to determine that their phase rotation is correct so that when they are connected to the load they will operate in synchronism. The Master Power Meter Panel (TM 11-2510) is not equipped with instruments that will aid in synchronizing two or more power units. It contains a frequency meter, voltmeter, ammeter, and other associated switches, and indicator lamps and is used only to measure the combined frequency, current, and voltage of a group of power units, when operated in parallel. The synchronizing equipment (lamps and switches) for operating two or more power units in parallel is usually provided on the control panel of each individual power unit.

(*2*) The Master Power Meter Panel, obtainable with special engineering through Army Communications Service, is used when a group of two to four power units of 25- to 50-kw capacity are operated in parallel. It has means for measuring the output frequency, voltage, and current is each phase lead. It is wall-mounted and can be used in a power room or in the communication equipment room. The panel is for use with power generating equipment rated at 240 volts, 3-phase, 3-wire, or 3-phase, 4-wire, 60 cycles ac. The a-c ammeter switch is wired to permit reading currents

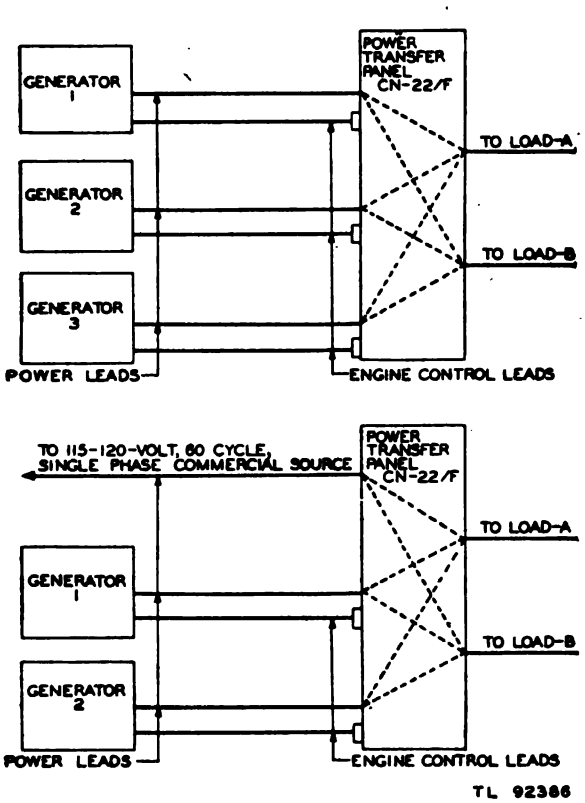


Figure 7-4. Power plan using Power Transfer Panel CN-22/F.

from 0-300 or 0-600 amperes in phases 1, 2, or 3. The ammeter selector switch will also short circuit the secondaries of all current transformers not being used. The voltmeter selector switch is wired in a manner suitable for reading the voltages in all phases as well as from one phase to neutral for 4-wire WYE (Y) systems. The 9-reed frequency meter is wired across any two of the 3-phase leads and all meters are suitably protected by fuses. The cabinet is made of sheet steel, 32 inches high by 22 inches wide by 17 inches deep.

708. POWER RINGING UNITS.

a. General. Power ringing units for use with telephone switchboards may be classified as follows: rotating, vibratory, and static.

b. Rotating Type. The rotating type ringing equipments are essentially motor-driven generating devices, arranged for connection to either a-c or d-c sources of power supply. For the a-c motor-driven ringing generators, either a commercial or engine alternator power supply of the proper voltage and frequency can be used, while for the d-c motor-driven units, storage batteries of the proper voltage and capacity can be utilized. In addition to the motor-operated ringing equipments, the ordinary type of magneto, such as the type found in a magneto switchboard and certain field telephones, is also of the rotating type, the rotor being operated by the turning of a crank by hand.

c. Vibratory Type.

(*1*) *D-c Operated.* The vibratory type of d-c operated ringing equipment, commonly called an *interrupter,* is an electrically operated automatic pole changer producing alternating ringing currents from a direct electromotive force. It consists usually of an electromagnet operating an armature having contacts which vibrate between two contacts connected to a source of direct current. Interrupter PE-248-( ) (Western Electric Company type 84F) is an example of this type of equipment (TM 11-487). Units of this type are arranged for operation from either storage batteries or dry cells of the proper voltage and capacity.

(*2*) *A-c Operated.* A-c operated vibratory type ringing equipments usually use a vibrating reed as a frequency changer which is so designed that 20-cycle ringing current can be obtained from a 60-cycle a-c power supply. Interrupter PE-250-( ) (Telkor Model H Telering) is an example of this type of equipment (TM-11-487).

d. Static Type. The static type of ringing equipment differs from the rotating and vibratory types in that it has no moving parts in the fundamental generating circuit. The static type is confined to operation on ac only. An example of this type of ringing equipment is Ringer TA-13/TT, commonly referred to as the *Subcycle.* It is shown in figure 7-5 and is described in TM 11-438, TM 11-2002, and TM 11-2021. It consists essentially of a tuned circuit designed to resonate at a frequency of 20 cycles when connected to a 60-cycle a-c supply or 16-2/3 cycles when connected to a 50-cycle a-c supply. The absence of moving parts makes this type particularly free of maintenance difficulties.

Figure 7-5. Ringer TA–13/TT.

e. Application. For fixed plant applications, the ringing equipments may consist of any, or combinations of any, of the units outlined above, arranged and furnished as a part of the particular telephone central office equipment. In one tactical application, power ringing equipment is a part of Telephone Central Office Set TC–12 while in another application it is a part of a complete power panel (Panel BD–90). On the power panel are mounted an a-c interrupter as a regular source of ringing current, and a d-c interrupter as a standby source, in addition to battery fuses, alarm circuits, and other power equipment.

f. Detailed Information. For further information giving details of ringing equipments together with specific data thereon, see TM 11–487.

709. IMPROVISED MANUAL VOLTAGE REGULATOR.

a. A manually operated voltage regulator may be improvised from a step-down transformer such as one used for filament supply, and a continuously tapped autotransformer such as a *Variac* or *Transtat,* or a variable resistor. Schematic diagrams of two arrangements are shown in figure 7-6.

b. In figure 7–6–A the regulator acts to increase or decrease the line voltage depending upon whether the primary and secondary windings of the booster transformer are connected to aid or to oppose each other. Reversing either the primary or secondary windings of the booster transformer reverses the action of the voltage regulator. In selecting the booster transformer the voltage rating of the primary winding should equal the line voltage and the current rating of the secondary winding should not be less than the load current.

c. Figure 7–6–B shows a connection in which voltages higher or lower than the line voltage may be obtained without changing connections. In selecting the booster transformer the secondary (low-voltage) winding should have a current rating equal to or greater than the load current and the primary winding should have a voltage rating equal to ½ the normal line voltage. However, almost any transformer may be operated on line voltages which are lower than the transformer's voltage rating but not on line voltages which are approximately 25 percent higher than the transformer's voltage rating.

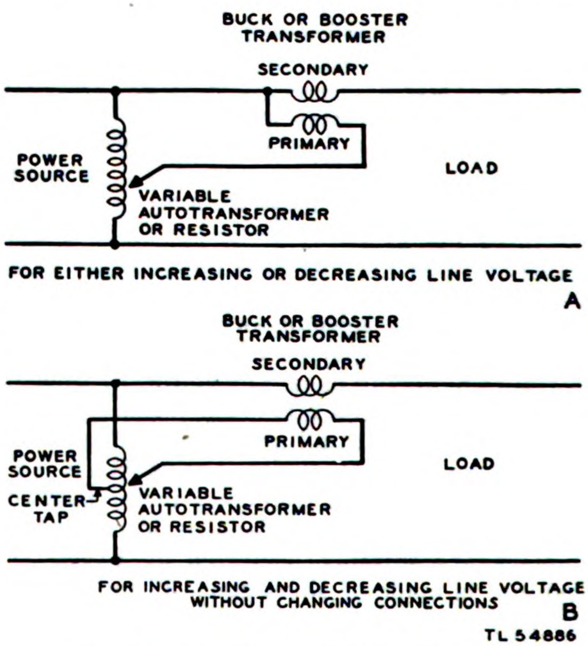


Figure 7-6. Improvised voltage regulators.

Section IV. ENGINE-DRIVEN GENERATORS

710. TYPES AND CAPACITIES.

Direct-current engine generator sets are available in sizes from 0.25 kw to 5.0 kw and

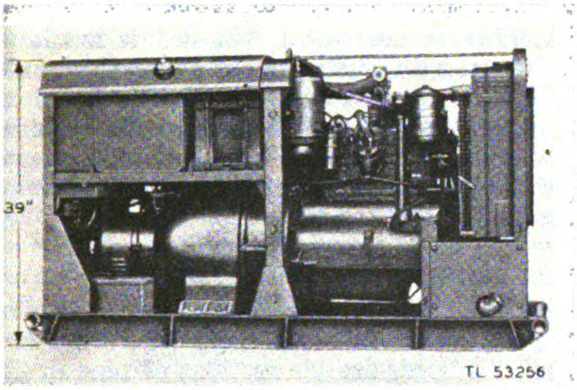


Figure 7-7. Power Unit PE–95–G.

a-c engine generator sets from 0.3 kw to 100 kw. The sets up to 2.5 kw rating are of light construction permitting transportation by man-power for short distances. Sets of 4 kw to 30 kw should be transported by truck or trailer. The 50-kw and 100-kw diesel sets are designed for use at permanent or semiper-manent locations. Details of the various sets, such as voltages, frequencies, dimensions,

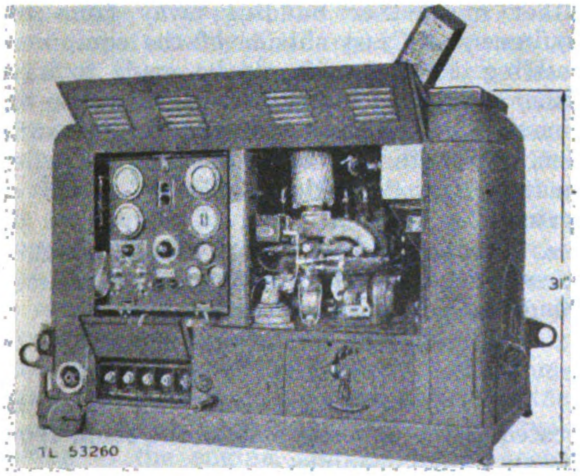


Figure 7-8. Power Unit PE–197.

weights, etc. are covered in TM 11–487. Photographs of two tactical and one fixed plant engine-generator sets are included. Figure 7-7 is a photograph of Power Unit PE–95–G. This set is normally used in tactical situations, weighs about 1,560 pounds, uses gasoline for fuel and is inherently regulated (par. 715e). It has a rated output capacity of 10 kw at either unity power factor or 0.8 power factor, however, at 0.8 power factor the terminal voltage is low, as indicated in paragraph 715e(2). Figure 7-8 is a photograph of Power Unit PE–197. This set is normally used in tactical situations weighs about 790 pounds, uses gasoline for fuel, has automatic voltage regulation (par. 715f), and has an output

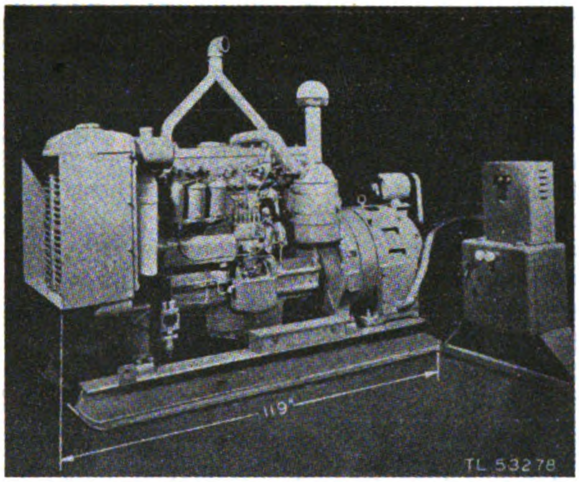


Figure 7-9. Power Unit PE–215–A.

capacity of 5 kw at 0.8 power factor. Figure 7-9 is a photograph of Power Unit PE–215–A. This set is used in the fixed plant, weighs about 5,600 pounds, uses oil for fuel (diesel), has automatic voltage regulation (par. 715f), and has an output capacity of 50 kw at 0.8 power factor.

711. APPLICATION.

a. General.

(*1*) In planning a system using an engine-generator set, two factors are of primary importance, namely: the generator must have adequate capacity, and special supplies must be provided if it is to operate in a cold climate.

(*2*) The type of engine used will depend upon the condition under which it is to operate. If the equipment requiring power from an engine-generator set is mobile, and is to be moved frequently, light weight gasoline-engine-driven generator units should be used. If commercial power is available, and the power unit is to be used for standby service, gasoline-engine-driven power units should be used. For semipermanent locations where the engine-generator set is to be used on an almost continuous basis, the use of diesel-engine-driven power units should be considered.

b. Capacity. In addition to the wattage required by the equipment to be served, it is well to know the volt-amperes or power factor, particularly where the required power is near the nominal capacity of the generator, since overheating may prove to be a controlling factor, particularly in hot climates. Consideration should be given to the location in which the equipment is to be used. If the equipment is to be moved into a location by manpower, the use of two or more small sets may be found desirable provided the load can be split into separate components which are less than full load capacity of the sets. Although it is possible to operate some units in parallel it is generally more satisfactory to split the load into separate components because it is difficult to operate engine-generator sets in parallel unless provision has been made in the controls for parallel operation, since they are normally not sufficiently stable to assure that each will carry its proportion of the total load. For combat areas, the use of a small engine-generator set for each equipment, rather than one larger generator serving several equipments, is usually desirable to insure continuity of service.

c. Cold Climate. If the engine generator set is to be used in cold climates, antifreeze for the cooling system will have to be shipped with the set if not already available at the place where the set will be used. Heating equipment for warming the set or the crankcase oil will be needed. Fuel with a suitable Reid vapor pressure should be available to facilitate starting. Most gasoline engines will start at subzero weather if the proper diluent is in the crankcase oil and if gasoline is used at the following Reid vapor pressures:

80 octane fuel per U. S. Army Spec. 2-103-B	*Reid vapor pressure—(pounds per square inch)*	*Engine starting should be satisfactory at*
Grade A (for summer use)	8	−25°F
Grade C (for arctic use)	12	−40°F

Gasoline is normally supplied as a diluent. It should be put in the crankcase when the engine is in an operating condition so that the gasoline and oil mixture will circulate through the engine oiling system and reach the valve stems. Starting in cold weather will be facilitated by preheating the oil and cooling liquid. The Miller 0G31A heater (stock No. 6Z5058-1A, 115v ac and -1A.1, 12v dc) is available for heating the cooling liquid. When the crankcase oil is diluted with gasoline it should be changed more frequently because the gasoline evaporates through the breather system leaving the lead compounds to reduce the lubricating qualities of the oil.

712. INSTALLATION.

a. For engines installed on a semipermanent or permanent basis, especially where the fuel tank is buried, flexible sections of pipe in the fuel and exhaust lines should be used. The fuel tank and the piping for a gasoline engine should be genuine galvanized wrought iron. The fuel tank and piping for a diesel engine should be genuine black wrought iron. Suitable ventilation equipment should be provided for the engine room.

b. Engines should not be used inside of buildings having weak structural characteristics, such as wood floors, if other equipment will be affected by the vibration or noise transmitted from the engine. In most cases it will be found more desirable to locate the engine either in another building away from the equipment, or just outside of the equipment building. Provision should be made to have either a suitable foundation to which the engine may be bolted, or to have a floor of sufficient strength to hold the engine when mounted on vibration isolating pads or springs.

c. If an engine is located in a small house or other enclosure the following precautions should be taken in its installation:

(*1*) Adequate intake opening should be provided for cooling and combustion air.

(*2*) Outlets for the cooling air should be located at the opposite side of the room from the air intake openings.

(*3*) The engine exhaust pipe should be terminated outside, and distant from the air inlet opening, because the exhaust gases contain a considerable amount of deadly carbon monoxide which is a colorless and odorless gas.

(4) When gasoline is stored in tanks outside of the building in which an engine is located, the fill and vent pipe openings should be located away from the building air intake to avoid the drawing of fumes into the building, particularly during filling operations.

d. Sufficient clearance should be allowed around the engine to permit easy access to the parts that will require attention during operation. In the case of engines having a pusher type of fan on the engine radiator, that is, a fan that blows air thru the radiator, obstructions to the flow of air should not be mounted in front of the radiator because they will deflect the air back against the flow of air from the radiator, causing the water to boil. However, if the engine cannot be moved easily, and if the engine radiator is located so that strong winds blow against the flow of air from the radiator, a baffle should be located about 8 to 10 feet in front of the radiator. For an engine having a suction type fan for the radiator, the engine should be located so that the radiator air inlet is not obstructed.

713. NOISE REDUCTION.

All commercial engines, unless mounted in suitable acoustic chambers and equipped with adequate exhaust silencers, will create noise that may reveal the location of the equipment to the enemy. The most objectionable noise from a gasoline or diesel engine is created by the engine exhaust. With the exception of the 2-cycle type of engine, the exhaust can be silenced satisfactorily if a large silencer can be tolerated. In most cases, the size of the set has to be kept down and, therefore, small inefficient silencers have been used with the consequent result that the exhaust noise from the set can be heard by ear for about 2/3 of a mile on a quiet day. On the small sets operating about 2,000 revolutions per minute, the noise of rotating parts can be heard for about the same distance as the exhaust. The small 2-cycle engines present an exhaust silencing problem which is difficult to solve without imposing excessive back pressure on the engine resulting in too much loss of power and overheating of the engine. On small high-speed engines the use of a small acoustic box or enclosure around the set is impractical due to overheating and the difficulty of maintenance on the set. The use of sandbag enclosures with about 2-feet clearance around all sides of the set and having a wall-height of 4 to 4½ feet, with one sandbag layer for the roof and with air openings at the tops of all four side walls, will reduce the set noise so that it cannot be heard by ear further than about 700 feet from the set.

714. USE OF LEADED GASOLINE.

a. General.

(1) Because of the increased demand for high-grade gasoline fuel for aviation engines, the use of tetraethyl lead in larger quantities per gallon of fuel has been necessitated to insure fuels that will not detonate in the modern high-compression engines now being used. Aviation engines use 100-octane fuel in most cases (SB 10–139); and in order to supply the ever increasing need for 100-octane aviation fuel, it has become necessary to remove some of the high octane fractions from the fuels to be used for ground equipment engines. The 100-octane fuel contains a maximum of 4 cubic centimeters of tetraethyl lead per gallon, and 80-octane fuel for ground equipment contains a maximum of 3 cubic centimeters of tetraethyl lead per gallon. The 100-octane fuel will be fairly uniform in lead content because only prime crude oil stock is skimmed off for this fuel. The amount of lead in the 80-octane fuel will depend upon the base crude from which it is made and the amount of high-octane fractions removed to produce 100-octane aviation fuel. Modern gasoline engines, such as used for generating sets, are not suitable for continuous operation on highly leaded fuels without considerable increase in engine maintenance.

(2) Efforts have been made to overcome the harmful effects of lead deposits in the combustion spaces of the engine, such as by equipping them with stellite valves and stellite valve seat inserts, by automatically rotating the engine valves while the engine is operating and by relieving and changing the shape of the valve stem guides. These measures tend to prevent the build up of lead sulphate, lead chloride and lead oxide on the valve stem, which causes the valve to stick. However, these efforts do not overcome the trouble of lead deposits to the extent desired. A number of the engines used for generator sets are used satisfactorily in automobiles without the troubles encountered when used to drive generators. The only difference in the operation is that the engines

in automobiles operate at variable speed whereas the engines when used to drive generators, operate at fairly constant speed. It is probable that the variable speed of the engine in an automobile results in blowing a considerable amount of the lead deposits out of the exhaust line. There appears to be no practical way at this time of removing the lead or reducing the amount of lead in the fuel when used for engine-generator sets and the maintenance of these engines will be increased when heavily leaded fuels are used.

b. Maintenance, 4-cycle Engines. When gasoline containing more than 2 cubic centimeters of tetraethyl lead per gallon is used in small 4-cylinder engines driving generators rated up to and including 2.5 kw, the spark plugs will usually have to be cleaned after each 50 hours of operation and the life of the plugs will be shortened to about 100 to 150 hours of operation. For larger engines, the plugs should be cleaned after every 100 hours of operation and the plug life will be 200 to 300 hours. After about 250 hours of operation, the carbon and lead should be removed from the cylinders and after 500 hours of operation the engine valves should be ground. The lacquer that forms on the governor butterfly valve will have to be removed at this time also. After 600 hours, the engine exhaust manifold, exhaust line and muffler should be cleaned or replaced. Heavy deposits of lead form in these parts and impose a back pressure on the engine exhaust that results in loss of power and exhaust valve burning.

c. Maintenance, 2-cycle Engines. On small 2-cycle engines, the spark plug will have to be cleaned approximately every 24 hours of operation and the plug life will average 100 hours when highly leaded fuels are used. The deposits of lead should be removed from the exhaust ports and explosion chambers and the muffler cleaned after about every 250 hours of operation. Since carbon is the more easily removed, more satisfactory operation can be obtained from a 2-cycle type gasoline engine than from a 4-cycle type, when aviation or other heavily leaded gasolines are used.

715. EFFECT OF POWER FACTOR ON GENERATOR OUTPUT.

a. General. A full appreciation of the effect that the power factor of the connected load has on the performance of engine-driven a-c generators, especially the smaller tactical types, will prevent disappointing field results.

b. Definitions.

(*1*) *Power Factor.* In an a-c circuit which has reactance (inductive or capacitive) as well as resistance, the current is not in phase with the voltage. The power consumed in the circuit is the product of the voltage and that component of the current which is in phase with the voltage. The mathematical expression for electrical power delivered to a load is

$$P = EI \cos \theta,$$

where E is the terminal voltage, I the current and θ is the phase angle between the current and voltage. The expression $\cos \theta$ is known as the *power factor* of a circuit and is determined by dividing the power in watts as read on a wattmeter by the voltamperes (product of volts and amperes without regard to phase angle). With a resistance load, the current and voltage are in phase, the phase angle is zero, $\cos \theta$ is 1, and the power factor is unity. When the load has inductance or capacitance, the power factor is less than unity. The power factor is lagging or leading depending upon whether the load is inductive or capacitive. The loads imposed by communication equipment are usually inductive and the discussion below, therefore, ignores the effects of capacitive loads. The power factor of an inductive load can sometimes be improved by adding capacitors in parallel with the load.

(*2*) *Voltage Regulation.* Voltage regulation of a generator is the ratio, expressed in percent, of the difference between the no-load and full-load voltages to the full-load voltage.

c. Power Rating.

(*1*) In rating engine-driven generators the a-c power output is usually given in both kva and kw, and the kw rating is usually 0.8 of the kva rating, that is, 0.8 power factor. Some manufacturers give only the kva rating in which case a power factor of 0.8 may be assumed. If the rating is in kw only, unity power factor is assumed.

(*2*) In the operation of engine-driven generators, the load must not exceed the kw rating of the generator, even though the power factor of the load is greater than 0.8. For example, assume a generator rated at and loaded to 12.5 kva at 0.8 power factor. The power delivered to the load is 10 kw. The remaining

2.5 kva is known as *wattless power* since, except for secondary heating effects, it imposes no load on the driving engine. If the load were 12.5 kva at unity power factor the load would be 12.5 kw, and the driving engine would be overloaded and the performance would be unsatisfactory for reasons brought out below. The generator may overheat without overloading the engine if the full load rated amperes of the generator is exceeded.

d. Regulation Factors. As the load on a generator rises, the increase in current through the armature or stator causes the generator terminal voltage to drop. To minimize this effect, means are provided in some generators for increasing the field excitation as the load increases. The method of regulating the field excitation may be automatic or manual. In other generators the only regulation provided is that which is inherent in the generator design.

e. Inherent Regulation.

(*1*) Inherently regulated generators, that is, those which depend upon their own internal construction for voltage regulation over the load range are usually rated for unity power factor only. Inherently regulated generators which are available are of the conventional saturated field type, wherein the regulation is reasonably good up to the rated load at unity power factor. If the load is increased beyond this point or if, at full load, the power factor is materially less than unity, the terminal voltage drops away so rapidly that it may fall below the minimum voltage required for the operation of some types of communication equipment. The explanation of this rapid voltage drop is somewhat involved and is beyond the scope of this manual.

(*2*) An example of this type of generator is Power Unit PE–95–G. The voltage at various load conditions and the voltage regulation for a typical Power Unit PE–95–G are as follows:

Kw	*Power factor*	*Volts*	*Percent voltage regulation*
12.5	1.0	112	4.9
10	0.9	105	11.9
10	0.8	100	17.5
5	0.9	112.5	4.3
5	0.8	110	6.8
0	—	117.5	—

(*3*) Various sizes of inherently regulated generators are also coming into use which utilize permanent magnets in the field structure instead of the conventional wound field. In these generators the voltage drop is not so severe on low power factor loads.

f. Automatic Regulation.

(*1*) Where close regulation is required generators are equipped with automatic voltage regulators whereby a resistance is varied automatically to increase the exciting current of the generator field as the load increases. Generators of this type are usually rated in kva and kw with 0.8 power factor. They are capable of giving the full kw rating for any power factor from 0.8 to unity.

(*2*) For good design, engine-driven generators should have little margin between the rated power output of the generator and the capability of the driving gasoline engine. For this reason, any attempt to obtain from the generator more than the rated power output (kw), will result in a drop in engine speed which will cause the terminal voltage and frequency to drop and the engine cooling system to overheat. An increase in load beyond the rated capacity of the generator will also result in a rise in temperature of the generator windings. This is usually of secondary importance.

(*3*) An example of an automatically regulated generator is Power Unit PE–197. It has a kva rating of 6.25 or, at 0.8 power factor a kw rating of 5.

CHAPTER 8

FOREIGN CIVIL CENTRAL OFFICES

Section I. INTERCONNECTION OF ARMY CENTRALS AND CIVIL CENTRAL OFFICES

801. GENERAL.

a. The Signal Corps may frequently find it advisable to connect to a local central office in a foreign country as an auxiliary to its own facilities. Signal Corps telephone loops may be connected directly to the civil central offices the same as subscribers lines, or Signal Corps centrals may be connected by trunks and operated as private branch exchanges (PBX's) of the civil central office. Depending on the supply situation, the equipment used for these arrangements may be of standard Signal Corps types or it may be necessary to resort to commercial equipment of American or foreign manufacture.

b. The problems involved in effecting an interconnection with a foreign central office will depend on the combination of Signal Corps terminating equipment and the type of equipment used in the central office. Many combinations are possible and it would be difficult to set down exact rules for all of them. This chapter is intended to provide certain essential general information which will serve as a guide to the factors which must be considered and the types of technical trouble which are apt to occur in interconnecting the various kinds of switching systems.

c. The problems of interconnection with foreign equipment will be simplified considerably if the aid of local personnel familiar with the system can be enlisted, provided this is consistent with the requirements of security and antisabotage precautions.

802. TYPES OF INTERCONNECTION.

a. The most flexible type of interconnection with a foreign central office consists of one-way or 2-way lines used as PBX trunks[1] between the central office and a Signal Corps switchboard. All telephones terminated on this switchboard will thus be given communication through the local central office facilities with civilian telephones and other similarly interconnected Signal Corps switchboards in the central office area. Access will also be given to the toll network through the central office's usual connection to a manual toll office and sometimes also to a toll network over which calls can be dialed directly.

b. Where only a limited number of telephones are to have communication through the central office they may be connected to the central office on a direct line basis, that is, without going through the Signal Corps switchboard. This may be the only type of interconnection used or it may supplement the arrangement described under subparagraph a. In some cases it may be advantageous to assign individual numbers to these direct lines. In others they may be treated as a single PBX trunk-hunting group[2] in the central office.

c. The central office may serve in place of a Signal Corps switchboard as a PBX for a substantial number of telephones by connecting all of them as direct lines to the central office. These direct lines may be used for intercommunication between telephones or for outside connections. This has, in some cases, permitted the release of a switchboard urgently required in other locations. In such applications it is important that all Army users have up-to-date directory information.

803. FEASIBILITY OF INTERCONNECTION.

a. Many varieties of switching equipment are used in local telephone central offices in foreign countries, but in most cases it is pos-

[1] A PBX trunk is a line between a PBX and a central office. One-way lines handle outgoing or incoming calls only; 2-way lines handle both.

[2] A group of trunks, listed as a single number, over which an operator tests, or a switch hunts for an idle trunk in the group.

sible to use some type of standard Signal Corps switchboard for connection to the central offices without any serious technical difficulties. Commercial PBX's of American or foreign manufacture and telephones used on direct lines will involve limitations and special arrangements with some types of central offices, but interconnection is generally still practicable. Finally, there may be encountered any of numerous special, obsolete, or improvised switching systems which use unusual methods of signaling. To operate with these, the Signal Corps would have to use equipment specifically intended for use with these systems and obtained locally or would have to modify other types of equipment. These systems are fortunately not used extensively and are generally found only in small central offices.

b. In cases where it is possible to use telephones or PBX equipment obtained from the local telephone administration, there is little question as to the workability of the arrangement, but unless local maintenance people and supplies are available there may be some difficulty due to unfamiliarity with this equipment and lack of spare parts. Descriptive matter pertaining to the principal types of switching equipments used in foreign countries is given in section III. Problems which will be encountered in interconnecting to these systems are given in paragraph 817.

804. GENERAL SUITABILITY OF FOREIGN CENTRAL OFFICE.

a. Capacity. If the number of lines or trunks involved in the proposed interconnection is substantial compared with the number of lines already working in the office, it will be necessary to check for adequate terminal capacity and to assure that the office will not be overloaded by the added traffic. In general, conditions will not permit equipment changes or additions in the central office at the time of the interconnection, so if civilian traffic is at all normal it will be necessary to disconnect some or all of the civilian lines to compensate for new traffic, bearing in mind the relatively heavy traffic on military lines as compared to civilian lines. Foreign offices are usually engineered closely, both from a traffic capacity and spare terminal standpoint and it will sometimes be necessary to disconnect some civilian lines even to obtain line circuits on which to terminate Signal Corps lines or trunks.

b. Reliability. If the proposed interconnection is to be an important communication link, it is necessary to consider the reliability of service of the central office involved. The principal technical factors which may make service unreliable are:

(*1*) Unreliable power supply.

(*2*) Danger of overloading by panic or sabotage. This is especially important in remote control offices, in small register type (sender) dial systems which have only a few senders, and in very small dial offices of the all-relay type which have capacity for only a few simultaneous calls.

(*3*) Timed cut-off features in dial offices where those features cannot readily be cancelled (par. 816).

(*4*) Dependence of a dial office on a single distant tandem office. In some cases all traffic outside of the local area is routed through a distant tandem office. Toll service would be interrupted by failure of tandem equipment or the circuits to the tandem office. In the cases of some dial satellite offices even the completion of local calls would be prevented by loss of the distant office.

(*5*) Dependence of remote control offices on a single control trunk to a distant office. Loss of this trunk or the control office would block all traffic.

(*6*) Unusual use of interposition trunking. Some manual offices which should really use multiple type switchboards will be found with a considerable number of nonmultiple switchboards, sometimes of different types, connected together by an interposition trunking scheme. This arrangement may be conducive to slow completion, false disconnects, and poor transmission.

(*7*) Poor maintenance conditions due to lack of personnel or spare parts.

(*8*) Equipment in poor condition to start with.

805. PLANNING INTERCONNECTION.

a. In planning the interconnection with a foreign commercial switching system, it is necessary to know in advance at least whether the switching system involved is of the magneto (par. 810), common battery manual (par. 812), central battery signaling (par. 811), or dial type (par. 813) so that switchboards or telephones with the proper types of signaling can be provided. However, a picture of any possible special problems in a particular case cannot be obtained without some additional information, and it cannot even be safely assumed that the interconnection is practicable until such information is available.

b. In obtaining information on specific telephone offices, as well as in planning and effecting interconnection, there is no substitute for the assistance of qualified and friendly personnel familiar with local details.

c. The following are the more important steps in planning an interconnection:

(1) Identify central office equipment and determine special problems (par. 817 and sec. III).

(2) Check terminal and traffic capacity of office and determine if changes are required (par. 804a).

(3) Check battery and charging equipment to assure adequate capacity for handling increased load resulting from Signal Corps traffic.

(4) Check reliability of office (par. 804b).

(5) Determine if there are transmission or signaling complications (pars. 808 and 809).

(6) Determine what equipment is required at Signal Corps end for connection to line circuits at central office. If not readily available, determine if central office has other line or trunk circuits suitable for terminating other types of equipment (pars. 806 and 807).

(7) Check resistance of available conductor facilities against range of central office to determine if suitable (par. 809).

(8) Arrange for termination of line or trunk circuits at central office (pars. 806 and 807).

(9) If area is dial, check numbering system used and provide suitable dial number plates (par. 814).

(10) If PBX battery and generator feeders are required, check if office has provision for same (probably not) and take necessary action (par. 815).

(11) Arrange for completion of work and testing.

806. TYPE OF EQUIPMENT REQUIRED AT SIGNAL CORPS END.

a. The type of equipment required for connection to commercial central offices will generally be determined by the fact that in most offices PBX trunks or direct line telephones must be terminated on regular subscriber line circuits. Figure 8-1 shows the types of equipment required with these circuits.

b. In some, cases the telephone or trunk equipment which is most readily available or most suitable for the required service is not of the right type for connecting to the subscriber line circuits of the office involved (fig. 8-1). In these cases it may still be possible to use this equipment by connecting to other types of line or trunk circuits sometimes provided in the central office (par. 807).

Kind of foreign office	*Type of direct line telephone or trunk equipment required*
Magneto (LB) manual	Magneto
Central battery signaling (CBS) manual	Common battery trunks on noncut-through PBX's or direct line telephones with common battery signaling and local battery talking
Common battery manual	Common battery
Common battery remote control dial	Common battery
Local battery remote control dial	Magneto
Semiautomatic	Common battery
Demiautomatic	Dial
Dial (full automatic)	Dial

Figure 8-1. Type of equipment required to connect to subscriber line circuits in various types of foreign commercial offices.

807. COMMERCIAL CENTRAL OFFICE TERMINATION OF SIGNAL CORPS LINES OR TRUNKS.

a. Magneto (Local Battery) (LB) Manual Offices.

(1) The various types of line and trunk circuits which may be found in these offices may be used for terminating Signal Corps circuits as shown in figure 8-2.

(2) Some ringdown toll line or interoffice trunk circuits will be found in practically all magneto offices. With multiple switchboards these lines may appear on toll or other positions in which case these circuits might provide better toll transmission and service than regular line circuits.

(3) Special common battery subscriber line circuits will permit use of Signal Corps equipment of the common battery type. These circuits are generally found only in the larger offices and terminate on positions equipped with universal cords.

Type of foreign line or trunk circuit	*Possible Signal Corps switchboard or telephone termination*
Magneto subscriber line	Magneto loop or 2-way ringdown trunk
Subscriber or toll line multiple jack circuit	Magneto loop or ringdown trunk outgoing from central office
Ringdown subscriber or toll answering jack and signal circuit	Magneto loop or one-way ringdown trunk incoming to central office
Special common battery subscriber line	Two-way common battery line or trunk
Two-way ringdown toll line or interoffice trunk	Magneto loop or 2-way ringdown trunk
Common battery toll line or interoffice trunk	None

Figure 8-2. Foreign magneto office and Signal Corps terminations.

b. Central Battery Signaling (CBS[3]) Manual Offices.

(*1*) There may be difficulty in connecting to some of these offices (par. 811).

(*2*) Direct line telephones connected to subscriber line circuits in these offices must be arranged for common battery signaling and local battery talking, such as Telephone EE-8-( ). PBX's must have trunks of the common battery type and noncut-through cords.[4] The various line or trunk circuits which may be used for terminating Signal Corps circuits are shown in figure 8-3.

Type of foreign line or trunk circuit	*Possible Signal Corps switchboard or telephone termination*
CBS subscriber line	Two-way trunk or line (subpar. b (*2*) above)
Magneto subscriber line circuit	Magneto loop or 2-way ringdown trunk
Two-way ringdown toll line	Magneto loop or 2-way ringdown trunk
Automatic toll line	None

Figure 8-3. Foreign central battery signaling office and Signal Corps terminations.

(*3*) Ringdown toll or magneto subscriber lines are frequently available and may permit the use of Signal Corps equipment of the magneto type, thus avoiding the complications peculiar to CBS signaling.

c. Common Battery (CB) Offices.

(*1*) Lines or trunks connected to these offices should generally be terminated on regular line circuits and be of the common battery type. Many of these offices will be found equipped with a substantial number of magneto line circuits used for rural or toll lines. These may be used for terminating lines or trunks of the *magneto type*. These circuits may appear at switchboard positions having special cord circuits and sometimes direct access to toll lines. Use of these lines for terminating Signal Corps equipment may then result in improved service and transmission on toll calls.

(*2*) The various types of line or trunk circuits which may be found in common battery offices, may be used for terminating Signal Corps facilities as shown in figure 8-4.

Type of foreign line or trunk circuit	*Possible Signal Corps switchboard or telephone termination*
CB subscriber line circuit	Two-way CB line or trunk
Subscriber multiple jack circuit	One-way CB line or trunk outgoing from central office
CB subscriber signal and answering jack circuit	One-way CB line or trunk incoming to central office
Magneto subscriber line circuit	Magneto loop or 2-way ringdown trunk
Two-way ringdown toll line or interoffice trunk	Magneto loop or 2-way ringdown trunk
CB or automatic toll line circuit	Not useful
CB interoffice trunk circuits	Not useful

Figure 8-4. Foreign common battery office and Signal Corps terminations.

d. Dial Offices.

(*1*) While Signal Corps equipment connected to dial offices can generally be served satisfactorily by connecting to subscriber line circuits, there are instances where it may be desirable to connect to other lines or trunks which appear in manual assistance or toll switchboards in the same building with the dial office. This will permit the Signal Corps equipment to be of the common battery or

[3] Or BCS for French *Batterie Central Signalisation.*
[4] In PBX's with cut-through cords, transmitter battery is obtained from the PBX on extension-to-extension connections and from the telephone central office on trunk connections (ch. 2).

magneto type, and will often provide more direct access to toll channels with improved toll transmission and service.

(2) Where a number of trunks to a PBX are to be arranged as a trunk-hunting group[5] at the central office, these trunks must be assigned to consecutive terminals on final connectors with the last trunk treated the same as an individual line and the preceding trunks treated as trunk-hunting lines. Provision is made for this type of service in all large dial offices. In some step-by-step offices such trunk-hunting groups are handled in special connector groups provided with 4-wire banks. In others, like some of the Siemens-Halske offices, the final connectors in certain groups are fitted with special hunting terminals. With other types of offices, trunk-hunting lines may be assigned to any connector groups as the trunk-hunting is accomplished by marginal sleeve circuits.

(3) Ordinarily the maximum number of trunks handled in a single PBX group is 25 for Ericsson power-driven systems, 30 for power-driven rotary systems, and 10 for step-by-step and other systems. Graded multiple[6] arrangements can be provided in most cases to increase these capacities. All large dial offices are arranged for some trunk-hunting groups. The following types of offices very frequently have no provision at all for PBX trunk-hunting: small all-relay offices, remote control offices, semiautomatic offices, and small rural step-by-step offices.

(4) A list of the line and trunk circuits which may be found available in the various types of dial offices with the possible Signal Corps terminations are shown in figure 8-5.

Type of foreign line or trunk circuit	*Possible Signal Corps switchboard or telephone termination*
Full dial and demiautomatic	
Subscriber line	Two-way dial line or trunk
Subscriber line finder terminal or line switch circuit	One-way dial line or trunk incoming to central office
Subscriber final connector multiple circuit	One-way line or trunk outgoing from central office
Common battery subscriber line circuit to manual switchboard	Two-way common battery manual line or trunk
Common battery subscriber line circuit with final connector multiple	Two-way line or trunk with manual originating and dial terminating service
Local battery subscriber line circuit to manual switchboard	Magneto loop or 2-way ringdown trunk
Two-way ringdown toll line to switchboard	Magneto loop or 2-way ringdown trunk
Semiautomatic	
Subscriber line	Two-way CB Manual line or trunk
Common battery remote control	
Subscriber line	Two-way CB Manual line or trunk
Magneto remote control	
Subscriber line	Magneto loop or 2-way ringdown trunk

Figure 8-5. Foreign dial office and Signal Corps terminations.

Section II. TECHNICAL PROBLEMS

808. TRANSMISSION PROBLEMS.

a. The most common transmission problem in connecting to foreign central offices will be caused by the rather widespread use of telephones with high-resistance transmitters and the corresponding use of high-resistance talking battery supply circuits in the central offices. As an example, the *standard* arrangement of the Ericsson power-driven dial system uses transmitters of about 200 ohms with a central office transmitter battery supply of 24 volts through a 400—400-ohm coil. Telephones having relatively low-resistance transmitters such as the common American types, would operate with reduced efficiency at the low currents obtained from such a battery

[5] A group of trunks, listed as a single number, over which an operator tests, or a switch hunts for an idle trunk in the group.

[6] A split trunk group so arranged that some of the trunks can be reached by all selectors and others by only a portion of the selectors.

supply circuit. Consequently if such telephones should be used on direct lines to the above mentioned type of dial system, or connected to it through a PBX with cut-through cords, the transmitting level would be below par (sec. III of ch. 2). It would probably be passable on short loops.

b. However, where the trunks or lines involved are long, and anything other than emergency operation is required, it may be necessary to improve the transmitting efficiency in some way. One method is to avoid direct lines and to set up all connections to the central office through a PBX with noncut-through cords. Another method is to use telephones of the local battery talking, common battery signaling type, such as Telephone EE–8– ( ) which means that dry cells must be furnished for each telephone. In case only a few lines are in difficulty, it may be advisable to use telephones of the design normally used in the central office area. These might be obtained locally.

c. The high-resistance battery supply circuit may be encountered in both common battery manual and dial systems and is optional in some systems to meet the requirements of the operating administrations.

d. In some cases the values of high resistance battery supply circuits will differ from the foregoing example. For instance, another arrangement of the Ericsson power-driven dial system uses 48-volt battery through an 800—800-ohm supply, which would also be unsatisfactory with low-resistance transmitters. A special arrangement of the same system uses 50 volts through 200—200-ohms which is intended for use with low-resistance transmitters.

e. With some systems the high-resistance battery supply is compensated for to some extent by using 60-volt battery, but in many cases low-resistance transmitters will still not operate satisfactorily under this condition.

f. In general, where there is an indication that high-resistance battery supply circuit is used, but details are not available, it may be assumed that the characteristics are effectively the same as in the first illustration and the treatment would be as described.

g. Another phase of the same transmission problem will be involved with manual switchboards of the type known as central battery signaling (CBS). These can easily be mistaken for common battery types because of the presence of battery on the lines and the fact that the boards look like and operate like common battery boards. However, they are actually common battery signaling, local battery talking arrangements. In case of doubt, this type can readily be identified by the fact that all subscriber sets will be equipped with batteries, but not with magnetos. With these switchboards the battery supplied to the line is intended for signaling only. All station equipments must be of the common battery signaling, local battery talking type unless served through noncut-through PBX's. In some cases there will also be a signaling problem with this type of switchboard (par. 811).

809. SIGNALING RANGES.

a. Where information on the line signaling ranges (supervision and ringing) for particular offices is not available locally, the values shown in figure 8-6 may be used as approximate.

b. Special terminating facilities for long lines or PBX trunk circuits are seldom available in foreign central offices, so, in general, the conductor facilities will have to be such as to fall within the resistance range of the regular central office equipment.

Type of office	*Maximum conductor loop*	*Minimum insulation*
Magneto	5,000 ohms	1,000 ohms
Central battery signaling	900 ohms	10,000 ohms
Common battery manual	900 ohms	10,000 ohms
Dial	800 ohms	15,000 ohms

Figure 8-6. Signaling ranges of foreign central offices.

810. SIGNALING PROBLEMS, MAGNETO (LB) OFFICES.

Magneto offices, sometimes referred to as local battery or LB offices, are still extensively used for small areas. The following irregular signaling arrangements should be watched for:

a. With some very old types of boards the line signals are of low resistance of about 100 ohms. This limits the line to a conductor loop of about 1,000 ohms instead of the usual higher range.

b. In some boards all or part of the lines are arranged for party-line service with a secrecy scheme for signaling the central office. The station magnetos normally ring across the line to call other stations and signal on a simplex basis to call the central office under control of a key operated while ringing.

c. Some offices provided with a ringing vibrator require the omission of the series ringer condenser at the stations as the ringing vibrator is started by d-c flowing through the ringer when the cord circuit ringing key is operated.

d. Some offices use 50-cycle ringing current.

e. Some old designs require d-c bells or signals at the stations or on PBX trunks.

811. SIGNALING PROBLEMS, CENTRAL BATTERY SIGNALING (CBS) MANUAL OFFICES.

a. Most CBS boards (par. 820) will offer no signaling difficulties but PBX's connected to them must always be equipped with noncut-through cords (par. 807b(2)).

b. Some types of obsolete boards may be found in which the line signal is operated on a metallic basis by the station loop and the cord supervisory signal is operated by a ground through a low-resistance station ringer connected to one side of the line when the switchhook is depressed. Noncut-through PBX cords or telephones of the common battery signaling, local battery talking type will operate the line signal of such a system, but disconnect or recall would be dependent on having the operator monitor. PBX trunks or telephones can, of course, be modified to give suitable signaling, but it will probably be better to attempt to obtain suitable terminating equipment from local sources. This peculiar type of signaling arrangement can be identified by testing on a subscriber's line. A potential will be found across the line when not in use. When a bridge is placed across the line the condition will change after the operator answers so that there is no potential across the line, but a potential from both sides to ground.

c. In some CBS areas the ringing current frequency is 50 cycles.

812. SIGNALING PROBLEMS, COMMON BATTERY (CB) MANUAL OFFICES.

a. In the majority of cases there will be no signaling difficulty in interconnecting with common battery offices.

b. There are, however, some types of common battery boards which have high-resistance transmitter battery in the cord circuits and a few types in which transmitter battery is obtained from the line relay, which is high resistance. PBX's served by these boards must be equipped with noncut-through cords (par. 808).

c. In some areas these boards use 50-cycle ringing current.

d. Some common battery offices have most line circuits arranged for message rate service with message registers at the stations. Connection can be made to these line circuits only with special station or PBX trunk circuits. Occasionally these offices will have some standard line circuits which may suffice for Signal Corps use.

813. SIGNALING PROBLEMS, DIAL OFFICES

a. The characteristics of foreign dial systems with respect to pulsing, supervision, and ringing are such that, in general, satisfactory operation with Signal Corps or commercial dial telephones or PBX's will be obtained. Signal Corps dials operate at 10 pulses per second. While some American commercial dials operate at 20 pulses per second, these can seldom be used with foreign equipment.

b. In some localities dial offices will be found which are arranged for message rate lines with the message register at the station. Most lines in such offices will require the use of special dials or auxiliary push buttons at the station or PBX for proper central office operation. However, a limited number of regular line circuits may be provided which may suffice.

c. It should be noted that foreign dials have characteristics which differ slightly from American dials and the central office equipment is designed for operation with these characteristics. The differences in general are:

(*1*) In foreign practice most station dials are held to speed limits of ±5 percent, or 9.5 to 10.5 pulses per second, as compared with American practices of 8 to 11 pulses per second.

(*2*) As a general rule, the percent break requirements on foreign dials vary slightly from American dials. However, the difference is not significant if the speed of the dials is maintained properly (subpar. d below).

(*3*) In most cases the period from the release of the dial to the beginning of the first pulse is 250 milliseconds as compared to 100 milliseconds in American practice. This affects the interdigital time where station users attempt to rush the dial but the difference will not give trouble unless the dialing practices are bad.

d. Under maximum loop conditions or in cases where the central office equipment is in questionable adjustment, some trouble might be experienced with wrong numbers if the speed of dials used with foreign systems is allowed to fall to 8 pulses per second, particularly if the dial used should have a higher percent break than customarily used in the area involved. The best performance will be obtained by holding the dial speeds as close to 10 pulses per second, as possible, or at least within the limits of 9.5 to 10.5 pulses per second. With frequently used dials on switchboard positions this problem will be simplified by using close limit dials such as the Western Electric Company 5LA dial, or by using locally obtained dials intended for operation with the system involved, and mounting them on the switchboard with improvised arrangements.

814. DIAL NUMBER PLATES.

a. Where both figures and letters are used on dial number plates in foreign countries, the letters used and their locations will vary considerably with different countries and even in different localities in the same country and do not in any case correspond to American practices.

b. Figure 8-7 shows foreign dial number plate arrangements of the more commonly used varieties, and figure 8-8 shows two typical American arrangements.

c. If dials must be provided in advance for general use in foreign countries, they should have dial number plates carrying only the figures. Where necessary to use letters, suitably marked cards can be inserted under the dials escutcheon plates as shown in figure 8-9.

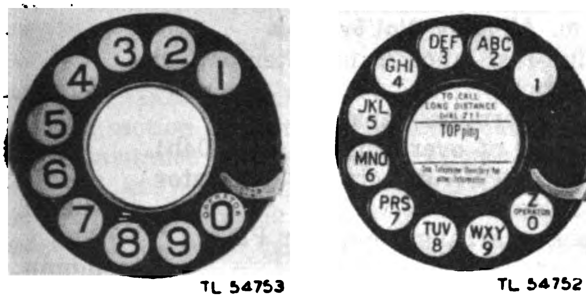
815. PBX BATTERY AND GENERATOR FEEDERS.

a. In foreign countries PBX's are generally not supplied with battery and ringing current feeders from the central office, and provision for such feeders is commonly omitted in the central office. This will often make it necessary to provide Signal Corps switchboards with their own battery supply and ringing supply except where the latter can be avoided by use of hand generators.

b. Battery and generator supply feeder connections in the central office can be improvised where necessary. It would be advisable, however, to first check the capacities and voltages of the battery and ringing power sources to determine if adequate. The ringing machines are sometimes operated on a start-stop basis

					LONDON AND OTHER METROPOLITAN AREAS IN GREAT BRITAIN.					
Numbers	1	2	3	4	5	6	7	8	9	0
Letters		ABC	DEF	GHI	JKL	MN	PRS	TUV	WXY	O
					PARIS, FRANCE, METROPOLITAN AREA.					
Numbers	15	2	3	4	5	6	7	8	9	0
Letters		ABC	DEF	GHI	JKL	MN	PRS	TUV	WXY	OQ
					COPENHAGEN, DENMARK, METROPOLITAN AREA.					
Numbers	1	2	3	4	5	6	7	8	9	0
Letters	Central	ABD	EFG	HIK	LMN	OPR	STU	VXY	ÆØ	Hjælp
					SOME DANISH RURAL AREAS.					
Numbers	1	2	3	4	5	6	7	8	9	0
Letters	A	B					X	Y		Central
					SOME AREAS IN GERMANY AND AUSTRIA.					
Numbers	1	2	3	4	5	6	7	8	9	0
Letters	A	B	C	D	E	F	G	H	J	K

Figure 8-7. Foreign dial number plate arrangements.



TL 54753 TL 54752

Figure 8-8. Two typical American dial number plate arrangements.

which would have to be changed to continuous operation (a simple change).

c. Some of the small, cheap, vibrating type of ringing machines used on a start-stop basis in very small offices would not be reliable for continuous operation for a long period of time because of contact wear.

TL 54754

Figure 8-9. American dial with number card marked for use in foreign area.

816. TIMED CUT-OFF OF CONVERSATIONS.

a. In foreign countries, dial offices are frequently arranged so that local or toll calls, or both, will be cut off automatically after a fixed time interval which may be from 4 to 12 minutes depending upon the particular locality. In some places operators disconnect calls after a predetermined time.

b. These practices are apt to interfere seriously with important military calls. In manual offices timed cut-off can be eliminated by changing the operating practices.

c. To eliminate this feature in dial offices requires simple circuit changes, but the work will involve numerous circuits and will require detailed knowledge of the office arrangements.

d. Where this feature is not eliminated all personnel making important calls through the central office lines or trunks should understand that such calls may be *time-released.*

817. PRINCIPAL LOCAL SWITCHING SYSTEMS, POSSIBLE INTERCONNECTION TROUBLE.

a. General. The following is a summary of the principal types of local switching systems used in foreign countries with a list of possible sources of interconnection trouble. In some cases an opinion is given of the general prevalence of the condition which may give trouble.

b. Magneto (Local Battery) (LB) Manual Switchboards.

Low-resistance line signals............rare.
Simplex signaling from subscriber......rare.
Use of bells or trunk signals...........rare.
Use of 50-cycle ringing
current...........common in small offices.
Other special signaling conditions.......rare.
Lack of PBX battery and
generator feeders................general.
Insufficient capacity......many small offices.
Unreliability.......many offices (par. 804b).

c. Central Battery Signaling (CBS or BCS) Manual Switchboards.

Signaling and
transmission.........consider in all cases.
Special signaling........few very old offices.
50-cycle ringing.....................rare.
Lack of PBX battery and
generator feeders...............common.
Inadequate capacity.......many small offices.

d. Common Battery (CB) Manual Switchboards.

High-resistance transmitter
battery supply.................common.
Line circuits arranged for message register
at station.................Denmark only.
Lack of PBX battery and
generator feeders...............common.
50-cycle ringing ....rare.
Difficulty in segregating Signal Corps from civilian calls where *automatic call distributing* arrangements
are used.........not frequent (par. 821e).

e. Rotary Power Driven Dial System.

High-resistance transmitter battery
supply..........not standard but used in some cases.
Lack of PBX battery and
generator feeders.............rather common, especially in small offices of 7D code.
Danger of overloading
registers......small offices (par. 804b(2)).
Senders arranged for message registers at stations.............probably Denmark only.

f. Ericsson Power-driven Dial System.

High-resistance transmitter battery supply..........standard—quite common.
Special high-resistance transmitter battery supply..............used only in Sweden.
Lack of PBX battery and generator feeders..................rather common, especially in small offices.
Danger of overloading registers......small offices (par. 804b(2)).

g. Step-by-step Dial Systems.

High-resistance transmitter battery supply......not standard for this type of system but used in some countries, notably Germany.
Timed cut-off............recently adopted in some places—use so far is rare.
Lack of PBX battery and generator feeders..................rather common, especially in smaller offices.
Use of line circuits requiring message register at station...probably only used in Denmark.
Lack of connector terminals arranged for PBX hunting...........small offices only.

h. R–6 Dial System (Thomson-Houston).

Lack of PBX battery and generator feeders .... common.
Danger of overloading registers................(par. 804b(2)).

i. Haslor Dial System.

Lack of PBX battery and generator feeders...............common.
Danger of overloading registers................(par. 804b(2)).
Timed cut-off....................possibly.

j. Merck *Fallwaehler* Dial System.

Lack of PBX battery and generator feeders.

k. Demiautomatic System.

Senders arranged for message registers at stations.
Lack of PBX battery and generator feeders.
High-resistance transmitter battery supply.

l. Semiautomatic Dial System.

(Do not confuse with remote control systems)
High-resistance transmitter battery supply..................common.
Lack of PBX battery and generator feeders...............common.
50-cycle ringing......................rare.
Difficulty in segregating Signal Corps from civilian calls........common, (par. 829d).

m. All-relay Dial Systems.

High-resistance transmitter battery supply .... rare.
Small terminal capacity.
Danger of overloading (par. 804b).
Lack of PBX battery and generator feeders .... general.
Lack of arrangements for PBX hunting .... common.
50-cycle ringing......................rare.
Timed cut-off...........more common than in other types of offices, but not extensive.

n. Magneto Remote Control Dial Systems.

(Note: Called *semiautomatic* in some countries but do not confuse with previously listed semiautomatic).
Signaling range limited to 400-ohm conductor loop in few offices Siemens-Halske type.
50-cycle ringing.....................rare.
Questionable reliability under war conditions (par. 804b).
Insufficient capacity.
Lack of PBX battery and generator feeders .... general.
No arrangements for PBX trunk hunting .... general.
Impossible to segregate Signal Corps from civilian calls........common, (par. 831c).

o. Common Battery Remote Control Dial Systems.

(Called *semiautomatic* in some countries but do not confuse with previously listed semiautomatic.)
High-resistance transmitter battery supply.
50-cycle ringing.....................rare.
Insufficient capacity.
Lack of PBX battery and generator feeders .... common.
No arrangements for PBX trunk hunting .... common.
Questionable reliability under war conditions (par. 804b).
Difficulty in segregating Signal Corps from civilian calls........common, (par. 832c).

p. Crossbar Systems.

These systems are used only in the United States and Sweden.
The following applies only to systems used in Sweden.
High-resistance transmitter battery supply.
No provision for PBX hunting...rural offices.
No PBX battery and generator feeders....................rural offices.

Section III. PRINCIPAL FOREIGN LOCAL SWITCHING SYSTEMS

818. GENERAL.

This section contains descriptive matter for the assistance of personnel having only a general knowledge of switching systems, in obtaining some idea of the principal differences between the various foreign systems as classified herein. It also gives pointers which will help in identifying the various types of switchboards without detailed technical checks together with the localities wherein the particular systems are likely to be found.

819. MAGNETO (LOCAL BATTERY) (LB) MANUAL SWITCHBOARDS.

a. Each telephone at or connected to this type of switchboard must be equipped with a magneto for signaling the operator. The operator completes calls manually to all lines and trunks served by the switchboard by means of connecting cords. The station magneto gives this type of switchboard its name *magneto* in American practice. Each station is also equipped with batteries for a local talking battery supply, from which comes the name *local battery* or equivalent in foreign practice.

b. In size these switchboards may vary from a few lines to many thousands of lines. The simplest forms consist of wall-mounted or desk-mounted units with a set of bells, a jack, and a connecting cord for each line. The larger sizes use floor type switchboards with key and cord shelves provided with conventional types of cord circuits and have a line jack and signal field in the face of the switchboard. The line signals and the cord supervisory signals in these cases are usually ringdown drops similar to those used in Signal Corps telephone central office sets of the magneto type. Sometimes, however, the signals may be of bullseye, shutter, or target types or may consist of relay controlled lamps. In these cases the switchboards appear like some other manual types and can be identified as magneto only by examination of the circuits or by noting that the stations use magnetos.

c. This type of switchboard is used to some extent in practically all countries, mostly in rural areas, but will be found even in large cities. Most of the telephone switchboard manufacturers in the world have made some switchboards of this type. There is not enough essential difference between the various makes of these switchboards to affect interconnecting problems. However, special signaling arrangements (par. 810) may be encountered very infrequently with all makes.

820. CENTRAL BATTERY SIGNALING (CBS OR BCS) MANUAL SWITCHBOARDS.

a. The name for this type of switchboard results from the fact that the switchboard battery furnishes the power for operating the line and supervisory signals under control of the station switchhook. This battery is generally small, sometimes only a set of dry cells. It is not used for talking battery supply, and each station must be equipped with batteries for this purpose. Magnetos are not used at the stations although some station sets may actually consist of converted magneto sets with the magneto disabled.

b. In size these boards vary from less than 10 lines to about 1,000 lines. The small sizes are table-mounted units, but the larger sizes use conventional floor-mounted switchboard positions. The line and supervisory signals may be of bullseye, shutter, or target types or may be lamps. The key and cord equipment is mounted on a shelf in a conventional manner. The line signals and jacks may appear together in the face of the switchboard or separately. On large jobs the line jacks are sometimes multipled, but in some cases no multiple is provided and interposition trunks are used.

c. Because of the similarity of the signals, this switchboard is often difficult to distinguish from magneto types, and it is impossible to distinguish it from some common battery types by inspection only. Identification can be definite only by examination of the circuits or by noting that all stations use dry cells but do not use magnetos for signaling.

d. These switchboards are not used anywhere in large numbers but are found in many foreign countries, principally in the British Empire, in France, and the French Colonies. They appear to have been made mostly by British and French factories. The variations in different makes of these switchboards do not particularly affect interconnection problems. However, there are some unusual circuit arrangements not peculiar to any one manufacturer which affect interconnection seriously as covered in paragraph 811.

821. COMMON BATTERY (CB) MANUAL SWITCHBOARDS.

a. This system is called common battery or equivalent in both American and foreign practice because the battery supply to the telephone for both signaling and talking is provided by the central office or common battery. With this board the subscriber calls the operator by removing the receiver from the switchhook and the operator completes calls manually with conventional cord circuits. The normal telephone station is of the common battery manual type without dial, magneto, or local batteries, but exceptions occur on special lines.

b. This type of board sometimes occurs in small sizes as table or wall-mounted units, but in most cases a conventional floor type position is used. In both multiple and nonmultiple arrangements the features of these boards follow about the same variations as in American practice. Generally, the cord circuits are of the listening key, manual ringing type without flashing recall. However, such features as automatic listening and ringing and flashing recall are also found. In some cases A boards have no subscriber multiple, all calls being completed through B boards[7]. In some localities calls from these switchboards to dial offices are completed by operator's dials, but key sets are used exclusively for this purpose in some areas. The line and supervisory signals in multiple installations are usually lamps, but in the nonmultiple jobs they are frequently of the bullseye, shutter, or target types.

c. It is sometimes difficult to distinguish this type of switchboard from other manual types by superficial examination. However, it should be noted that this type of switchboard uses a substantial battery as compared to magneto or CBS jobs. If the telephone stations are not equipped with magnetos or local batteries then it is safe to assume that the associated manual switchboard is of the common battery type.

d. Common battery manual switchboards will be found in practically all countries, generally in larger towns or cities. Almost all telephone switchboard manufacturers throughout the world have made some of these switchboards. The various makes of these switchboards do not differ insofar as interconnection problems are concerned as all manufacturers make these switchboards more or less to customers' specifications. However, there are certain features, mostly peculiar to certain localities, which will affect interconnection problems as noted in paragraph 812.

e. Some fairly large cities are provided with common battery manual switchboards arranged for *automatic call distribution*. With this arrangement lines do not have individual answering jacks. Instead, they are connected to common automatic equipment which routes originating calls to answering jacks or directly to completing cords appearing before idle operators in rotation in such a manner as to equalize the operators' loads. It should be noted that with this system, calls from Signal Corps and civilian lines could not readily be segregated for handling by separate operators.

822. ROTARY POWER-DRIVEN DIAL SYSTEM.

a. This is a register (sender) system which provides full dial service. In some localities special contacts are used on the dial, and message register equipment is provided at the station (par. 813b). By means of a standard dial telephone the subscriber may dial calls into the register which controls the operation of the switches in setting up the call. The switches are of the power-driven rotary type as shown in figures 8-10 and 8-11. The switch frame for a small office is shown in figure 8-12.

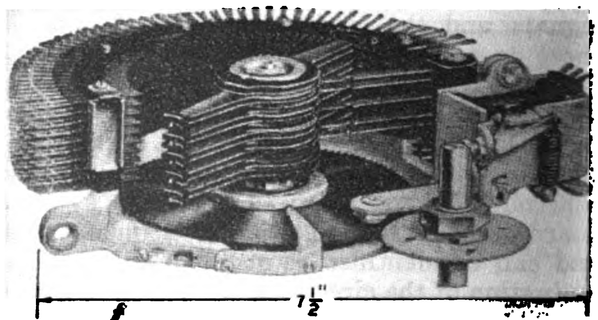


Figure 8-10. Power-driven rotary switch for 100 lines or trunks.

b. The switches and general appearance of the switch frame distinguish this type of dial system from all other full dial systems. However, in Denmark, it is necessary to distinguish this type of system from the demiauto-

[7] An A board is a switchboard at which calls from subscribers are answered. A B board is a switchboard at which incoming trunks from A boards terminate for connection to subscriber loops.

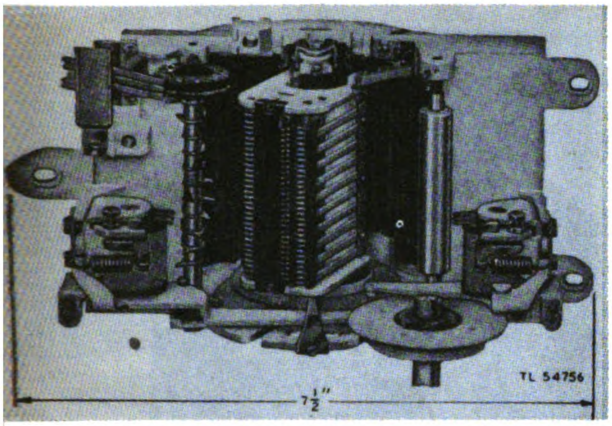


Figure 8-11. Power-driven rotary switch for 300 lines or trunks.

matic system which uses the rotary power-driven equipment for originating traffic, but has a manual B position for completing terminating calls.

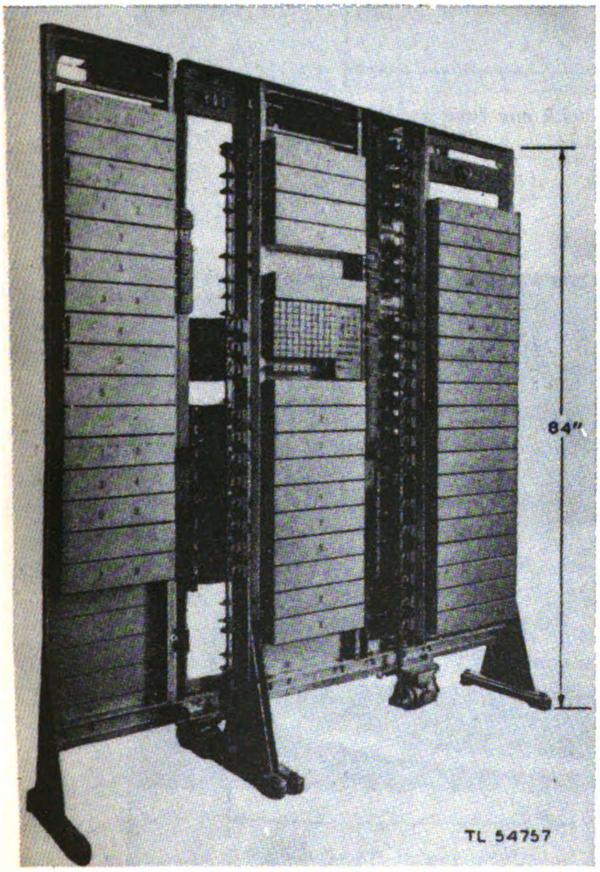


Figure 8-12. Frame of equipment for small office of the rotary power-driven type.

c. Rotary power-driven dial equipment is found in many countries in Europe and South America, in Mexico, and in a few places in China. None is used in Great Britain, Sweden, or Germany. This equipment is used in offices from several hundred lines to large multiunit offices in large cities and is manufactured by the various affiliates of the International Standard Electric Corporation in different countries. The largest manufacturers in the past have been Le Materiel Telephonique of Paris and The Bell Telephone Manufacturing Company of Antwerp. There are no important variations in this equipment as made by the different factories. However, there are some differences in features as specified by different customers which may affect interconnection problems (pars. 813 and 817e).

823. ERICSSON POWER-DRIVEN DIAL SYSTEM.

a. This is a register (sender) system which provides full dial service. With a dial telephone usually of the conventional type, the subscriber dials his call into the register which controls the operation of the switches in setting up the call. In some cases the telephone dials have some added features which are related to the method of charging for service but which are not otherwise essential. The unique switches which distinguish this system from all others, are all of the Ericsson power-driven type as shown in figures 8-13 and 8-14.

b. This system is used in sizes from several hundred lines to multiunit offices in large cities. The equipment is made by various branches of L. M. Ericsson Company in different countries with the principal factory in Stockholm, Sweden. This type has also been made by the Russian government. Ericsson power-driven equipment will be found in many countries in Europe, South America, and Asia. None is used in Great Britain or Germany. The variations in this system as supplied from the different factories are only those specified by the different customers. See paragraphs 808a and 817f for the most important variations.

824. STEP-BY-STEP DIAL SYSTEMS.

a. With foreign step-by-step dial systems (sometimes called Strowger Automatic System) the subscriber receives full dial service.

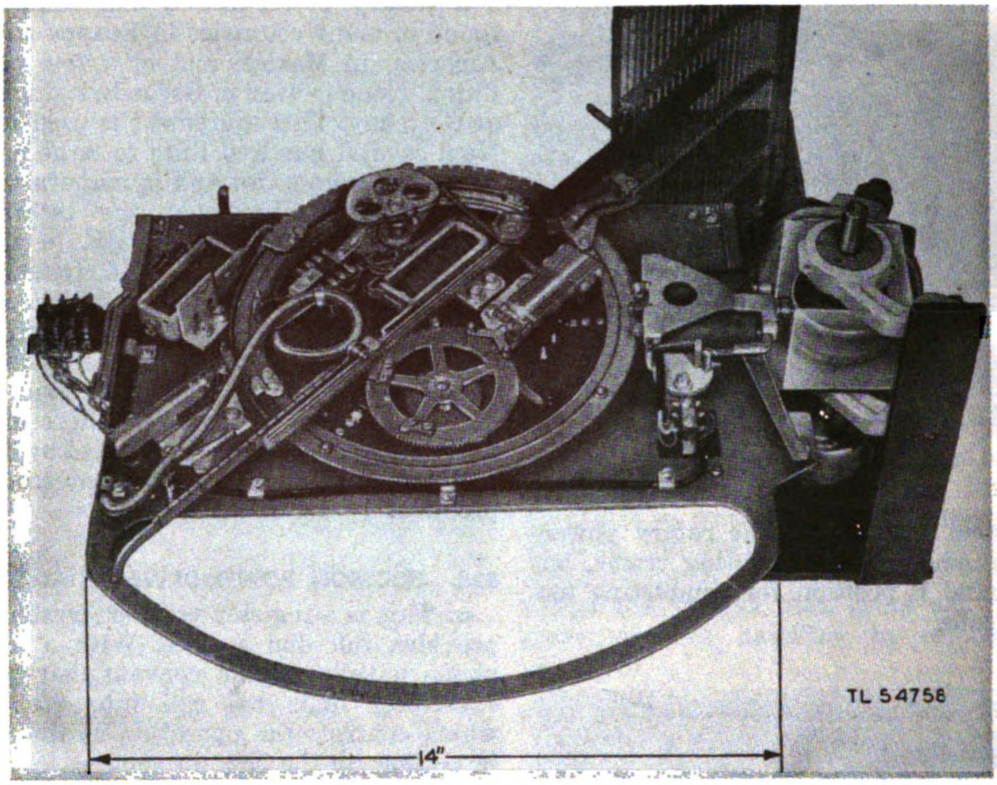


Figure 8-13. Ericsson power-driven switch with one bank section.

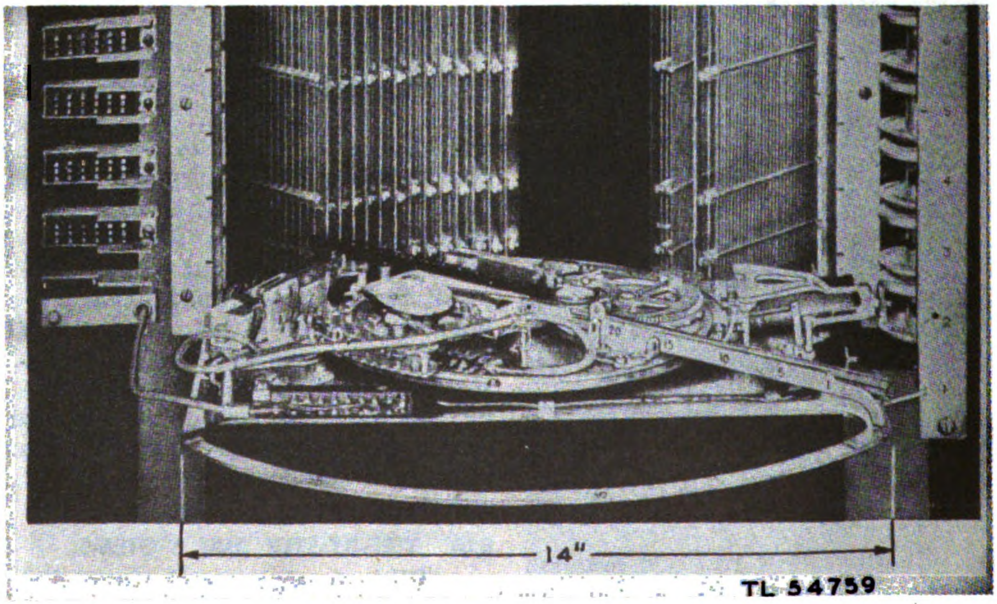


Figure 8-14. Typical Ericsson power-driven switch multiple arrangement.

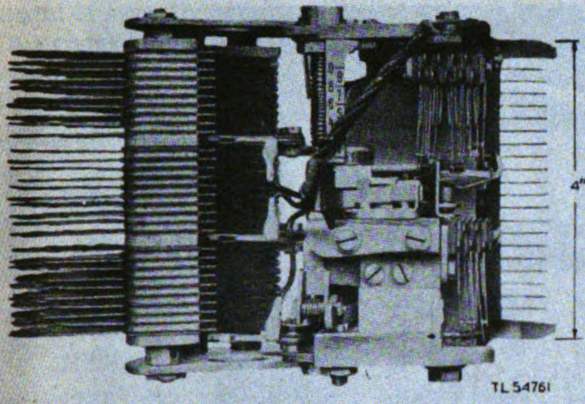


Figure 8-15. German type step-by-step switch.
(Siemens-Halske, Berlin)
(Used generally in German offices)

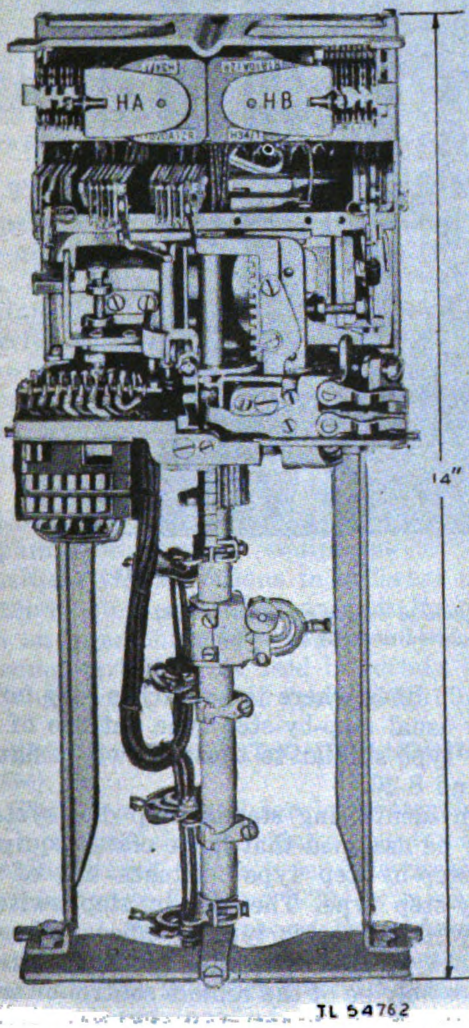


Figure 8-16. British type step-by-step switch.
(Automatic Telephone Manufacturing Company, England)
(Used extensively in Great Britain and also made for export trade)

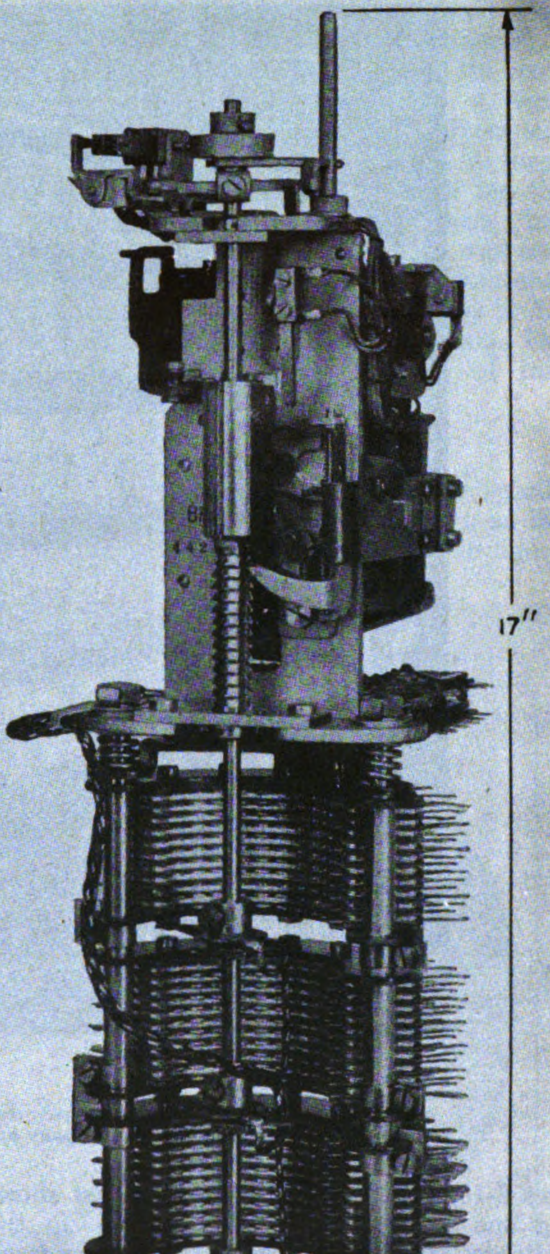


Figure 8-17. German type step-by-step switch.
(Mix & Genest, Berlin)
(Made for PBX & export trade)

The station equipment is a conventional dial set except where some special condition must be met. In the most usual form of this system the step-by-step switch is the basic element and distinguishing feature. Samples of different types of these switches are shown in fig-

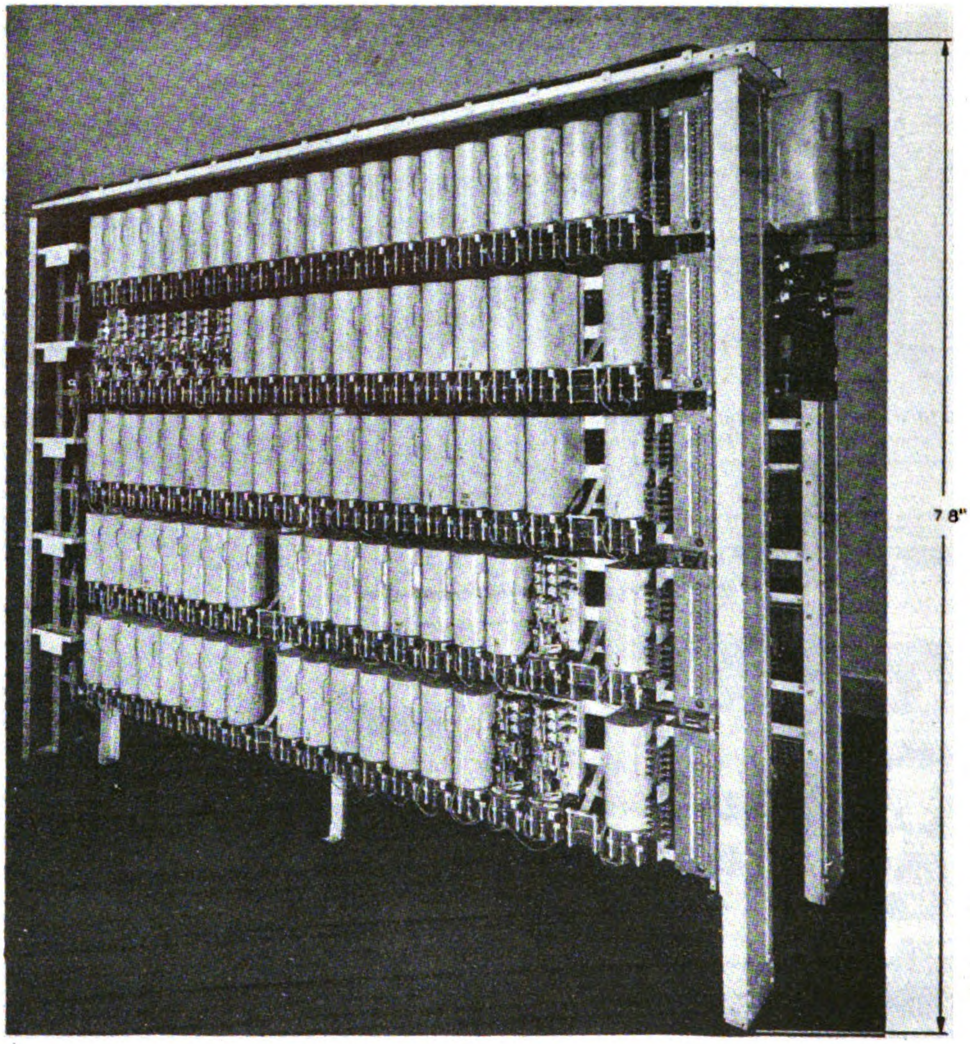


Figure 8-18. American type step-by-step switches mounted on one variety of frame. (Automatic Electric Company of Chicago, exported to many countries)

ures 8-15, 8-16, 8-17, and 8-18, the last showing one type of switch frame also. In the ordinary arrangement, registers (or senders) are not used and successive step-by-step switches make selections as each digit is dialed, each switch following the dial pulses for one or two digits as received. An exception to the usual arrangement is the director type of step-by-step system which uses step-by-step switches but the subscriber dials into the director (sender) which controls the selecting operations of the switches. This variation of the system is used in larger cities in Great Britain and also in Havana, Cuba. Another exception is the case of very small offices of less than 100 lines where the switches may not be of the usual step-by-step type but are of the rotary type similar to those shown in figures 8-19 and 8-20.

b. In identifying step-by-step dial systems it may be assumed that large offices equipped with step-by-step type switches are of the step-by-step type. The step-by-step switches usually identify this type of office. Offices of 200 lines or less with step-by-step switches may possibly be of the remote control or semiautomatic type (pars. 829, 831, and 832). Small offices with rotary switches may also be of types other than step-by-step, but by noting that the calling subscriber dials the called number and that the switches make selection in synchronism with the dialing it can be concluded that the system involved is of the step-by-step dial type.

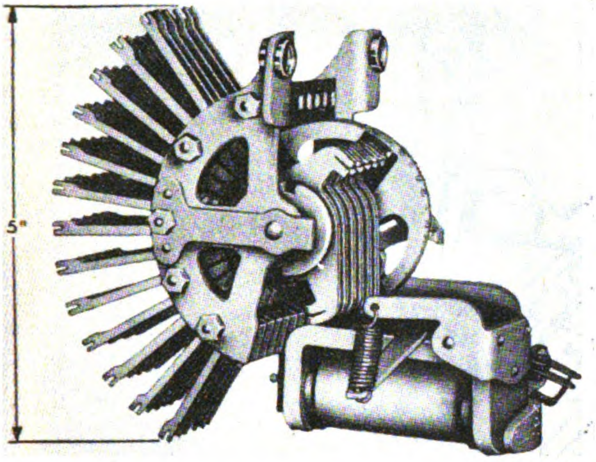


Figure 8-19. Typical rotary switch of magnet-driven type.

c. The step-by-step dial system is used more extensively in foreign countries than any other type of system. Sizes of offices run from less than 100 lines to full 10,000-line units in multiunit areas in large cities. The principal varieties of this equipment are made by the following companies and their affiliates: Automatic Electric Company, Chicago; Automatic Telephone Manufacturing Company, England; Siemens-Halske Company, Berlin; and various branches of the International Standard Electric Corporation. Some other companies make this equipment in small quantities. The variations in different makes of step-by-step equipment are not important from an interconnecting standpoint but there are some variations as used in certain localities which must be noted (par. 817g).

825. R–6 DIAL SYSTEM (THOMSON-HOUSTON SYSTEM).

a. This is a full dial service system which uses a magnet-driven rotary selector in all switching stages. These types of switches are shown in figures 8-19 and 8-20. By means of a conventional dial telephone the subscribers dial calls into registers which control the operation of the selectors involved in the calls.

b. The identifying features of this system are the type of switch used plus the fact that these switches do not, as in step-by-step operation, follow the subscribers dial pulses directly.

c. This system appears to have been used only in France and the French colonies. It is used extensively around Lille and the outskirts of Paris and in the North African colonies. These offices occur in sizes from less than 100 lines to about 7,000 lines. A large part of this equipment was made by the Thomson-Houston Company of Paris, but some practically identical equipment was also made by other affiliates of the International Standard Electric Corporation, notably by Le Materiel Telephonique (LMT) of Paris. The differences between various makes of this equipment are not significant.

826. HASLER DIAL SYSTEM.

a. The Hasler system uses a rather special type of magnet operated switch known as the Hasler 121 point selector, illustrated in figure

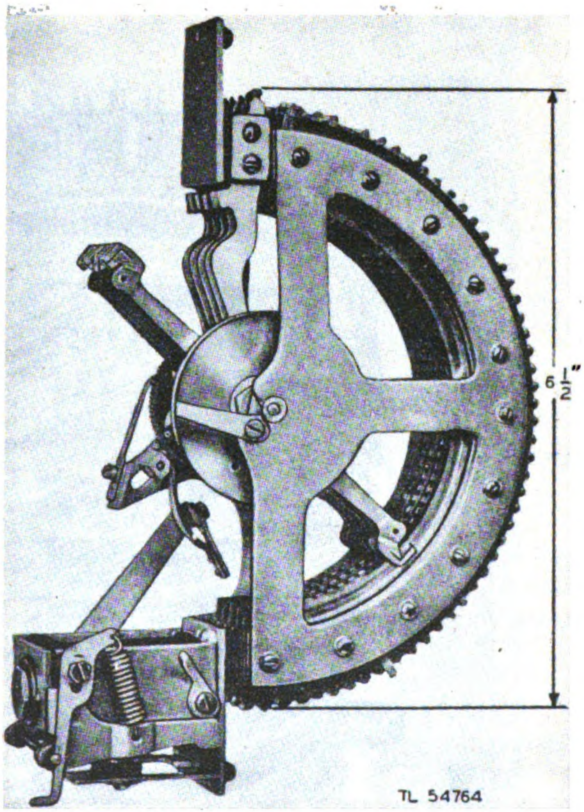
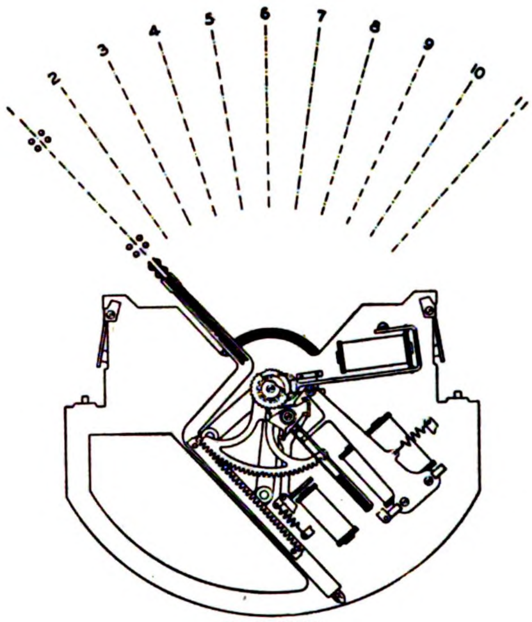


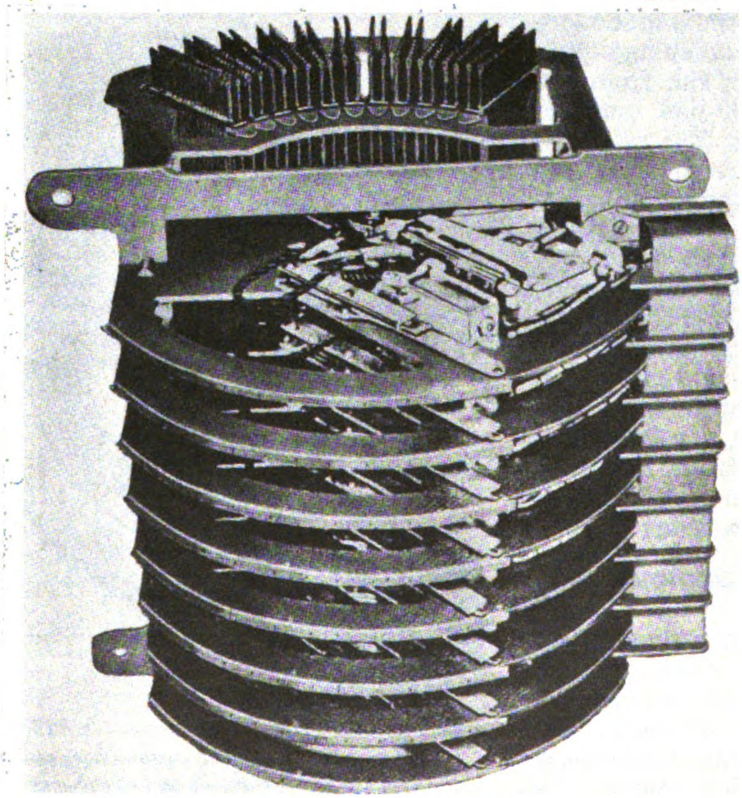
Figure 8-20. Thomson-Houston rotary switch. (Used in R–6 system and elsewhere)

8-21. It provides full dial service and uses the conventional dial telephone. The subscribers dial into registers (senders) which control the operation of the switches.

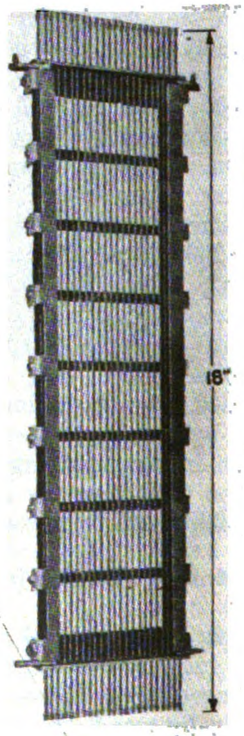


PLAN VIEW

TL 54766



GROUPS OF SELECTORS
WITH BANK SECTIONS



BANK SECTION

TL 54767

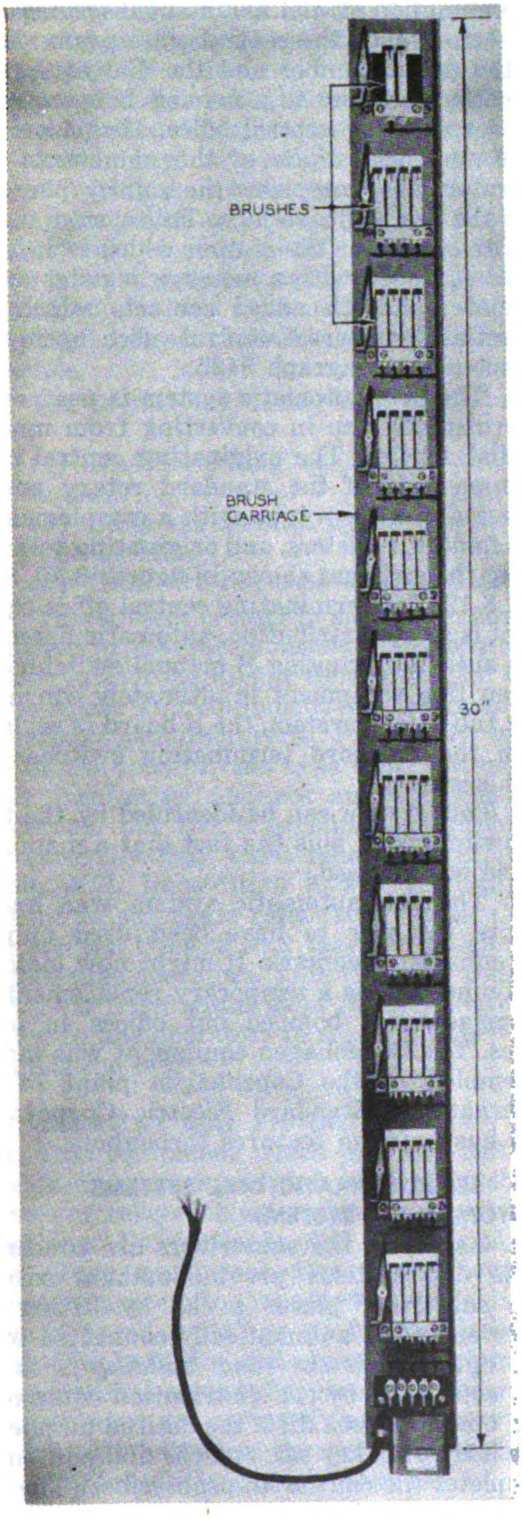
Figure 8-21. Hasler 121-point selector and banks.
(Manufactured by Hasler S.A., Berne, Switzerland)

b. The identifying feature of this system is the Hasler selector. Superficially this resembles the Ericsson selector (par. 823), but is magnet-operated instead of power-driven and has access to 121 points instead of 500 points.

c. This system will be found in sizes from 100 lines to 10,000 lines. It is used extensively in Switzerland and has so far been made only by Hasler, S.A., Berne, Switzerland. There is no information as to places to which this system may have been exported.

827. MERCK *FALLWAEHLER* DIAL SYSTEM (DROP SELECTOR)

a. This system uses a distinctive selector which selects in a vertical motion from the top downwards under direct control of the telephone dial, which gives the system its name. This selector and a typical switchframe are shown in figures 8-22 and 8-23 respectively.



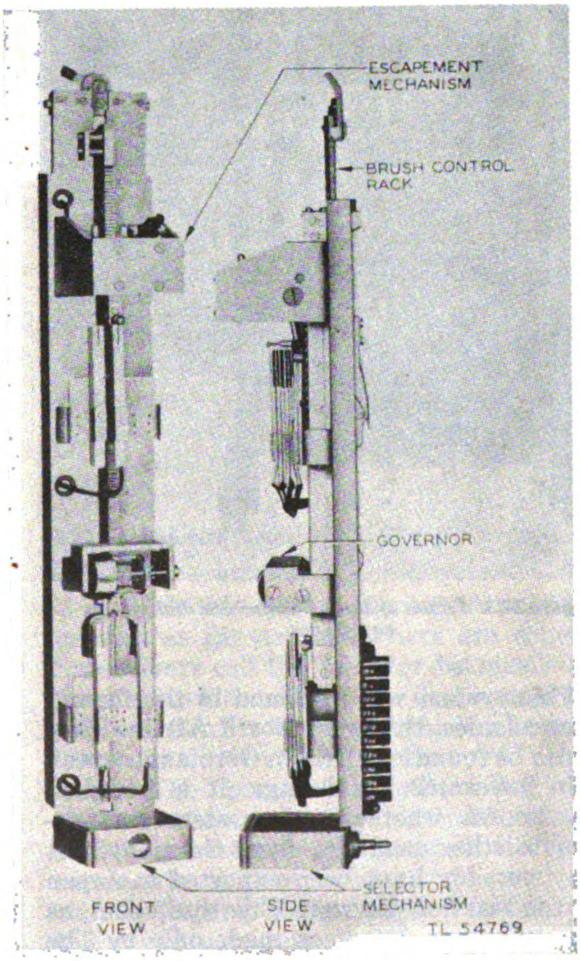


Figure 8-22. Merk Fallwaehler *Selector*

It provides full dial service and uses telephone equipment of the conventional dial type.

b. This type of system can be immediately identified by the appearance of the selector. In size it varies from less than 100 lines to about 6,000 lines.

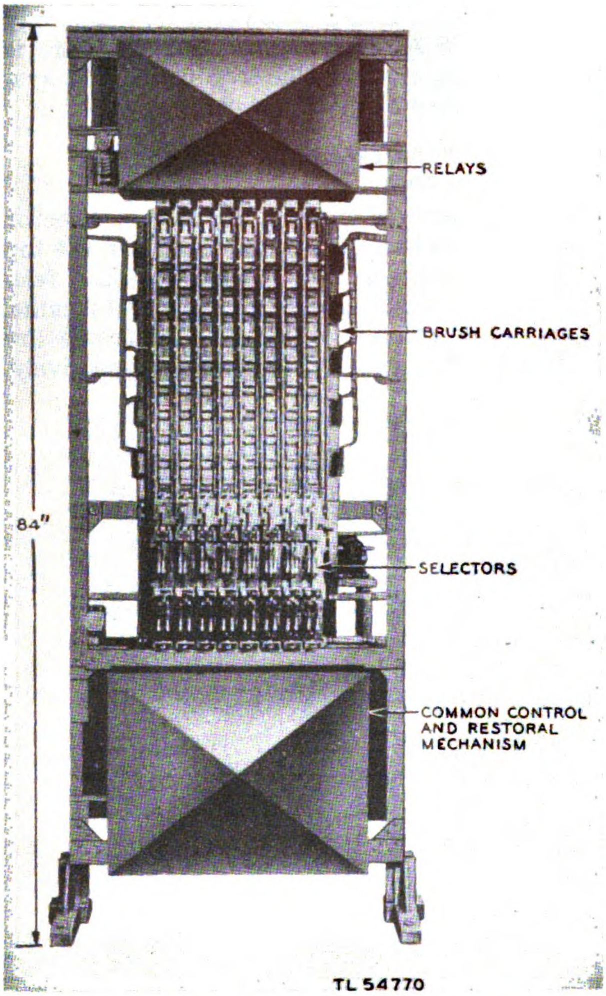


Figure 8-23. Frame of Merk Fallwaehler *dial system equipment.*

c. This system will be found in the former Italian colonies, chiefly in North Africa. They will also be found in PBXs in Germany, especially in government buildings. It is not definitely known whether this system was exported to other countries from Germany, but it may possibly have been exported to Japan since the start of the war. This equipment, as far as is known, has been made only by The Telefonbau u. Normalzeit A.G. of Frankfort-am-Main, Germany.

828. DEMIAUTOMATIC SYSTEM (D SYSTEM).

a. With this system the subscriber receives a combination of dial and manual service. The subscriber dials the central office prefix digits of the called number and the dial equipment then connects him to a manual B operator in the terminating central office. He passes the four numerical digits of the number to this operator, who completes the call by plugging into the line multiple jack. This system uses a dial telephone at the station which is in most cases equipped with a message register and a special dial with added contacts which are essential for correct central office operation, as noted in paragraph 813b.

b. The demiautomatic system is used as an intermediate step in converting from manual to dial service. The originating central office equipment is of the standard rotary power-driven dial system type with a complement of line finders, registers, and originating selectors using the switches shown in figures 8-10, 8-11, and 8-12. The terminating central office equipment is a call distribution, automatic listening, and automatic ringing B manual switchboard. When this equipment is ultimately converted to a full rotary system, the B board is replaced with the standard terminating switches for that system.

c. This system can be identified by the type of switch used, plus the fact that a manual B board is also used.

d. The demiautomatic system was known before the war to have been used only in Copenhagen, Denmark. It might now logically be found also as a temporary replacement arrangement for bombed out offices in other cities. The Copenhagen equipment was mostly assembled in the Copenhagen plant of the International Standard Electric Corporation and has uniform features throughout.

829. SEMIAUTOMATIC DIAL SYSTEMS (AUTOMANUAL SYSTEM)

a. As far as the subscribers are concerned these dial systems provide manual service. The subscriber places a call by lifting the receiver and is automatically connected to an idle operator *in the same building with the dial equipment* by call distribution equipment. The operator then dials the desired number or sets it up on a key set, and the dial equipment completes the call for the subscriber. The station equipment consists of a conventional common battery telephone.

b. The manual switchboard positions associated with this equipment are usually of the cordless type with about 50 sets of supervisory lamps and keys on each position, each set corresponding to a connection handled by the operator. In some cases these keys and lamps are not used, and only a dial or key set and a few master keys are used on each position. The switching equipment generally uses step-by-step switches or rotary switches either power-driven or magnetically operated, but all of the types of switches previously shown have been used in this system. This switching equipment has also been built on the all-relay principle.

c. The identifying features of this system are:

(*1*) Dial switching equipment of some type is used.

(*2*) Calls are handled by an operator in the same building.

(*3*) Dials are not used at the telephone.

d. This system is used in sizes from several hundred to several thousand lines scattered mostly in Europe except Germany. The total use is small. This equipment has been made by numerous manufacturers. Practically every one of the jobs of this type differs from the other insofar as features and equipment is concerned, but the interconnecting problems are generally only those mentioned in paragraph 817l. In addition it will generally be difficult to segregate calls from Signal Corps and civilian lines so that they can be handled by different operators. This is due to the fact that calls from subscribers are automatically routed to idle operators in rotation in order to equalize the load.

830. ALL-RELAY DIAL SYSTEM.

a. This equipment which provides full dial service, consists mainly of small cabinets or frames of relays which perform the switching functions. Conventional dial telephones are used. Very small jobs, like those shown in figure 8-24, are often mounted on walls, inside or outside of buildings or on standards or poles. The batteries and charging equipments are sometimes mounted separately. Sometimes these systems are operated from a power supply without batteries, the system then being out of order during power failures.

b. This system can be identified by the fact that the switching equipment consists of relays plus the fact that dials are used at the stations. The latter fact distinguishes the system from remote control and semiautomatic systems using relays for switching.

c. All-relay dial systems are occasionally used in foreign practice in sizes of several hundred lines, but the usual sizes range from about 10 lines to 100 lines. Some of these systems have been made by all major suppliers of dial equipment. These systems are found more frequently in Europe than elsewhere. While there is considerable detailed variation in these systems, these differences do not affect interconnection problems as much as the inherent limitations of this type (par. 817m).

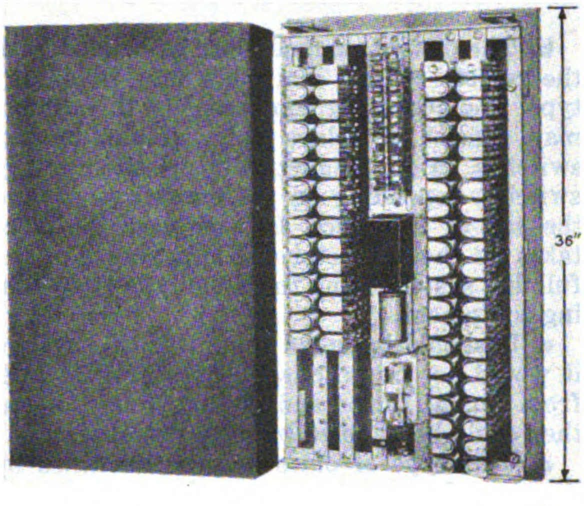


Figure 8-24. Typical small all-relay dial system.

831. MAGNETO REMOTE CONTROL DIAL SYSTEM.

a. With this system the service is magneto manual as far as subscribers are concerned. Subscribers call the operator by means of the magneto which causes the dial equipment at the central office to connect the line to an operator in a *distant* manual office over a control trunk. The operator dials the called number back over the control trunk which causes the switching equipment to complete the call and release the control trunk. At the end of the call the calling party rings-off which causes the switches to release. The stations use conventional magneto sets with local batteries for talking.

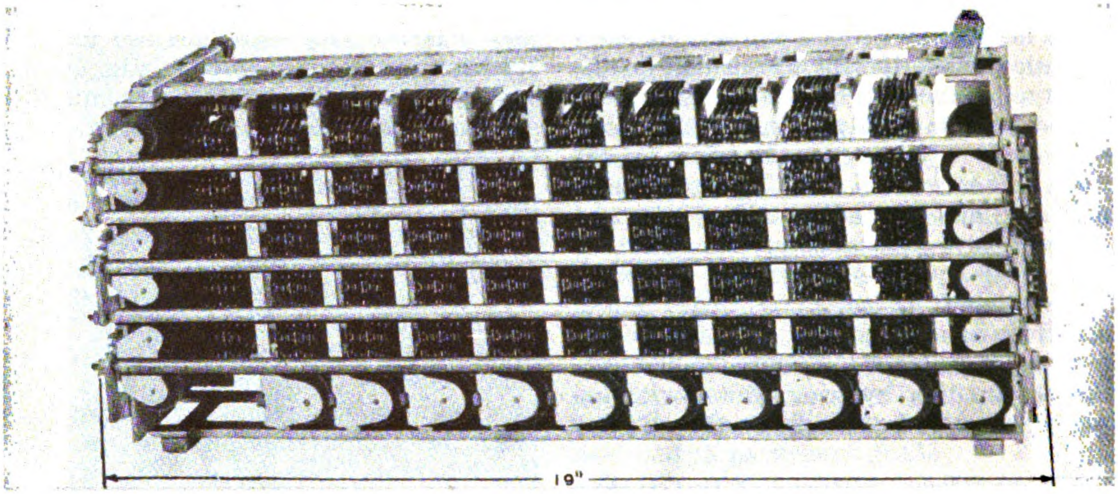


Figure 8-25. Swedish crossbar switch.

b. The distant manual office associated with the remote control dial office may be of any type. The switching equipment of this system may consist of relays only, of step-by-step switches, or of magnetically operated rotary switches depending on the manufacturer and the size of the office. In each case the office takes on the characteristic appearance of the full dial system using the same type of switching equipment.

c. It should be noted that with this system it would not be practicable to segregate calls from Signal Corps and civilian lines so that they could be handled by different operators.

d. This type of office may be identified by the use of magneto sets at the stations and the absence of any manual switchboard in the immediate vicinity of the switching equipment. In sizes these offices range from about 10 lines to 200 lines.

e. The small amount of this equipment in use is scattered throughout all countries except Germany. Some of this equipment has been made by all manufacturers of dial equipment but most systems will be found to have been made by the following companies and their affiliates: Automatic Electric Company, Chicago; Automatic Telephone Manufacturing Company, England; Siemens-Halske, Berlin. (The last named company has made these systems for export only.)

832. COMMON BATTERY REMOTE CONTROL DIAL SYSTEM.

a. This system provides common battery manual service as far as the customers are concerned. Subscribers call the operator by lifting the receiver, which causes the dial equipment to connect the calling line to a *distant* manual office over a control trunk. The operator dials the called number back over the control trunk which causes the switches in the dial office to complete the connection and release the control trunk. When the calling party hangs up at the end of the call the switching equipment releases. The station equipment is a conventional common battery telephone without a dial.

b. The remote manual office serving as a control center may be of any type. The switching equipment consists of relays for small offices and usually of step-by-step or magnetically driven rotary switches in the larger offices.

c. With this system it would not be practicable to segregate calls from Signal Corps and civilian lines so that they could be handled by different operators.

d. This type of office may be identified by the fact that the stations are of the common battery types and that there is no *nearby* manual switchboard associated with the dial equipment. Equipment of this type may be used in offices which serve from 50 to 200 lines.

e. This system is not extensively used anywhere but is apt to be found in almost all countries except Germany. Some of this equipment has been made by all dial system manufacturers but most of it by the following companies and their affiliates: Automatic Electric Company, Chicago; Automatic Telephone Manufacturing Company, England; Siemens-Halske, Berlin (export trade only). The different varieties all present about the same interconnection problems (par. 817o). However, Siemens-Halske jobs seem to make more general use of high-resistance transmitter battery supply circuits than other systems.

833. SWEDISH CROSSBAR SYSTEMS.

a. This system which provides full dial service uses the crossbar switch shown in figure 8-25 as line finders, selectors, and connectors. Conventional dial telephones are used except where special features are required. All switches except the line finders follow dial pulses in performing the selecting functions, in contrast to the American crossbar practice of using common control.

b. The crossbar switch provides a ready identification of this system.

c. Swedish crossbar systems have, as far as is known, been used only in Sweden. This equipment was originally made only by the Swedish government in its own factories, but may now also be made by the L. M. Ericsson Company of Stockholm, Sweden. A large number of small rural offices with capacities of 20, 50, and 90 lines have been installed and in addition some large capacity offices have been installed in cities.

Type of plant	Approx. weight and ship space[a] for 25 miles		Estimated man-days[b] for constructing 25 miles
	Short tons	Cu. ft.	
Long range field Wire W-143 and Cable Assembly CC-358-( ) (Spiral-four).			
Wire W-143			
Aerial construction—150′ span			
Erecting pole line and cable, 1 pair	46	2,700	258
Erecting cable on existing pole line	5.2	230	110
Ground surface-construction,[d] 1 pair	4.8	210	31
Buried[c] construction,[d] 1 pair	4.8	210	76
2 pairs	9.6	420	98
Cable Assembly CC-358-( )			
Aerial construction—150′ span			
Erecting pole line and one cable	52	3,100	258
Erecting one cable on existing pole line	11.5	630	110
Ground surface construction[d]	11	610	46
Buried[c] construction,[d] 1 cable	11	610	71
2 cables	22	1,220	105
Open wire.			
Tactical open wire line—150′ Span			
1 Pair—4″ x 4″ lumber supports	54	3,100	283
4 Pair—4″ x 4″ lumber supports	72	3,900	365
8 Pair—round poles—22′ class 9	179	8,800	625
Tactical open wire line—200′ span			
1 Pair—round poles—20′ class 9	100	5,100	290
4 Pair—round poles—20′ class 9	111	5,500	363
8 Pair—round poles—22′ class 9	146	7,100	528
Fixed plant open wire line—150′ span			
4 Pair—round poles—30′ class 7 (average)	254	12,700	538
8 Pair—round poles—30′ class 7	297	14,300	733
Lead-covered cable.[e]			
Aerial[f]—150′ span (51 pr. 19 ga. CNB)[h]	334	15,000	625
Buried[g] (51 pr. 19 ga. CNB[h] jute protected)	132	5,100	1,300

[a] The material lists given in the respective manuals were used as a basis for determining approximate weight and ship space figures. In the case of Wire W-143, estimates are based on material requirements and construction methods similar to those given in TM 11-369 for Cable Assembly CC-358-( ). A material surplus of 25 percent is included.

[b] Assumes commercial crews and conditions including 8-hour day. Work time variations with locality can be expected. The hours required to build a pole line vary with the kind of soil encountered and with climatic conditions. For example, if holes must be dug in rock or if the ground is frozen, blasting will be required which will slow the work. Swamp land also will cause the work to take longer. Digging holes in frozen swamp land may be expedited by means of the Blast Driven Earth Rod (expected to be available soon), which is used to drive a small hole into which a charge of *PRIMACORD* is placed and then exploded to spring the hole to the desired diameter. The estimates assume that the work is done in mild weather and that ordinary earth digging is encountered. Hand digging in frozen ground will add about 50 per cent to the time and in rock it will double the time estimate. If tree trimming is required this will take 25 to 50 man-hours per mile.

[c] Assumes use of Plow LC-61.

[d] Does not include material or time for constructing overhead crossings. If highways or roads are crossed aerially an allowance may be made for each overhead crossing (of the type described in TM 11-369) as follows: poles and accessory hardware, 350 lbs., 10.5 cu. ft.; construction time, 0.65 man-days.

[e] Does not include splicing time; this usually takes from 20 to 25 man-days per mile.

[f] Provision is not made in materials list for terminals, drop wire, protectors, and terminating equipment. Job includes erecting pole line, placing strand and cable.

[g] Only time and material required for delivery and burying of cable are included. In the burying operation a plow and automotive equipment are required.

[h] Western Electric Company designation for 19 gauge cable with capacitance of 0.084 mf per pair mile.

Figure 9-1. Weight, space, and construction time.

CHAPTER 9

OUTSIDE PLANT

Section I. INTRODUCTION

901. INTRODUCTION.

This chapter covers important features of outside plant engineering. Section II gives the general considerations of importance in planning wire facilities, in surveying routes, in assembling materials, and in organizing construction work so as to make efficient use of personnel and equipment. Section III discusses the various types of wire plant, their physical characteristics, and methods of installation. Particular reference is made to the attention which should be paid to storm loading, and the sags and spacings of aerial wires. In sections IV and V notes are given on aspects of recovery and rehabilitation of communication lines in occupied territory. In section VI tentative information on the construction of lines suited to jungle use is set forth.

Section II. PLANNING

902. GENERAL.

a. Early decision is required as to the traffic facilities needed and the type of plant to be used. Only when these decisions have been reached can a survey of the line route be carried out, a list compiled of the needed material and equipment, and arrangements made for their supply. Factors to consider from the standpoint of traffic and of transmission are outlined in chapter 11 and in chapter 5 respectively. In selecting the type of line, the following should be taken into account:

(*1*) Time available for construction.
(*2*) Terrain and weather conditions.
(*3*) Length of line.
(*4*) Number and types of circuits.
(*5*) Availability of material and manpower.
(*6*) Availability of civil plant.
(*7*) Expected permanence of line (tactical or fixed plant).
(*8*) Future growth.

b. If, after a consideration of these factors, the use of aerial wire or cable lines is indicated, construction plans should take into account such factors as expected storm loadings, importance of line, and weight of wire or cable to be used. Information concerning construction of aerial lines is given in section III of this chapter. Typical problems in TM 11–487, give the relative material requirements for obtaining various circuit facilities, together with weights, volumes, and ship tons. A brief summary of this information is given in figure 9-1. Further information on the construction of open wire lines is given in TM 11–368 and TM 11–2253. In tactical situations, if enough circuits for two crossarms are required, consideration should be given to building single-crossarm lines over different routes to improve the likelihood of good continuity of service.

903. SURVEYING AND STAKING LINE.

a. A tentative selection of the route is usually made by reference to topographical maps, aerial photographs, or a preliminary survey. When the type of line and general route have been selected, the route should be covered by a *survey party* and the line staked. The care with which this work should be carried out is dependent upon the type and importance of the line. In the case of pole lines, the procedure should be followed that is outlined in TM 11–368, TM 11–369, or TM 11–2253, that is, span lengths should be measured, each pole staked, and notations made of the location of cross-

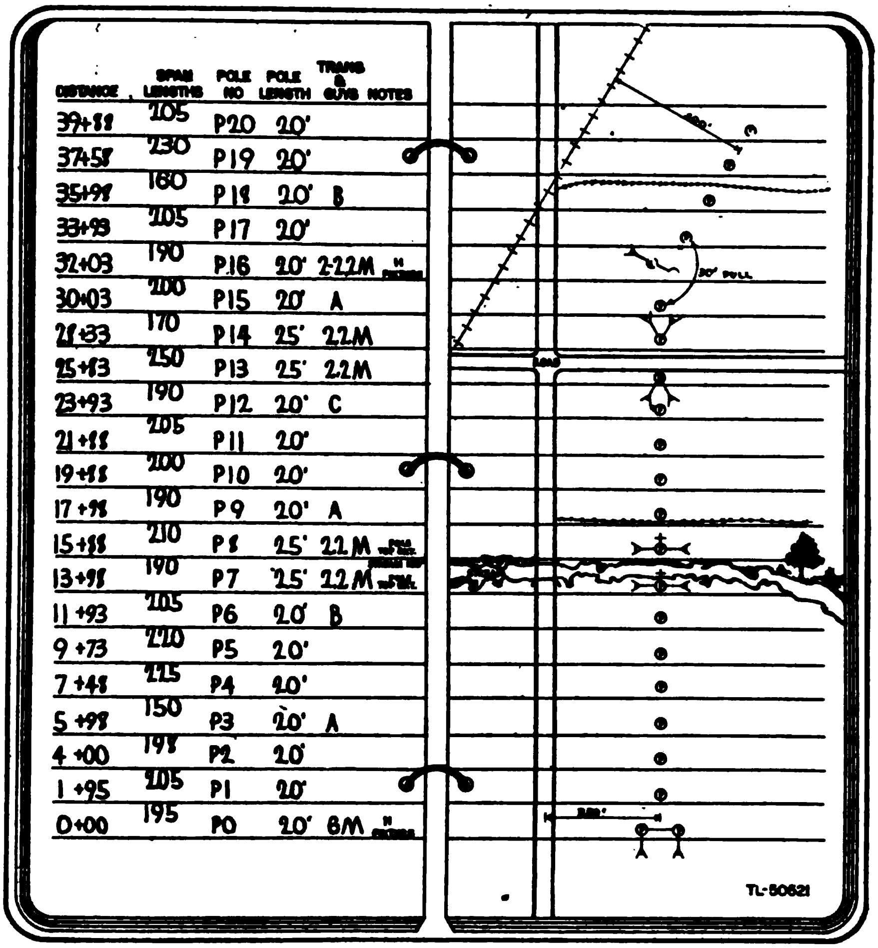


Figure 9-2. Typical line survey notes.

ings of all types, as well as changes in the type of line caused by conditions of terrain, etc.

b. It is important to avoid exposing aerial lines to electrical or physical hazards. If feasible, stay at least ¼ mile away from paralleling power lines, highways, and railroads. The detailed information gathered (fig. 9-2) should contemplate the necessity for compiling a list of needed material and information which will aid in its subsequent distribution.

904. MATERIAL CONSIDERATIONS.

Assistance in compiling a list of the materials required to construct various lengths of different types of line can be had by referring to the examples given in TM 11–487 and also to similar lists in TM 11–368 and TM 11–2253. The line materials should be distributed along the route where they will be ready for use by the construction forces.

905. ORGANIZING CONSTRUCTION.

The type and number of crews which should be organized to carry out the construction is dependent upon the available manpower and equipment, such as line construction trucks, pole hole diggers, plows, tools, etc., which are set forth in TM 11–487, TM 11–368, TM 11–2253, and TM 11–369. The latter three manuals outline typical crews for carrying out the respective types of construction whether pole line, ground surface, or buried. The main objective is to form crews of the proper size and experience to carry out the work in an orderly and logical sequence. For instance in building pole lines, in addition to a survey crew, there might be a crew to carry out each of the following functions: deliver materials, dig pole and anchor holes, equip and set poles, place anchors and guys, and install wire.

Section III. CONSTRUCTION

906. STORM LOADING.

a. In the United States, aerial communication lines are designed to withstand three type of storm loading (see storm map in TM 11-368), namely:

(*1*) Light loading: a wind pressure perpendicular to the line, of 12 pounds per square foot (about 70 mph, indicated) on the projected area of wires at a minimum temperature of 30° F.

(*2*) Medium loading: a wind pressure perpendicular to the line, of 8 pounds per square foot (about 60 mph, indicated) on the projected area of wires covered with 1/4 inch radial thickness of ice at a minimum temperature of 15° F.

(*3*) Heavy loading: a wind pressure perpendicular to the line of 8 pounds per square foot on the projected area of wires covered with 1/2 inch radial thickness of ice at a minimum temperature of 0° F.

b. Under conditions of severe exposure to high winds and ice, a still heavier type of construction may be warranted as indicated in TM 11-368.

c. European and Asiatic Countries have somewhat different storm loading requirements. In some foreign countries lines are designed to withstand three classes of loading and in others, two. In general, the heavy loading requirements result in about the same strength of line whether in Europe, Asia, or in the United States. In selecting the type of line for a given area where ice and temperature conditions are not known, an attempt should be made in advance of occupancy to obtain this information from communication or electric light agencies familiar with the countries involved. Where this cannot be done a general rule to follow is to use heavy loading construction in latitudes higher than 40°, medium loading between latitudes 30° and 40° and light loading in latitudes under 30°. There are exceptions to this rule. For instance, even in latitudes under 30° there are locations having elevations where ice and temperature conditions would indicate the advisability of using heavy loading area construction.

907. SELECTION OF POLES.

a. As discussed in paragraph 912d and in TM 11-368, 4 x 4 square poles or class 9 round poles are used in the construction of tactical aerial lines. To meet the more extensive needs of the fixed plant, data are given in figure 9-3 which will provide the necessary information required to select poles for various types of lines in different storm loading areas. The weight and circumference, 6 feet from the butt of various classes of round poles, are given in TM 11-487. The length of poles may be estimated from the information given in the notes accompanying figure 9-3.

b. Round poles are classified in such a manner that a pole of a specified class will support a given load regardless of the length of the pole. In other words, longer poles have a larger ground circumference than shorter poles of the same class.

c. If native poles are used they should be classed on the basis of the length and the circumference 6 feet from the butt as described in TM 11-487. They should also be given a preservation treatment as described in paragraph 925b.

908. CONDUCTOR SAGS AND WIRE SPACINGS.

a. The sag and the tension in a suspended member such as wire or field cable are related, and these will change with temperature and with external loads of ice or wind. To provide a line which will operate with a minimum of service interruptions and require a minimum of maintenance, it is advisable to select installation sags and tensions which will prevent subsequent stress of the suspended member beyond the elastic limit when it is subjected to low temperatures and a recognized degree of storm loading (note a of figs. 9-9 and 9-14, note b of fig. 9-19, and par. 906).

b. The nominal span may be 150 to 200 feet depending upon the degree of loading anticipated or the urgency for facilities. The shorter span provides a line of greater strength than the longer one, other factors being equal. Recommended span lengths for use in the various loading areas are given in TM 11-368, TM 11-369, and TM 11-2253. Figure 9-4 shows the relations of individual span lengths, sag, wire size, tension, and temperature for a nominal span of 150 feet. Figure 9-5 provides the same information for a nominal span of 200 feet. Since it is desirable to have all wires on the same line as well as the same crossarm at

Number of wires on line[a]	Class of pole[b, c, d] for various loading area and span length					
	Heavy		Medium		Light	
	150 ft.	200 ft.	150 ft.	200 ft.	150 ft.	200 ft.
1–8	9	7	9	9	9	9
9–16	7	6	9	9	9	9
17–24	5	4	7	7	9	9
25–32	4	3	7	6	9	9
33–40	4	2	6	5	9	9

[a] The number of wires is the sum of the following wire equivalents of all of the attachments which the line is ultimately to support:

Attachment	Wire equivalents for various loading area		
	Heavy	Medium	Light
Bare open wire 109 or 104, per wire	1	1	1
Bare open wire 128, 134, or larger, per wire	1.5	1.5	1.5
Covered paired wire, per pair, or covered single wire, per wire	1.5	1.5	2.5
Rubber-covered cable, per cable	2	2.5	5
Wire messenger (stranded), all sizes	2	2.5	5
Lead-covered cable up to 1¼" diameter, per cable (not including messenger)	3	4.5	10
Lead-covered cable from 1¼" to 1 15/16" diameter, per cable (not including messenger)	4	6	17
Lead-covered cable greater than 1 15/16" diameter, per cable (not including messenger)	5	8	25

[b] In the preparation of this table shielding of one wire by another has been taken into account, as is the custom, for heavy and medium loading. Where the number of wires exceeds 10, only 2/3 of the actual number of wires are considered to offer wind resistance, provided that the resulting number is not less than 10.

[c] In determining the length of pole required, make allowances for the following:

(1) The depth the pole is to be set in the ground.
(2) The distance from the top of the pole to the wires on the top crossarm (about 4 inches).
(3) The number of crossarms (spaced 3 feet apart).
(4) The sag of the wires or cable.
(5) The clearance required between the wires and the ground at the middle of the span, normally 14 feet, (18 feet at highways and 27 feet at railroads).

[d] At dead-ends and at corners having a pull of more than 20 feet (interior corner angle less than 158°), use poles of a lower class number. At a corner having a pull of more than 50 feet (interior corner angle less than 122°), divide the corner equally between two poles of lower class number (TM 11-368 or TM 11-2253).

Figure 9-3. Recommended sizes of treated poles for aerial lines (American standard).

about the same sag because of the possibility of swinging wire contacts, appearance, etc., sag tables are based on the sag requirements for the weakest conductor. Figures 9-4 and 9-5 should be used when the lowest tensile strength conductors are either 104 copper or 080 copper-steel. Figure 9-6 provides similar data where the weakest wire to be used is 104 copper-steel. Therefore the sags given in this latter table for the same lengths of span and

Span length (feet)	Conductor	Sag and tension at various temperatures							
		0°F.		30°F.		60°F.		90°F.	
		Sag (inches)	Tension (pounds)	Sag (inches)	Tension (pounds)	Sag (inches)	Tension (pounds)	Sag (inches)	Tension (pounds)
100	080 C-S	2¼	125	2¾	100	3½	75	5	55
	104 C-S	2¼	230	2¾	185	3½	140	5	100
	104 CU	2¼	230	2¾	185	3½	140	5	100
	109 GS	2¼	225	2¾	180	3½	135	5	95
125	080 C-S	3¼	125	4¼	100	5½	75	8	55
	104 C-S	3¼	230	4¼	185	5½	140	8	100
	104 CU	3¼	230	4¼	185	5½	140	8	100
	109 GS	3¼	225	4¼	180	5½	135	8	95
150	080 C-S	4¾	125	6	100	8	75	11½	55
	104 C-S	4¾	230	6	185	8	140	11½	100
	104 CU	4¾	230	6	185	8	140	11½	100
	109 GS	4¾	225	6	180	8	135	11½	95
175	080 C-S	6½	125	8¼	100	11	75	15½	55
	104 C-S	6½	230	8¼	185	11	140	15½	100
	104 CU	6½	230	8¼	185	11	140	15½	100
	109 GS	6½	225	8¼	180	11	135	15½	95
200	080 C-S	8½	125	10¾	100	14½	75	20¼	55
	104 C-S	8½	230	10¾	185	14½	140	20¼	100
	104 CU	8½	230	10¾	185	14½	140	20¼	100
	109 GS	8½	225	10¾	180	14½	135	20¼	95
225	080 C-S	10¾	125	13½	100	18	75	25¼	55
	104 C-S	10¾	230	13½	185	18	140	25¼	100
	104 CU	10¾	230	13½	185	18	140	25¼	100
	109 GS	10¾	225	13½	180	18	135	25¼	95

Figure 9-4. Sags and tensions for lines supporting conductors with strength of 104 copper or greater and 150-foot nominal span.

Span length (feet)	Conductor	Sag and tension at various temperatures							
		0°F.		30°F.		60°F.		90°F.	
		Sag (inches)	Tension (pounds)	Sag (inches)	Tension (pounds)	Sag (inches)	Tension (pounds)	Sag (inches)	Tension (pounds)
100	080 C-S	1¼	200	1½	175	1¾	150	2¼	125
	104 C-S	1¼	365	1½	320	1¾	280	2¼	230
	104 CU	1¼	365	1½	320	1¾	280	2¼	230
	109 GS	1¼	355	1½	310	1¾	270	2¼	220
150	080 C-S	3	200	3½	175	4	150	5	125
	104 C-S	3	365	3½	320	4	280	5	230
	104 CU	3	365	3½	320	4	280	5	230
	109 GS	3	355	3½	310	4	270	5	220
200	080 C-S	5½	200	6	175	7	150	8¾	125
	104 C-S	5½	365	6	320	7	280	8¾	230
	104 CU	5½	365	6	320	7	280	8¾	230
	109 GS	5½	355	6	310	7	270	8¾	220
250	080 C-S	8½	200	9¾	175	11	150	13½	125
	104 C-S	8½	365	9¾	320	11	280	13½	230
	104 CU	8½	365	9¾	320	11	280	13½	230
	109 GS	8½	355	9¾	310	11	270	13½	220
300	080 C-S	12¼	200	14	175	16	150	19½	125
	104 C-S	12½	365	14	320	16	280	19½	230
	104 CU	12¼	365	14	320	16	280	19½	230
	109 GS	12¼	355	14	310	16	270	19½	220

Figure 9-5. Sags and tensions for lines supporting conductors with strength of 104 copper or greater and 200-foot nominal span.

temperature, are less than those given in the other tables for bare wires. Similar data for field wires and spiral-four cable are given in figures 9-15 and 9-18. Sag and tension data are given for a range of temperatures. If data are required for other temperatures they may be approximated by interpolation or extrapolation.

c. Sag information for span lengths and conductors other than those covered in subparagraph b above can be obtained by interpolation in figures 9-4 to 9-6. In addition there are rough rules which can be used. For instance, when placing a conductor aerially in a span of moderate length in a heavy loading area, it should be tensioned at not more than about 1/5 of its breaking strength at an average temperature, say 60° F. In light loading areas, this tension might be increased to ¼ of the breaking strength. Where feasible, less tension

Span length (feet)	Sag (inches) at various temperatures			
	0°F.	30°F.	60°F.	90°F.
100	1½	2½	3	4
125	2½	3½	4	5½
150	4	5	6	8
175	5½	6½	8	11
200	7	8½	10½	14

Figure 9-6. Sags for lines supporting conductors with strength of 104 C-S or greater.

should be used since some conductors will stretch more than others. A simple expression can be used to determine the sag equivalent to any tension. This is as follows: $d = wL^2/8T$, where d = sag in feet, w = weight of suspended wire in pounds per foot, L = span length in feet, and T = tension in pounds.

d. The preferred method of sagging wires is through the use of Scale LC–64, which indicates the tension at the pulling end (TM 11–368). Initially the tension at the scale should be carried slightly above the correct value so as to achieve the desired sag in the spans remote from the tensioning apparatus. The tension can then be slacked off until the correct value of sag is obtained in the spans at the pulling end.

e. Sag may be measured by actual sighting, using a sag gauge, or by the more convenient oscillation method (TM 11–368, TM 11–369, and TM 11–2253). This latter method makes use of the relationship between the sag and the time required for a wave set up in a wire at one support to travel to the other support and back. This relationship is $d = 1.006 (t/n)^2$, where d = sag in feet, t = time in seconds for n returns of the wave. This relationship is independent of span length. The wave is usually set up by striking the wire with the side of the hand near one support. Where sags are small, 10 returns of the wave can easily be counted. Where sags are large, greater accuracy can be obtained by swinging the whole span of wire in a direction transverse to the line as a pendulum, and determining the time required for the wire to swing through a complete cycle, over and back, a given number of times. The same relationship holds as in the former method. A stop watch is helpful in obtaining accurate results. A curve giving the above relationship between sag and time for 10 swings of the span of wire or returns of the wave is given in figure 9-7.

f. One of the factors which has to be taken into account in engineering open wire lines is swinging wire contacts. The wires should be spaced and sagged so that such contacts will not take place at wind velocities which frequently occur. The nomogram in figure 9-8 gives the relationship between sag, wire spacing, span length, and threshold wind velocity[1]. In the average location it is sufficient to engineer for threshold velocities of around 40 miles per hour at average temperatures.

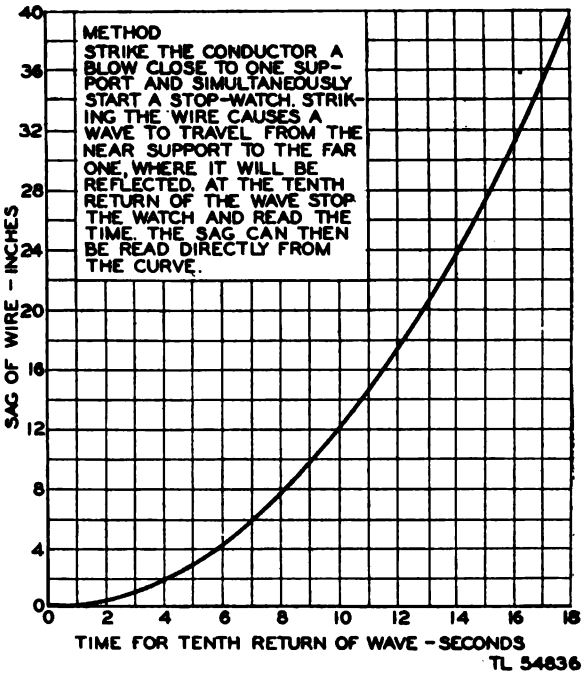


Figure 9-7. Oscillation method of measuring sag.

909. RUBBER-COVERED WIRES, GENERAL.

a. Rubber-covered conductors are provided either as a twisted pair, a parallel pair, a spiral-four quad, or a 5- or 10-pair cable (pars. 910 and 911). They can be installed rapidly by simply paying out on the surface of the ground from a reel mounted on a truck, from a hand-drawn reel cart, or from reels carried by one or two men, depending upon weight.

[1] The threshold wind velocity is the instantaneous velocity at which the wires of a pair begin to contact. The instantaneous wind velocity has been found by experiment to be about 1.4 times the U. S. Weather Bureau 5-minute average velocity.

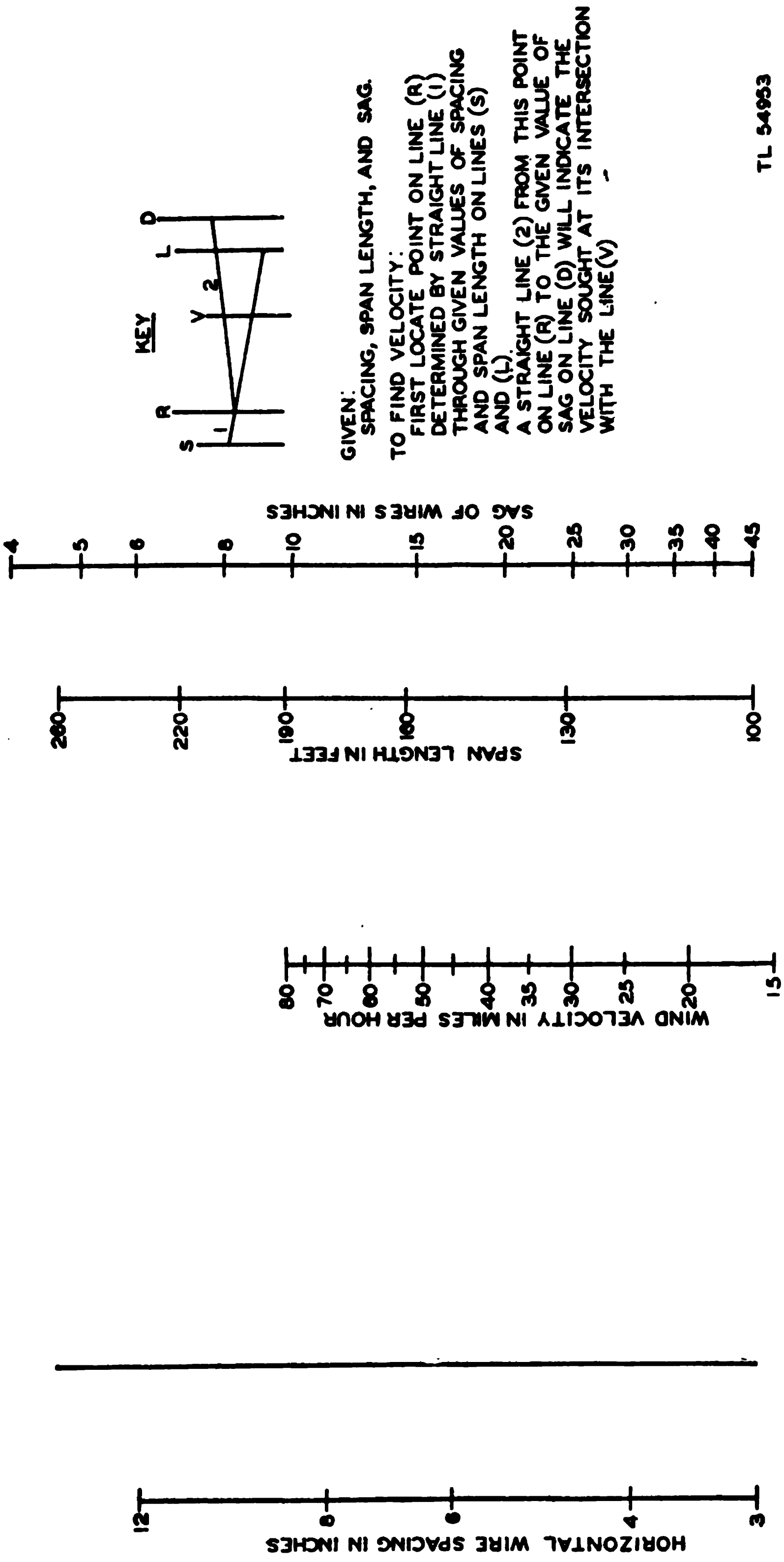


Figure 9-8. Wind velocity (threshold) perpendicular to the line at which wires of a pair begin to contact.

In such cases it is usually necessary to make special provision against injury to wires from motor vehicles, artillery, tanks, or maneuvering troops. This is especially true at road crossings where these wires should either be buried or elevated on poles or trees. Buried or elevated construction is required at railroad crossings. Where exposure to injury is general throughout the route of the wire, it is usually advantageous to either bury cable or support it on poles or trees throughout its length. Surveys for buried construction should contemplate the possibility of interference from bulldozers which may be used in road building. The installation features vary somewhat with the type of wire or cable, as discussed below.

b. Information on captured enemy field wires is given in TB Sig E–15.

910. SINGLE PAIR WIRES.

a. General. The physical characteristics of the rubber-covered wires described in the following subparagraphs are given in figure 9-9 and their electrical characteristics are given in chapter 5.

b. Wires W–130, W–130–A, W–130–C, WD–3/TT (Assault wire). These wires, when furnished in ¼-mile lengths on Reel DR–8, weigh 9 pounds and can be carried by one man using Reel Equipment CE–11 which includes a sound-powered telephone and thus permits easy communication back to the command post as he advances. When furnished in 2-mile lengths on Reel DR–4 it can be carried by two men using Axle RL–27–( ) (fig. 9-10). Wire W–130–( ) is furnished also in ½-mile lengths on Reel DR–8. Because transmission over assault wires is affected by moisture, its performance is improved somewhat when supported off the ground on trees or bushes. Methods of splicing and handling this wire are covered in FM 24–20.

c. Wire W–110–B (Field wire).

(*1*) This wire is the most widely used and generally available. It is now insulated with synthetic rubber instead of rubber. When supplied in 2,400-foot lengths on Reel DR–4, it can be carried on Axle RL–27–( ) by two men as it is payed out. Either Reel DR–4, or Reel DR–5 which carries one mile of this wire, can be mounted on a hand-drawn Reel Cart RL–16 or on Reel Unit RL–31–( ). Reel DR–5 may be mounted on Reel Unit RL–26–( ) which is a power-driven unit that can be used either for paying out or reeling up (fig. 9-11). When this wire is used as an insert in an open wire line, it is preferable to install one Wire W–110–B (two conductors) for each open wire and to maintain, if possible, the same spacing between the sides of the circuit as used for the open wire. While this wire may occasionally have to be buried at highway and railroad crossings it is not suitable for extensive buried installations. The practices relative to the use, installation, and maintenance of Wire W–110–B are covered in FM 24–20.

(*2*) In commercial practice it is recognized that in construction work, good appearance and good workmanship are closely related. The appearance factor has its justification in army practice but there are conditions where its influence might be carried too far. One instance is the tendency to bunch and lash together in the form of a cable considerable numbers of Wire W–110–B or other types of field wire in approaches to switching centrals. It is obvious that during humid or wet weather conditions, such construction provides a cellular structure which invites and retains moisture, causing troubles associated with low insulation resistance that might not develop if each pair were suspended individually. In addition, individual suspension will improve transmission in wet weather and make it easier to locate trouble should it occur. The preferred method is to place crossarms and attach pairs to insulators in the manner of bare wire. Where this is not feasible a method reported as used with success in one theater uses slots for the wires in a crossarm or wooden member at suitable intervals with the support mounted either horizontally or vertically as indicated in figure 9-12. A latch or keeper spanning two adjacent slots and secured by a thumbnut is useful to hold the wires in position. Another method shown in figure 9-12 and used in another theater, uses a horizontal crossarm with slots but no keepers. A corner pole using this type of construction is shown in figure 9-13.

d. Wire W–143 (Long range tactical wire).

(*1*) This wire is furnished on Reel DR–5 which can be mounted on Reel Unit RL–31 or Reel Unit RL–26–( ) as in the case of Wire W–110–B and payed out or reeled up in the same manner. It can be installed similarly on the ground or aerially, and in addition can

Nomenclature	Approximate major dimension of cross-section (inches)	Breaking[a] load (pounds)	Usual[b] type of reel	Length on reel (feet)	Weight—(pounds)[c] Per reel (wire plus reel)	Per mile (without reels)	Description[d]
Wire W-130 (Assault wire)	0.126	110	DR-8 DR-4	1,320 10,560	10 82	30	Twisted pair; each rubber covered; no braid; one 0.010-inch copper and six 0.0095-inch steel strands per conductor; nonstabilized. Classified, substitute standard as of 7-44.
Wire W-130-A (Assault wire)	0.12	110	DR-8 DR-4	1,320 10,560	9 91	38	Twisted pair same as W-130 except that vinylite insulation is used; nonstabilized. Classified, standard as of 7-44.
Wire W-130-C (Assault wire)	0.12	110	DR-8 DR-4	1,320 10,560	10 82	31	Twisted pair same as W-130 except that polyethylene insulation is used; nonstabilized. Classified, standard as of 7-44.
Wire WD-3/TT (Assault wire)	0.18	120	DR-8 DR-4	1,320 5,280	13 67	45	Same as W-130 except with braid on each conductor. Classified, substitute standard as of 7-44.
Wire W-110-B[e] (Field wire)	0.29	300	DR-5 DR-4 Coil	5,280 2,400 1,000	154 82 23	120	Twisted pair; each rubber and braid covered; three 0.0135-inch copper and four 0.013-inch steel strands per conductor; nonstabilized.
Wire W-143 (Long range tactical wire)	0.304	270	DR-5	3,300	184	240	Parallel pair; rubber covered; stabilizing carbon-saturated paper around pair; over-all braid; seven 0.0226-inch copper strands per conductor; stabilized. TB SIG 101.
Wire W-50	0.46	400	Coil	1,000	61	320	Twisted pair; each rubber and braid covered; 14 ga. (0.064 inch) hard-drawn copper; nonstabilized.
Wire W-108	0.26	400	Coil	1,000	32	170	Parallel pair; rubber; cotton braid; weatherproofed; 17 ga. (0.045 inch) tinned copper-steel or bronze; nonstabilized.
Wire W-108-A	0.26	340	Coil	1,000	30	158	Same as W-108 except 18 ga. (0.040 inch).

[a] The tensions to which these wires may be subjected in service should not exceed 30 percent of the breaking load for assault wire and 40 percent of the breaking load for the other wires listed.

[b] Wire furnished in coils is generally wrapped with paper or fiber covering and net weight and packed weight are about the same.

[c] Weights per mile or per reel of product.

[d] Nonstabilized wire has transmission characteristics which vary between wet and dry weather.

[e] Factory splices, which may be a point of weakness, are indicated by red lacquer markings on insulation on wire manufactured since late in 1943.

Figure 9-9. Physical characteristics of insulated wires.

be buried if the splices are made properly so as to be well insulated. If buried, the work can be expedited by the use of cable Plow LC–61, as covered in TM 11–369 for similar installations of spiral-four cable. It is superior to Wire W–110–B for inserts in open wire lines and should be used with one Wire W–143 (two conductors) in each side of the open wire circuit and with a separation similar to the open wire spacing.

Figure 9-10. Assault Wire on Reel DR–4 and Axle RL–27–( ).

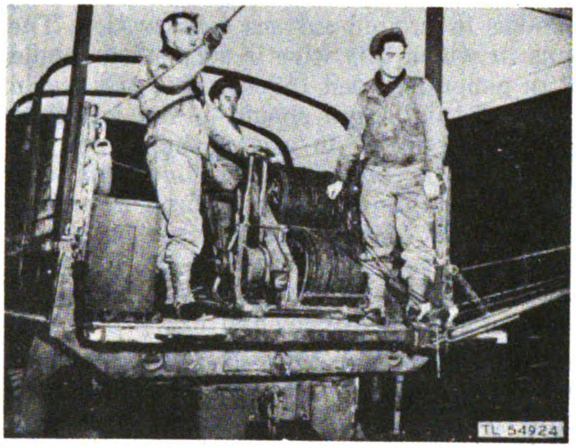


Figure 9-11. Laying field wire with Reel Unit RL–26–( ).

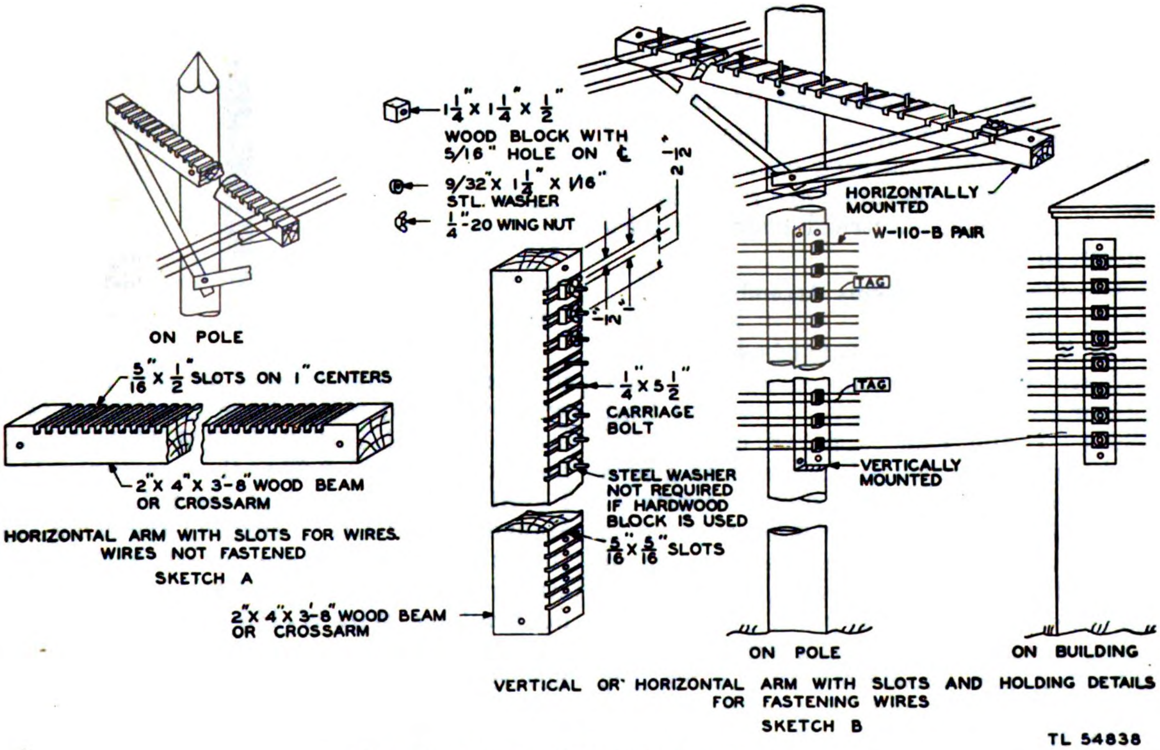


Figure 9-12. Improvised field wire crossarms.

(*2*) When placed aerially, it may be suspended between poles and trees like spiral-four cable through the use of Drive Hook PF–81 and Cable Hanger PF–203/G for spiral-four cable. In using this hanger a short length of Wire W–143 is placed in the hanger alongside the wire to be supported, to fill the hanger and afford a firm grip on the wire. At corners and terminal poles this wire may be supported by drop wire Clamp PF–84. This type of clamp may be used also in anchoring to stakes in ground surface construction. The spans in which this wire is suspended should not in general exceed 150 feet and the sag in a span of this length should be not less than 3½ feet. If spans do exceed this figure the sags should be commensurate. Since this wire does not have the strength per unit of weight that Wire W–110–B has, it must be placed with larger sags than Wire W–110–B. Methods of splicing, terminating, and installing this wire aerially are covered in TB SIG 101.

e. Wire W–50 and Wire W–108. These are commercial types of drop wire and are sufficiently like Wire W–110–B and Wire W–143, that the same general practices may be used in their installation. More care must be taken in handling these two wires since they have solid conductors and are, therefore, not as flexible as the field wires.

911. MULTIPAIR RUBBER-COVERED CABLES.

a. General. The physical characteristics of the multipair rubber-covered cables listed in the following subparagraphs are given in figure 9-14, and their electrical characteristics are given in chapter 5.

b. Spiral-four Cable (Cable Assembly CC–358–( )).

(*1*) This cable is furnished on Reel DR–15 which can be mounted on Reel Cart RL–16 or –35, Reel Unit RL–31, or Reel Unit RL–26–( ) and can be payed out on the ground surface, suspended in spans on a pole line or trees, or buried. In surface construction it is necessary to bury it or suspend it aerially with proper clearance above ground at railroad or highway crossings, and at other points where it may be exposed to vehicular hazards. Detailed instructions for installing, maintaining and recovering this cable are found in TM 11–369 and TB 11–369–1.

(*2*) In aerial construction it should be sagged in accordance with information in figure 9-15 or as in subparagraph (3) below if ice conditions are expected to be severe. If supported on trees a special floating type suspension is necessary to prevent breakage due to tree sway (TM 11–369). Where clearances are critical or spans unusually long, but ice loads are not a factor, one of two alternatives may be used. Light poles, such as the lance type, may be installed half way between each line support, thus shortening the span and reducing the sag; or the cable may be supported by means of messenger wire. A method which

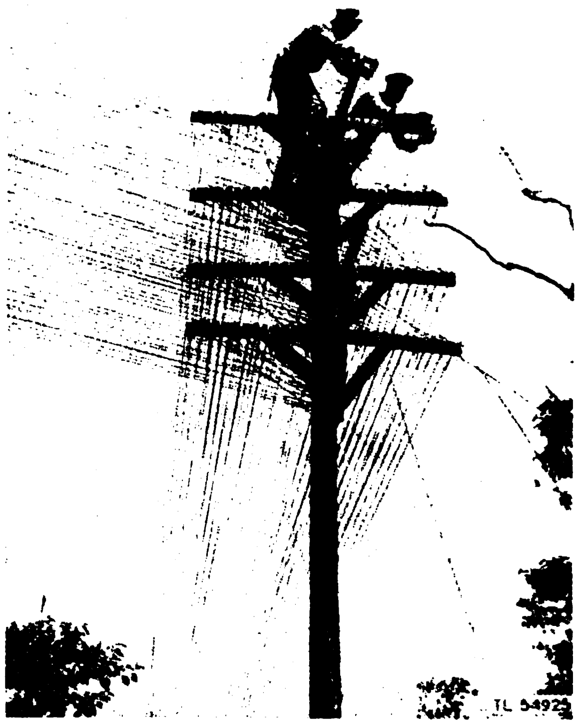


Figure 9-13. Field wire supported by slotted crossarms.

utilizes this latter type of support and which will withstand most storm conditions, is described in TM 11–369. In TM 11–369, use is made of Wire WS–3/U as the messenger, Hook PF–81 as the support at the pole, and Cable Hanger PF–203/G to suspend the cable from the messenger. Where speed rather than strength is important and these materials are not available, Wire W–145 (109 high strength) or 134 GI wire may be used as a messenger. Several means may be used for suspending the cable from the messenger, such as Wire W–110–B ties. In using this material a clove hitch should be made around the cable and

Nomenclature	Approximate major dimension of cross-section (inches)	Breaking load[a] (pounds)	Usual type of reel	Length on reel (feet)	Weight—(pounds) Per reel, or coil (cable plus reel)	Weight—(pounds) Per mile (without reels)	Description
Cable Stub CC-344	0.50	425	Coil	10	2	—	5-pair, consists of Cable WC-534, 10 feet length, with plug on one end only, 0.036 inch copper, solid, each rubber covered; rubber overall, non-stabilized. TM 11-371 and TM 11-367.
Cable Assembly CC-345	0.50	425	DR-7 or DR-15	2,640 1,000	340 150	600	5-pair, consists of Cable WC-534 with plug on each end; 0.036 inch copper, solid, each rubber covered; rubber overall, nonstabilized. TM 11-371 and TM 11-367.
Cable Assembly CC-355 or CC-355-A	0.70	750	DR-7	1,000	270	1,200	10-pair, consists of Cable WC-535 with plug on each end; 0.036 inch copper, solid, each rubber covered; rubber overall, nonstablilized. TM 11-371 and TM 11-367.
Cable Stub CC-356	0.42	500	Coil	12	2	—	Spiral-four, consists of 12 feet length of Cable WC-548, one end only equipped with connector containing 6 millihenry load coil; 2 pairs, each conductor consists of 7-0.015 inch copper strands; each conductor rubber covered; stabilized; steel braid and rubber or substitute overall. TM 11-369, TB 11-369-1, and TM 11-2001.
Cable Assembly CC-358-( )	0.42	500	DR-15	1,320	175	540	Spiral-four, consists of ¼-mile length of Cable WC-548, each end equipped with connector containing 6 millihenry load coil; 2 pairs, each conductor consists of 7-0.015 inch copper strands; each conductor rubber covered; stabilized; steel braid and rubber or substitute overall. TM 11-369, TB 11-369-1, and TM 11-2001.
Cable Assembly CC-368	0.42	500	Coil	100	12	—	Spiral-four, consists of 100 feet length of Cable WC-548, each end equipped with connector, but no load coil; 2 pairs, each conductor consists of 7-0.015 inch copper strands; each conductor rubber covered; stabilized; steel braid and rubber or substitute overall. TM 11-369, TB 11-369-1, and TM 11-2001.
Coil C-114-A							An 88 millihenry loading coil, with d-c resistance of 8.4 ohms, weighing approximately 3 pounds having a waterproof phenol plastic case, about 3⅛" x 4½" x 2¾". Binding post terminals, FM 24-20 and TB SIG 101.

[a] The tensions to which these cables may be subjected should not exceed 30 percent of the breaking load for 5- and 10-pair cables or 40 percent for spiral-four cable.

Figure 9-14. Physical characteristics of rubber-insulated cables.

A. Sags and tensions without messengers

Span length (feet)	Conductor	Sag and tensions at various temperatures									
		0°F		30°F		60°F		90°F		120°F	
		Sag (inches)	Tension (pounds)	Sag (inches)	Tension (pounds)	Sag (inches)	Tension (pounds)	Sag (inches)	Tension (pounds)	Sag (inches)	Tension (pounds)
100	CC-358-( )	12	135	12½	130	13	125	14	120	14½	105
	W-50	12	75	12½	70	13	70	14	65	14½	60
	W-110-B	12	30	12½	30	13	30	14	25	14½	20
125	CC-358-( )	19	135	20	130	21	125	22	120	23	105
	W-50	19	75	20	70	21	70	22	65	23	60
	W-110-B	19	30	20	30	21	30	22	25	23	20
150	CC-358-( )[a]	27	135	28	130	30	125	31	120	32	105
	W-50	27	75	28	70	30	70	31	65	32	60
	W-110-B	27	30	28	30	30	30	31	25	32	20
175	W-50	37	75	39	70	40	70	42	65	44	60
	W-110-B	37	30	39	30	40	30	42	25	44	20

B. Sags for messenger supporting Cable Assembly CC-358-( )

Span length (feet)	Sag (inches) at various temperatures				
	In strand with cable attached		In strand with no cable attached		
	30°F	120°F	30°F	60°F	120°F
200	9	12	3¾	4¼	5
300	24	32½	10¼	12	15½
400	53	68½	31	36	44½
500	103	127	70	75	90

[a] Where span lengths exceed 150 feet and ice is not expected to be a factor spiral-four cable should be supported by messenger having minimum sags shown in B above (TB 11-369-1). In areas where ice and sleet might be experienced, messenger should be used and installation made in accordance with figure 9-18.

Figure 9-15. Sags and tensions for field wires and spiral-four cable.

then the ends of the tie joined in a square knot over the messenger. The spacing of the ties should be about 6 feet. The cable and messenger should be tied together on the ground, then raised into position and the *messenger only* tensioned. An alternative method of supporting the cable from the messenger, reported as used successfully in one theater, is to make wire hangers which are somewhat similar to the commercial type of cable suspension ring. The method of making these hangers is shown in figure 9-16. Experience has shown that unless the cable is installed with some slack, conductor breakage may result from shell concussions. Suspended spiral-four cable of relatively early manufacture has under some conditions been found to stretch noticeably with time. Cable which is over-tensioned is apt to stretch similarly. This difficulty can be overcome in cable of early manufacture by supporting it with messenger as described above. Representative aerial construction features of spiral-four cable are shown in figure 9-17.

(3) Where ice or sleet conditions are expected to be severe and strength is the primary requisite, even in spans as short as 100 feet a messenger support should be used for spiral-four cable. Wire WS-3/U should be used for span lengths up to 200 feet and Wire W-115 for span lengths from 200 to 400 feet. Figure 9-18 indicates the recommended stringing sags for each of these messenger wires with cable attached. When Wire W-115 is used to support the cable the methods outlined in TM 11-363 should be used, except that the

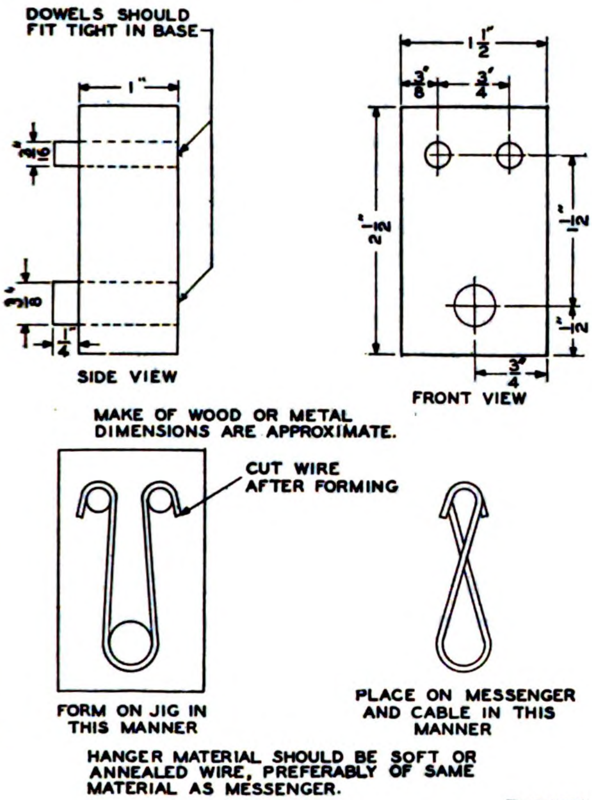


Figure 9-16. Jig for making spiral-four cable hangers.

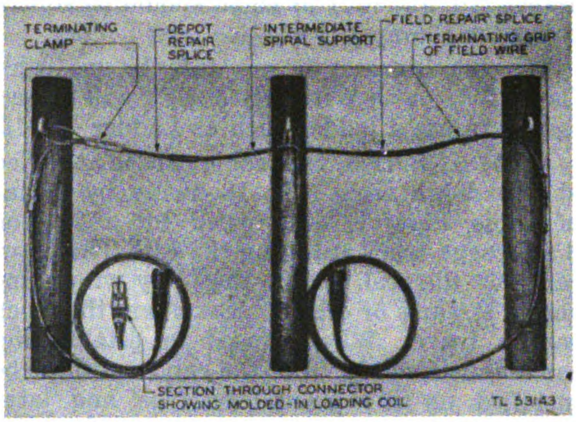


Figure 9-17. Spiral-four aerial construction using Cable Assembly CC-358-( ).

Messenger wire	*Span length (feet)*	*Sag and tension at various temperatures in strand with cable attached*[a]					
		0°F		*30°F*		*60°F*	
		Sag (inches)	*Tension (pounds)*	*Sag (inches)*	*Tension (pounds)*	*Sag (inches)*	*Tension (pounds)*
WS-3/U	100	1½	1,625	1¾	1,535	2	1,415
	150	4	1,455	4½	1,370	5	1,245
	200	9	1,245	10	1,135	11	1,025
W-115	200	8¾	2,300	10¼	1,950	12	1,645
	300	29¾	1,525	34¾	1,300	40½	1,120
	400	78	1,030	85½	940	92¾	870

[a] Sags for nonsleet areas are given in figure 9-15.

Figure 9-18. Sags and tensions for messengers used in supporting spiral-four cable in snow and ice areas.

messenger and cable should be assembled on the ground, using Wire W–110–B as described in subparagraph (2) above. When Wire WS–3/U is used, these same methods apply with the following exceptions:

(*a*) Since no standard suspension clamps can be used for Wire WS–3/U, it is recommended that Hubbard No. 7401 one-bolt guy clamp (stock No. 5B3448) or equal be used. The messenger should be placed in the top groove of the clamp and if necessary a piece of strand may be placed in the bottom groove to insure a firm grip on the messenger.

(*b*) The method of dead-ending this messenger, outlined in TM 11–369 for long span construction, may be used as an alternate to the method outlined in TM 11–363, except that a Hubbard No. 7402 2-bolt guy clamp (stock No. 5B3402) or equal should be substituted for Clamp PF–61.

(*c*) Since it is not safe to use cable Car LC–41–A on Wire WS–3/U, it will be necessary to use a ladder such as Ladder LC–15.

(*4*) If buried, this cable can be installed at any depth from 6 to 18 inches by means of cable Plow LC–61 towed by a 2½-ton 6 x 6 cargo truck carrying the reel. The plow, carrying the reel, can be towed by winch line across streams or other places where the truck cannot travel. Where speed in establishing communications is vital, the cable can first be installed on the ground surface and later picked up by the plow and buried without interrupting service. If Plow LC–61 is not available a bulldozer or ditching machine can be used to make a trench in which the cable can be buried. Under favorable conditions, this cable can be laid on the ground, tested and connected at the rate of about 3 miles per hour, including the work of burying or elevating at road crossings.

(*5*) The connectors on each end of this cable may become corroded or fouled with mud, fungus or other foreign matter to such an extent that poor or high resistance contacts will result. It is important to guard against these conditions and make sure the connectors are clean and dry before they are connected. In some of the early installations of spiral-four cable trouble was experienced in wet weather due to connector defects including leakage around the bolts, and it was found necessary in some cases to tape the connector after coupling. If such conditions are encountered and exposures are severe, the method of taping covered in TB SIG 67 should be followed.

c. Cable Assembly CC–345 and Cable Assembly CC–355. These 5- and 10-pair field cable assemblies use Cable WC–534 and Cable WC–535 respectively (fig. 9-14 and TM 11–371). They may be installed much the same as Cable Assembly CC–358–( ) except, that if supplied on 19-inch x 36-inch wooden reels, the reels must be mounted on a bar (Axle LC–31) in the truck or on the cable reel jacks (Jack LC–13). Experience in some theaters indicates that the plugs should be cleaned and dried before connecting, and then taped to exclude moisture in all cases. In any event, when these cable assemblies are placed underground the connectors should not be buried. However, if they are buried they should be carefully taped in the manner described in TB SIG 67. When placed aerially spans should be limited, in general, to about 100 feet, with a sag of not less than 2 feet. Cable WC–534 and Cable WC–535 are also available in various lengths without connectors.

912. OPEN WIRE LINES.

a. General. The design of open wire lines adopted by the Signal Corps has been very much simplified as compared to commercial systems. It is still necessary, however, to vary the line structures to a limited extent in order to care for such factors as economy of shipping space, speed of erection, ground clearances, swinging wire contacts, availability of materials, terrain, and storm loading. These factors explain the need for having available a lighter type of construction for tactical use (TM 11–368) than for fixed plant application (TM 11–2253).

b. Crossarms. An 8-pin crossarm (PF–92–A), 3¼ x 4¼ x 88 inches, is standard for use in both the tactical and fixed plants. It can be converted into two 4-pin crossarms by one saw cut. In general, no more than two 8-pin crossarms will be carried over one route. The wire capacity of a line will be therefore, usually either 4 wires, 8 wires, or 16 wires. Occasionally, where only one pair of wires is required, they may be supported on wooden pole brackets instead of a crossarm.

c. Insulators. For tactical construction two types of insulator satisfy practically all requirements. A double-groove insulator (IN–128, sometimes called TW) is used for provid-

Name or material[a]	*Type No.*	*Nominal diameter (inches)*	*Breaking load (pounds)*[b]	*Weight per mile (pounds)*	*Remarks*
080 C-S	W-153	0.080	770	94	Conductivity 40% of copper wire
104 C-S		0.104	1,170	159	Conductivity 40% of copper wire
128 C-S		0.128	1,650	240	Conductivity 40% of copper wire
104 C-S		0.104	1,275	159	Conductivity 40% of copper wire
128 C-S		0.128	1,800	240	Conductivity 30% of copper wire
080 Copper		0.080	330	102	Hard drawn
104 Copper	W-74	0.104	530	173	Hard drawn
128 Copper		0.128	820	262	Hard drawn
165 Copper		0.165	1,325	435	Hard drawn
109 GS	W-145	0.109	790	170	High strength
083 GI	W-76	0.083	250	99	
109 GI		0.109	425	170	
134 GI		0.134	645	359	
Wire Messenger	WS-3/U	3/16	2,400	410	2.2M[c], GS wire with 7-0.065 inch strands
Wire Messenger	W-115	5/16	6,000	1,190	6M, GS wire with 7-0.109 inch strands
Wire Messenger	W-90	3/8	11,500	1,425	10M, GS wire with 7-0.120 inch strands
Wire Messenger	W-116	7/16	18,000	2,060	16M, GS wire with 7-0.144 inch strands

[a] C-S=Copper-Steel, GI=Galvanized Iron, GS=Galvanized Steel.

[b] The elastic limit is equal to approximately 55 percent of the breaking load.

[c] Commonly used designation for nominal breaking strength; M equals 1,000 pounds.

Figure 9-19. Physical data for bare wires and wire messengers.

ing a rolling type of transposition and for dead-ending from opposite directions. A single-groove insulator (IN-15) which is lighter in weight than the double-groove insulator meets all other requirements. On the longer open wire lines in the fixed plant, D.P. (double petticoat) insulators are used instead of Insulator IN-15 (TM 11-2253).

d. Tactical Construction; Wires, Poles, and Spans.

(*1*) For tactical construction the wire used is 080 copper-steel. However, if wire is obtained from the supplies of Allied Nations or from locally manufactured stocks in foreign countries it might be copper or bronze. The physical properties of bare line wires are given in figure 9-19. Single-crossarm open wire lines may use 20-foot sawed 4 x 4 poles, or 20-foot class 9 round poles. Pole classes are explained in TM 11-487.

(*2*) Where poles cannot be quickly set in the ground because of soil conditions a guyed X-frame made of 20-foot 2 x 4's may be used. Lines carrying two crossarms require 22-foot round poles. The above poles provide 14-foot ground clearance for the wires on cross country leads. At highway crossings an 18-foot clearance is usually provided by using an extra crossarm as a vertical extension fixture carrying the regular crossarm (TM 11-368). Lo-

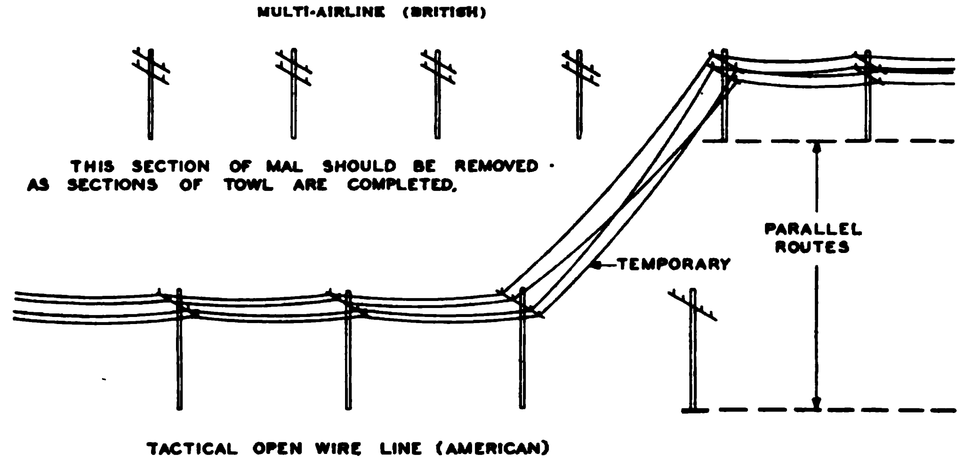


Figure 9-20. Replacement of temporary by permanent construction.

cally cut timber may be used where it is available. Nominal span lengths are as follows: in light storm loading areas, spans of 150 feet are used with 4 x 4 supports, and 200 feet with round poles; in medium or heavy storm loading areas only the latter of these arrangements is used. There is also a tactical construction called *extra heavy,* which uses class 9 round poles with nominal 150-foot spans and additional guying. The planning, construction, and maintenance of tactical open wire lines are covered in TM 11–368.

e. Fixed Plant Construction; Wires, Poles, and Spans. Fixed plant lines may be of several types. They may be commercial lines that have been taken over for Signal Corps use, American or Allied tactical lines, or they may be newly constructed to meet fixed plant needs. For those lines in the latter category the span length should average 150 or 200 feet depending upon storm loading requirements. The wire should be 104 copper-steel and the poles should conform to the requirements set forth in paragraph 907. As repairs or replacements are required in inferior lines taken over by the fixed plant, it should be the aim to use materials which will bring the line structure into conformity with fixed plant standards. Additional information on the planning, construction, and maintenance of fixed plant open wire lines is set forth in TM 11–2253.

f. Guying. The extent and strength of the guying required increases with the degree of storm loading. The application of proper guying is a very important feature of aerial line construction. Unless guying is adequate and anchors properly placed, the line will not be dependable.

g. Two-by-four Supports. A preliminary issue of TM 11–368 described a type of rapid open wire construction (RPL) in which 4 x 4 poles fabricated from short lengths of 2 x 4's were permitted. Field experience has shown that this type of pole is unsatisfactory and its use has been discontinued. While fabrication of 4 x 4 supports from full length 2 x 4's is permitted, solid 4 x 4 supports are preferred.

h. Decay and Termites. With the temperature and moisture conditions prevailing in tropical climates, untreated timber will be destroyed in a few months either by decay or termite attack. In proceeding from torrid to more temperate climates the rate of deterioration from these causes becomes progressively less, and termites disappear at about the middle of the temperate zones, at which points the hours per year favoring decay are also quite limited. To protect against these hazards and to insure a physical life permitting reuse of pole timbers, the crossarms, 2 x 4's, 4 x 4's, and round poles furnished for pole lines are treated either with creosote or a preservative salt (par 925b).

913. BRITISH MULTI-AIRLINE (MAL).

a. The British MAL is a lightweight tactical open wire line which offers as its principal advantages economy in transportation and speed of installation. *It is usually used as temporary construction* and should be replaced as soon as possible by tactical open wire or fixed plant. The material for four-wire construction weighs about one short ton per mile.

b. The line is supported by 16-foot tapered wood poles with a 2½ inch maximum diameter. Poles made of steel and of a telescoping design are sometimes used. The poles are set about 18 inches in the ground and normally spaced at 115-foot intervals, with double pole construction, H fixtures, every 8th span. Each pole is guyed with stranded iron wire attached above the crossarm and anchored to stakes driven in the ground. There are two types of crossarms. The 2-pin type is 15 inches long and the 4-pin type 33 inches. Each is 1½ x 1½ inches in cross-section and is attached to the pole by clamps. The insulators are of a 2-piece design. The bottom piece with a slot for the wire is cast on a J shaped pin. The second piece is a cap which screws on to the bottom piece, securing the line wire after it has been given a wire serving and placed in the slot of the bottom section.

c. The wires, which are usually 70 pounds per mile cadmium copper, although 40 pounds bronze or 60 pounds iron may be used, are generally placed on two crossarms in the figuration of a 12-inch square. No transpositions are used with the 2-pin crossarm unless there is exposure to power. In this case the wires are rotated 90 degrees in each span. When the wires are placed on a 4-pin crossarm they are point transposed by dead-ending each wire in opposite directions on two insulators carried on double J type pins. Thus, it will be seen that most all of the MAL line equipment differs in design from that of the Signal Corps.

d. The MAL is useful in temporarily bridging gaps when rehabilitating open wire lines. It is useful also, when available, to extend American open wire tactical lines in emergencies. When constructing such an extension it should be built adjacent to the route the tactical line is to take so that the tactical line can be cut into service by sections, as they are completed. This type of construction is shown in figure 9-20.

e. The material for the Signal Corps tactical line weighs about twice as much per mile as the MAL and requires longer to construct, but these lines are superior to the MAL in strength, stability, and endurance. The American facility nearest to the MAL, with regard to the number of circuits which can be speedily obtained, is spiral-four cable. Experience indicates that where this cable can be suspended from trees or existing supports, with sufficient ground clearance without messenger, it can be installed at twice the speed of the MAL, and the material weighs about half that of the MAL.

914. COMPARISON OF WIRE SIZES.

Figure 9–21 gives a comparison of American, British, and French wire sizes used in telephone circuits.

915. LEAD-COVERED CABLES.

a. General.

(*1*) The use of lead-covered cables is confined generally to the fixed plant. The types of cables usually stocked by the Signal Corps are given in TM 11–487. They may be installed aerially, buried, or pulled into underground ducts, but are not suited to ground surface construction. When used aerially they are suspended on a supporting steel strand which must be previously installed in a substantial manner on a well guyed pole line.

(*2*) A list of associated suspension materials arranged according to the weight of the cable is given in figure 9-22. An example is given in TM 11–487 of the materials required to build a 100-mile aerial cable line. Some information on weights and volumes of materials along with time figures for constructing a 25-mile length are given in figure 9-1.

(*3*) When buried in the ground it is the usual practice to have the cable supplied with a covering of asphalt, paper, and jute to prevent sheath corrosion, although for service periods up to approximately three years this feature could ordinarily be dispensed with. Where jute covering does not provide sufficient protection, gopher-proof, or single tape armored cable should be used. Construction practices used in the installation of paper insulated lead sheath cables are covered in TM 11–363. For extensive buried installations, large cable laying plows can be used to advantage, and hand trenching can be facilitated by using cable Plow LC–61 as a rooter. Small lead sheath cables with corrosion protection up to about one inch over-all diameter can be buried by means of Plow PL–61. The installation of Army cable in underground ducts is seldom warranted unless the duct system is already available.

Diameter[a] (inches)	American wires gauge[b]	British wires pounds per conductor mile	French wires diameter (millimeters)
0.224	—	800	—
0.197	—	—	5.00
0.194	—	600	—
0.177	—	—	4.50
0.165	No. 8 BWG	—	—
0.162	No. 6 AWG	—	—
0.158	—	400	—
0.157	—	—	4.00
0.138	—	—	3.50
0.137	—	300	—
0.128	No. 10 NBS	—	—
0.118	—	—	3.00
0.112	—	200	—
0.109	No. 12 BWG	—	—
0.104	No. 12 NBS	—	—
0.102	No. 10 AWG	—	—
0.098	—	—	2.50
0.097	—	150	—
0.080	No. 14 NBS	—	—
0.079	—	100	2.00
0.072	No. 13 AWG	—	—
0.066	—	70	—
0.059	—	—	1.50
0.055	—	—	1.40
0.051	No. 16 AWG	—	1.30
0.050	—	40	—
0.047	—	—	1.20
0.043	—	—	1.10
0.039	—	—	1.00
0.036	No. 19 AWG	—	—
0.033	—	20	0.90
0.032	—	—	0.80
0.028	—	12½	—
0.025	No. 22 AWG	10	—
0.024	—	9¼	0.60
0.020	No. 24 AWG	6½	—
0.016	No 26 AWG	4¼	—

[a] One millimeter is 0.03937 inch.

[b] American cable conductors are designated by Gauge (AWG, American Wire Gauge; the same as B&S, Brown and Sharp Gauge). American open wire conductors used by the Signal Corps are designated by diameter in thousandths of an inch, or sometimes by gauge. BWG is Birmingham Wire Gauge. NBS is New British Standard Wire Gauge. Blank spaces indicate wire sizes not generally used.

Figure 9-21. Wire sizes; American, British, and French.

b. Splicing. Splicing paper insulated cable requires men specially trained for the work. Likewise, specially trained men are needed for testing and fault locating.

c. Terminals.

(*1*) Cable terminals for use outdoors are generally of the sealed chamber type. They are provided with stub cables, the conductors of which are connected to binding posts projecting through a face plate. The conductors of the terminal stub are spliced to the main cable conductors.

(*2*) Where a distributing frame is used, as at centrals, it is usual to splice the paper-insulated cables to short lengths of textile-insulated lead-covered cables. The other ends of the textile-insulated wires are stripped of their cable sheaths and laced into forms with the individual wires terminated so as to match the spacing of the protector mounting lugs on which they are terminated.

(*3*) For terminating small cables (up to 51 pairs) there are available indoor type sealed chamber terminals having facilities for electric protection equipment equivalent to that ordinarily used in centrals. These terminals are illustrated in TM 11–487.

d. Loading Coils. The loading coils used for loading lead-covered cables are usually potted in welded-steel or lead-sleeve cases. The loading coil cases which are available, together with their mounting hardware are given in TM 11–487.

e. Transportation. Transportation of lead-covered cable requires special equipment because of the weight of the reeled cable and of loading coil cases. For instance 1,500 feet of 51-pair 19 gauge cable weighs about 2,200 pounds. The reel on which this cable is shipped weighs about 500 pounds. In handling this heavy material Trailer K–37 and trucks equipped with derricks and power winches are needed (fig. 9-23).

916. SUBMARINE CABLES.

a. Spiral-four Cable. In the tactical plant. Cable Assembly CC–358–( ) (spiral-four), and Cable Assembly CC–345 (5-pair) and Cable Assembly CC–355 (10-pair) are suitable for use as submarine cables in depths of water at least up to ½ mile, and will probably be satisfactory for somewhat greater depths. Life expectancies of the order of one year are considered reasonable. The transmission prop-

Cable[a]		Type and size of supporting messenger, [b]	Size of cable rings (inches)	Guying		Size and Stock No. of serial cable support
Weight (pounds per foot)	Diameter (inches)			Type and size of guy messenger	Size of eye bolt and eye nut (inches)	
2.24 or less	1 3/16 or less	W-115 (5/16", 6M)	1½, for 5/16" strand (PF-63)	W-90 (3/8", 10M)	¾	No. 2 (National) 5B17842
2.25 to 4.99	1¼ to 2	W-90 (3/8", 10M)	2½, for 3/8" strand (PF-69)	W-116 (7/16", 16M)	1	No. 3 (National) 5B17843
5.00 or over	2 or over	W-116 (7/16", 16M)	3½, for 7/16" strand W. E. Co. type D (stock No. 5B9481)	W-116 [c] (7/16", 16M)	1	No. 4 (National) 5B17844

[a] The following are the approximate sizes and weights of various gauges of cable:

Gauge*	No. of pairs	Approx. diam. (inches)	Approx. weight (pounds per foot)
19	51	1	1½
19	76	1 3/16	2
19	202	1 7/8	4¼
19	455	2 5/8	8½

Gauge	No. of pairs	Approx. diam. (inches)	Approx. weight (pounds per foot)
22	152	1 3/16	2
22	404	1 7/8	4¼
22	909	2 5/8	8½

* All 19 gauge cables are Western Electric Company CNB type, (0.084 mf per pair mile).

[b] Based on an average span length of 150 feet.

[c] In terminating messenger Wire W-116 use two 3-bolt guy Clamps FT-56; one clamp is sufficient for terminating messenger Wire W-115 or W-90.

Figure 9-22. Aerial lead-covered cable placement data.

Figure 9-23. Laying lead-covered cable.

erties of such cables, when properly laid, will be about the same as those obtained when the cables are used normally. The method of installing these cables as set forth in TB SIG 67 is abstracted here.

b. Splicing.

(*1*) Underwater splices in rubber- or plastic-covered cables should be avoided whenever feasible in short submarine cables. Except in the case of the spiral-four cable which is supplied with loading coil connectors, standard (vulcanized) splices should be used whenever possible. For underwater use the insulation of spiral-four cable connectors should be reinforced by means of rubber cement, DR or rubber tape, and friction tape as set forth in TB SIG 67.

(*2*) If it becomes necessary to utilize expedient cable splices, rubber cement should be used when applying the insulation to the joint. Conductor splices in 5- and 10-pair cable made without the use of copper splicing sleeves, and all expedient splices in spiral-four cable, should be relieved of stress by means of a tension bridge. (TM 11–369).

c. Cable Laying Methods.

(*1*) Tactical submarine cable may be laid by means of suitable boats or amphibious vehicles directly from reels, or it may first be unreeled and coiled in the form of a figure eight on the deck. This will permit it to be payed out without twisting. It is advantageous to use a method which permits, in so far as possible, the making of all splices and preliminary tests before the actual laying starts.

(*2*) One of the most satisfactory methods of laying is to use Truck, Amphibian, 2½ ton, 6 x 6 (Duck). Four or five miles of prespliced tactical cable can be stowed in the form of a figure eight in this truck. The cable should be laid on the floor of the cockpit so that the cross point of the figure eight is at the center, with one loop extending forward and the other aft. The cable should be payed out over the stern. A suitable device for guiding the cable over the stern is an empty reel mounted in Reel Unit RL–31–( ), erected on the after deck.

(*3*) When the water is covered with ice, a slot may be cut through the ice along the cable route. The cable is laid along the slot, spliced, and then dropped into the water through the slot.

(*4*) The placing, in the field, of armor or additional protective covering on tactical cables for submarine use is not considered to be feasible or desirable. The outer covers of the tactical cables are tough and will resist considerable abrasion. Even though sheath breaks due to abrasion and to repeated flexure should be rare, movement of the cable should be kept to a minimum.

(*5*) Where possible, cables should be laid on the bottom and additional weight should be applied as necessary in order to hold the cables in position. The best method for increasing the weight of tactical cable in the field is to lash it to Wire W–115 (6M–messenger) at approximate 3-foot intervals by means of a combination clove hitch and square knot tie made with short lengths of Wire W–110–B. Cables so reinforced with messenger should be used all the way across short channels with currents faster than about 2 or 3 miles per hour. Reinforcement with messenger is not required in calm water or at sheltered sandy approaches, but is required at approaches that are exposed to breaking waves or large tidal changes.

(*6*) Approaches that are rocky or have formations of coral reef also require reinforcement with messenger. Under these conditions the reinforcement should extend from a log anchor well above the point of high tide or high-water mark to a rock anchor well out in deep water. If a rocky reef is traversed, soundings should be made to determine the extent of the reef and the anchor placed off the seaward edge of the reef.

(*7*) Cable laid in calm water or in deep water between rock anchors usually needs no special reinforcement, but is simply laid with sufficient slack to permit it to conform to the contours of the bottom and to permit raising to clear trouble. Experience has indicated that time expended in making *thorough preparations*, including soundings to determine the nature of approaches, *will eliminate the occurrence of troubles* which might seriously delay operations.

d. Fixed Plant Cables. Generally in the fixed plant, armored submarine cables will be used. A list of those usually stocked by the Signal Corps is given in TM 11–487. The engineering of these installations should be referred to the Army Communications Service.

Section IV. REHABILITATION OF CAPTURED PLANT

917. REHABILITATION OF OPEN WIRE PLANT.

a. Wire lines abandoned by the enemy will often be found destroyed or rendered inoperative. However, a careful check of their condition may show that some of the facilities can be restored with less effort than is required to install new lines.

b. On open wire lines where poles of the smaller sizes have been sawed off above ground, it may be possible to restore them by splicing with a wood splint to bridge the cut and binding the splint to the pole by a tight serving of construction or line wire applied with a serving stick. Lines taken over in occupied territory may be of copper or bronze and splices will generally have to be made with so-called *Western Union* type joints, that is, wires twisted together without the use of a sleeve, since the gauge of the wire will probably not correspond to standard Signal Corps sleeves.

918. REHABILITATION OF TOLL CABLE PLANT.

a. Toll cables differ in several respects from those common in the United States. The sizes of conductors correspond in a general way with those used in this country but are classified in pounds per wire mile or by diameter expressed in millimeters (fig. 9-21). In Europe some cables may be found of the Krarup type in which the conductors are continuously loaded by a wrapping of fine iron wire. The electrical characteristics of such cables are quite different from the coil-loaded type. In Europe toll cables will generally be found buried, as not much use has been made of aerial suspension or manhole and duct construction. In American practice, loading pots are equipped with single cable stubs, color coded and carrying both in and out conductors. British pots have separate stubs for in and out conductors and the German type (Siemens & Halske) has a splice chamber on the top into which the main cable is brought from both directions. The electrical considerations which should be taken into account in rehabilitating captured cable and its loading equipment are discussed in chapter 5.

b. Before physical restoration can be intelligently started, it will be necessary to have certain information as to the design features of the cable system and its associated equipment, as well as the condition in which it has been left. It will also be necessary to know what materials are available for making repairs. A survey of the situation should provide full information on the route, type of installation, cable properties, arrangement of cable circuits, type of loading, and extent of damage. Much of this information may be available from commercial records that can be obtained before entering the territory.

c. Since the repair of toll cable networks calls for specially trained personnel and equipment, provision must be made in advance for staff and personnel, for transport, for mechanical and electrical depot-repair equipment, for field splicing materials, for tools and test equipment, and for stocks of replacement cable and loading coil equipment.

919. REPAIRING CABLES.

a. Where necessary to insert a patching length of cable it should preferably be identical cable, but urgency and availability of materials will be determining factors. If cable can be easily recovered and reinstalled as in an underground duct system, it may be possible to reassign many of the longer lengths to shorter subway sections to save splicing. For the longer sections, short pieces will have to be joined by means of duct splices (long splices with small diameter sleeves that can be pulled into the ducts) and eventually some new cable must be provided. With duct splices care should be used in their making, the pulls should be arranged so that the travel of the sleeve in the duct will be a minimum and the records should be marked with their location. If a cable length is to be pieced out in its present location it may be possible to apply a basket grip to one end in order to pull it into the manhole for splicing on a patching length. Before doing this, however, a core hitch will have to be made at the other end in order to permit pulling back enough cable for splicing in the adjacent manhole after the patching length has been added. Making the core hitch will probably involve breaking out the manhole wall or digging down from the surface and breaking open the duct. A basket grip is not recommended in this case since if pulled backwards into the duct line it would be apt to lose its hold on the cable.

b. If damage at the loading points is limited to cable stubs, it may be possible to cut back the remaining sheath or covering toward the pot so as to gain sufficient access to cable conductors for testing and splicing purposes. Where the loading pot is badly damaged, repairs can best be made at a repair depot. In any event there is a definite preference for recovering, repairing, and reinstalling the loading equipment originally associated with the cable as new pots may be difficult to obtain and will often have different complements or different weights of loading.

c. If repairs are carried out in the field, test should be made for low insulation resistance, open circuits, grounds, and crosses. At repair depots, tests should also be made for magnetized coils and for short circuited turns; also, the stub conductors, if not provided with an identifying code, as in American practice, should be tagged and marked to show the type of coil with which the pairs are associated.

d. There are methods of tracing the path of buried cables which should be useful in recovery work. One method which can be used with either rubber- or lead-covered cable is described in detail in TM 11–369. This method is also covered in Bell System Practice G72.275. The principle of this method is to place an audible frequency on the cable and to trace this tone through the use of a specially designed detector or exploring coil. There are various commercial devices for locating buried cables which work on the same principle; one of these uses three coils to give a direct reading of the cable depth as well as its plan position. The 3-coil locator, locally assembled in a theater depot, has been used with considerable success in Europe for anticipating the amount of effort required to uncover cable, and to make effective use of bulldozers without damaging the cable where large quantities of earth must be moved in the uncovering process.

Section V. RECOVERY AND RECONDITIONING PLANT

920. GENERAL.

During a rapid advance, time may not permit the recovery of wire lines over which service has been discontinued. When the opportunity presents itself, however, these materials should be recovered where feasible, using such care in the operation as to insure that as much as possible may be reconditioned and reused.

921. AERIAL PLANT.

a. On open wire lines the rolling type[2] of transposition used in Signal Corps practice, facilitates the removal of the wire in convenient lengths for rereeling. In general, recovered material should not be reused until it has been inspected, tested, and if necessary, repaired at a supply depot. *In the case of wires and cables particularly, there should be no question as to their serviceability when issued for reuse.* A definite system should be established for segregating and marking reconditioned wire and cable so as to avoid reissuing any that has not passed inspection.

b. Recovered spiral-four cable and probably other insulated wires should be tested for d-c telegraph serviceability with Test Set I–48 or a *Megger* applying at least 250-volts dc; if satisfactory for telegraph it will also be satisfactory for telephone. Spiral-four cable when installed in self supporting spans is suspended by clamps, hangers, or basket hitches that can readily be removed to clear the cable for rereeling. If spiral-four cable has been suspended on messenger wire it can be recovered most readily by first lowering the cable and messenger assembly to the ground. Poles can often be loosened in the ground and lifted out.

922. UNDERGROUND PLANT.

When spiral-four or 5- or 10-pair rubber-covered cables have been buried at shallow depths in light soils for short periods, they may often be ripped out of the ground without injury. In other cases the use of the cable Plow LC–61 equipped with attachments for unearthing cable will be of assistance. The path of the cable can be determined as discussed in paragraph 919d.

[2] As contrasted to the point type transposition used in American commercial high grade carrier construction.

Section VI. CONSTRUCTION OF JUNGLE LINES

923. GENERAL.

It has been found expedient in jungle areas to depart from the standard types of construction described previously in this chapter under conditions where materials for standard construction are not available, where there is insufficient time to clear a suitable right-of-way, where a clearly visible right-of-way is undesirable for tactical reasons, where the construction is known to be temporary, or where the density of traffic does not warrant the effort required for standard construction. Some types of wire line construction which have been found to give reasonably good service in jungle areas are outlined in this section as temporary information until standard instructions become available.

924. JUNGLE EFFECTS.

a. Transportation of large quantities of supplies through the jungle is difficult on account of the thick growth and because jungle ground is generally damp and spongy, and in the low areas becomes quickly flooded during rains. Jeeps may be the largest vehicles for practical use and in many cases entire reliance has to be placed upon man-pack or mule-pack. Waterways and native trails can be used advantageously for transporting small quantities of supplies. It has been found that the practicable man-load is 40 pounds per man, including his personal equipment and food (about 20 pounds). The average mule can carry 120 pounds (60 pounds on each side) and large Army mules can carry 90 pounds on each side or a total of 180 pounds.

b. In the construction of light pole lines across grasslands, swamps, and beaches, it may be advantageous to use lance-poles, cut native saplings, or bamboo poles, lashed together in groups of three, to avoid the necessity of transporting 4 x 4's through the jungle.

c. It is extremely difficult to maintain jungle lines, particularly bare open wire, because the lush, rapid growing, and frequently saturated foliage coming in contact with the line lowers the insulation resistance, and falling branches and palm fronds cause excessive wire breakage. The jungle conditions also contribute to rapid deterioration of the covering on insulated wires, attack of the braid by molds and abrasion by foliage being factors. The high temperatures and humidities hasten the impairment of both the physical and electrical properties of the insulation. The life expectancy of insulation on Wire W–110–B and Wire WS–1/TS (single wire similar in construction to Wire W–110–B) under these conditions is from 1 to 4 months and on Wire W–130–A its life expectancy is from two weeks to one month. Even less life can be expected from untreated wood poles (except mahogany and teakwood) because of destruction by termites and other insects.

925. OPEN WIRE CONSTRUCTION.

a. If a dependable pole line has to be constructed, a right-of-way or clearing must be cut through the jungle wide enough so that falling trees on either side will clear the line. Pole spacing and wire sags and clearances should conform to standard practices where practicable.

b. If only locally-cut timber (other than mahogany or teakwood) or untreated lumber is available, it is vital to apply a preservative treatment such as Osmoplastic B, which is a mixture of coal tar, pentachlorphenol, and sodium fluoride thinned with benzol. This mixture is issued in 5-gallon containers under Signal Corps stock number 6G1625. All bark should be removed and the poles should be treated as soon as possible thereafter, applying the mixture with a paint brush to the portion to be buried and also up to a point at least 2 feet above the probable ground line. This area should be covered with a layer 1/64 to 1/32 of an inch thick and allowed to set before handling. Certain precautions should be followed when handling this mixture since *it is poisonous*. The personnel should wear gloves when applying and handling this mixture and, before meals, should wash their hands thoroughly with a moderately strong soap. The empty containers should never be used for water or food and should be destroyed beyond the possibility of reuse. Further information on tropical maintenance of ground signal equipment may be obtained from TB SIG 72 and TM 11–368.

c. Where soft-wood trees or poles are used in pole line construction, tree climbers with long gaffs (about 5 inches) should be used instead of the ordinary Climbers LC–5.

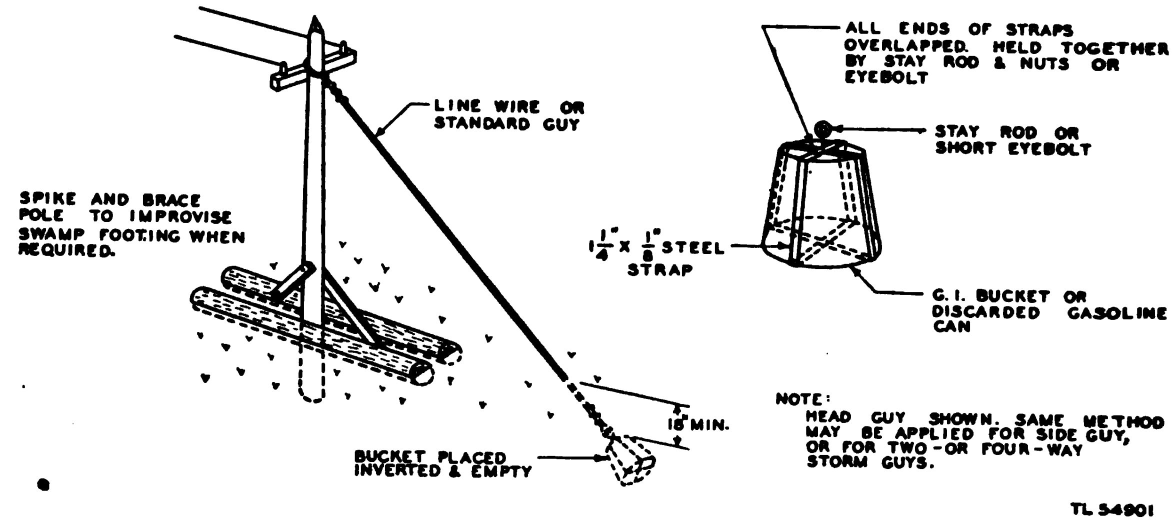


Figure 9-24. Guying through mucky or spongy ground.

d. As a substitute for treated wood poles, iron or steel poles have been used in some cases where they are available. This is not, however, a Signal Corps stock item.

e. Where the ground is quite spongy and mucky, it will be necessary to provide proper swamp footings as covered in TM 11–368, to prevent the pole from sinking. Extra guying will also be required in this type of ground. One suggested method of guying, where ordinary guy stakes or anchors will not hold satisfactorily, is to use an inverted ordinary GI bucket as shown in figure 9-24.

f. When crossing ravines it is undesirable to place poles at the bottom, especially where the ground is soft and spongy, since the wire pull may be sufficient during the rainy season to lift the pole out of the hole. Poles placed in river beds may be washed out during high water. Where such locations are unavoidable it may prove desirable to place a log crib filled with stones or earth around the pole and to anchor the pole to the crib.

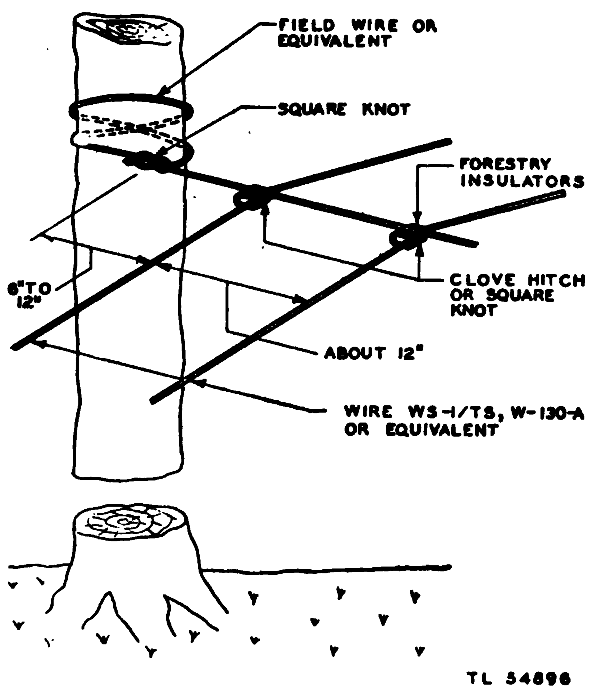


Figure 9-25. Tree slung construction using single support.

926. TREE-SLUNG CONSTRUCTION.

a. Several methods may be followed to construct lines with trees as supports. Spaced insulated wires which are fastened to the trees by slings of one form or another may be used. This has been called *tree slung construction.* One form of this construction is shown in figure 9-25. Each line conductor is supported by forestry type insulators (Graybar Electric Company No. 6651 or equivalent) which are tied to the trees with scrap wire. It is contemplated that only insulators and line wire will be taken into the jungle. The forestry type insulator is preferred because it is a split type and does not have to be strung on the wire in advance. If this type is not available, Insulator IN–75 or equivalent may be substituted.

b. In dense jungle where the line cannot be kept free from foliage, it will generally be necessary to use insulated wire such as Wire

WS–1/TS (single wire similar in construction to Wire W–110–B), Wire W–130–A, or other jungle type wire which may be available. If Wire W–130–A is used it should be used as spaced pairs (ch. 5).

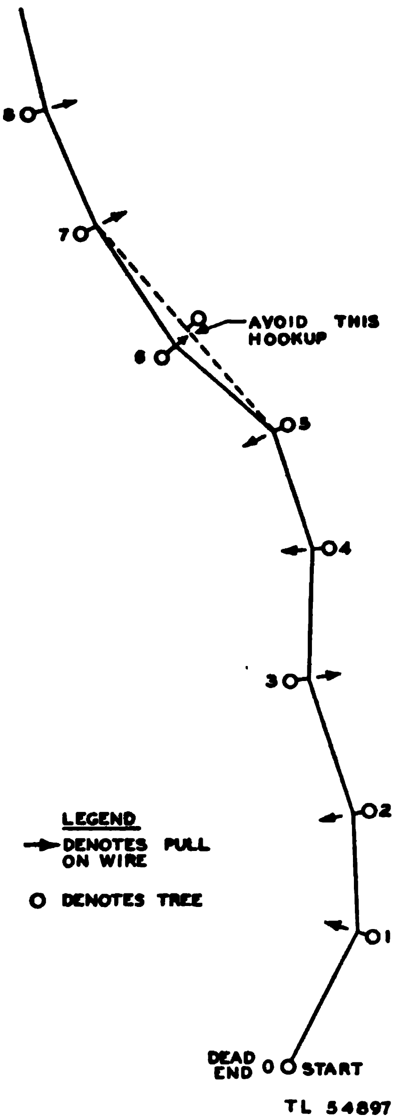


Figure 9-26. Layout of tree slung route.

c. One object of the above type of construction is to prevent shorts or high leakage between tip and ring of a single pair from causing circuit troubles. Another object is to increase the transmission range beyond that obtainable with a single pair. Where paired wire such as Wire W–130–A is used in place of a single field wire it should be spliced as if it were to be used as two single conductors.

d. Where it is necessary to use the construction shown in figure 9-25, supporting trees should be selected along the general direction of the desired route and chosen as illustrated in figure 9-26 so that there will always be a pull on the wire away from the tree to avoid abrasion at the point of support. The distance between supporting trees should preferably be no greater than 100 feet but may vary plus or minus 10 feet.

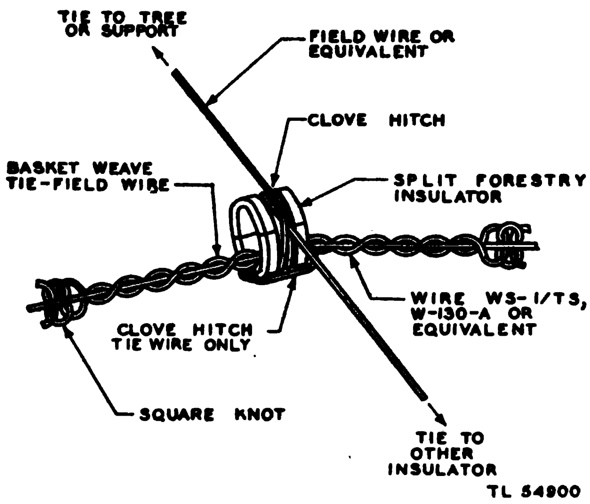
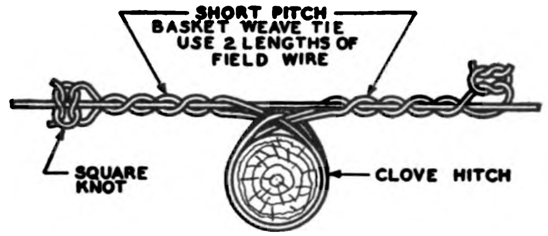


Figure 9-27. Tying line wires at fixed points.

e. The line wires are allowed to slip freely through the insulators except at the ends and at intermediate points about every 1,000 feet where they are fixed or tied to the insulator. The wire is allowed to slip through the insulators in order to minimize wire breakage from fallen tree branches. In case the wire breaks, the loose ends generally will not run through more than one insulator. The sag should be great enough to permit the wire to be pulled to the ground as determined by test; this test should be made close to one of the supporting trees and not at the mid-point of the span. A method of tying the line wire to the insulator at the fixed point is shown in figure 9-27. It is arranged so that the tie wire can not make contact with the line wire and thereby cause grounds or shorts in the line.

f. The line route or signal trail should be as far as possible from the side of the main trail or road and, if a crossover is necessary, clearance should be 15 feet or more. Fixed supports on each side of the crossing are desirable.



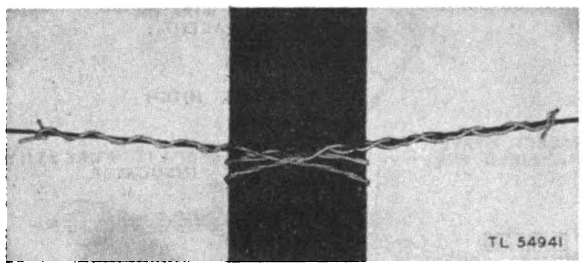


Figure 9-28. Weave tie supporting a straight section of wire.

g. It may prove desirable to guy the trees which serve as fixed supports, particularly where the trees sway substantially. Line wire will be used for guys attached to anchors, stakes or to the base of suitably located trees.

h. If there is noise from external interference, it may be possible to reduce it somewhat by making transposition at the 1,000-foot intermediate tie points (subpar. e above), or at the end of each wire coil or reel.

927. USE OF INSULATED WIRE IN JUNGLES.

a. The objections to bunching pairs of insulated wires as noted in paragraph 910c(2), are particularly important in the jungle on account of the rapid deterioration of the insulation. Paired wire may be supported aerially by tying it to trees with short lengths of the same wire, leaving sufficient slack to take care of tree sway. The method of tying field wires, using the weave tie, is described in TB SIG 121. Figure 9-28 shows a line drawing and a photograph of the weave tie supporting a straight section of wire.

b. When the individual pairs have deteriorated so that excessive leakage between wires of a pair appears, it may be feasible to use two pairs in place of one, making each pair a single line conductor, and thus extend the life of the wire line although obtaining fewer circuits.

c. Insulated wire should not be buried nor laid on the ground in jungles unless extremely short life is satisfactory, since the insulation deteriorates rapidly due to ground contact and attack by insects.

d. It may be possible to bypass dense jungle areas in cases where waterways or ocean shores can be used for the line route. In this case Wire W–110–B can be used as a submarine circuit. All splices should be waterproofed as discussed in paragraph 916b. Life expectancy may vary from a few days to several months depending upon the amount of movement caused by the water and the character of the water bottom. It is sometimes advantageous to use the expedient of laying spiral-four cable or Wire W–143 under water along stream beds or off shore to avoid dense growth. Spiral-four cable should have a longer life under water than Wire W–110–B.

CHAPTER 10

ELECTRICAL PROTECTION

1001. PURPOSE OF PROTECTION.

Protection is provided for communication apparatus and cables to avoid damage from excessive voltages and currents which may be impressed on communication lines by lightning or by accidental contact with or induction from power lines. Protectors also minimize hazard to personnel.

1002. EXTENT REQUIRED.

a. In general, protective devices are supplied as an integral part of tactical equipment. At the front it is unlikely that power lines will be energized; hence, for small-capacity equipment, protection is primarily against lightning. Larger-capacity equipment, normally used close to the front, is also protected against power line faults, since such equipment is also used farther to the rear in areas where power lines are energized.

b. Where protection is not an integral part of the equipment, provision should be made to install it unless there are no working power lines in the locality and thunderstorms are infrequent for the period and locality in question. In considering the need for protection against power line faults, it should be borne in mind that such faults are apt to develop in areas subject to bombing or other enemy action.

c. Protective equipment available for use on electrical communication systems is described in TM 11–487.

1003. PROTECTORS.

Three types of protective devices are used, namely, voltage limiting gaps, fuses, and heat coils. A protector is a combination of one or more of these devices in a suitable mounting. These protective devices are illustrated in figure 10-1.

a. **Protective Gaps.** The voltage-limiting device is usually a small air-gap between two conducting blocks called protector blocks. One protector block is connected to the line and the other to ground. An excessive voltage on the line breaks down the gap; hence the voltage across the apparatus cannot exceed the breakdown voltage of the gap. Protector blocks used with communication equipment generally have a gap of 0.003 to 0.004 inch, with a breakdown of 350 to 500 volts peak. Sufficient protection for cables is obtained with a gap of approximately 0.006 inch with a breakdown of about 700 volts peak.

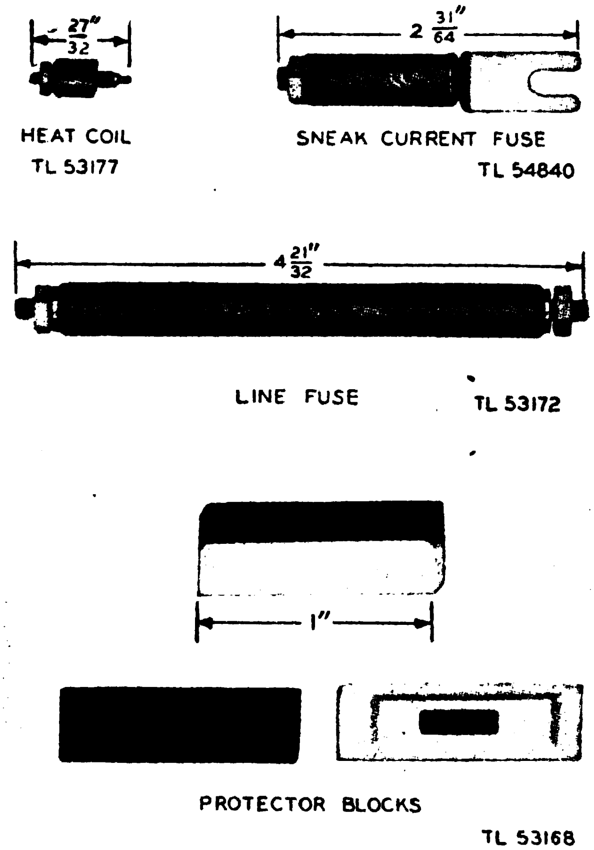


Figure 10-1. Typical protector blocks, fuses, and heat coil.

b. Line Fuses. Fuses are placed in the line ahead of protector blocks to limit the current which may result from an accidental contact between power and communication conductors. These fuses usually have a 5 to 7 ampere rating and are capable of interrupting 2,500 volts at 200 to 300 amperes. Fuses having a lower rating (1 to 3 amperes) are sometimes used on small switchboards, to insure blowing when the ground resistance is relatively high.

c. Sneak Current Protection. Accidental contact with power circuits may result in a voltage too small to break down the protector blocks. The current resulting from such contacts, while not large (commonly called sneak current) may, if long continued, overheat apparatus. To prevent this, a low-capacity fuse or heat coil is inserted between the protector blocks and the equipment. Sneak-current protection is generally required on local circuits at switchboards, but usually is not placed in long distance circuits nor at telephones since the equipment used makes it unlikely that overheating will occur. For large switchboard installations, heat coils, which ground the line when operated, are used. Where there are only a few lines, low-capacity fuses which open the circuit are used. Ordinarily these heat coils and fuses are rated at 0.35 ampere.

1004. PROTECTION OF SWITCHBOARD EQUIPMENT.

a. Tactical Switchboards. The protection required for small tactical switchboards is generally furnished as an integral part of the equipment. When such swithchboards are put in service, it is necessary, for the protection to function properly, to connect the ground post to a suitable ground (par. 1011).

b. Other Switchboards. Where protection is not included as an integral part, separate mountings must be provided. At large switchboard locations, a multiple mounting, designed for protector blocks and heat coils only, is generally used, a separate mounting being used for fuses if required. For smaller switchboards, a multiple mounting suitable for installing protector blocks, fuses, and sneak-current protection is used. A typical switchboard protector is shown in figure 10-2. Unless circuits are entirely in underground lead-covered cables in well built-up areas, protector blocks should always be used at switchboards, since cables and rubber-covered conductors, even when buried, may be subjected to excessive lightning potentials. Fuses may be omitted at switchboards where the circuits are in lead-covered cable if not less than 6 feet of the cable, between any power exposure and the equipment, is made up of conductors not larger than 24 gauge. Such small conductors will limit the current to such an extent that fuses are not necessary. Fuses may also be omitted where communication circuits are entirely in rubber-covered wires even where exposed to contact with power circuits. Experience has shown under this condition that a sustained contact with power circuits is unlikely.

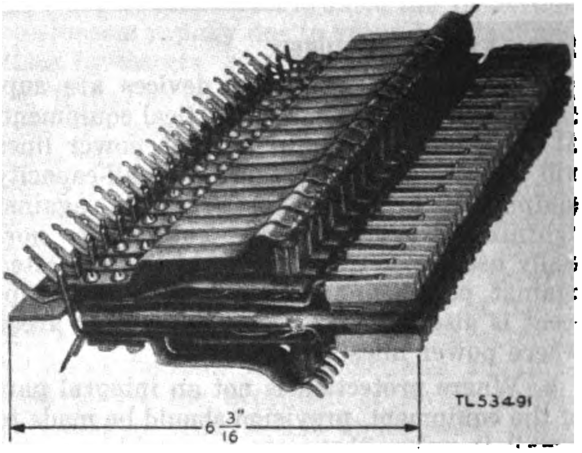


Figure 10-2. Switchboard protector.

1005. PROTECTION OF TELEPHONES.

a. Portable Telephones. Portable telephones are ordinarily not provided with protection, largely because it is difficult to apply it and to provide suitable grounds. The hazard is small, since the circuits are usually not exposed to power contact and when not too long, they receive a measure of protection from the protector in the switchboard to which they are connected.

b. Fixed Telephones. Except in well built-up areas where circuits are entirely in underground lead cable, or where circuits from switchboards to telephones do not extend outside of a building, fixed telephones should be provided with fuses and protector blocks. In general, an individual protector is used for each pair of wires. If it is necessary to locate protectors outside, they should be guarded against the weather by a suitable housing. A typical protector used at fixed telephones is shown in figure 10-3.

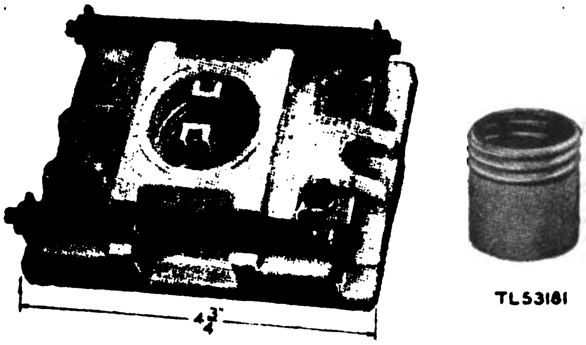


Figure 10-3. Telephone protector.

1006. LOCATION OF PROTECTORS FOR SWITCHBOARDS AND TELEPHONES.

The best location for protectors varies with the type of plant and local conditions. Unless protectors are an integral part of equipment, they should be located at an accessible point as near as practicable to the entrance of the wires into a building. They should not be installed in damp locations nor near easily ignitible materials.

1007. ILLUSTRATIVE EXAMPLES.

The application of the protection principles discussed above is illustrated in figures 10-4, 10-5, and 10-6.

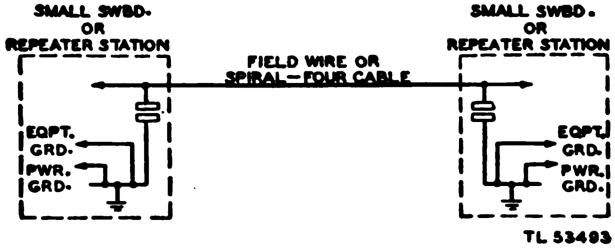


Figure 10-4. Protection when there is no open wire between equipment.

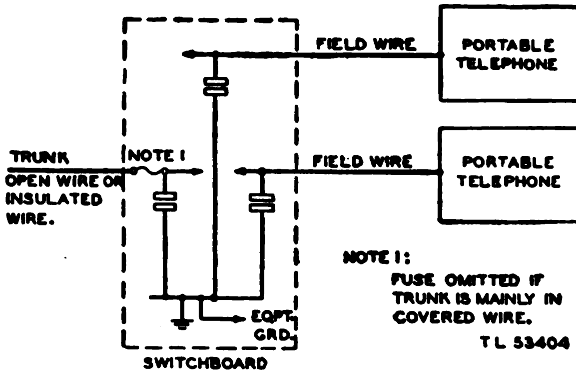


Figure 10-5. Protection for portable switchboard.

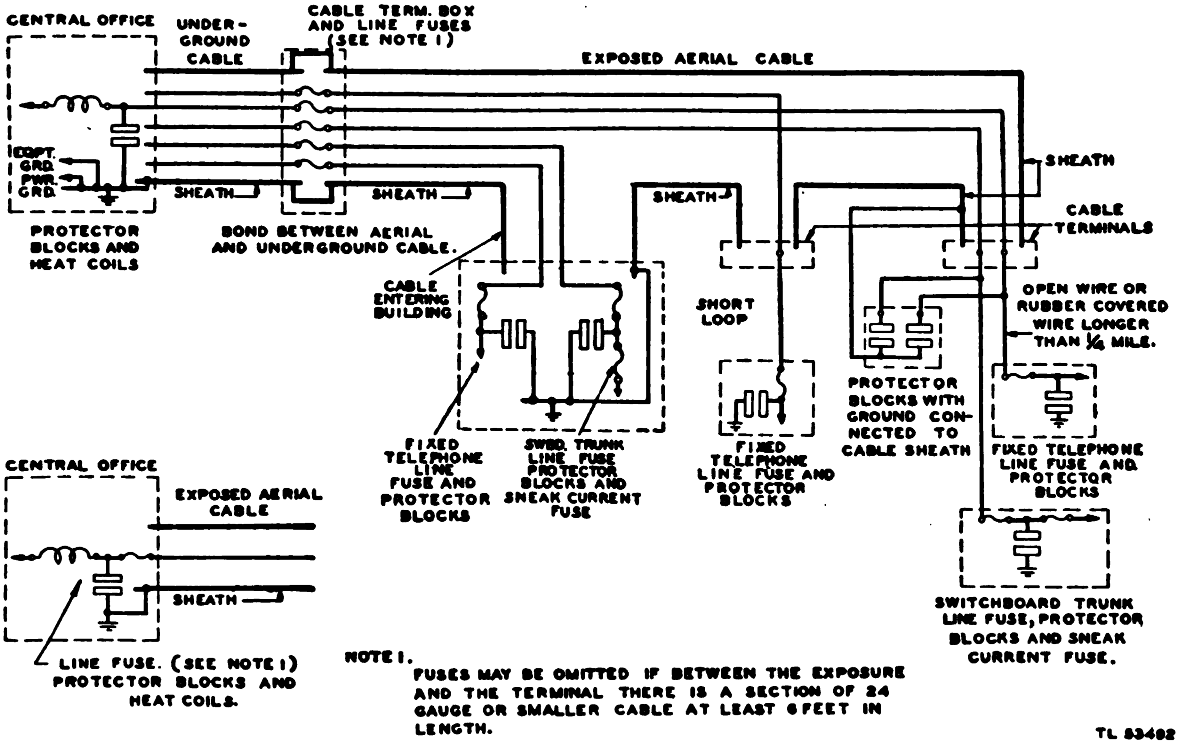


Figure 10-6. Protection for an extensive communication system.

1008. PROTECTOR DRAINAGE.

Operation of protectors by lightning may cause false operation of carrier telegraph equipment due to metallic-circuit voltage set up by lack of symmetry in the discharges through the protective gaps. This trouble may be largely reduced by replacing the ordinary protectors with protector drainage. This drainage consists essentially of a well-balanced 2-winding coil with each winding connected in series with protector blocks to ground. This coil equalizes the discharges through the gaps. A typical equipment and schematic circuit of protector drainage are shown in figures 10-7 and 10-8. Protector

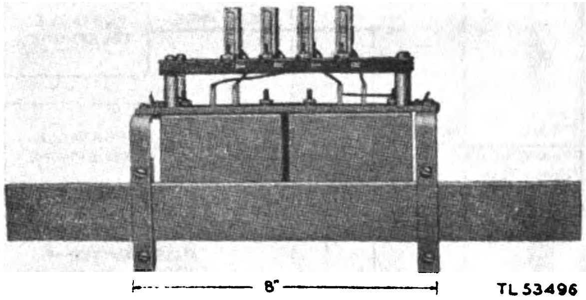


Figure 10-7. Office type protector drainage assembly.

drainage is in general supplied with both the packaged and portable types of carrier telephone line transmission equipment. The drainage has been physically located with the equipment. Where lead-covered paper-insulated entrance cable is used, protector drainage may be required at the junction of open wire and entrance cable in situations where lightning is prevalent enough near the entrance cable to cause serious effects on carrier telegraph.

1009. PROTECTION OF CABLES.

a. Protection of Lead-covered Cables at Aerial Wire Junctions.

(*1*) To protect lead-covered cables against lightning, aerial wires (open wire, field wire, spiral-four) over ¼ mile long and connected to cable conductors should be equipped with protector blocks at their junction with the cable. If, on this basis, one or more cable circuits require protection, all other wires connected to the same terminal, regardless of their length, should also be provided with protector blocks, to avoid excessive potential between cable conductors. Unless the length of one or more open wire circuits at a particular terminal is over ¼ mile, no protection is required at that terminal.

(*2*) At the junction of aerial wire and cable, the protectors may be an integral part of the cable terminal; however, a more common method is to use a separate mounting suitable for attachment to a pole or crossarm similar to that shown in figure 10-9.

(*3*) Protectors installed at the junction of cable and aerial wires should have the grounding terminal connected to the cable sheath. Where an aerial cable is small, especially where the soil resistivity is high and lightning is severe it is desirable to install a ground on the cable sheath at the open wire junction. Such a ground should have as low a resistance as can be practically obtained (par. 1011).

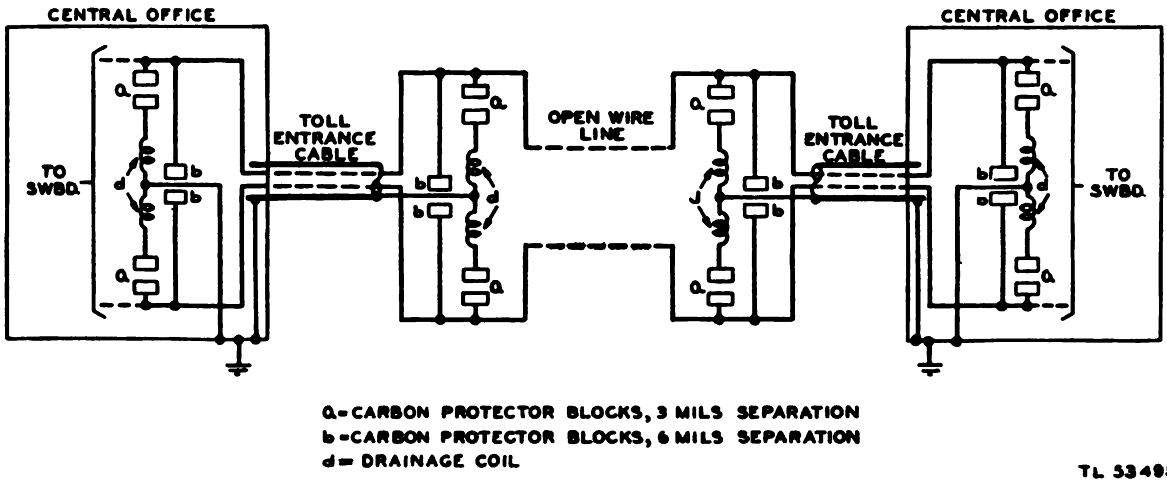


Figure 10-8. Protector drainage.

b. Protection of Lead-covered Long-distance Cables. For aerial or buried lead-covered long-distance cable, most of the lightning damage is due to direct strokes to the cable sheath. Such strokes may give rise to excessive voltage between the sheath and the cable conductors, particularly when the cable is of small size and the earth resistivity is high. Small-size paper insulated cable provided with extra insulation between the conductors and the sheath may be used in such areas to reduce the likelihood of these voltages causing conductor failures.

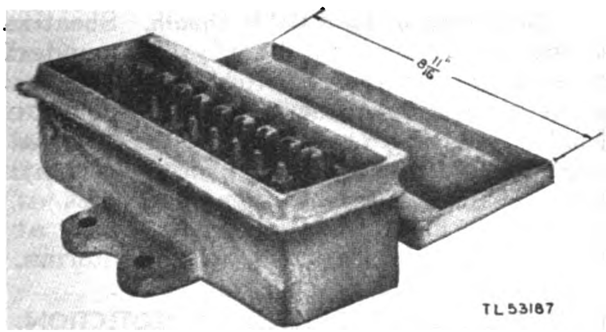


Figure 10-9. Cable protector.

c. Junction of Open Wire with Field Wire or Spiral-four Cable. No protection is ordinarily placed at the junction of open wire with field wire or spiral-four cable, since the likelihood of failure, in general, is small. However, in areas where lightning storms are frequent and buried spiral-four cable is inserted in an open wire line, as for example at a railroad crossing, it may be desirable to place protection (0.006-inch gap) at the junctions of the open wire and spiral-four cable (ch. 5). An effective ground can be obtained by installing a bare wire (No. 14 or larger) with the buried cable. The same considerations apply to buried field wire inserts in an open wire line.

1010. PROTECTION AT RADIO STATIONS.

a. Portable Equipment. No protection is required for portable radio equipment since with the short antennas used, the hazard from lightning is slight.

b. Fixed Stations.

(*1*) Stations using short antennas, as a rule need no special protection, for the same reasons as in the case of portable stations. Where protection is desired, as in exposed locations with frequent lightning storms, it may be provided as described below.

(*2*) Protection methods for large stations depend on the type of antenna and associated transmission line used. Tall radiating masts insulated from ground should be provided with a gap (horn or sphere type) across the base insulator. In severe lightning localities, wooden poles used as antenna supports should be protected against shattering, as described in paragraph 1012a. Where a single antenna lead-in wire or an open wire transmission line is used, protective gaps suited to the equipment to be protected should be installed between such conductors and the station ground, or the buried grid (network of ground wires) at or near the station. Where a coaxial transmission line is used, the outer coaxial conductor should be connected to the station ground and also grounded at the base of the pole or tower to the buried grid, if available, otherwise to a driven ground. If the coaxial cable extends up a steel tower, it should be bonded to the tower both at the top and bottom.

(*3*) Where coupling equipment is placed at the junction of coaxial line and antenna, sphere gaps or equivalent (usually furnished with the equipment) are placed between the antenna terminals of the equipment and the coaxial outer conductor. Equipment installed in series with antenna conductors, such as the resistor placed in the far end of a rhombic antenna, should have a protective gap (generally a horn gap) bridged across it.

(*4*) As discussed in paragraph 1011b, all grounding connections at the station, including the buried grid, if any, should be made to a common ground bus.

1011. GROUNDING.

a. Grounding Connections.

(*1*) Every reasonable effort should be made to get low-resistance grounding connections. Under emergency conditions, it may be necessary to use a very rudimentary connection, such as a bayonet plunged into the earth. Under other conditions, a very extensive system may be warranted, such as the grounding grid for a high-power radio transmitter.

(*2*) Water pipes, gas pipes, or other extensive underground metallic structures should be utilized where available; otherwise driven grounds or buried wires should be used.

(*3*) Driven grounds are made by driving one or more ground rods (preferably at least 5-feet long and ½ inch in diameter) in the earth. The grounding resistance of a ground rod may be anywhere from a few ohms to several thousand ohms, depending on the resistivity of the earth and the depth to which it is driven. High grounding resistance is found in sandy or rocky ground, and very dry or frozen ground. The grounding resistance may be reduced by using rods connected in parallel, or by applying a salt solution, or both. Salt treatment may be applied by pouring a solution of about 5 pounds of rock salt into the ground at each rod. With high-resistivity earth, this may reduce the grounding resistance by as much as 10 to 1. A ground rod should be driven into the earth for all or most of its length when practicable. Several 5-foot rods in parallel will give lower resistances than a single long rod, except where a conducting layer is reached below a high-resistance layer of some depth or the soil is deeply frozen. Sometimes a depression in the ground, which collects moisture, can be chosen for grounding. Rods should be spaced at least 6 to 10 feet apart to be effective in reducing the resistance when connected in parallel. For ordinary conditions one rod is used at individual telephones or small switchboards, and 3 to 10 rods at larger switchboards.

(*4*) Where it is difficult to drive rods, and where space permits, an effective low-frequency ground can often be obtained by burying a bare wire in a shallow trench for a few hundred feet. If more than one trench is used, the trenches should preferably be at right angles or at a separation of not less than 10 feet.

(*5*) The length of the ground lead used for carrier telephone systems should be as short as practicable, to keep its reactance low.

b. Common Grounding. Grounds may be required at a particular location for more than one purpose, such as protection of communication equipment, a-c power supply ground, cable ground, and equipment ground. For protection reasons, it is best to connect all grounds to a common bus, particularly where lightning is prevalent. This will prevent excessive potential differences when one of the grounds is carrying large currents, as may happen in a lightning storm. Such potential differences, unless avoided, may cause insulation failures and hazard to personnel. For a similar reason it is advantageous from the protection standpoint to interconnect grounds of different communication systems installed at one point. In some cases where the resistance of the ground is high, it may be necessary to use separate equipment grounds to avoid transmission difficulties; however, wherever practicable a single low-resistance ground should be used, and the ground lead should be as short and direct as practicable.

c. Grounding of Lead Cable Sheath. Sheaths of lead cables should ordinarily be grounded where they terminate at switchboards. Sheaths of underground and aerial cables should be bonded, where both are used. Sheaths of aerial cables should be electrically continuous from end to end, to prevent large differences of potential, which would otherwise occur at sheath discontinuities during lightning storms.

1012. SPECIAL APPLICATIONS OF PROTECTION.

Some of the more common situations occasionally arising and requiring special protection are briefly discussed in this paragraph.

a. Protection of Poles.

(*1*) Shattering by lightning of wooden poles in a wire or aerial cable line can be largely avoided, where necessary, by running a wire (for example, 104 copper or 109 iron wire) from the top of the pole to a short distance below ground. If new poles are being placed, such wires can be stapled on for the entire length. For the protection of linemen, it is frequently desirable to avoid having a ground at the top of the pole. For this purpose a gap about a foot long may be left in the wire approximately 7 feet above the ground.

(*2*) The scheme just described cannot ordinarily be employed where wooden poles are used as antenna masts, since it may interfere with radio communication. For such cases, a series of short gaps may be placed in the wire at intervals not exceeding a quarter wavelength.

b. Protection of Equipment Inserted in Open Wire Lines. Equipment such as repeating coils, portable repeaters, and short sections of spiral-four cable installed in open wire lines is vulnerable to lightning if not protected. The principle of protecting such equipment is shown in figure 10-10. It is important that the protection applied to the lines in both directions be connected to a common ground. The resistance of the ground in this case is not important.

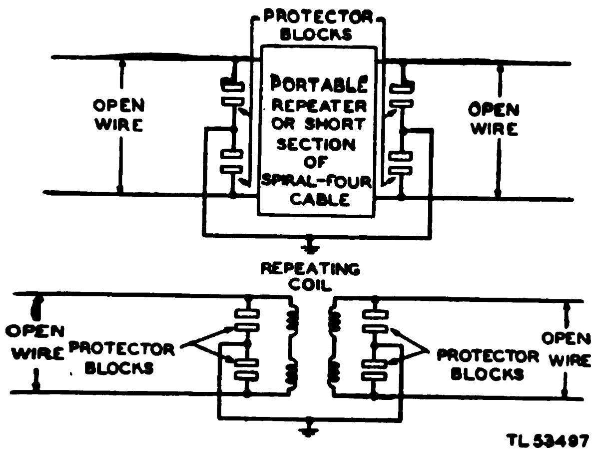


Figure 10-10. Protection of equipment in open wire lines.

1013. EARTH RESISTIVITY.

In the above discussion, earth resistivity is mentioned a number of times. Special test apparatus is required to obtain an accurate measurement of earth resistivity. An approximate estimate can be obtained by driving two ground rods 5 feet apart and 5 feet into the earth whose resistivity is desired, and measuring the resistance between the two rods with Test Set I–49 or equivalent. The average of the two readings obtained by reversing the leads to the test set should be used. The resistance between rods, in ohms, about equals the earth resistivity in meter-ohms at the spot tested. Resistivities may be rated as follows: low, up to 100 meter-ohms; medium, around 300 meter-ohms; high, 1,000 meter-ohms and up. The above method of obtaining a rough approximation of earth resistivity should not be confused with the measurement of the resistance of a grounding connection. Information on the measurement of grounding connection resistance is given in TM 11–2008 and TM 11–755 (when published).

CHAPTER 11

TECHNICAL ADMINISTRATION

Section I. INTRODUCTION

1101. GENERAL.

This chapter outlines the technical functions of the organization that is to engineer, install, operate, and maintain a communication system, and supplies certain of the necessary basic engineering data required. Information is included for telephone and telegraph (wire and radio) traffic engineering, and for estimating man-hours and time intervals required to install wire system offices. Desirable records, routines, and maintenance practices are suggested. Information relative to the procedure to be followed in the planning of a telephone system, together with the engineering of switchboard installations and wire telephone lines, is given in chapters 2, 5, and 9. Telegraph system engineering is covered in chapter 3, and radio in chapter 6.

1102. THEATER EXPERIENCE.

In planning a communication system it is necessary to estimate the number of calls and the duration of the average call expected to be originated by the telephones and teletypewriters. It is also desirable to know the call-carrying capacity of switchboard positions and of wire and radio telegraph and telephone channels or trunk groups, and the construction and installation time intervals. Experience from the theaters of operation should be valuable on many of these technical details in plans for a new communication system. The material herein reflects information which has become available from the theaters.

1103. PLANNING A COMMUNICATION SYSTEM.

a. Three Stages. Provision of a communication system usually involves planning at three distinct stages: long range and procurement planning to insure delivery of proper quantities and types of materials at the proper time; detailed project planning for specific facilities; and day to day planning for growth, rearrangements, and repair of major damage.

b. Coordination in Planning. The numbers of trunks and local circuits are a traffic problem. The type of switchboard to be selected for a particular situation requires both traffic study and a knowledge of equipment features and limitations. Selection of the types of facilities needed for circuits involves, among other considerations, a knowledge of transmission, signaling, and construction. Wire and radio facilities must be effectively integrated. These examples are sufficient to illustrate that complete coordination of the work by all groups concerned is essential to the proper execution of each project.

c. Long Range and Procurement Planning.

(1) This planning must allow 3 to 6 months or more for delivery of materials.

(2) The estimated requirements as to the quantity, type, and geographical location of speech and telegraph facilities including radio, of all ground, air, naval, and service forces should be obtained at the earliest possible date to insure adequacy of supplies and efficiency in combining requirements in common user groups, location of long distance centrals and the larger signal centers, and maximum utilization of civil plant. Consideration should be given to the return of some civil circuits for essential civil needs. Later requirements for American military government may need to be considered and decision made as to whether such requirements shall be allowed for initially in order to minimize future work.

(3) The *communication system* layout should show the location of all centrals and signal centers. The number and calling rate of the local telephones and teletypewriters to be served by each central must be estimated. The number of switchboard positions can then be

determined. The average holding time per call must be estimated. The number of trunks to other centrals can then be determined. Procurement lists of material and equipment for the entire system can then be prepared.

(4) A communication plan requires forecasts for major users, such as:

Theater headquarters:
- Operational and administrative.
- Joint and combined control and liaison.

Ground forces:
- Operational and administrative.

Air forces:
- Operational and administrative.
- Aircraft warning.
- Weather.

Communications zone:
- Administrative.
- Base, intermediate, and advance sections.
- Transportation and utilities control.

Governmental and civil agencies.

(5) Intelligence reports may indicate the location of civil telephone lines, cables, radio equipment, central offices, or repeater stations in the area of the proposed operation. If not, highways and railroad routes may be presumed as possible line routes, although these are frequently not the best military routes, on account of liability to physical damage and electrical interference. Using the possible routes as a basis, the wire circuit requirements can be consolidated on a circuit diagram indicating circuit concentrations between various points. An analysis of the circuit length and concentration will result in the selection of a type of construction and the formulation of a general transmission plan. The existing civil facilities, if known, may have a major bearing on the plan.

(6) Communications planned 3 to 6 months or more in advance of use may not be built exactly as planned, but the planning aids in assuring materials adequate for the job, however built, and provides a transmission plan as a guide in the type and grade of facility to be provided. Consideration should be given in the over-all plan for the possible use of tactical construction as part of fixed plant after its use in the tactical phase.

d. Detailed Project Planning.

(1) This planning is required when the specific need for facilities arises. The materials needed can then be ordered from the available stocks, for construction or installation, operation, and maintenance. The projects will be individual, such as a telephone or telegraph central for a particular location or an open wire pole line, a spiral-four cable between two definite points, radio relay systems, etc.

(2) Typical problems illustrating this type of planning and ordering are given in TM 11–487.

e. Day to Day Planning. This planning which is for unpredictable work such as growth, changes, and damage repair will be more accurate than the long range planning or the detailed project planning because it can be based on known results or situations, such as counts of traffic, service observations, or inspections. The reasons for changes include: the move of a headquarters from one place to another; change in the volume of traffic from time to time, growing in the early stages and possibly declining in the later stages of an operation; the shift of a highway which will require moving a pole line; and shell or bomb damage, etc.

Section II. TECHNICAL FUNCTIONS

1104. GENERAL.

a. This section covers the technical functions of an organization for planning, constructing, operating, and maintaining a communications system. These functions are tabulated in figure 11-1 but the form of organization is not indicated.

b. The division of functions for a theater communications system is broadly by *staff* and *field* categories. Those responsible for staff planning will rely upon the staff engineering people for estimates, advice, and consultation.

1105. FUNCTIONS.

a. Staff Functions. Radio, wire, and traffic engineering in general are staff functions be-

THEATER COMMUNICATIONS COORDINATION
(NORMALLY CARRIED OUT ON THEATER HEADQUARTERS LEVEL)

STAFF ENGINEERING | **STAFF PLANNING**

RADIO	WIRE	TRAFFIC-RADIO & WIRE	CLERICAL	
PROJECT PLANNING FREQUENCY ASSIGNMENT CALL SIGN ASSIGNMENT CIRCUIT ASSIGNMENT - MAJOR CIRCUITS STANDARDIZATION OF OPERATING AND MAINTENANCE PRACTICES CONSULTATION WITH STAFF AND FIELD ORGANIZATIONS	PROJECT PLANNING STANDARDIZATION OF TELEPHONE & TELEGRAPH MAINTENANCE PRACTICES CIRCUIT ASSIGNMENT TELEPHONE DIRECTORY NAME ASSIGNMENT CONSULTATION WITH STAFF AND FIELD ORGANIZATIONS	ESTIMATES OF INITIAL THEATER REQUIREMENTS STANDARDIZATION OF OPERATING PRACTICES-TELEPHONE & TELEGRAPH CONSULTATION WITH STAFF AND FIELD ORGANIZATIONS STATISTICS & RECORDS	RECORDS OFFICE ROUTINES DRAFTING DUPLICATING (MIMEOGRAPHING & BLUEPRINTING)	LONG RANGE PLANS AND PROCUREMENT

COORDINATION FOR COMMUNICATIONS ZONE
(NORMALLY CARRIED OUT ON COMMUNICATIONS ZONE HEADQUARTERS LEVEL)

FIELD COORDINATION FOR TYPICAL AREA
(SUBDIVISION OF BASE SECTION)

RADIO | **WIRE**

PLANT	TRAFFIC	PLANT	TRAFFIC
SITING INSTALLATION MAINTENANCE SUPPLY CURRENT ENGINEERING RECORDS	OPERATING CIRCUIT ASSIGNMENT LOCAL CIRCUITS CURRENT ENGINEERING RECORDS	LINE CONSTRUCTION INSTALLATION MAINTENANCE SUPPLY CURRENT ENGINEERING RECORDS	OPERATION DIRECTORIES INFORMATION SERVICE SERVICE OBSERVING CURRENT ENGINEERING RECORDS

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Figure 11-1. Technical functions for theater communications systems.

cause the work must be started well in advance of construction and installation. Centralization of engineering functions generally leads to the most effective coordination of the requirements of the several branches of the Armed Forces. Efficient use of personnel and facilities also results. A subdivision between wire and radio functions at a fairly high level may be necessary because of specialized personnel, but close coordination of these two functions is necessary. Close coordination also is essential with civil authorities in the use of civil plant to supplement existing military plant. Engineering, traffic, and plant matters may be involved. A communication organization requires routine clerical work and also special records such as circuit diagrams, equipment records, service observing data, directories, trouble records, etc. which are mentioned in various sections of this chapter.

b. Field Functions. A communication system may have sufficient plant remote from headquarters to warrant the establishment of subdivisions of base sections for effective administration. These field subdivisions are called areas in this chapter. When field functions are divided among areas, even the plant around headquarters may be operated as an area. Coordination of these areas from headquarters is desirable. The area functions include traffic management, plant work, and some aspects of engineering. Plant functions are field functions because they begin with the establishment of the first telephone or telegraph facilities. They continue in the extension of plant and in maintenance after the plant is placed. It is impracticable to supervise the plant work for a large system from one central location. Traffic management is largely a field function. As with plant work, it is impracticable to supervise telephone central operations from one central location.

c. Circuit Control. When long distance circuits pass through several test stations or test offices, which may lie in several areas, experience has demonstrated the necessity for a definite rule for the delegation of control authority.[1] This is necessary for the orderly control of procedures such as the allocation of repeater gains and the reassignment of circuits under emergency conditions. A simple and clearly understood rule is desirable. A rule which has been successfully utilized is that *a circuit which terminates at an intermediate point on a long distance route will be controlled by the terminal nearest theater headquarters.*

Section III. TELEPHONE TRAFFIC MANAGEMENT

1106. TELEPHONE CENTRAL WORK.

a. General. Telephone traffic management is concerned chiefly with supervising the operation of telephone centrals and related work such as information service, trouble report handling, directory, and service observing work. The activities include: personnel work; operator training; standardization of methods of handling various types of calls and related operations; determination of operating force and switchboard requirements; service observations and study of operating practices to see that efficient use is made of existing facilities; position load adjustment; record work of various kinds; etc. Reference may be made to TM 11-462, FM 24–20, and FM 24–75.

b. Written Practices. Written practices are desirable for some of the traffic functions. Items to be covered should include operating technique and phraseology for handling the several types of calls. These may be calls to distant or local points, switched calls, complaints, information calls, and trouble reports. The instructions may vary somewhat for different types of switchboards. Operating technique includes proper rotation of calls between cords, ringing intervals, monitoring, handling delayed calls, conference calls, routing of calls, etc. Directions should be provided for making traffic-load counts (peg counts), holding-time records, and service observations. Directory preparation, distribution, and maintenance should be prescribed.

1107. TELEPHONE CENTRAL MANAGEMENT.

a. General. Operation of telephone centrals requires an adequate and well-trained force, good traffic load distribution between switchboard positions, suitable switchboard equipment location, correct marking of trunks and lines, and careful clerical work.

b. Duties of Officer in Charge. Each central requires local supervision and the officer in charge should have rank commensurate with the size of the central. He should exercise general supervision and be responsible for operation as a whole; interpret and apply directives; select and train personnel, and provide them with necessary operating instructions, materials, and equipment; establish operator-force schedules and coordinate shifts; see that security features are properly observed; make analyses of traffic conditions with a view to effecting improvement; adjust complaints and procedure difficulties; assign equipment locations in the switchboards; supervise the preparation of directories; and provide the necessary traffic diagrams and bulletins.

c. Duties of Chief Operator. A chief operator is required to supervise each central to see that proper and prompt service is given. Assignment of operators to positions, supervision of information service, etc., are additional responsibilities. At long distance switchboards it is essential to watch the progress of traffic and to post delay information for the guidance of operators when trunk group trouble or congestion occurs. The chief operator should supervise the activities of personnel on duty in his shift; carry out instructions with particular reference to moving traffic rapidly and accurately, preserving security and dealing effectively with delays, difficulties, and emer-

[1] The importance of establishing a control point in European international telephony was recognized at the Budapest plenary meeting of the CCIF (International Consultative Committee on Telephony) in September 1934 at which the following rule was recommended: "One of the stations through which a circuit passes is responsible for satisfactory transmission on that circuit. This station is called the *control station;* it is chosen by agreement between the technical departments of the Administration and operating companies involved. Unless otherwise arranged between the technical departments interested, the control station will be one of the terminal stations of the circuit."

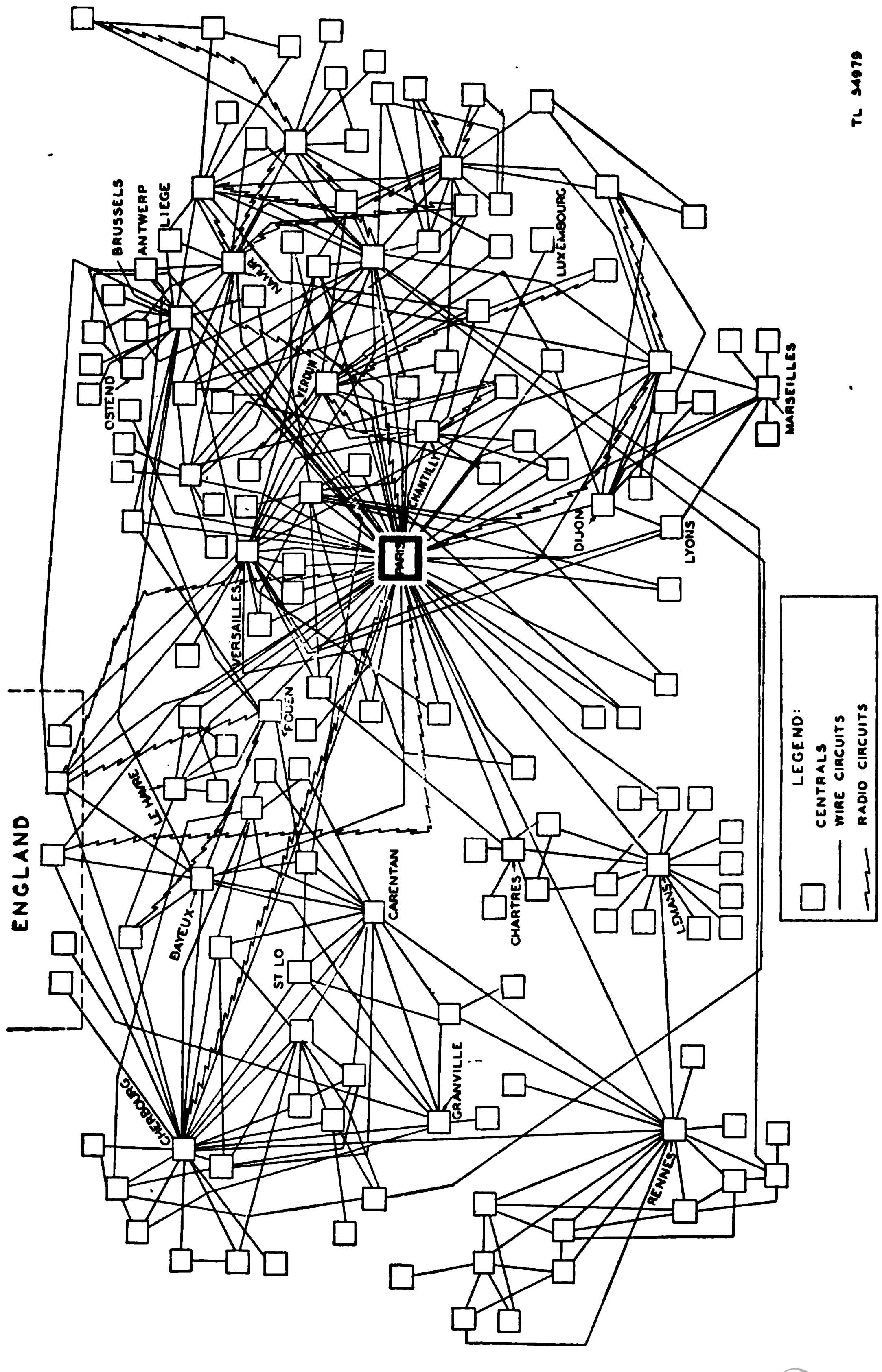
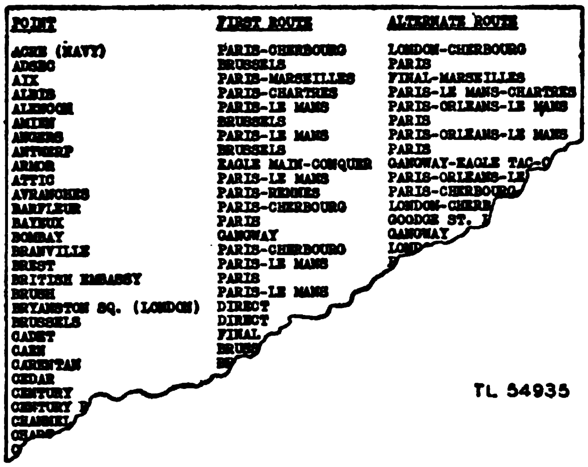


Figure 11-2. Diagram of telephone traffic routes.



POINT	FIRST ROUTE	ALTERNATE ROUTE
ACHE (NAVY)	PARIS-CHERBOURG	LONDON-CHERBOURG
ADSEC	BRUSSELS	PARIS
AIX	PARIS-MARSEILLES	FINAL-MARSEILLES
ALBIS	PARIS-CHARTRES	PARIS-LE MANS-CHARTRES
ALENCON	PARIS-LE MANS	PARIS-ORLEANS-LE MANS
AMIEN	BRUSSELS	PARIS
ANGERS	PARIS-LE MANS	PARIS-ORLEANS-LE MANS
ANTWERP	BRUSSELS	PARIS
ARMOR	EAGLE MAIN-CONQUER	GANGWAY-EAGLE TAC-
ATTIC	PARIS-LE MANS	PARIS-ORLEANS-LE
AVRANCHES	PARIS-RENNES	PARIS-CHERBOURG
BARFLEUR	PARIS-CHERBOURG	LONDON-CHERB
BAYEUX	PARIS	GOODGE ST.
BOMBAY	GANGWAY	GANGWAY
BRANVILLE	PARIS-CHERBOURG	LOND
BREST	PARIS-LE MANS	
BRITISH EMBASSY	PARIS	
BRUSH	PARIS-LE MANS	
BRYANSTON SQ. (LONDON)	DIRECT	
BRUSSELS	DIRECT	
CADET	FINAL	
CAEN	BRUSS	
CARENTAN		
CEDAR		
CENTURY		
CENTURY		
CHANNEL		

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Figure 11-3. Telephone route bulletin.

gencies; and keep the officer in charge informed of any unusual developments. A large switchboard may require section or subsection supervisors with duties similar to those of the chief operator in relation to the operators under his direction. Supervisors also may be required for the evening and night shifts to take charge of the central, with responsibilities similar to those of the chief operator as to the moving of traffic during their shifts. Such supervisors should report to the chief operator.

d. Operator Attitude. The successful working of a central depends upon the operators. Prompt answers and completions, courtesy, and strict observance of instructions are important. Instructions are necessary as a guide but in addition common sense, secrecy, tact, and discretion on the part of the operator are required.

e. Trunk Designation Strip Marking. Clearly marked designation strips with a minimum of abbreviations are important for good switchboard operation. The difference between via and terminal grade long distance trunks necessitates marking their designation strips so that operators can distinguish between them where both grades exist between two centrals. One method is to use the initial V, placed on the designation strip after the group name in the case of via trunks, and the letter T in the case of terminal trunks.

f. Traffic Diagrams. Either traffic diagrams or route bulletins, or both, should be provided for every central, located where they will be readily accessible to operators, to indicate how to reach other centrals. This is particularly necessary when the distant central is reached through another central or has an alternate route. At tactical switchboards, route information is by diagram as illustrated in FM 24–20 and TM 11–462. At fixed plant switchboards, if space is available, diagrams can be posted on or above the face of the switchboard positions with one diagram for every two operating positions. A diagram of traffic routes for a large fixed plant network is illustrated in figure 11-2. For such networks the routing is complex, and it is impractical for operators to use traffic diagrams for all calls. The best arrangement for such situations is to provide route bulletins in ring binders, with the names of centrals and routings arranged in alphabetical order as shown in figure 11-3. These binders can be kept at information positions which can be reached over special lines by all of the operators at the switchboard. In this case, the traffic diagrams located at the operator's positions would cover only nearby points, direct points, and most frequently called points.

Hour	*Percent of busiest hour traffic*
2400-0700	[a]
0700-0800	40
0800-0900	70
0900-1000	95
1000-1100	100
1100-1200	80
1200-1300	50
1300-1400	75
1400-1500	100
1500-1600	90
1600-1700	90
1700-1800	90
1800-1900	60
1900-2000	50
2000-2100	40
2100-2200	40
2200-2300	25
2300-2400	25

[a] For the night assignment, a single row of 10 or less positions will require one operator, but a second is desirable for relief and safety. Larger numbers of positions or double lines of positions will require more.

Figure 11-4. Typical telephone switchboard traffic distribution by hours.

g. Traffic Distribution by Hours. Where no data are available from the specific central or a comparable one, the information shown in figure 11-4 which is typical of military field conditions, may be used to estimate the number of calls in the various hours. It is important, however, to secure actual data as soon as the switchboard is working.

h. Operating Personnel Requirements. The number of positions in the switchboard lineup usually determines the number of operators on duty at the switchboard during the busiest hour of the day. Since the traffic in most of the other hours is less than that in the busy hour, the operating force can be reduced during those hours in relation to the calls handled. The number of operators required for each hour may be read from figures 11-10, 11-11, and 11-12 depending upon which table applies. When the number of operators required for each hour has been determined a schedule of assignments should be drawn up to cover the actual operating requirements, supervisory requirements, meal hours, and periodic relief periods. In general, the total number of operators on the force will be from 2.0 to 2.5 times the number of operators required in the busy hour.

i. Position Load Balance. The load on a switchboard should be distributed so that the traffic flow from each switchboard position will be approximately equal. The number of line lamps allowed per line may not always permit lamps in all the appearances of the line multiple. This, in general, will not become a problem in military switchboards of a type which permit five lamps per line except for switchboards of more than 10 positions. At the Western Electric Company No. 12 switchboard, which is limited to one line lamp per line (two may be used but this limits the lamp brilliancy), the lamps should be distributed so that each position has approximately the same number. Lamps generally should be placed as fully equipped strips of twenty because it is difficult to keep a record of scattered lamps.

j. Line Priority Marking. The traffic on a switchboard may result in periods of overload for which it may be desirable to have distinctive marking on lines that should be given priority. This can be done by use of colored lamp caps on the lines that must have priority service. Another method is to insert color disks made from transparent material such as theatrical gelatin sheets inside the lamp caps, or to slip over the switchboard lamp half of a colored gelatin medicine capsule. Color applied to lamp caps inside or outside, or to switchboard lamps is not entirely successful because it is difficult to obtain uniform colors on a group of lamps by this method. Colored designation cards can be used on lines equipped with designation strips.

k. Operating Room Quieting. The room noise usually prevailing in an operating room, and especially the noise near the operators' heads, should be kept as low as practicable, in order to minimize transmission impairment, and provide more pleasing working conditions, both of which will tend to improve service. Noise in operating rooms results from voice sounds and from many local sources such as footsteps, bells and buzzers, clocks, cord plugs and weights, dials, fans, keys, and miscellaneous room equipment such as typewriters, chairs, doors, windows, etc. In some cases outside noise, such as street noise, is an important factor. The noise may not rise to an objectionable value in centrals of a few positions of switchboard but may be high enough to require treatment in large centrals. Remedial measures include: removal of typewriters and adding machines to other quarters; local maintenance treatment of squeaky chairs and door hinges, curtains that flap in a draft, noisy fans, and windows that rattle; fastening of linoleum to the cord well panels to deaden the sound of cord weights striking them; and elimination of unnecessary travel in or through the operating room.

1108. TELEPHONE SWITCHBOARD OPERATION.

a. General. Military switchboards are of various types as described in chapter 2 and in TM 11–487. Operating practices differ for the different types. For example, strictly local switchboards use practices that differ in many respects from the practices required at strictly long distance switchboards. It probably will be necessary to use variations to meet local conditions in some cases.

b. Local Switchboard Operation. Cord pairs should be used in rotation until all have been used. It is usual to work from left to right. Disconnected cords will not be used until reached again in rotation. Cords should be picked up by the plug shell. When idle, an operator should hold the plug of the next cord to be used, with listening key open, waiting for a call except, of course, during light traffic hours. Signals within reach, in front and to right and left should be answered in order of appearance. If a signal exists in a position that the operator cannot answer promptly, an adjacent idle operator should be signaled by hand to take the call. Correct action on disconnect signals is important. *One-lamp disconnects* usually indicate need for challenge before disconnecting, but *two-lamp disconnects* do not. It is desirable to monitor and challenge on magneto-line to magneto-line calls before disconnecting because many magneto line users fail to give the operator a ringoff signal.

c. Long Distance Switchboard Operation. Cord rotation from left to right is suggested as at local boards. A rear cord should be held in the hand while the operator is idle, with the listening key open on this cord pair. Answers on calls from a local telephone should be by the words *long distance*. Incoming calls from distant places should be answered by giving the name of the central. Service users should be informed of the progress of calls at reasonable intervals. Monitoring is required frequently to assist in call completion. The called number need be repeated by the operator only if in doubt. On calls delayed because of *no circuit* or *called party busy* the operator should ask for the user's name and telephone number and the calling party should be told that the call will be recorded and completed later. The details should be entered on a ticket described in subparagraph e below, which entry should include filing time. These tickets should be passed along the board to one operator whose duty is to handle them, if the operating practices requires this method of completing. Delayed calls should be completed in the order of filing unless they are urgent (FM 24–20). The originating long distance office is responsible for all calls. At an intermediate point where through calls are switched, no ticket is required on through calls that are not delayed because of trunks busy beyond the switching point. However, on through calls that are delayed at an intermediate point because of no circuit beyond, a call order ticket also described in subparagraph g below, should be made at the intermediate point. No information calls should be handled by a long distance operator, but should be referred either to a supervisor at centrals large enough to have them, to a special position, or to a special desk in the switchboard room. At small centrals they can be referred to the chief operator.

d. Combined Local and Long Distance Switchboard Operation. Operation of combined local and long distance switchboards requires use of the practices of both local and long distance switchboards. The local switchboard practices are used for handling local calls and the long distance switchboard practices are used for handling long distance calls. These are the practices that are given in subparagraphs b and c above.

e. Delayed Call Tickets. Tickets are required to be written by the operator at long distance and at combined local and long distance switchboards, only on calls delayed because of *no circuit* or *called party busy*. Figure 11-5 shows a suggested form of delayed call ticket. An operator at the long distance switchboard should initiate the subsequent attempts to complete the call. The service user should initiate subsequent attempts to complete local calls or calls to nearby centrals which do not require use of long distance trunks, when the first attempt finds *no circuit* or *called party busy*.

f. Delayed Call Recording Desk. One or more local telephone lines may be installed on a nearby desk to which long distance operators can connect calls for delayed call recording during periods of peak traffic or at other times, such as circuit interruptions, when it is desirable to relieve operators of as much work as practicable. The person assigned to answer these telephones can also inform telephone users of posted delays, maintain delayed call tickets in proper order, and distribute tickets to switchboard operators for completion. This work should revert to the regular operator when the load falls off.

g. Call Order Ticket. Call order tickets may be used for certain types of delayed calls. For example, when a call which is switched through an intermediate central encounters a delay in reaching a circuit to the distant point, it may be desirable for the intermediate operator, particularly on congested groups, to write a call order ticket and call back the originating operator when a circuit becomes available. Figure 11-5 shows a suggested form of call order ticket. Such calls should be completed in the order of filing time.

h. Urgent Calls. The operator may be called upon to handle calls which have been given the precedence of *urgent* by proper authority. Such calls may originate on loops at the operator's switchboard or may come in on trunks. If the called party is busy, or if all trunks to the called switchboard are busy, an existing call may be interrupted.

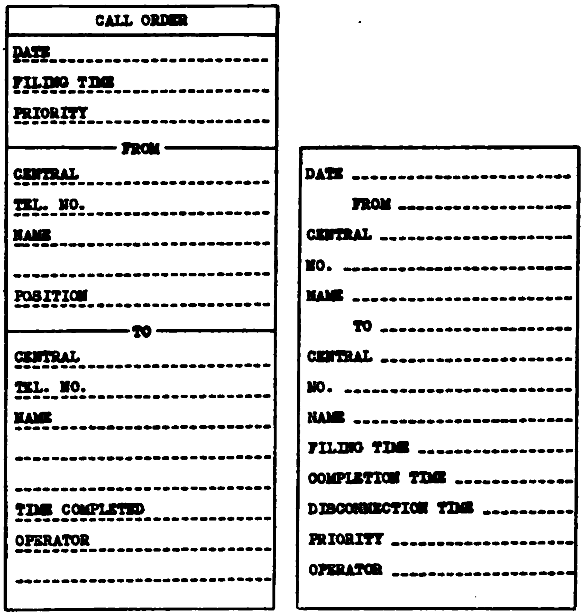
i. Order of Attention to Signals. All signals should be answered in the order of their appearance. Occasionally signals of different kinds will appear at the same time, and it will be necessary for the operator to decide which signal should be answered first. In such cases, the following order of precedence should govern: first, flashing supervisory signal, because the operator of the position is the only operator who can answer it; second, incoming trunk signal in order to obtain maximum trunk efficiency; third, line signal; and fourth, one-lamp disconnect signal, because one party may desire additional service. Two-lamp disconnect signals require no answer and the cords should be pulled down as promptly as possible as an overlap operation so that lines and equipment will be available for use on other calls. An exception to these rules is in the case of priority lines on which the signals should, of course, receive precedence over the other signals.

j. Phraseology. The phrases and practices contained in FM 24–20 and FM 24–75 are to be used where applicable. To avoid confusion both to the users and to operators, it is necessary that common practices be used throughout a communication system. Military courtesy applies in the operation of all centrals.

k. Special Services.

(*1*) *Information Calls.* Information calls for telephone numbers not listed in directories can be handled by either of two practical methods at local switchboards. If the volume of calls is small, a card with listings in alphabetical order can be mounted between each two operators on the face of the switchboard or key-shelf. For larger volumes, two interposition trunks should be provided to a table which should always be occupied, and where the record should be kept. The two trunks should be multipled before all operators. This table can also handle trouble reports. It is not practicable to attempt information service at a separate long distance switchboard because of the difficulty of maintaining directories of the many centrals involved. It is better to put the calls through to the called central where the desired information can be obtained.

(*2*) *Trouble Reports.* Trouble reports



TL 54879

Figure 11-5. Call order and delayed call tickets.

can be taken by the operator or passed to the chief operator at small centrals, and also at large centrals in the hours of light traffic when the volume of trouble is not great. The trouble reports can be recorded on trouble tickets shown in figure 11-6. These can be delivered to the wire chief who can maintain the line record cards of figure 11-46 on which he can record the trouble report, the nature of the trouble found, and the time it is cleared. The trouble tickets do not need to be retained. When the volume is too great for this method, the calls can be passed over interposition trunks which terminate at a table which is occupied by a repair service clerk as discussed in paragraph 1162.

(*3*) *Service Complaints.* Service complaints on slow operator answer or action, or on handling of urgent, delayed, or information calls should be given to the chief operator, regardless of number of switchboard positions.

(*4*) *Special Operation for Priority Lines.* One position of a switchboard can be used for giving special service to high priority users. This is suggested as an alternative to providing a small switchboard to serve the high priority lines.

(*5*) *Changed Numbers.* Where necessary a list of changed numbers may be posted on the face of the switchboard between each two operators.

WAR DEPT.
S. C. U. S. Army
S. C. Form 41

TROUBLE REPORT

(For all trouble affecting telephone lines or equipment)

Telephone number 682 Location BLDG 58
Reported by SUB. Date and hour 10-2-42, 0930 M.

Trouble reported (check which)

Bells don't ring	Can't get opr. ✓	Tel. don't answer
Bell rings faintly	Can't hear	Cuts out
Permanent signal	Can't be heard	Noisy

Other trouble

Trouble found LINE LAMP BURNED OUT
Date and hour 10-2-42, 1000 M.
Date and hour cleared 10-2-42 1000 M.
By whom J.H.D.
SOS, Wire Chief.
TL-7468

War Department, Signal Corps Form 41

L-11 TROUBLE TICKET

Date 1943 3 MARCH	Office Freedom	No. 1
Pos.	Cord	Trunk #1 Long Distance
Misc.		
Trouble Appearance: Can't Meet		
Rep't by AM	Time 0800 A	Out of Svc Yes ✓ No
Trouble Found: Loose connection tip side distributing frame - Frame		

CLEARED		PLACED IN SVC		
By	Time	By	Time	Date
HO	0810 A	AM	0812 A	3/3/43

TL 54933

Locally printed form

Figure 11-6. Trouble tickets.

1109. TELEPHONE DIRECTORIES.

a. General. Telephone directories will be required immediately when switchboards are put in service and will require revision from time to time. The frequency for making printed revisions will be controlled by the rate at which additions and changes are made in telephone lines. A master list should be maintained at each switchboard for connected stations. The service orders must provide for a copy to be routed to a clerk in the central who will be responsible for maintenance of a master record. The master record can be used by the operator who is assigned to answer calls routed to *Information*.

b. Form and Content of Directory. Reference is made to this subject in FM 24–20, which covers the practice for the smaller size directories. For the larger switchboards the size and nature can be varied as required. The cover may list emergency numbers such as: fire station, military police, and ambulance; also instructions as to priority of calls. A page inside the front cover should give brief instructions to users of the service. The items covered should include: how to make long distance calls; restrictions on long distance calls, and limiting conversations; how to make complaints, trouble reports, and information calls; security; and requests for facilities. Office code names may be listed. Local conditions will dictate the set-up used in listing station numbers as, for example, division of the book into sections, one section for each branch of service. Publication may be required once a month or at more frequent intervals. Distribution probably will be required at least to each station using the service. Extra copies may be desirable where more than one person uses the same telephone..

1110. TRAFFIC COUNTS AND OBSERVATIONS.

a. Traffic Counts. Traffic data form the basis for line and equipment engineering and for the provision of operating forces. Therefore, reliable data are important. Counts of local and long distance calls (*peg counts*) are desirable. Attempts should be counted rather than completed calls. Meters which operate by push button and give visual count are preferable for taking counts but, if not available, stroke records can be made. This information may not be required for the small switchboards of one or two positions but will be required for large centrals. The counts can be made after operations in a new system have reached a settled stage, taking counts for example, for 2 weekdays at weekly or longer intervals. Peg counts may not be practicable in a rapidly changing situation. If they can be taken they will be useful, provided personnel with enough experience to interpret the results are available.

b. Continuous Record. A continuous narrative record of all pertinent information as to what occurs on a single long distance line for a period of perhaps one hour in a busy period will provide information which will be helpful in improving effective circuit usage. Such information may be interpreted usefully by an engineer familiar with long line operating.

c. Service Observing. Service observations on 30 local telephone loops can be made by using the multiline observing cabinet described in TM 11–487. Trained observers are required to obtain satisfactory results. In order to draw any conclusions as to the quality of service being given at a central, it is necessary to obtain an adequate sample of several hundred *observations* or records of individual calls. Personnel experienced in the interpretation of the collected data is also required. A simpler method of service analysis is by visual observation of the work at the switchboard, and by monitoring with a head receiver connected in parallel with the operator's telephone receiver at the switchboard position. The monitoring will check use of correct phrases, pronunciation of names and digits, and courtesy. Visual observations permit correction of poor work as to speed, order of attention to signals, ticket handling, and attention to supervisory signals. These observations will be found useful at the larger centrals for improving service.

d. Circuit Holding Time. Circuit holding time is the expression used to indicate the length of time connections are held in use. The circuit holding time of a long distance call is the time interval from plugging in on the trunk until removal of the plug at the end of the call. Holding time data are used in determining the number of trunks in a trunk group between centrals. This information can be obtained from four sources. One source is from service observations and another is from the narrative record. A third method is to make tickets which show elapsed time on all long distance calls for short periods, for example, in the busiest hour of two weekdays each week. This source is particularly useful in newly established centrals. A fourth method is by taking *plug counts* as described in subparagraph e below. After service has become well established, the intervals between the observation periods can be as required, probably every 2 or 3 months.

e. Plug Counts.

(*1*) Plug counts may be taken to show the average number of circuits in use in the busiest hour. From this information and the number of calls handled, the average holding time per call can be determined.

(*2*) A *plug count* consists of a visual count of the number of cord plugs connected to the trunk jacks, a visual count of the trunk busy lamps, or a count made of busy trunks by an electrical test of the trunk jacks. The count may be taken at 2- or 3-minute intervals for several representative busiest hours. When plugs are counted it is necessary to count the sum of the number in each appearance of the jacks. The busy lamp or busy test counts may be made at one appearance of the jacks.

(*3*) The average *circuit holding time* per call, in minutes, is determined by multiplying the average plug count by 60 (min per hour) and dividing by the number of calls. For example, assume that the count is taken at 2-minute intervals (30 times per hour) and the total number of plugs counted in the busiest hour for a given group is 123, then the average number of circuits in use during the busiest hour is $\frac{123}{30} = 4.1$. Assuming that a traffic count (subpar. a above) made during the same hour shows that 49 calls are handled by the group, the average circuit holding time per call will be: $\frac{4.1 \times 60}{49} = 5$ minutes. This example, for simplicity, derives the average holding time per call from one hour's observation. Observations over the busiest hours of several days are necessary to arrive at a reliable average for engineering purposes.

Section IV. TELEPHONE TRAFFIC ENGINEERING

1111. GENERAL.

Telephone traffic engineering for a communication system is required for the following purposes: to decide the type, size, and layout of new switchboard installations; to determine the number of trunks in each trunk group between switchboards; to determine the need for equipment and trunk circuit additions, based on growth, peg counts, and service observations; to see that efficient use is made of existing facilities by study of operations and service observing; and to provide for desirable rearrangements. Traffic engineering for a new communication system should be made from the best possible estimates as to the location and extent of the new layout, and should reflect experience as far as practicable. The size and type of switchboard can be decided from the information given in this section, in chapter 2, and from the switchboard descriptions in TM 11–487.

1112. TRAFFIC EXPERIENCE DATA.

a. Experience in various theaters of operations has provided some useful data for engineering both tactical and fixed plant telephone centrals.

b. The following data apply to combined local and long distance centrals.

(*1*) Military telephones originate an average of two to three calls per telephone in the busiest hour. This compares with commercial PBX calling rates in which three calls in the busiest hour is a high average rate.

(*2*) A typical distribution of calls at a combined local and long distance central, by types of calls, is:

Item	*Type of call*	*Percent of total traffic*
1.	Local	30
2.	Outward trunk	25
3.	Inward trunk	25
4.	Through (switched) trunk	20
	Total traffic	100
	Total originating traffic (item 1+item 2)	55
	Total outward and inward traffic (item 2+item 3)	50
	Total trunk traffic (item 2+item 3+item 4)	70

(*3*) Assuming three originating calls per telephone in the busiest hour, the total traffic (originating, incoming, and through) at a combined local and long distance central is: $\frac{100}{55} \times 3 = 5.5$ calls per telephone in the busiest hour.

c. The following data apply to separate long distance centrals.

(*1*) Experience indicates that the number of long distance calls (outward, inward, and through) handled at a long distance switchboard in the busiest hour amounts to 0.3 to 0.4 times the number of telephones served on outward long distance calls. This number includes the telephones in nearby local centrals whose long distance outlet is through this switchboard but does not include telephones whose outlet is through other switchboards. To achieve any appreciable reduction in the factors given above, it will be necessary to restrict more than 50 percent of the telephones, because in any event the unrestricted telephones generally are the chief long distance service users.

(*2*) A typical distribution of calls at a separate long distance central, by types of calls, is:

Item	*Type of call*	*Percent of total traffic*
1.	Outward	35
2.	Inward	35
3.	Through (switched)	30
	Total traffic	100

d. The following data apply to separate local centrals.

(*1*) A typical distribution of calls at a separate local central, by types of calls, is:

Item	*Type of call*	*Percent of total traffic*
1.	Local	40
2.	Outward trunk	30
3.	Inward trunk	30
	Total traffic	100
	Total originating traffic (item 1+item 2)	70
	Total trunk traffic (item 2+item 3)	60

(2) Assuming three originating calls per telephone in the busiest hour, the total traffic (originating and incoming) at a separate local central is:

$\frac{100}{70} \times 3 = 4.3$ calls per telephone in the busiest hour.

1113. CHOICE OF SWITCHBOARDS.

a. Available Switchboards. The Signal Corps tactical and fixed plant switchboards are described in TM 11–487. Certain of the fundamental features are discussed in chapter 2 and in subparagraphs below.

b. Factors in Selection. Choice of the type of switchboard for a certain location depends upon the questions which follow:

(1) How many local telephones will be connected to it if it is a local switchboard, or served by it if it is a long distance switchboard (par. 1114)?

(2) What will the total traffic be, in number of calls in the busiest hour (par. 1114a)?

(3) Is magneto or common battery service required (ch. 2 and subpar. g below)?

(4) If common battery, will a nonmultiple or multiple switchboard be required (ch. 2)?

(5) Is speed of installation important (subpar. d below)?

(6) Will it do tandem switching for surrounding centrals (ch. 2 and subpar. f below)?

(7) Is it to operate as a long distance as well as a local switchboard (ch. 2 and par. 1114b)?

(8) Will the selected switchboard provide all of the necessary features (subpar. c below)?

(9) Is there suitable space available for accomodating the central (sec. X)?

c. Available Features. The switchboard data in TM 11–487 indicate that not all the desirable features may be available in any one switchboard and that a choice will depend on the more important features available in the switchboard selected. Considerations involved are discussed in the following subparagraphs.

d. Commercial Versus Tactical Centrals. Commercial type switchboards for the larger headquarters centrals have proven satisfactory. These headquarters remain at one location long enough and are large enough to justify commercial installations. Also single position commercial type switchboards can be used for the smaller headquarters centrals. These can be connected to the commercial switchboards at the larger headquarters where switching can be performed for them to pass calls to other centrals in the system. However, delivery and installation intervals for commercial type multiple switchboards, which may be 2 to 6 months or more, may necessitate use of tactical switchboards for headquarters in the initial phases of an operation. Tactical switchboards are primarily designed for use where speed of installation and mobility are required.

e. Large Versus Small Centrals. Other factors being equal, a few large centrals are preferable to several small ones. The alternatives are illustrated schematically in figure 11-7.

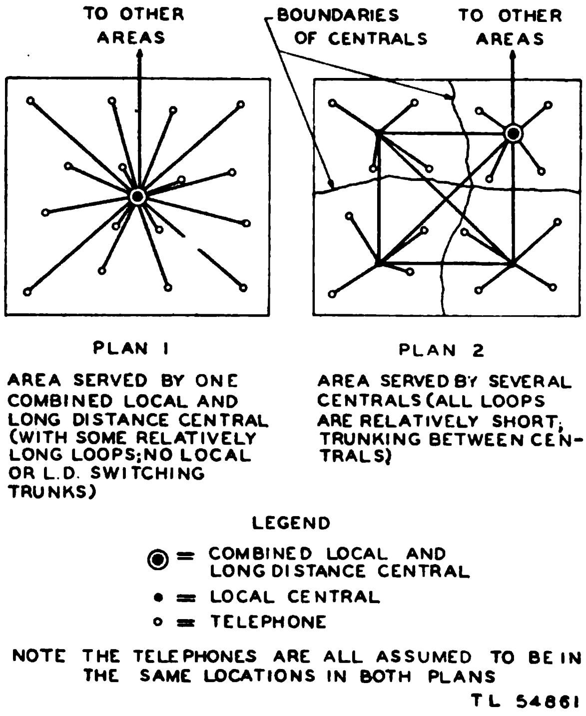


Figure 11-7. One large versus several small centrals.

With large centrals the service is better and more uniform because the operators can be more effectively trained and supervised; there is less switching of calls, with reduced chances of faulty routing and cut-offs; the trunk plant is more economical (subpar. f below); the operating and maintenance personnel are reduced because they work in larger and hence more efficient teams; and the reduction in the number of power plants, particularly engine-driven generators, simplifies maintenance and supply. On the other hand, with larger centrals the loops to outlying telephones may be longer. The loops must not exceed the operating limits of the switchboard, and the transmission loss in the loops should not exceed what is permitted under the transmission plan (ch. 2). In specific situations it is frequently desirable to use two or more smaller centrals rather than one large one for practical reasons. For example, by establishing separate centrals at air fields, hospitals, or dock areas some distance from the community center, important economies in material can be realized by not bringing the resultant long loops into the main switchboard, even though the transmission and operating limits would not be exceeded. Dispersal is another advantage of several rather than one switchboard.

f. Tandem Switching. A central at which trunks from local centrals are interconnected is known as a *tandem switching point* (ch. 2). Most long distance centrals are, in effect, tandem switching points. As compared to direct trunking of all calls, tandem switching results in a smaller number of and more efficient trunk groups. There are, however, certain hazards in placing complete reliance on tandem switching, since the loss of the trunk group to a tandem central results in complete loss of trunk service. A compromise, with tandem trunks and some direct trunks for alternate routes, gives both safety and economy of plant. In general, tandem trunks will be of the 2-way ringdown type. Figure 11-8 illustrates the difference in the number of trunk groups required with and without tandem switching.

g. Common Battery Versus Magneto Service. A better grade of service can be given with common battery than with magneto centrals. Magneto lines have certain advantages however, because they will operate over longer loops and under bad line leakage conditions, power plants are not required, and the centrals can be installed quickly. The advantages of common battery lines are that they require less effort by the user; they provide automatic signals to the operators on disconnection and more positive recall signals to operators; and, if telephones such as the TP-6 are used, battery maintenance at the telephones is avoided. These factors indicate that common battery telephones and switchboards are best suited for stable situations and heavy concentrations of telephones; magneto telephones and switchboards become more desirable as the front lines are approached and in the less stable areas where the number of telephones is small. Certain of the tactical and fixed plant switchboards are arranged to work with both common battery and magneto telephones. This gives the advantage of common battery operation on most loops, with provision for serving

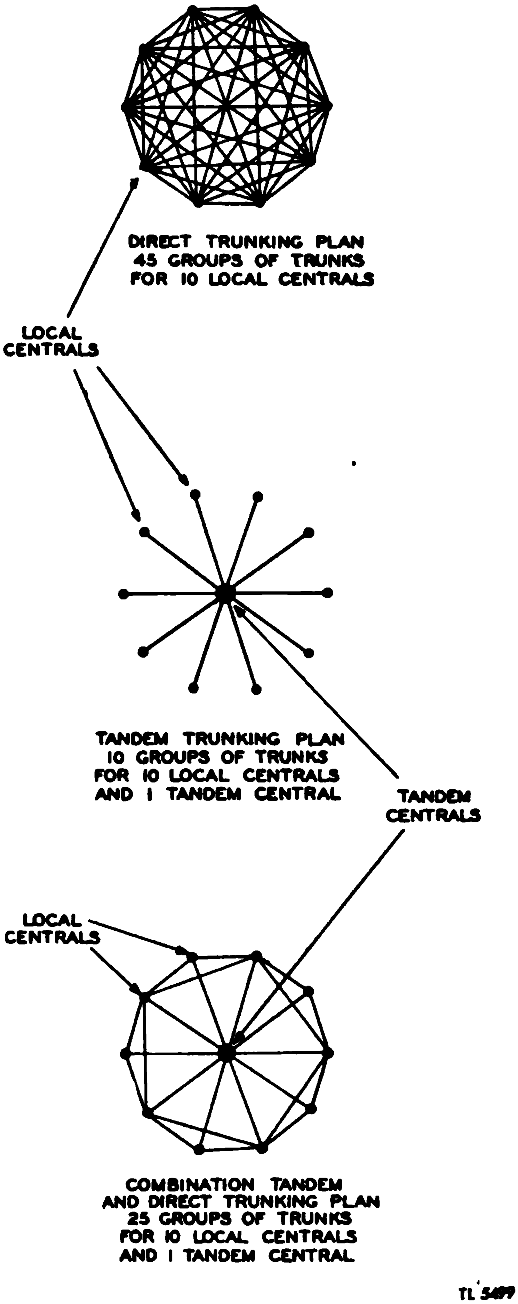


Figure 11-8. Advantages of tandem interoffice trunking plans.

the more remote telephones on a magneto basis.

h. Combined Versus Separate Local and Long Distance Centrals. A separate long distance central, that is, one which has access to long distance lines and direct access to only a few loops or no loops, usually can be justified only when the volume of long distance calls is sufficient to utilize a relatively large and efficient group of long distance operators. Such situations are comparatively rare in the Army, occurring only at large headquarters, major port or supply installations, or other similar concentrations. In most cases, long distance calls can be handled more effectively at a combined local and long distance central having access to both local loops and long distance lines. This will usually be the largest central in the area if there are more than one. All operators handle both types of calls, thus giving maximum team efficiency and avoiding one switching operation on the calls that originate from or terminate on the loops appearing in that board.

i. Switchboard Cord Circuits. The type of cord circuit provided in a switchboard is an important factor in the selection of a switchboard for a particular kind of service.

(*1*) In magneto switchboards, nonring-through cord circuits (ch. 2) with separate supervisory signals on front and back cords are preferable to the ring-through type because a ring-off or a rering signal from one line does not ring the other line.

(*2*) In common battery switchboards, universal cord circuits (ch. 2) are preferable. These permit nonring-through connection between magneto trunks or lines and common battery lines. Experience indicates the desirability of rering or recall supervisory signals which *lock-in,* that is, continue to indicate after they are actuated. If they are the *non-lock-in* type they light only momentarily while the actuating ringing current is flowing. Lock-in is particularly desirable where switching of calls from one 2-way ringdown trunk to another is desired. If a common battery switchboard is equipped with local common battery cord circuits (ch. 2), it is desirable to have 2-way ringdown trunks of the type that give rering signals on the cord circuit supervisory lamps, rather than on drops or line lamps. If the 2-way ringdown trunks do not give the rering feature, the result is one-lamp supervision on a connection between a 2-way ringdown trunk and a loop. Furthermore it is not desirable to connect one of these ringdown trunks to another because the lack of supervisory signals would make it necessary for the operator to monitor. Ringing on both front and back cords is preferable to having it only on the front cord because it is frequently desirable to recall the party on the answering cord without changing cords.

(*3*) A commercial PBX type cord circuit has several features which are not generally advantageous in Signal Corps switchboards, although in many cases they can be tolerated. Among these are the cut-through feature which may require special consideration with common battery trunks (ch. 2); the night-and-through-dial keys which are used only with common battery trunks (ch. 2); the relatively small battery supply currents on connections between two loops, or between loops and ringdown trunks; and the relatively small conductor resistances permissible in the loops particularly from the nonmultiple type PBX's which were designed for operation on less than 24 volts. The battery supply with a cut-through cord circuit comes over the trunk from the distant central. The loop limit of the distant central in this case includes the sum of the local loop and the trunk loop resistances, which permits only rather short loops for the local telephones. Figure 11-9 indicates this situation, showing the battery supply to a local loop when connected to a common battery trunk to a distant common battery central. The Signal Corps usually provides 24-volt battery at each common battery PBX-type switchboard. The Western Electric Company No. 551B (X–66070) PBX switchboard permits longer local loops by using a special trunk circuit in the PBX, which supplies talking battery to the local telephone loop from the PBX switchboard instead of from the distant central. This is also illustrated in figure 11-9.

(*4*) A dial associated with each operator's circuit is preferable to having a separate dial cord because less operator effort is required to complete a call, and the dial cord arrangement necessitates a dial jack for each dial-office trunk. However, where the number of dial calls is a small part of the total traffic, the additional effort is not controlling.

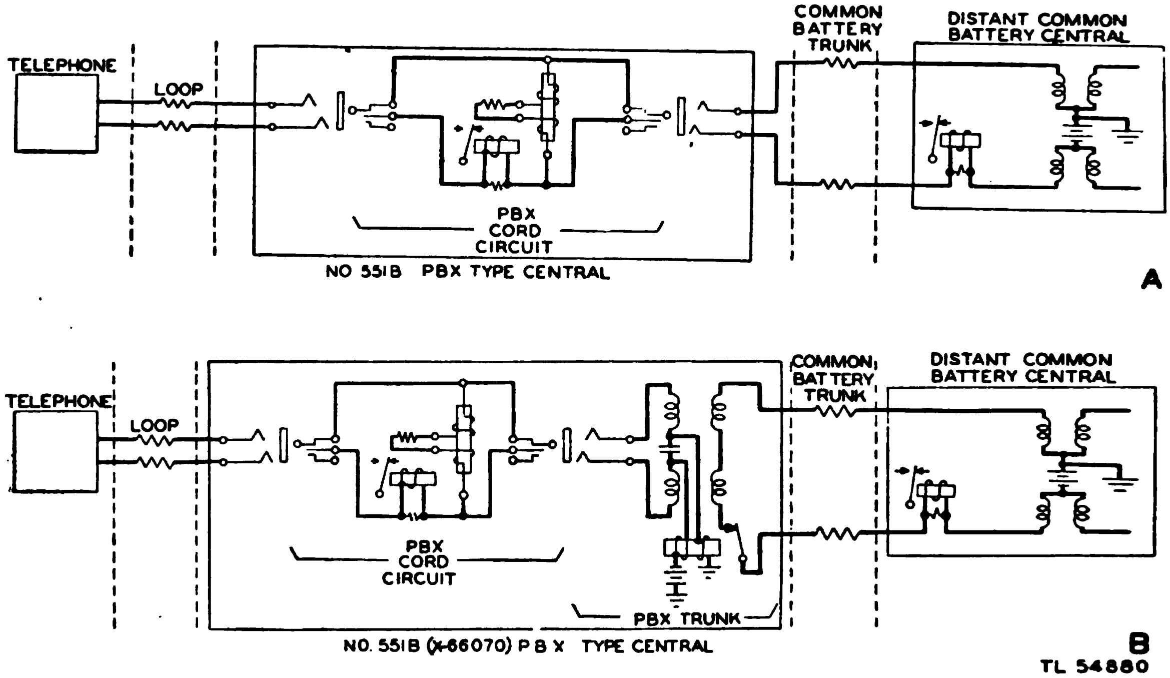


Figure 11-9. Battery supply circuit to a local loop when connected to a common battery trunk.

1114. TELEPHONE SWITCHBOARD POSITION REQUIREMENTS.

a. General.

(*1*) The number of positions required to serve a certain number of local telephones is referred to as the *position requirements*.

(*2*) The position requirements are determined by the number of calls handled in the busiest hour and by the type of switchboard provided. The traffic in the busiest hour will depend on the number of local telephones and the average number of calls per telephone. The number of telephones must not be confused with the number of lines (subpar. f below). The fundamental plans for a communication system laid out by use of the information given in this and other chapters will determine the type of switchboards to be used at specific locations and the type of trunk plant used. Some switchboards will be local, some will be long distance, and others will be combined local and long distance. When the number of calls to be handled in the busiest hour has been determined, the number of positions can be determined as stated in subparagraphs b to e below.

(*3*) In engineering a new telephone switchboard installation, it may be necessary to estimate the busiest hour traffic from arbitrary assumptions. If the assumptions for a new installation prove to be inadequate as to the busiest-hour traffic, service restrictions can be imposed to reduce the traffic until the facilities can be increased. Additions can be engineered from known data and peg counts.

b. Combined Local and Long Distance Switchboard. Figure 11-10 shows the position requirements for this type of switchboard based on the estimated traffic which is to be handled in the busiest hour. It also shows the number of local telephones which can be served if the average originating calling rate per telephone is two or three calls in the busiest hour. More telephones can be served if the average calling rate is less and, conversely, fewer can be served if the calling rate is higher. The traffic in the busiest hour depends on the number of local telephones connected to the switchboard and the average number of calls per telephone in the busiest hour, including local (loop-to-loop), outward trunk, inward trunk, and through trunk (switched) calls. Long distance calls originated by telephones connected to this type switchboard are completed by the operators at the switchboard.

c. Separate Long Distance Switchboard. Figure 11-11 shows the position requirements for this type of switchboard based on the esti-

Total busiest-hour traffic (originating, inward, and through calls)	Positions required	Number of telephones which can be served by combined local and long distance switchboards	
		At two orig. calls per telephone in the busiest hour	At three orig calls per telephone in the busiest hour
1-100	1	1-28	1-18
100-265	2	28-73	18-49
265-440	3	73-121	49-81
440-600	4	121-165	81-110
600-765	5	165-210	110-140
765-920	6	210-253	140-168
920-1,070	7	253-294	168-196
1,070-1,225	8	294-337	196-224
1,225-1,375	9	337-378	224-252
1,375-1,530	10	378-420	252-280
1,530-1,685	11	420-463	280-309
1,685-1,835	12	463-504	309-336
1,835-1,990	13	504-547	336-364
1,990-2,140	14	547-588	364-392
2,140-2,295	15	588-630	392-420
2,295-2,450	16	630-673	420-449
2,450-2,600	17	673-714	449-476
2,600-2,755	18	714-757	476-505
2,755-2,905	19	757-798	505-532
2,905-3,060	20	798-841	532-560

This table is based on the following assumptions:

1. The number of telephones served is 1.5 times the number of loops connected to the switchboard.
2. Each operator handles all types of calls.
3. The number of calls per operator in the busiest hour depends on the number in the team on duty. The number of calls per operator per hour is:
   - 1 operator 100 calls per operator hour
   - 2 operators 133 calls per operator hour
   - 3 operators 147 calls per operator hour
   - 4 operators 150 calls per operator hour
   - 5 or more operators 153 calls per operator hour
4. The distribution of traffic is as given in paragraph 1112 b but the table permits variations as indicated below:
   - Local calls..................40% to 20%
   - Outward trunk calls..........20% to 30%
   - Inward and through (switched) calls............40% to 50%
   - Total..................100% 100%
5. The switchboard face layout permits every operator to reach every local line and trunk. Additional positions (end positions) may be required to assure this.
6. Tickets are to be written on delayed long distance calls only.

Figure 11-10. Position requirements, combined local and long distance common battery switchboards.

mated traffic which is to be handled in the busiest hour. It also shows the number of local telephones which can be served if the average total long distance calls in the busiest hour (outward, inward, and through) per telephone served is 0.3 or 0.4 calls as indicated in the figure. More telephones can be served if the average calling rate is less and fewer can be served if the calling rate is higher. The traffic in the busiest hour depends upon the number of telephones in nearby local centrals whose long distance outlet is through this switchboard but the number does not include telephones whose outlet is through other switchboards.

d. Separate Local Common Battery Switchboard. Figure 11-12 shows the position requirements for this type of switchboard based on the estimated traffic which is to be handled in the busiest hour. It also shows the number of local telephones which can be served and which will generate this traffic if the average originating call rate is two or three calls per telephone in the busiest hour. More telephones can be served if the average calling rate is less and conversely, fewer can be served if the calling rate is higher. The traffic consists of local (loop-to-loop), outward trunk, and inward trunk calls.

Total busiest-hour traffic (outward, inward, and through calls)	Positions required	Number of telephones which can be served by long distance switchboards: At 0.3 total long distance calls (inward, outward, and through) in the busiest hour per telephone served	At 0.4 total long distance calls (outward, inward, and through) in the busiest hour per telephone served	Total busiest-hour traffic (outward, inward, and through calls)	Positions required	Number of telephones which can be served by long distance switchboards: At 0.3 total long distance calls (inward, outward, and through) in the busiest hour per telephone served	At 0.4 total long distance calls (outward, inward, and through) in the busiest hour per telephone served
1-60	1	1-200	1-150	920-1,010	11	3,067-3,367	2,300-2,525
60-160	2	200-534	150-400	1,010-1,100	12	3,367-3,667	2,525-2,750
160-260	3	534-867	400-650	1,100-1,200	13	3,667-4,000	2,750-3,000
260-360	4	867-1,200	650-900	1,200-1,290	14	4,000-4,300	3,000-3,225
360-460	5	1,200-1,533	900-1,150	1,290-1,380	15	4,300-4,600	3,225-3,450
460-550	6	1,533-1,833	1,150-1,375	1,380-1,470	16	4,600-4,900	3,450-3,675
550-640	7	1,833-2,133	1,375-1,600	1,470-1,560	17	4,900-5,200	3,675-3,900
640-740	8	2,133-2,467	1,600-1,850	1,560-1,650	18	5,200-5,500	3,900-4,125
740-830	9	2,467-2,767	1,850-2,075	1,650-1,750	19	5,500-5,833	4,125-4,375
830-920	10	2,767-3,067	2,075-2,300	1,750-1,840	20	5,833-6,133	4,375-4,600

In addition to the basic assumptions in paragraph 1112 c, this table assumes:

1. The traffic is of both long and short haul type.
2. The number of calls per operator in the busiest hour depends on the number in the team on duty. The number of calls per operator per hour is:
   1 operator 60 calls per operator hour
   2 operators 80 calls per operator hour
   3 operators 88 calls per operator hour
   4 operators 90 calls per operator hour
   5 or more operators 92 calls per operator hour
3. The switchboard face layout permits every operator to reach every line and trunk. Additional positions (end positions) may be required to assure this.
4. Tickets to be written on delayed calls only.

Figure 11-11. Position requirements, separate long distance switchboards.

e. Magneto Switchboard. Figure 11-13 shows the approximate number of local telephones and trunks that can be served by 1- and 2-position magneto switchboards, for two different originating busiest-hour call rates. It gives data for both local and combined local and long distance switchboards. It should be noted that even though a position can be equipped for 100 lines, satisfactory service can seldom be given to that number of lines by one operator. The traffic is assumed to consist of local (loop-to-loop), outward trunk, and inward trunk calls only.

f. Ratio of Telephones to Loops. The position requirements of figures 11-10, 11-11, and 11-12 show the number of positions required based on the number of telephones served and not on the number of telephone loops that are connected to the switchboards. More than one telephone on a loop is common and therefore in most centrals there are more local telephones served than there are loops connected. The switchboards listed in TM 11–487 do not, in general, provide for selective-ringing party-line service, and the extra telephones on a loop are extension telephones in which the ringers (bells) may or may not be connected, as desired. On magneto loops it is common to have more than one telephone because the loops are long and it becomes more desirable to add to the number of telephones on a loop rather than build additional loops. The ringing is done by code, using one short ring to signal the central; and two, three, and four short rings, and combinations of long and short rings if more are necessary, to call individual stations. The probable resulting ratio in fixed plant may be 1.5 telephones per common battery loop and two telephones per magneto loop.

Total busiest-hour traffic (originating and inward calls)	Positions required	Number of telephones which can be served by local common battery switchboards: At two orig. calls per telephone in the busiest hour	At three orig. calls per telephone in the busiest hour
1-150	1	1-53	1-35
150-400	2	53-140	35-93
400-650	3	140-228	93-152
650-900	4	228-315	152-210
900-1,150	5	315-402	210-268
1,150-1,380	6	402-483	268-322
1,380-1,610	7	483-563	322-375
1,610-1,840	8	563-644	375-429
1,840-2,070	9	644-724	429-483
2,070-2,300	10	724-804	483-536
2,300-2,530	11	804-885	536-590
2,530-2,760	12	885-965	590-643
2,760-2,990	13	965-1,046	643-697
2,990-3,220	14	1,046-1,126	697-751
3,220-3,450	15	1,126-1,206	751-804
3,450-3,680	16	1,206-1,287	804-858
3,680-3,910	17	1,287-1,366	858-911
3,910-4,140	18	1,366-1,448	911-965
4,140-4,370	19	1,448-1,528	965-1,019
4,370-4,600	20	1,528-1,608	1,019-1,072

This table is based on the following assumptions:

1. The number of telephones served is 1.5 times the number of loops connected to the central.
2. The switchboard handles local and incoming calls. Outward long distance calls are passed to a long distance board for handling.
3. The number of calls per operator in the busiest hour depends on the number in the team on duty. The number of calls per operator per hour is:
   - 1 operator 150 calls per operator hour
   - 2 operators 200 calls per operator hour
   - 3 operators 220 calls per operator hour
   - 4 operators 225 calls per operator hour
   - 5 or more operators 230 calls per operator hour
4. Distribution of traffic (par. 1112 d)
   - Local calls........................ 40%
   - Outward trunk calls.............. 30%
   - Inward calls...................... 30%
   - Total........................ 100%
5. The switchboard face layout permits every operator to reach every local line and trunk. Additional positions (end positions) may be required to assure this.
6. No tickets are to be written.

Figure 11-12. Position requirements, separate local common battery switchboards.

Calling rate, combined local and long distance switchboard	Telephones per position: 1 pos.	2 pos.	Trunks per position: 1 pos.	2 pos.
Two originating calls....	20-25	30	6-8	6-8
Three originating calls...	15	20	6-8	6-8

Calling rate, local switchboard	Telephones per position: 1 pos.	2 pos.	Trunks per position: 1 pos.	2 pos.
Two originating calls....	40-45	55	8-10	8-10
Three originating calls...	25-30	35	8-10	8-10

This table is based on the following assumptions:

1. The number of telephones served is double the number of loops connected to the central.
2. An operator at a magneto switchboard can handle 80 percent as many calls as one at a common battery switchboard.
3. For a 1-position board all trunks are assumed to be in one group, and for a 2-position board in two groups.
4. Distribution of traffic (par. 1114 e):
   - Local calls........................ 40%
   - Outward trunk calls.............. 30%
   - Inward calls...................... 30%
   - Through (switched) calls........... 0
   - Total........................ 100%
5. Five minute holding time for trunked calls.

Figure 11-13. Telephone and trunk capacity, 1- and 2-position magneto switchboards.

1115. TELEPHONE TRUNK CIRCUIT REQUIREMENTS.

a General. The number of trunks required in a group between two switchboards to handle a certain number of calls is termed the *trunk requirements*. In order to determine the size of a trunk group, it is necessary to estimate the total number of calls in the busiest hour and the average holding time per call to be carried by the group. In telephone practice it is recognized to be wasteful of facilities to provide trunks so liberally that no calls will ever be delayed. As the number of calls increases beyond the number for which the group was engineered, the percentage of delayed calls increases. To maintain a desired grade of service the number of trunks in a group must be increased as the number of calls increases. With respect to the percentage of delayed calls, the grade of service it is feasible to render will in some cases depend on the availability of facilities such as conductors, carrier equipment, etc.

b. Total Trunk Equipments. The holding time and the number of calls in the busiest hour to be handled by each trunk group should be estimated. The number of trunks per group can then be selected from figures 11-14 and 11-15. The sum of the numbers of trunks in all the groups gives the minimum number of trunk equipments required. Some allowance should be made, of course, for growth. If the total number of trunk equipments can not be estimated by the above method at the time the total trunk equipments are specified, the following method may be used. Assume the traffic distribution given in paragraph 1112 and determine the number of trunked calls in the busiest hour originated per telephone. The product of this figure and the total number of telephones is the total number of trunked calls. Divide this figure by 7.5 calls to determine the total number of trunk equipments. Theater experience has shown that each trunk will carry on the average about 7.5 calls in the busiest hour for the central as a whole. Trunks usually will be either of two types. One type is 2-way ringdown, for use as long distance trunks and local trunks to magneto switchboards, and the other is the common battery type to other nearby common battery centrals and to manual or dial common battery centrals operated by civil organizations. In the average common battery central, about an equal number of each kind of trunk will be required.

c. Local Trunks. Figure 11-14 may be used in estimating each local trunk group between centrals such as those within a city and its environs. Local trunks usually do not exceed 10 miles in length; however, where lines are available they may extend to distances as great as 25 miles. The grade of service resulting from the use of these tables should under normal conditions be comparable with that from private branch exchanges in the United States. In interpolating, to find the trunk requirements, for example for 13 calls, judgment based on knowledge of the availability of conductors, the accuracy of the estimate, etc., should be the deciding factor in determining whether to use the figure for 12 or for 14 calls.

d. Long Distance Trunks. Figure 11-15 may be used in estimating each long distance trunk group between centrals separated by greater distances than mentioned in the preceding paragraph. The grade of service resulting from the use of this table should under normal conditions be comparable with that on long toll lines in the United States. In interpolating between the values shown, judgment is necessary, as in the case of local trunks.

e. Trunk Efficiency. Trunk groups are used most efficiently if all trunks between two centrals are used as one group to serve all users, rather than with a separate circuit or group reserved for a particular branch of the service. For example, figure 11-15 shows that eight trunks will carry 80 5-minute calls per group in the busiest hour, whereas two groups of four will carry only 35 each, or a total of 70 calls in the busiest hour. There may be situations where a trunk reserved for a particular user should be considered; this is seldom justified, however, unless each trunk will be required to handle at least 40 calls per day, even where it is not particularly difficult to provide the trunk.

f. Divided Route for Protection. A method sometimes used to protect the continuity of service on a trunk group between two centrals is to have two separate pole lines or cables between them using different routes for the two lines. However, the trunks would be used as a common group from the traffic standpoint for efficiency. The divided route idea is illustrated in figure 11-16-A.

g. Alternate Routes. An alternate route for reaching another central is desirable for use in case of trouble on the direct route or for use when the direct route is overloaded and the

Busiest-hour calls per group	*Trunks per local group*		
	3-min holding time	*5-min holding time*	*7-min holding time*
1–3	1	1	1
4	1	1	2
6	2	2	3
8	2	3	4
10	3	4	5
12	3	4	5
14	4	5	5
16	4	5	6
18	4	5	6
20	4	6	7
22	4	6	7
24	5	6	7
26	5	6	8
28	5	7	8
30	5	7	9
35	6	8	9
40	6	8	10
45	7	9	11
50	7	10	12
55	7	10	13
60	8	11	14
65	8	11	14
70	9	12	15
75	9	13	16
80	9	13	17
85	10	14	18
90	10	14	18
95	11	15	19
100	11	15	20
105	11	16	21
110	12	17	21
115	12	17	22
120	12	18	23
125	13	18	24
130	13	19	24
135	13	19	25
140	14	20	26
145	14	20	27
150	14	21	27

Figure 11-14. Local trunk requirements.

alternate route is not. These are usually available to reach most of the network centrals, but if a central has but one outlet, it may become necessary to build a line to provide it with an alternate route. Switching of calls at an intermediate point is required in the use of alternate routes. The alternate route arrangement is illustrated in figure 11-16-B.

h. Switchboard Face Equipment Layout. The trunk multiple should be located above the piling rail and below the local line multiple. The number of panels per trunk multiple and per local line multiple is determined by the type of board to be provided. When end positions are required, some of the trunk and local line multiples are extended through part of these positions in order to place all jacks within the reach of the first or last operator position. The common battery trunks to civil centrals or other nearby military centrals should be located in the top part of the trunk multiple space and the long distance ringdown trunks below these. In

Busiest-hour calls per group	*Trunks per long distance group*		
	3-min holding time	*5-min holding time*	*7-min holding time*
2	1	1	1
4	1	1	1
6	1	1	2
8	1	1	2
10	1	2	2
12	1	2	2
14	2	2	3
16	2	2	3
18	2	2	3
20	2	3	3
22	2	3	4
24	2	3	4
26	2	3	4
28	2	3	5
30	3	4	5
35	3	4	6
40	3	5	6
45	3	5	7
50	4	6	7
55	4	6	8
60	4	7	9
65	5	7	9
70	5	7	10
75	5	8	11
80	5	8	11
85	6	9	12
90	6	9	12
95	6	10	13
100	7	10	14
105	7	11	14
110	7	11	15
115	7	11	16
120	8	12	16
125	8	12	17
130	8	13	17
135	8	13	18
140	9	14	19
145	9	14	19
150	9	15	20

Figure 11-15. Long distance trunk requirements.

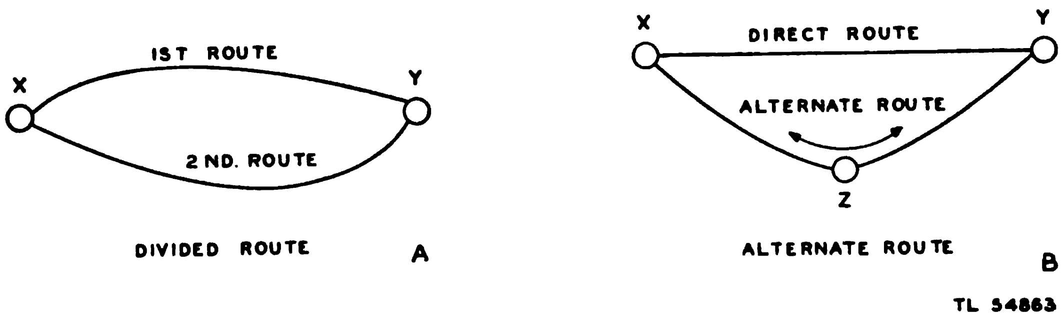


Figure 11-16. Divided and alternate trunk routes.

1-, 2-, or 3-position switchboards, the trunks should be centrally located so that all operators may have ready access to them.

1116. RADIO TELEPHONE TRUNK CIRCUIT TRAFFIC CAPACITY.

a. Point-to-point radio telephone circuits are usually on a push-to-talk basis, which results in the average conversation time being longer than on a point-to-point wire telephone circuit because the push-to-talk technique is inherently slower and, besides, the listener cannot break in on the speaker. Furthermore, the percentage of circuit time lost on high-frequency circuits due to repetitions caused by noise may be greater. Therefore, a radio telephone channel may have as little as 50 percent of the message capacity of a point-to-point wire circuit.

b. Radio telephone circuits which use a separate frequency for each direction, as in radio links in a wire channel, do not use the push-to-talk method of operation. On v-h-f circuits noise is frequently negligible. Hence such circuits may have a traffic capacity per channel equal to that of wire circuits.

1117. TELEPHONE SWITCHBOARD REQUIREMENT CHECK LIST.

a. **General.** A requirement check list should be used in preparing a request for a central that is to be ordered through the Army Communications Systems, for the guidance of the personnel that will order equipment. The check list given in the following subparagraph is applicable for commercial-type multiple switchboards. It can also be used as a guide in ordering nonmultiple switchboards as well as tactical switchboards, by omitting the items that do not apply. Notes should be added to a request for a switchboard covering any special features that are desired.

b. **Check List.** The following check list is typical for use in setting up requirements for a commercial-type common battery multiple switchboard and associated equipment.

Number of operational positions.
Number of common battery line relay equipments.
Number of common battery lines carried through the multiple.
Number of magneto line equipments for long distance trunks and magneto lines, arranged to operate line lamps and busy lamps.
Number of magneto lines carried through the multiple.
Number of common battery trunk equipments, manual.
Number of common battery trunk equipments, dial.
Number of common battery trunk jacks in each appearance of the trunk multiple.
Number of interposition trunk equipments.
Number and distribution of interposition trunk answering jacks and lamps.
Number and distribution of miscellaneous trunk jacks for intraoffice and miscellaneous use.
Number of lamps.
Number of lamp caps and colors. (Total required equals the total number of lamp sockets provided in the switchboard.)
Number of vacant line signal plugs (to plug up unassigned jacks).
Number of cord circuits per position.
Type of cord circuits.
Number of supervisors' circuits.
Number of operators' head and chest sets.
Number of operators' chairs.

c. **Other Information.** The notes to accompany a requirement check list can include such items as: maximum loop resistance of local common battery lines to be served; resistance of trunk loops (dial and common battery manual); working limits of trunk equipment in connecting centrals; whether the repeating coil type of trunk circuit is requested; phase, voltage, frequency, and reliability of available power supply, if known; operating room floor dimensions and ceiling height, if available; desired direction of growth, left to right or right to left; face layout of trunk and local line multiple; location of supervisors' jacks; location and number of ticket boxes in blank multiple space; quantity and type of designation strips; whether spring-driven switchboard clocks or a wall-type spring-driven clock, is desired.

Section V. TELEGRAPH TRAFFIC MANAGEMENT

1118. GENERAL.

a. Many considerations in connection with telegraph traffic are different from those for telephone traffic because telegraph traffic involves the handling of messages in written form. An over-all telegraph communication plan should include a tape-relay system, a switching service (exchange) system, and point-to-point private lines in combination with the tape-relay and exchange service systems. These facilities use wire and radio circuits which provide world coverage in the Army Command and Administrative Network for communication between headquarters within individual theaters of operation and for communication with the zone of the interior. In telegraph operation, switched (exchange) service is relatively less important than it is in telephony.

b. A tape-relay system is well suited to the accurate and efficient handling of large traffic loads at high speed. Communications to and from tributary stations are handled through relay centers equipped with reperforators and transmitter-distributors.

c. A switching (exchange) system permits direct to-and-fro communication between two or more stations through centrals and common trunk groups; relatively light traffic loads are handled economically in this manner.

d. Direct point-to-point private line service involves two or more stations on a fixed circuit and the facilities used are exclusive for interchange of messages between these stations.

e. This section pertains mainly to traffic management of *signal centers* where messages are received from, or placed on the network, and with *teletypewriter centrals* where switched calls are handled. For information relative to operating practices and traffic procedures, reference may be made to FM 24-8, FM 24-10, FM 24-14, FM 24-20, and Traffic Circular Letters 1, 2, 3, 4, 5, and 6 (available through Army Communications Service, O C Sig O).

1119. TYPES OF SERVICE.

a. Telegraph messages for transmission may be received by any means such as messenger, radio or wire telegraph, private-line teletypewriter, or a station on the teletypewriter switching network. Most messages are filed in written form in much the same manner as in commercial telegraph systems; in this case the originator of a message is not connected with the recipient for to-and-fro communication; the semiautomatic tape-relay teletypewriter network is used for the major part of the traffic. In the switched service, the calling station is connected to the called station through a switching system consisting of one or more teletypewriter centrals; the two stations are then in direct contact and can work to-and-fro as in commercial TWX (switched teletypewriter service). Teletypewriter equipment is used for practically all of the transmission throughout Army networks. Morse-code transmission is used only to a minor extent, largely on radio circuits and on field-wire lines in the forward areas.

b. In a signal center, the equipment and associated facilities for the tape-relay message service are sometimes at separate locations from that of the switched service, and the problems of management of the two are different. In the tape-relay network, many messages are received on typing reperforators and transmitted automatically from transmitter-distributors; practically all messages are cryptographed and many of them are in multiple-address form (par. 1122g).

1120. SIGNAL CENTER TRAFFIC MANAGEMENT.

a. **Duties of Officer in Charge.** At a signal center, it is of advantage to assign officer responsibility for handling traffic along the following general lines. The officer in charge should exercise general supervision and be responsible for operation as a whole; interpret and apply directives; select and train personnel and provide them with necessary instructions, materials, and equipment; establish schedules and coordinate shifts of watch officers and personnel; see that security features are properly observed; make analyses of traffic conditions with a view to effecting improvement; and adjust complaints and procedure difficulties.

b. **Duties of Watch Officer.** The communication watch officer should supervise the activities of personnel on duty in his shift; carry out instructions with particular reference to moving traffic rapidly and accurately, preserving security, and dealing with delays, difficulties, and emergencies; and keep the officer in charge informed of any unusual developments. Section supervisors have duties similar to those of the watch officer and report to him.

c. Operating Personnel. The number of people required to operate a signal center depends primarily upon the volume of traffic and its distribution throughout the day.

d. Traffic Distribution by Hours. The distribution of traffic by hours of the day for a large signal center in the zone of the interior is shown in figure 11-17 for general information. The peak in received traffic was at 1900 hours Z time (Greenwich civil time), which in this case corresponded to 1400 hours local standard time (Eastern time belt), and the peak in sent traffic was at 2000 to 2400 hours Z time. For a theater signal center, the time at which the peak occurs would be different, and the distribution of traffic over the 24 hours is apt to be less uniform than that shown in the figure. Hence a distribution chart of the traffic at a particular signal center should be made as soon as practicable after the center begins operations.

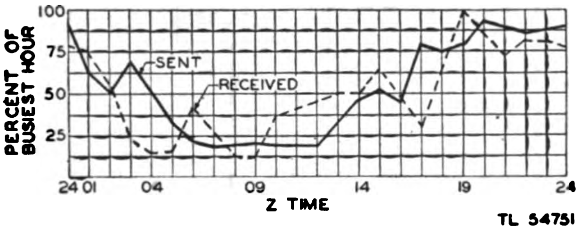


Figure 11-17. Distribution of teletypewriter traffic by hours of a day for a large signal center in the zone of the interior.

1121. LOCATOR SYSTEM.

For efficient delivery of messages to the various units, it is essential that the headquarters signal center arrange to be kept informed as to the location of every unit in its area, preferably by daily reports. Subsidiary centers need to have similar information for their respective areas. When a new unit arrives in an area it should be advised promptly where to pick up and where to file messages.

1122. TELETYPEWRITER NETWORK MESSAGE HANDLING METHODS AND OPERATION.

a. Manual-relay Station Methods. At manual-relay stations, messages are received on page-type teletypewriters. Each message is provided with transmission instructions and routing information. An operator may retransmit the message to the next station by direct keyboard operation, or perforated tape may be prepared locally, in which case the transmission to the next station will be automatic.

b. Tape-relay Station Methods. Reception at tape-relay stations is on typing reperforators, which record the message in the form of perforated tape; the message is typed at the same time on the perforated tape. This received perforated tape is then placed in a transmitter-distributor for automatic transmission to the next station in accordance with routing instructions. An elementary traffic flow diagram of messages to, from, and within a semiautomatic tape-relay signal center is shown in figure 11-18.

c. Traffic Diagrams. Traffic routing information as illustrated by figure 11-19 will be required at each signal center to indicate how to reach distant signal centers. If a network is extensive, and the traffic diagram such as illustrated in figure 11-19 is too complicated for the operators to use, a route bulletin along the same general lines as illustrated in figure 11-3 can be provided for the operators. Traffic diagrams may be satisfactory for use in small networks.

d. Message Heading. Each message as written by the originator is directed to one or several addressees. These addressees are not signal centers except in the case of service messages pertaining to the handling of traffic. The message may be transmitted to some addressees for action and to others for information only. Most transmitted messages have a heading which is divided into two primary parts, namely: the signal center's part and the originator's part. The signal center's part, which may be changed to suit conditions, consists of two portions, namely: the call and the preamble. The *call* consists of the called and calling station designations; the *preamble* consists of the message identifying number, the precedence and the transmission instructions. The *originator's part*, which is fixed, is also made up of two parts, namely: the message address and the message instructions. The *message address* contains the originator's name or equivalent, the date and time of filing, together with action

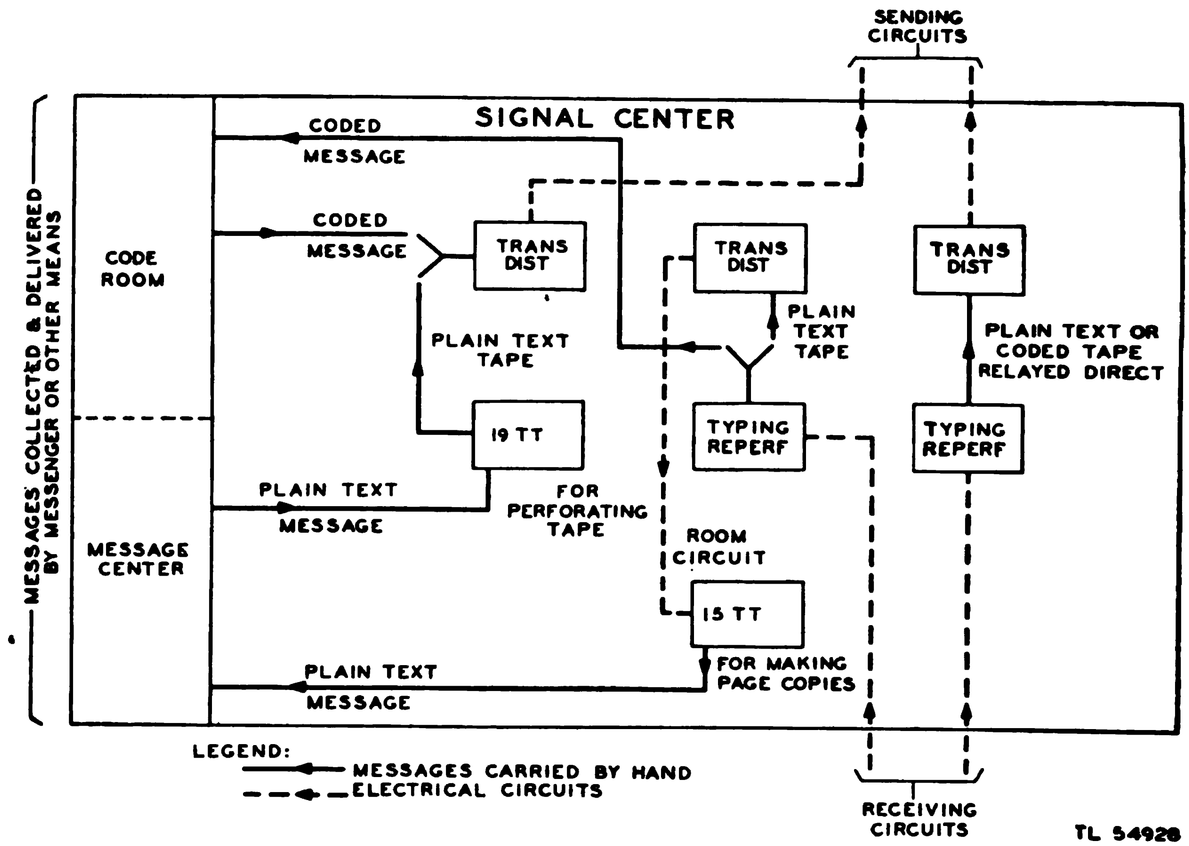


Figure 11-18. Elementary traffic flow diagram in a tape-relay signal center.

and information addresses as required. The *message instructions* contain signals to facilitate handling of multiple-address messages and the group count[2] for text of message only.

e. Message Numbering.

(*1*) In the operation of a network wherein messages are relayed (manually or automatically), it is important that established procedures be followed for identifying messages and for checking the continuity of traffic to prevent losing any messages.

(*2*) In general, messages handled on a station-to-station direct communication basis carry a *serial number* and both stations involved check the number of messages sent and received. When a message is relayed manually it receives a new serial number.

(*3*) In tape relaying, originating traffic is numbered consecutively with a *message-identifying number* including a *channel letter* when there is more than one circuit between the two signal centers. When a message is relayed, the message-identifying number is retained but preceded by a channel message number with a channel letter if necessary. These numbers serve to check the continuity of traffic between the first and last and all intermediate signal centers. In some cases, channel message numbers are inserted in the message tapes automatically. A new sequence of message-identifying numbers is commenced each 24 hours.

f. Message Number Checking. At a specified time, generally once every 24 hours, each station in the network makes a message number check with all stations to which messages have been transmitted during the past 24 hours, in order to find out if all sent messages have been received.

g. Multiple-address and Book Messages. A multiple-address message is one directed to a number of addressees and the contents of such messages often require coordinated action on the part of two or more of the addressees.

[2] Each combination of characters (letters, figures, or symbols) separated from other combinations of characters by spaces, is called a group.

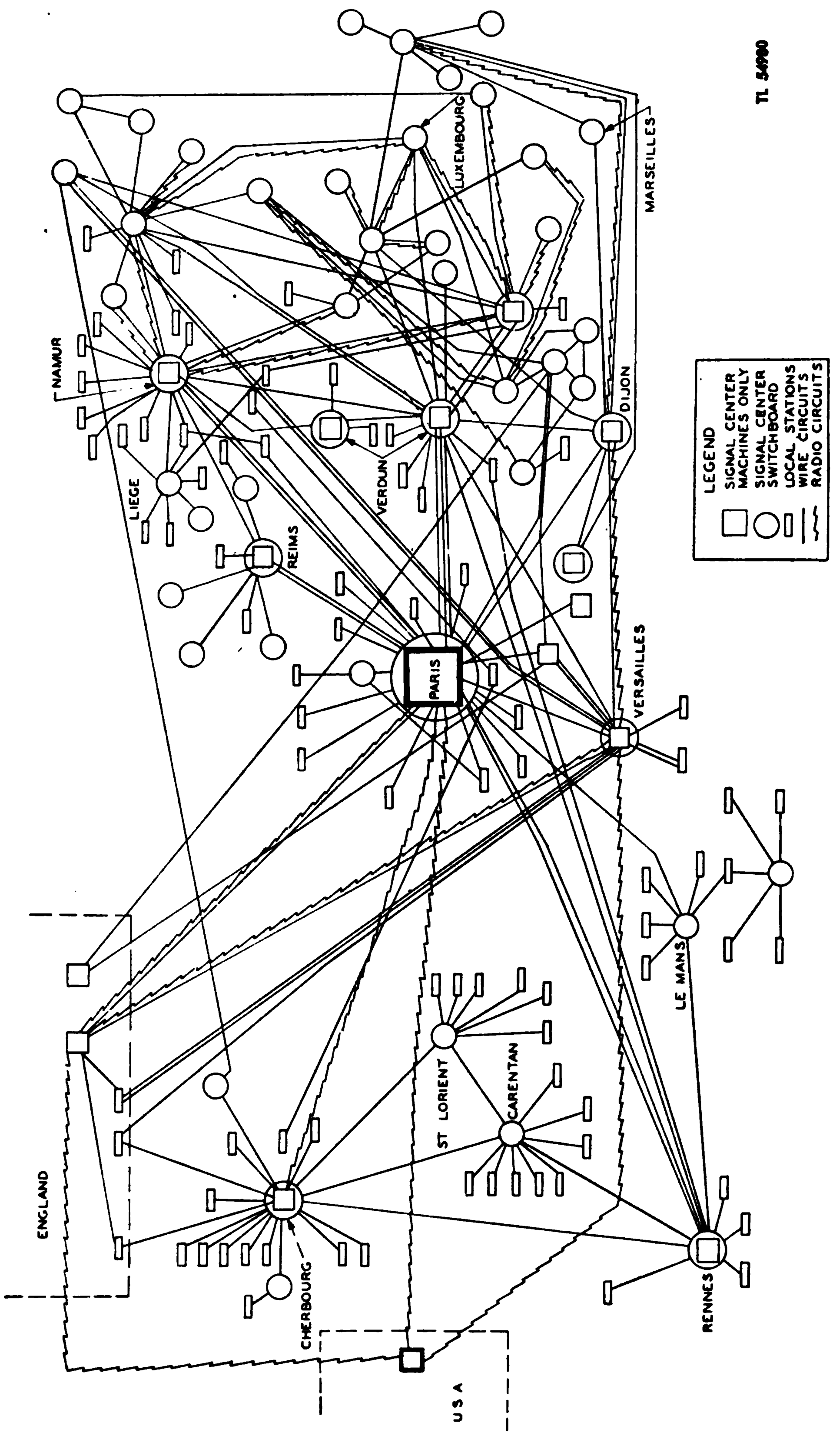


Figure 11-19. Diagram of teletypewriter traffic routes.

Book messages are multiple-address messages which do not require coordinated action on the part of two or more addressees. Traffic operation practices are available and these describe a procedure in which a single tape is prepared for the original multiple-address message which is handled basically like a single-address message. The message is relayed throughout the network, and the network signal centers or stations prepare the message for delivery to the addressees within their respective delivery areas.

h. Service Messages. Test and check messages are transmitted throughout a network at specified times or when traffic conditions permit, to check circuit continuity and quality of transmission. Verification and correction of messages are handled informally or by service messages.

1123. TELETYPEWRITER CENTRALS AND ASSOCIATED STATIONS; OPERATION AND MANAGEMENT.

a. General.

(*1*) At a teletypewriter central, it is advantageous to assign officer responsibility along the general lines stated for signal centers in paragraph 1120.

(*2*) Teletypewriter central management also is concerned with operation of teletypewriter switchboards and related work, such as trouble-report handling, information and directory services, and monitoring. The activities include: personnel work; operator training; assignment of operating forces; message numbering; study of operating practices and traffic flow to see that efficient use is made of existing facilities; record work of various kinds; etc. Practices used in operating teletypewriter centrals should be uniform within a communication system. Switchboard instructions will be needed on: placing and completing calls, teletypewriter privacy calls, precedence of calls, conference connections, disconnection of circuits, prosigns (conventional abbreviations or procedure signals), and handling delayed calls.

(*3*) Combined U. S. Army and British Army switching procedure has not been prepared because of differences between switchboards and teletypewriters. However, British 15-line and 40-line teleprinter switchboards are used in some cases by the U. S. Army. Interoperation of these switchboards and U. S. Army teletypewriter switchboards is not provided for.

(*4*) Instructions to the teletypewriter stations in regard to switched calls will be required which will fit in with the practices used at the switchboards. FM 24–14 prescribes the procedures for the establishment and control of teletypewriter connections involving one or more manual switchboards such as Switchboard BD–100. This manual also covers procedures for relaying messages manually and through centrals equipped with reperforators and transmitter-distributors but not with semiautomatic tape-relay equipment.

b. Operation of Switchboard BD–100. A teletypewriter station calls the switchboard by depressing the break key of the station teletypewriter for 2 or 3 seconds. This lights a line lamp on the switchboard. The switchboard operator calls a station by sending a short break and, if necessary, bell signals. The operator completes calls by means of patching cords, except when switchboards are arranged for group operation as described in chapter 3. In the latter case, cord circuits are used. (Refer to chapter 3 for traffic information on the handling of calls if the switchoards are arranged for group operation.) The operator signals a distant switchboard operator by plugging in on an outward trunk, waits 2 or 3 seconds, and then completes the patching connection to the calling station line. The necessary information is passed from the originating operator to the distant operator by typing. The operator may then disconnect the switchboard teletypewriter

Figure 11-20. Theater signal center operating room with teletypewriter switchboards.

for use on other calls. A disconnect signal, like a call signal, shows on a lamp; therefore the operator should monitor a circuit showing a lamp signal before taking down the connection. Figure 11-20 shows a teletypewriter operating room with means for switching, using Switchboards BD–100 arranged for group operation.

c. British Teleprinter Switchboards. The Britisn 15-line board has 7 cord circuits and the 40-line board has 15 cord circuits. The line circuits operate on a reversible one-way polar basis (switched simplex), the connections being cut through directly by means of the cords; the operator may then monitor by means of a high-impedance bridge circuit to ground. Station equipment may be British Mark IV Terminal Unit using Teleprinter 7B(WD). Broadcasting from the boards to as many as six lines is provided for. Further descriptive information on these boards will be found in chapter 3.

d. Traffic Diagrams. Either traffic diagrams or route bulletins, or both, should be provided for every teletypewriter central, located where they will be readily accessible to operators to indicate how to reach other centrals and stations. The information is particularly necessary when the distant central is reached through another central or has an alternate route. Route information is by diagram as illustrated in figure 11-19. For such networks ring-binder type route bulletins may be required with the names of centrals and routings arranged in alphabetical order similar to that shown in figure 11-3. In this case, the traffic diagrams located at the operators' positions would cover only nearby points, direct points, and most frequently called points.

e. Written Practices Required. The various situations that may develop in handling the different types of calls indicate need for written instructions. The latest material available with any necessary modifications and additions should be provided before communication system service begins and should be modified periodically to suit any changes in conditions.

f. Operators Required. The number of operators required for a teletypewriter central primarily depends upon the calling rate during the busiest hour and the traffic distribution throughout the day, and is limited by the number of operator positions. Since the traffic in most of the other hours is considerably less than that in the busy hour, the operating force can be reduced during those hours in proportion to the calls handled. In general, data will not be available to show the traffic distribution by hours of the day for a new installation, and it will be necessary to make arbitrary force assignments until data from actual operation of the switchboard can be obtained. An estimate of operator requirements for Switchboard BD–100 installations may be obtained from paragraph 1129.

g. Special Services.

(*1*) *Information Calls.* Information calls should be directed to the chief operator in busy hours but probably can be answered by operators in periods of light traffic.

(*2*) *Trouble Reports.* Trouble reports should be referred to the chief operator who should make a trouble ticket, similar to figure 11-6, which should be referred to the wire chief for attention.

(*3*) *Service Complaints.* Service complaints on such things as slow operator answer, delays, etc., should be referred to the chief operator.

h. Directories. Teletypewriter directory information is necessary for the use of operating personnel in the teletypewriter network at centrals and stations. Directory information can be transmitted by automatic tape transmission. The network control station can be responsible for the issuance of the directory. The frequency of reissue will depend on the activity in adding or removing stations in the network. Reports from each central as to changes since the last issue will be necessary in order to prepare copy for reissue of a directory. A directory should list the following: all teletypewriter switchboards alphabetically by name, with a list of circuits from this central to all others to which it has direct trunks; all major relay stations, with a list of circuits from each to all other centers; and all stations in operation, listed alphabetically by call signals, followed by the unit designation and the central to which they are connected. Example of items making up the above are:

(*1*) Teletypewriter Switchboards, ALMA SWBD-ALMA AREA-CCTS TO: LUCY SWBD.

(*2*) Major relay stations, LCDE-GHQ-CCTS TO: ALMA SWBD, LJAM SWBD.

(*3*) Stations in current operation, LBCD-5TH INF REGT-CCTS TO: ALMA SWBD.

i. Traffic Counts and Observations. Traffic counts may be made in a manner somewhat similar to that discussed in paragraph 1110. Service-observing equipment equivalent to that used in large commercial installations will ordinarily not be provided but checks of operation by monitoring will assist in maintaining high standards.

1124. TYPICAL SIGNAL CENTER LAYOUT WITH ASSOCIATED FACILITIES.

a. Figure 11-21 shows the different types of facilities and equipment likely to be involved at a large theater signal center using wire circuits and radio channels. The quantities of equipment and circuits are not specified and

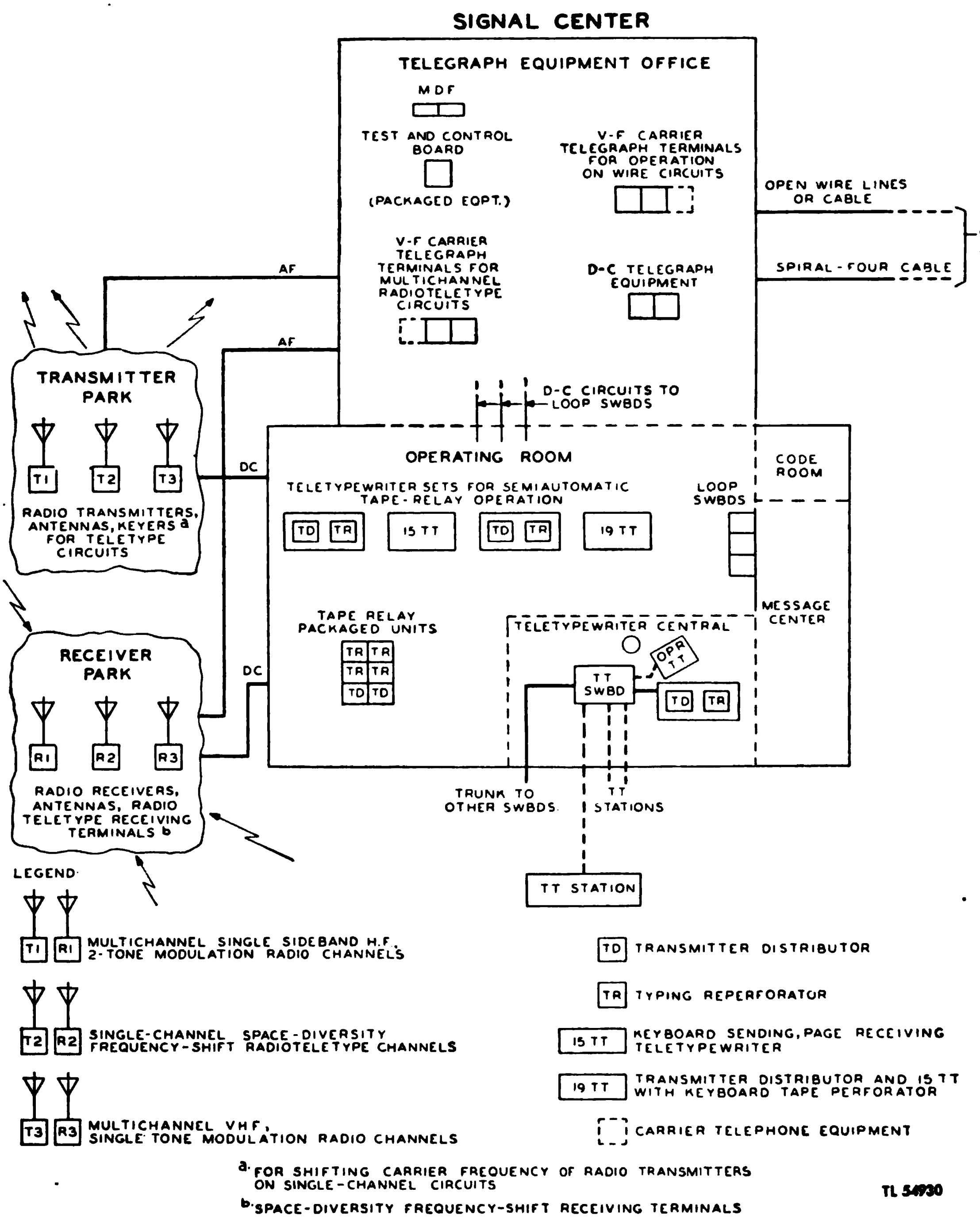


Figure 11-21. Signal center with associated transmitter and receiver parks.

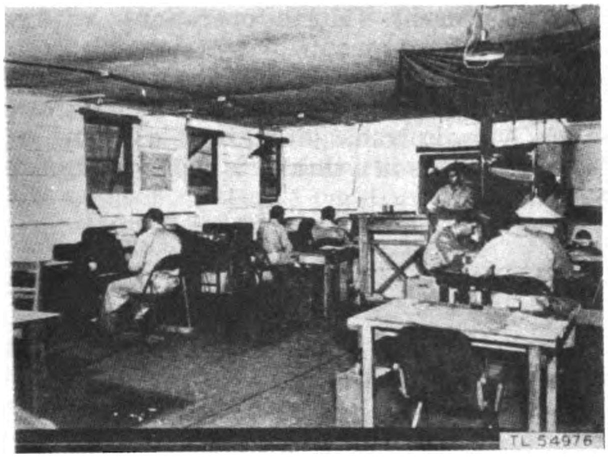


Figure 11-22. Signal center in a theater.

this sketch is not intended for use as a floor plan. From the signal center there will be, in addition to the wire and radio facilities, messenger routes for collection and delivery of messages.

b. Figure 11-22 shows a typical signal center in a theater, with sending and receiving teletypewriter equipment together with facilities for filing and delivering messages.

1125. TYPICAL WIRE AND RADIO NETWORKS.

a. Wire and Radio Teletypewriter Network. An example of a communication zone network using wire and radio for point-to-point circuits, and wire circuits for interconnecting teletypewriter switchboards, signal centers, and local stations is shown in figure 11-23. A teletypewriter installation at an operational base where messages may be received on page-type teletypewriters and transmitted automatically from transmitter-distributors, or manually from keyboards is shown in figure 11-24.

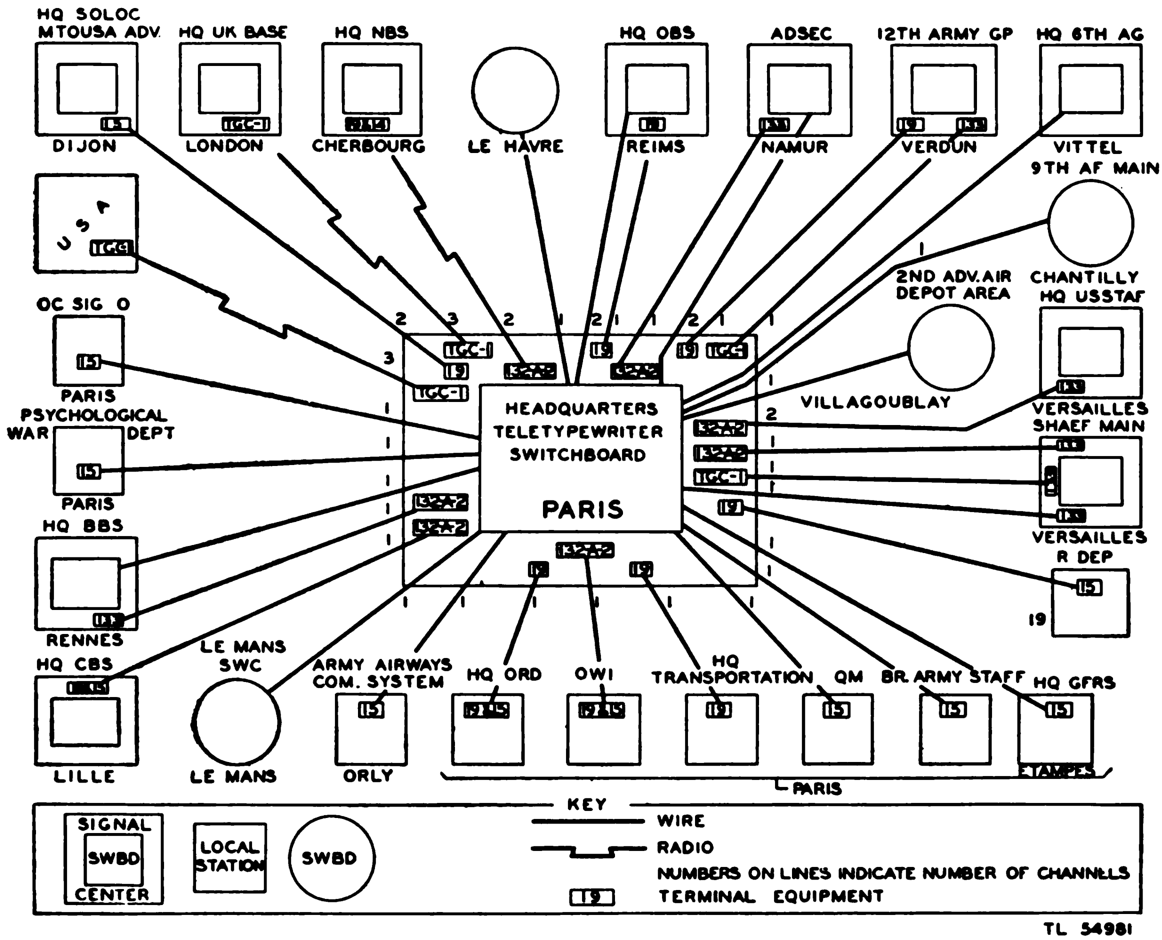


Figure 11-23. Typical communication zone teletypewriter network (wire and radio).

Figure 11-24. Installation of teletypewriter equipment at an operational base.

b. Radio Morse Network. An installation of radio equipment (Morse operation) where messages are sent manually by telegraph keys and received by ear in headphones and recorded with typewriters, is shown in figure 11-25. A radio traffic diagram of a group of Morse networks in a theater is shown in figure 11-26.

Figure 11-25. Manual Morse code radio telegraph installation.

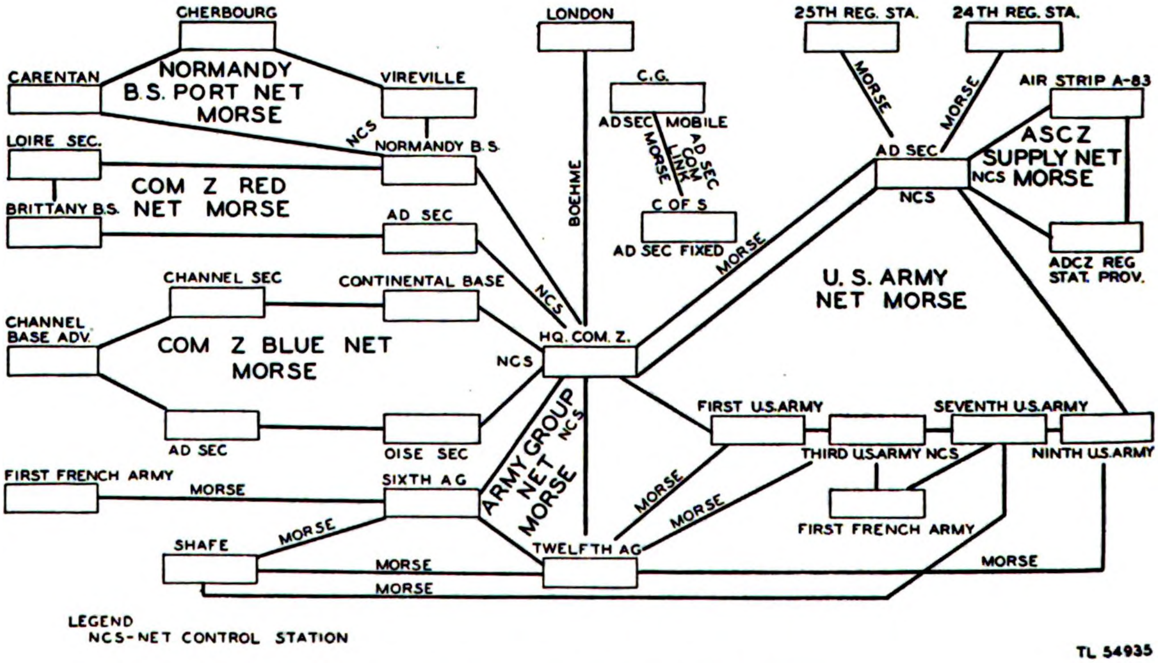


Figure 11-26. Radio Morse network traffic diagram.

Section VI. TELEGRAPH TRAFFIC ENGINEERING

1126. GENERAL.

a. Purpose.

(*1*) Telegraph traffic engineering information is given in this section for planning the number of trunks per trunk group, teletypewriter or manual, and the size of teletypewriter centrals based on estimated traffic. Some data, based on limited experience, are included as to average length of call, word groups[1] per message, and circuit capacity in word groups per day for both teletypewriter and Morse-code transmission. The tendency is to use teletypewriter operation for all of the heavier-traffic circuits and to confine usage of Morse code to certain mobile and front-line services.

(*2*) As a general rule, it will be advisable to use teletypewriter operation on any trunk which is required to handle traffic of over 10,000 groups per 24-hour day. Accordingly, very little traffic engineering will be required in the case of Morse-code operation and this section deals almost exclusively with teletypewriter traffic.

(*3*) The provision of private line facilities is seldom warranted between two stations that exchange an average of less than 40 calls a day.

b. Critical Considerations in Planning Teletypewriter Communications.

(*1*) The three most critical considerations in connection with furnishing military teletypewriter communication service are personnel, teletypewriter equipment, and line facilities. The relative importance of these items varies from time to time and in different areas. Army traffic is not stable; its peaks rise and fall and move from point to point, reflecting sudden changes in the course of the war and in the requirements of movement of troops and supplies. Therefore, the engineering methods should be sufficiently flexible to provide the relief required at any time, at any place, and for any of these considerations.

(*2*) The concentration of traffic into tape-relay network operation tends to reduce the over-all personnel requirements, but it may concentrate loads at relay centers which may materially overload personnel. Pending an increase in force, this may be relieved by handling as much of the traffic as possible by other facilities and by rerouting some of the traffic around the signal center affected.

(*3*) In case of shortage of teletypewriter equipment or of line facilities, the desirable procedure is to concentrate as much of the traffic as possible on the tape-relay network and minimize the switched and private line services.

(*4*) It is essential that the users of teletypewriter service understand the current problem and the treatment which is used so that they will cooperate promptly in making the routing changes and shifts from one type of operation to another to meet the changing conditions. Accordingly, steps should be taken to keep them informed.

c. Estimates Required.

(*1*) The number of point-to-point circuits in any group will ordinarily be determined by estimating the total volume of traffic and dividing this by the traffic-carrying capacity per circuit. Traffic data for normal days should be used, avoiding unusual peaks, such as semimonthly traffic peaks which arise from the handling of routine reports, since it is not necessary to engineer the layout for such large volumes of traffic. In exceptional cases the number of circuits may have to be increased on account of quick delivery requirements. It is sometimes necessary to provide additional equipment in a signal center in order to equip direct lines between particular stations.

(*2*) The size of a teletypewriter switchboard and the sizes of its associated trunk groups are determined by the traffic to be handled in the busiest hour. This in turn is a function of the number of stations served, the number of calls per station in the busiest hour, and the average length of call.

(*3*) In engineering teletypewriter switchboard installations, it will be necessary to estimate the busiest-hour traffic, either from known data or from arbitrary assumptions. Paragraph 1129 below discusses the determination of teletypewriter switchboard requirements from estimates of busiest-hour traffic.

[1] Each combination of characters (letters, figures, or symbols) separated from other combinations of characters by spaces, is called a group.

1127. TRAFFIC EXPERIENCE DATA, POINT-TO-POINT CIRCUITS.

a. Experience in various theaters of operations has provided some useful telegraph traffic engineering data on point-to-point circuits.

b. Hand sending by International Morse code on the single basis, described in chapter 3, permits an average of about 6,000 net text groups (fig. 11-30, note 1) per channel per 24-hour day. This includes allowance for procedure signals, correction of errors, circuit interruptions, etc. It is believed that the performance varies rather widely, however, from one case to another. With comparatively skilled operators and favorable circuit conditions, 10,000 to 20,000 groups per day are possible. With duplex operation, the volume of traffic can be approximately doubled, as compared to single; that is, each direction of transmission has a capacity of at least 6,000 groups per day.

c. A stable point-to-point tape-sending teletypewriter circuit operated single at a nominal 60-word-per-minute speed may handle as many as 50,000 net groups of text per day in addition to the headings (par. 1122d). In duplex operation, this amount of traffic may be handled in each direction simultaneously. Such loads are achieved by keeping the circuit working to full capacity about 75 percent of the time in each 24 hours, the net text group speed being about 50 words per minute for tape transmission and 25 for keyboard operation. With keyboard sending, the capacity will be about one half that with tape sending. Unstable circuits generally carry less than half the above amounts.

d. If the ordinary command and administrative circuit is engineered to carry about one half the 50,000 groups per day (25,000 groups per day) by tape-sending, there will be adequate facilities available for handling the service in the busiest hour.

e. The average number of net groups of text per message is generally between 70 and 120 groups for telegraph traffic within a theater. Between a theater headquarters and the zone of the interior, the average may be as high as 220 groups.

1128. TRUNK CIRCUIT REQUIREMENTS; POINT-TO-POINT SERVICE.

a. Teletypewriter Point-to-point Service.

(*1*) Telegraph trunk circuit requirements for signal centers are drawn up for a theater of operations so that they are coordinated properly with the general communication plan. General information on the traffic-carrying of trunk circuits is given in this paragraph.

(*2*) To determine roughly the number of half-duplex trunks required between two points, the total volume of traffic per day (sent and received) should first be estimated by multiplying the expected number of messages per day by the assumed groups per message; dividing this volume by the 25,000 (par. 1127d above) gives a figure for the minimum number of trunks required for tape-sending. If engineered on this basis, there is adequate provision for service during the busiest hour. If the result does not give an integral number, it is then necessary to decide whether or not to provide the next higher integral number. Where physical limitations preclude making adequate provision for service during the busiest hour, or where for other reasons substantial delays can be tolerated during the busiest part of the day, the capacity of the trunk group can be determined on the basis of the higher figure of 50,000 groups per trunk per day.

(*3*) In the case of full-duplex trunks, the required number of one-way channels must be figured separately for the two directions of transmission. The larger of the two numbers then determines the number of full-duplex trunks which must be provided.

(*4*) In multichannel long-haul radio telegraph systems, certain channels are in some cases operated on a one-way basis. In this case, it will be necessary to make computations of the type outlined above for such channels on a one-way basis.

(*5*) In engineering additional facilities, it is customary to determine the requirements on the basis that the volume for a representative day is the average of the two busiest days of a normal week. This average peak-day volume is generally about 1/26 that for the total month. Messages sent and received in the busiest hour (excluding deferred messages) are the basis for determining the busy hour circuit load in words.

(*6*) The determination of requirements for radio stations for part-time communication on a scheduled or nonscheduled basis with a number of distant stations will have to be handled on a special basis for each particular case. When the volume of traffic to be handled with each of the distant stations, has been estimated, a plan or schedule of operation may be drawn up from which a decision may be reached as to the number and types of transmitters and receivers, including spares, which should be provided.

b. Morse-code Point-to-point Service. The number of Morse-code trunks required, either manual or automatic, can be readily estimated from the volume of traffic expected and an estimate of the operating speeds. Operating speeds will depend upon the skill of the operators; the extent to which the circuits will be affected by interference, both natural and man made, including jamming; transmission instability resulting from fading; equipment instability; improper adjustment; distraction caused by battle noise, etc. Net text manual speed will usually be 5 to 10 words per minute. Net text automatic speed varies greatly, from about 20 to about 300 words per minute, depending on the grade of transmission over the circuit; hence estimates of the speed obtainable may have to depend on specific experience over the same or similar routes.

1129. TELETYPEWRITER SWITCHBOARD POSITION REQUIREMENTS.

a. Switchboard BD–100. Figure 11-27 shows the number of Switchboards BD–100 and the number of operators required for two different busiest-hour calling rates. The length of message is of secondary importance in determining the number of operators required, operator time being used chiefly in setting up and taking down connections and incidentally in monitoring. The traffic handled by a teletypewriter central consists of local calls and calls over trunks to and from other centrals. The distribution between various types of calls with Switchboard BD–100 is unimportant, figure 11-27 being generally applicable. Switchboard BD–100 is equipped for 10 line circuits which can be used for either station lines or trunks. Three positions are therefore limited to a total of 30 trunks and station lines. Thus, if there are 25 teletypewriter station lines, only five trunks can be installed. These switchboards are nonmultiple, and connections are made by means of patching cords. Eighteen-inch and 72-inch patching cords are supplied with each board. If more than three positions of switchboard are required, improvised group arrangements of the equipment should be considered (ch. 3).

Calling rates, in calls (outward and inward) in the busiest hour per line served[a]	*Number of Switchboards BD-100*	*Operators required*[b]	*Working lines*[a]
1.5	1	1	1-10
	2	1	11-13
	2	2	14-20
	3	2	21-30
	4	3	31-40
	5	3[c]	41-50
2.0	1	1	1-10
	2	2	11-20
	3	2	21-24
	3	3	25-30
	4	3[c]	31-40
	5	3[d]	41-50

[a] Station lines and trunks use identical switchboard terminations and equivalent supervisory features. Lines include station lines and trunks to other switchboards.
[b] One teletypewriter is required for each operator.
[c] Service may be slowed up during peak loads.
[d] Service may be unsatisfactory during peak loads.

Figure 11-27. Switchboard and operator requirements, Switchboard BD-100.

b. Commercial-type Multiple Teletypewriter Switchboards. Figure 11-28 shows the position requirements of commercial-type multiple teletypewriter switchboards. These switchboards allow teamwork between operators on adjacent positions which gives them a greater traffic-carrying capacity than that of Switchboards BD–100; which do not permit teamwork; that is, operators assist adjacent operators in handling peaks of traffic. These data have been included for general information, although it is expected that the Signal Corps will seldom use boards of this type.

1130. TRUNK CIRCUIT REQUIREMENTS; SWITCHED SERVICE.

a. General.

(*1*) The number of trunks bears no fixed relation to the number of station lines. In

Total busiest-hour traffic (outward, inward, and through calls)	Positions required	Number of teletypewriter loops plus trunks	
		At 1.5 calls (outward, inward, and through) in the busiest hour per teletypewriter loop served	At 2 calls (outward, inward, and through) in the busiest hour per teletypewriter loop served
1-20	1	1-13	1-10
21-48	2	13-32	10-24
49-78	3	32-52	24-39
79-104	4	52-70	39-52
105-138	5	70-92	52-69
139-169	6	92-113	69-85
170-202	7	113-135	85-101
203-238	8	135-159	101-119

This table is based on the following assumptions:

1. Each operator handles all types of calls and the total busiest-hour traffic is the sum of all types.
2. Distribution of traffic:

Local calls	20% to	10%
Outward trunk calls	40% to	45%
Inward calls	40% to	45%
Total	100	100

3. The switchboard face layout permits every operator to reach every loop and trunk.
4. If busiest-hour calls per teletypewriter are assumed to be different from the above, the number of teletypewriter loops shown should be reduced in inverse ratio to the calling rates.

Figure 11-28. Position requirements, commercial-type multiple teletypewriter switchboards.

order to determine the number of trunks required in an individual group, it will be necessary to estimate the number of calls to be carried by the group in both directions. An effort should be made to provide facilities and operating personnel adequate to handle the maximum volume of traffic which is likely to be offered in connection with preparing for and carrying out expected military operations.

(*2*) As in the case of telephone traffic (par. 1115e), more teletypewriter traffic can be handled if all service between two switchboards is handled over one trunk group, rather than by having certain circuits reserved for a particular branch of the service. One group can handle more traffic than two groups of half the size.

(*3*) Trunk circuit requirements may be estimated either from the *holding time* or from the *group count* as described in subparagraphs b and c below.

b. Trunk Requirements Based on Holding Time. Figure 11-29 shows the number of trunks required in a group for various numbers of busiest-hour calls of three different average holding times, namely: 15, 20, and 25 minutes. Trunks may be held in some cases for periods up to several hours and, if this condition is to apply to a large percentage of connections, the trunk groups may require liberalizing beyond what is shown in figure

Total busiest-hour calls per trunk group (outward plus inward)	Trunks per trunk group		
	15-minute holding time	20-minute holding time	25-minute holding time
1	1	1	1
2	2	2	2
3	2	2	3
4	2	3	3
5	3	3	4
6	3	4	4
7	3	4	5
8	4	4	5
9-10	4	5	6
11-12	5	6	7
13	5	6	8
14	6	7	8
15	6	7	9
16-17	6	8	9
18	7	8	10
19	7	9	10
20	7	9	11

Figure 11-29. Teletypewriter trunk circuit requirements based on holding time.

11-29. Available information indicates that the average length of call (holding time) is about 20 minutes in a teletypewriter exchange network.

c. Trunk Requirements Based on Group Count. Figure 11-30 shows the number of trunks required in a trunk group for various numbers of word groups transmitted in the busiest hour. The information in the table covers keyboard transmission at an average net speed of 23 groups per minute, and one based on tape transmission at an average net speed of 50 groups per minute (ch. 3). The requirement for trunks that are to be utilized for both keyboard and tape transmission may be obtained from these two columns by interpolation.

Total busiest-hour group count per trunk group (outward plus inward)		*Trunks per trunk group*
Keyboard transmission	*Tape transmission*	
1-650	1-1,400	1
650-1,550	1,400-3,400	2
1,550-2,600	3,400-5,700	3
2,600-3,700	5,700-8,000	4
3,700-4,700	8,000-10,300	5
4,700-5,900	10,300-13,000	6
5,900-7,200	13,000-15,700	7
7,200-8,400	15,700-18,400	8
8,400-9,700	18,400-21,100	9
9,700-10,900	21,100-23,800	10

This table is based on the following assumptions:

1. One group of text is assumed to consist of five typed characters and a space.
2. Twenty-three net groups per minute is taken as the average message speed with keyboard transmission.
3. Fifty net groups per minute is taken as the average message speed with tape transmission.
4. Group counts are for the message text only; they do not include headings. For definition of *group* see paragraph 1122d, note 2.

Figure 11-30. Teletypewriter trunk circuit requirements based on group count.

Section VII. LOCAL CABLE PLANT ENGINEERING

1131. INTRODUCTION.

a. General. Army fixed plant building projects or installations may justify cable distribution plant to serve a local area. The cable will be lead-covered, nonquadded, and paper-insulated, and is known as *exchange cable.* In general, the circuits will leave the central in *feeder cables* which will connect to *distributing cables.* Distributing cables are provided with terminals giving ready access to the cable pairs for connection to the drop wire or house wiring installed along with the telephone.

b. References. The methods of constructing aerial cable for this type of outside plant are given in TM 11–363. Some of this lead-covered, paper-insulated cable may be required along building walls or in buildings. Construction methods for this type of cable are given in American Telephone & Telegraph Company, Specification 3931, Block Cable Construction, and American Telephone & Telegraph Company, Specification 3933, House Cable Placing. Underground lead-covered, paper-insulated cable probably will be restricted to buried cable placed by hand or plow as described in chapter 9.

c. Information Required. A plan or map, drawn to scale, of the project, showing the estimated number of telephone, telegraph, and signal circuits required in each building will be necessary to plan the cable plant. All uses of cable conductors should be included, such as for fire alarms, crash alarms, emergency reporting systems, and radio control circuits. The conductor requirements for long distance trunk circuits must be determined so that necessary quadded cable and loading can be provided, as described in chapter 5. The location of the telephone and teletypewriter centrals and the signal and message centers should be shown.

1132. NECESSARY RECORDS.

a. General. The information mentioned in the preceding paragraph will permit the development of the cable plan and the records. The records are described in the following subparagraphs. In small installations, certain of the records can be combined. The function of these records is to supply all information relating to the cable, required by the planning engineer and cable test man. They furnish the means for maintaining a continuous record of cable fills which are the guides to future growth. The records should be tracings so that multiple prints can be made. A typical cable map record is shown in figure 11-31. The data recorded should include:

(*1*) The number of pairs, gauge of conductors, and count (pair numbers) of each cable.

(*2*) For quadded cable: the type of cable; the number of quads; their gauge and count; the number of nonquadded pairs, their gauge and count.

(*3*) The type of terminal, count (pair numbers terminated), and designation of each terminal by geographical location (pole number or serial number).

(*4*) Cumulative cable lengths from the telephone central main distributing frame end of the cable to the center of each cable terminal splice, each splice where a branch cable is spliced to the main cable, and other splices of importance to the planning engineer and cable test man.

(*5*) When the telephone lines are loaded, the location of each loading pot, type of case, its distance from the central, number and type of phantom and side circuit loading coils, and the count of the cable pairs to which they are spliced.

b. Cable Records. Cable records described above should be provided for the following:

(*1*) *Aerial Cable.* This map may suffice for the entire lead-covered, paper-insulated cable used in a small area, whether the cable is underground, aerial, block, or house cable. If the installation is large, this map can be limited to the aerial cable only.

(*2*) *Underground Cable.* A separate map for this type of cable will only be required in unusually large installations. In a medium or small installation, this map can be combined with the aerial cable map mentioned in subparagraph (1) above.

(*3*) *Block Cable.* This map is used where the distributing cable around a group of buildings is so extensive that the information about it cannot be included on the aerial cable record. These cables may terminate in a cross-connection box (cross-box) where they cross-connect to the cable that feeds them, which may be aerial or underground.

(*4*) *House Cable.* This map is used only where an extensive distributing cable system is used in a large building. In small installations, this cable information can also be carried on the aerial cable record.

c. Cable Pair Records. Cable pair records, discussed in paragraph 1149e, show the location of terminals on each cable and the count (pair numbers) that appears in each terminal. They show what service is on each working pair and at which terminal the service is connected. They are used and maintained by the circuit assignment personnel in preparing installation orders for telephones, teletypewriters, etc.

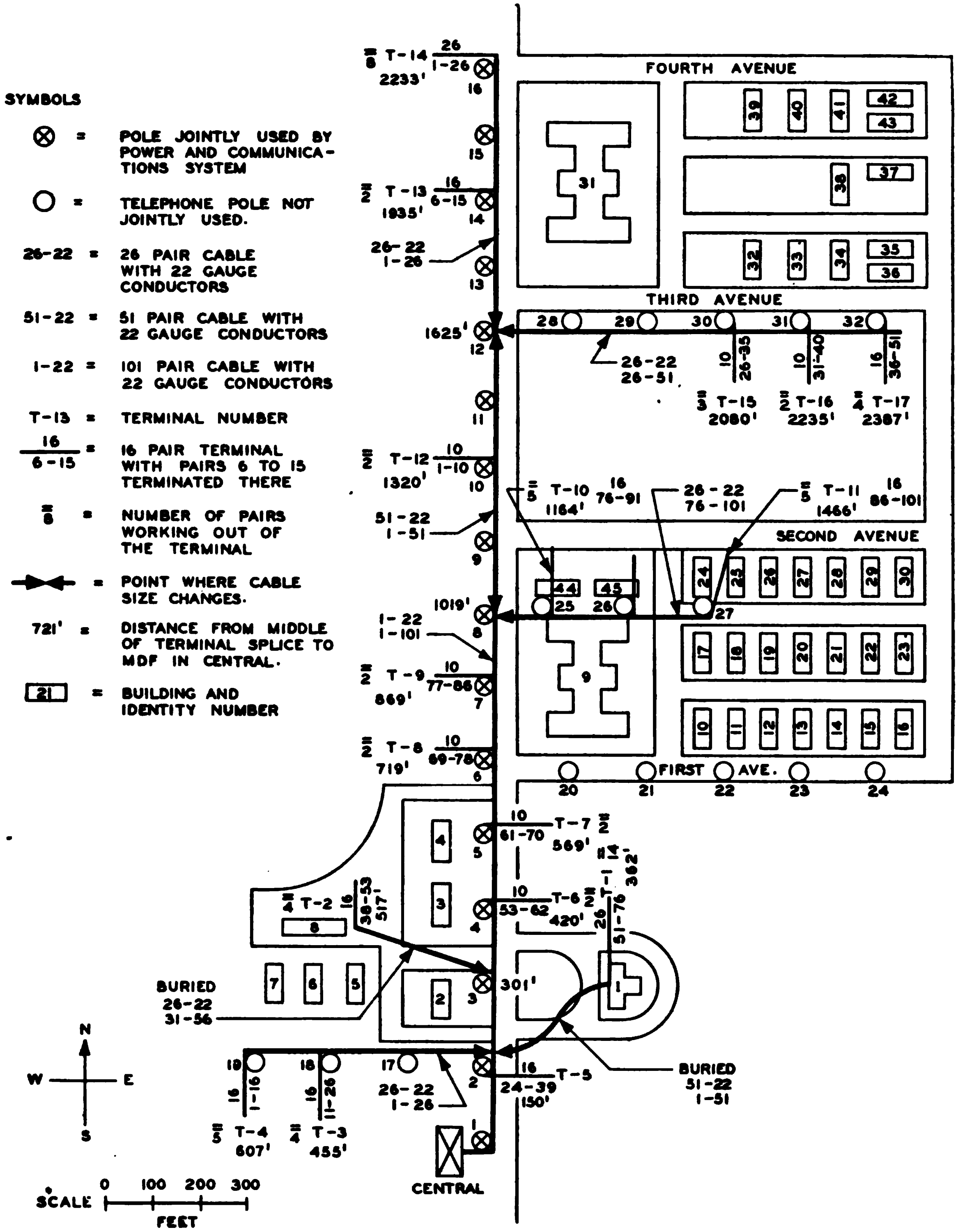
1133. CABLE SIZES AND GAUGE.

a. Cable Sizes. Ordinarily the cable sizes in numbers of pairs diminish progressively from the central out toward the cable ends, at suitable points, rather than being uniform from end to end. This is indicated in figure 11-31. The cable should ordinarily be reduced in size about 50 percent at each diminishing point. The diminishing points, which will be determined in accordance with the line requirements along the cable run, should be at junctions of branch cables, and the multipling explained in paragraph 1135 should be so arranged as to make greatest use of the pairs that are dropped at each point.

b. Gauge of Conductors. Satisfactory telephone service requires that the gauge of cable conductors be such that the transmission loss in the station loops served by a central will not exceed specified limits (ch. 2). Information as to limits of various switchboards is given in TM 11–487. The conductors provided usually will be 22 gauge.

1134. SIZE AND LOCATION OF TERMINALS.

The location of distribution terminals along aerial and block cables is determined directly by the location of equipment and the number of circuits that are to be established through the terminals to serve this equipment. As a general rule, a terminal should be placed where



NOTE: IT IS CUSTOMARY TO NUMBER ALL POLES

Figure 11-31. Cable record map.

TL54902

excessive use of drop wire paralleling the cable would otherwise be required to reach the equipment served. The usual terminal sizes are 10-, 16-, and 26-pair. The size chosen for a specific location should not be smaller than three times the number of circuits that are to be served through the terminal, with liberal interpretation of this rule. Therefore, a terminal should be placed on any pole that is located where three or more lines will terminate to serve the immediate vicinity, or where long runs consisting of one or two drop wires would be required to reach another terminal.

1135. CABLE MULTIPLING.

a. Distribution Cable Terminal Multipling.

(*1*) Repeated termination, or overlap of the same cable pairs at more than one terminal is known as *multipling.* The multipling of cable pairs offers almost unlimited permutations and combinations but practical considerations and operating features usually narrow the field to a comparatively few feasible plans. The choice of multipling arrangement must consider future requirements and the following objectives:

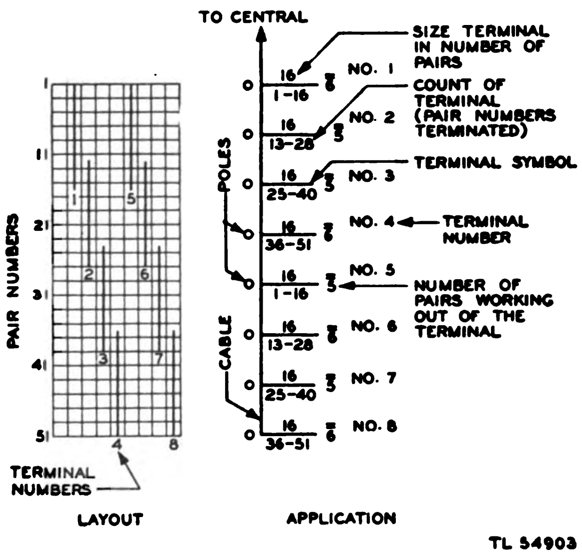


Figure 11-32. Cable multipling.

(*a*) To provide for probable variations in location and amount of growth with a minimum number of cable transfers.

(*b*) To make the same cable pairs (counts) available by overlap at a sufficient number of terminals to permit the best possible use of circuit pairs.

(*c*) To avoid early congestion in any one terminal or cable pair count.

(*2*) A method of multipling which provides good flexibility is illustrated in figure 11-32. The pair counts in a series of eight terminals are given, which illustrate the overlap of pairs so that each pair appears in more than one terminal. Figure 11-31 is an example of the application of the principles involved.

b. Feeder Cable Multipling. The multipling of feeder cables consists in assigning the pairs of distributing cables, subsidiary cables, terminals, and stubs. This presents a problem similar to that explained in the preceding paragraph for distributing cables. The main objectives are flexibility, even distribution of ultimate lines, and avoiding early congestion of cable counts which would necessitate cable transfers to provide relief.

1136. CABLE CONGESTION AND RELIEF.

a. Congestion. Periodic examination of the cable pair records (par. 1149e) will show whether cables or portions of cables are approaching *maximum fill,* that is, maximum number of pairs in use which it is practicable to permit before relief is decided upon. Excessive fill will restrict the freedom that is necessary in making new arrangements for the use of pairs. Congestion also will cause resort to temporary expedients, such as long drop wire runs, in order to connect additional telephones. Certain terminals or branch cables may approach congestion before the cable as a whole is in need of relief. When the line assignment personnel notice approaching congestion, it should be their responsibility to notify the proper authorities.

b. Relief.

(*1*) *General.* The object of relief is to provide adequate numbers of cable pairs and terminals in the congested location, without creating congestion in other localities. Allowance should be made for spare pairs for existing lines and for reasonable growth. Methods of relief for cables approaching congestion include cable transfers, the use of cross-connecting terminals, reinforcement, replacement, or division. The first two named are for short term or temporary relief. A complete relief plan may include various combinations of two or more of the methods as one project.

(*2*) *Cable Transfers.*

(*a*) A cable transfer is the shifting of one or more terminals, distribution circuits, or branch feeder circuits from certain conductors in one cable to other conductors either in the same or a different cable. The result of this plan is a redistribution of both existing lines and expected growth in existing cables, thus making idle pairs available where they can be used to the best advantage.

(*b*) Cable transfers will provide relief in specific terminals or sections of cable by changing the count of the pairs in congested terminals so as to effect a redistribution of existing lines. This method is applicable when the congestion results from the multipling of certain pairs at two or more points, and when it is feasible to transfer to other cables or to other counts in the same cable which contain spare facilities.

(*3*) *Cross-connecting Terminals.* A cross-connecting terminal (cross-box) may occasionally be used to provide relief to a congested cable or cable complements. These cross-connecting terminals permit a redistribution of working lines on the telephone-central side of the cross-connecting terminals. The cross-connecting terminals are inserted at some suitable point along the cable thus permitting any spare pair toward the central to be connected to any pair in the distant end of the cable. This method of relief is resorted to only when the possibilities of relief by cable transfers have been exhausted. Cross-connecting terminals also permit feeding one or more distribution cables in which the total pairs exceed the pairs in the feeder cable. They have the disadvantages that they increase the work of assignment, installation, and maintenance.

(*4*) *Reinforcement.* Reinforcement is the placing of cable parallel to the existing cable with the transfer of some of the branch distribution cables from the original to the new cable.

(*5*) *Replacement.* Replacement of a section of the cable is used when the relief must be confined to the original route and the capacity of the pole line or underground plant in that route has been reached.

(*6*) *Division.* Dividing the congested cable consists in cutting the existing cable at one or more points and providing a different feeder to the central for the severed section or sections. This arrangement is mainly applicable to the distribution cables but may, under certain conditions, be used to provide relief of a feeder cable. It results in two or more cables each of which provides facilities for some existing lines and a certain amount of growth.

Section VIII. TRUNK PLANT ENGINEERING

1137. GENERAL.

After determining the long distance trunk circuit requirements, based on traffic engineering procedures discussed in preceding sections, certain information must be available in order to make the best possible use of materials and equipment, so that an intelligent choice can be made between several different methods that might be used to provide the circuits. This information should be secured before making any definite plans as to how the circuits are to be obtained. Reference can be made to FM 24–20, TM 11–363, TM 11–368, TM 11–369, TM 11–462, TM 11–487, TM 11–2001, TM 11–2022, TM 11–2253, and to other chapters of this manual.

1138. INFORMATION REQUIRED.

a. General. When engineering long telephone and telegraph trunk circuits which are to be relatively permanent, a considerable amount of information should be assembled regarding the conditions involved and circuits required. The information needed is listed in the following subparagraphs. When engineering short telephone and telegraph trunk circuits which are to be less permanent, a number of the items listed will not be required; the amount of information needed in any specific case will depend on the circumstances. In general, more complete information will be required for the installation of fixed plant equipment than for tactical equipment. The procedure to be followed after this information has been made available is indicated in paragraph 1139.

b. Circuit Information Check List. The following list includes the items of circuit information required:

(*1*) Number of telephone circuits required between any two centrals or points and the desired net loss of each.

(2) Date each circuit is needed.

(3) Location of any intermediate bridges on each telephone circuit.

(4) Number of telegraph circuits required between any two or more centrals or points and the location of each station on each circuit.

(5) Type of operation of each telegraph station.

(6) Hours of use per day if the telephone or telegraph circuits are required to give only part-time service.

(7) Probable number and type of future telephone and telegraph circuits between the same centrals or points.

(8) Complete information on any special conditions or usage; such as for connections to existing circuits, or circuits provided by civil or Allied Army equipment; signaling used on connecting circuits; speed of telegraph operating; whether the circuits are operational or administrative; etc.

(9) Resistance of trunk loops of the interconnecting dial and common battery manual central office trunks.

(10) Working limits of trunk equipment in connecting centrals.

(11) Whether or not the repeating coil type of trunk circuit is requested.

c. Information for New Open Wire or Cable Lines. The following table lists the items of information required when a new open wire or cable line is to be constructed. This information is necessary before proceeding with the detailed outside plant and circuit engineering.

(1) Map of possible line routes, showing:

(a) Route miles between towns, proposed centrals, repeater stations, and line junctions.

(b) Terrain and soil conditions affecting line construction.

(c) Location of rivers or other obstructions which might affect line layout or type of cable or open wire required.

(d) Exposures to hazards such as highway traffic, bombing, maneuvering of troops, tanks, motor vehicles, etc.

(e) Exposures to hazards of weather (wind, floods, ice forming elevations, etc.).

(f) Transportation routes available for construction and maintenance of the line.

(g) Location and length of entrance and intermediate cables required for each route on open wire lines.

(2) Storm loading area (heavy, medium, or light) (ch. 9).

(3) Power exposures and hazards.

(4) Special factors, such as type of construction material available, maintenance conditions, expected life of line, etc.

d. Information for Existing Open Wire Lines. The following table lists the items of information required in engineering circuits on an existing open wire line.

(1) Route map (par. 1141a) or equivalent, showing:

(a) Route miles between offices (centrals and repeater stations).

(b) Type, gauge, and condition of existing wire.

(c) Type and condition of insulators.

(2) Entrance and intermediate cable data (ch. 5) showing:

(a) Location and condition.

(b) Gauge, length, loading, and present usage of each pair.

(c) Type of cable.

(d) Type of construction; that is, aerial, underground, submarine, or buried.

(3) Pole head diagram of each uniform section of the line showing idle and occupied pin positions. Spacing of pins and crossarms, and wire sizes should be shown on this diagram.

(4) Pole line construction data (ch. 9), showing:

(a) Height, size, average ground line dimension, and condition of poles.

(b) Type and condition of crossarms.

(c) Possibility of adding crossarms and wire.

(d) Adequacy of guying.

(e) Types of pins and transposition brackets.

(5) Transposition system of existing wire and location of each S pole (ch. 5).

(6) Long distance circuit layout map or equivalent such as office diagrams (par. 1141a), showing:

(a) Type and name of circuit in operation on each pair and each phantom group.

(b) The net loss of each telephone circuit.

(c) The location of all carrier terminals, carrier repeaters, voice-frequency repeaters, intermediate bridges, telegraph repeaters, telegraph stations, regenerative repeaters, and other equipment on each circuit.

(*d*) Which, if any, circuits or pairs are idle.

(*e*) The type, frequency allocation, and direction of transmission of each carrier telephone system.

(*f*) The output level of each carrier telephone terminal and of each voice-frequency and carrier telephone repeater in each direction.

(*g*) The type of signaling used on each circuit.

(*7*) Prevailing weather conditions along the line, including exposures to wind, floods, ice forming elevations, etc. (ch. 9).

(*8*) Power exposures and hazards.

(*9*) Special conditions.

e. Information for Existing Cable. The following lists the items of information desirable for engineering of circuits in existing cables. Information regarding rehabilitation of captured cables is given in chapter 5.

(*1*) Route map or equivalent:

(*a*) Route miles between offices (centrals and repeater stations).

(*b*) Type of construction; that is, aerial, underground, submarine, or buried.

(*2*) Cable data:

(*a*) Condition of cable.

(*b*) Type of construction; that is, paired, multiple-twin quads, or spiral-four quads.

(*c*) Gauge, capacitance, and total numbers of quads, or pairs of different gauges.

(*d*) Cable layup, that is, arrangement of pairs or quads in the cable, including method of segregating 4-wire circuits.

(*e*) Method used to reduce within-quad capacitance unbalances during installation; that is, by test-splicing or capacitance balancing; and location of capacitances in latter case.

(*3*) Loading data:

(*a*) Spacing of loading coils and location of loading points.

(*b*) Inductance of the loading coils and identification of pairs which are loaded.

(*c*) Physical characteristics of loading apparatus.

(*4*) Long distance circuit layout map or equivalent, such as office diagrams (par. 1141a):

(*a*) Type and designation (par. 1140) of circuit in operation on each pair and each quad.

(*b*) The net loss of each telephone circuit.

(*c*) The location of all voice-frequency repeaters or carrier equipment, intermediate bridges, telegraph repeaters, extensions, regenerative repeaters, and other equipment on each circuit.

(*d*) Which circuits or pairs are idle.

(*e*) General plan of the transmission layout covering such items as usage of 2-wire and 4-wire circuits, phantoms, transmission levels, etc.

(*f*) The type of signaling used on each circuit.

(*5*) Power exposures, hazards, and other special conditions.

f. New Office Information. The following table lists the items of information required when a new office (central or repeater station) is to be erected:

(*1*) Location of possible sites relative to route of line.

(*2*) Transportation routes available to each site.

(*3*) Feasible types of construction and the time required to complete construction.

(*4*) Amount of floor space required and the arrangement of equipment.

(*5*) Available methods of supplying power.

(*6*) Method of heating.

(*7*) Suitable living quarters for the operating personnel.

g. Existing Office Information. The following table lists the information required when an existing office (central or repeater station) is to be used:

(*1*) Floor plan, showing:

(*a*) Location of each existing apparatus cabinet or other item of equipment whose location is fixed.

(*b*) Location of each cable runway.

(*c*) Location and size of windows, doors, and passageways.

(*d*) Ceiling height.

(*e*) Location of all space available for the installation of additional equipment.

(*f*) Probable floor strength in permissible pounds per square foot.

(*g*) Location of existing cable entrance.

(2) Equipment record, showing as much information as necessary:

(a) Type and location on the floor plan of all equipment associated with each pair, quad, or phantom group entering the office.

(b) Type and location of all idle equipment.

(c) Amount and location of all vacant space in apparatus cabinets or bays suitable for use in mounting packaged equipment.

(d) An inventory of all testing equipment.

(3) Heating and lighting arrangements.

(4) Power record, showing:

(a) Voltage, frequency, and reliability of present power supply.

(b) Present power load and method of distribution.

(c) Permissible power load on present power supply.

(d) Size of each power lead and present load on each lead.

(5) Suitable living quarters for operating personnel.

(6) Special factors.

1139. SELECTION AND LAYOUT OF CIRCUITS.

a. The layout of a complete communication system or the addition of circuits to an existing system requires a choice to be made between various kinds of lines and wire and between various types of voice-frequency, carrier, and radio systems. Information describing the various systems and their limitations is given in chapters 3, 5, and 6. Line construction methods are covered in chapter 9. By using the information in these four chapters, together with the information assembled as indicated in paragraph 1138, selections of equipment and line facilities can be made to establish the required type and number of circuits. An example of a procedure for laying out circuits is given in TM 11–2022.

b. It will be noted from chapters 3 and 5 that each type of circuit and system has a maximum allowable line section length between repeaters. The system or circuit requiring the shortest repeater section length along a given route will determine the maximum distance between adjacent offices. In order to avoid having too many repeater stations, and also for coordination reasons, common stations should be used for the repeaters on all circuits or systems taking the same route.

c. In planning the layout of circuits, consideration should be given to the effect that a failure of a pair or carrier system will have on service to a central. It is desirable, when practicable, to assign circuits so that a failure will not interrupt all of the circuits to a given central. It is also desirable to arrange carrier systems so that a suitably transposed pair is available for use if any regularly assigned pair fails. The desirablility of providing extra equipment or wire in order to protect service will be determined by circumstances.

d. Arrangements for communicating between offices by telephone or telegraph should be available on all routes carrying long circuits. Telephone communication can be established through the switchboard at centrals where terminating circuits exist. A d-c telegraph circuit can be assigned to interconnect any number of offices and used as an order wire with a teletypewriter at each office. Bell signals on the teletypewriter may then be used as a code to call a particuar office. These circuits are usually called test or order wires.

1140. CIRCUIT DESIGNATIONS.

a. Circuits can be conveniently designated by the names of the terminal centrals, unless security requirements make it desirable to use fictitious names, in which case L. of C. (Line of Communication) numbers can be assigned without terminal names. The number series may be expanded if desired, to provide a different number series for a particular branch of the Armed Services, or for point-to-point circuits. The principal kinds of circuits and a suggested number series follows:

Type of circuit	*Number series*
Message telephone, via grade	1–50
Message telephone, terminal grade	51–100
Message telegraph, via grade	101–150
Message telegraph, terminal grade	151–200
Point-to-point telephone	201–300
Point-to-point telegraph	301–400

b. In the case of carrier systems, it is also desirable to include the type of carrier system in the carrier designation. For example:

Circuit	*Type*
Algiers-Tunis, H carrier system No. 1	Single-channel telephone
Algiers-Tunis, C carrier system No. 3	3-channel telephone
Algiers-Tunis, v-f carrier system No. 101	4-, 8-, or 12-channel telegraph

1141. CIRCUIT RECORDS, PREPARATION, DISTRIBUTION, AND MAINTENANCE.

a. Records Required.

(*1*) *General.* The information on existing and new wire lines and offices assembled as indicated in paragraph 1138 should be recorded so as to become a permanent set of records for the circuit assignment office. The amount of information assembled and recorded will depend on circumstances, but, in general, it should be adequate so that additions or circuit rearrangements can be planned in advance. In addition, adequate pertinent information should be recorded on circuits or carrier systems so that they can be properly installed and maintained. The form of the required records may vary, but, in general, forms similar to those described in the following subparagraphs will usually be required as a part of any system of records. TM 11–462 gives the meaning of the symbols used in these records.

(*2*) *Line Route Map.* A line route map of the type shown in figure 11-33 serves as a permanent record of the geographical location of the line and offices on the route.

(*3*) *Circuit Layout Chart.* A chart similar to that shown in figure 11-35 serves as a permanent record of an existing open wire line. The pole head diagram (par. 1138d(3)), together with the information shown, is sufficient so that additions of wire can be planned.

(*4*) *Circuit Diagram.* A circuit diagram of the type shown in figure 11-34 shows the present use of outside plant facilities, the types and gauges of pairs, the location of equipment, line assignments, etc. The diagram is built up, beginning with the selection of the types of wire and equipment to be used. It may be necessary to prepare several diagrams before the best arrangement of lines and equipment is secured. For convenience such diagrams will be schematic (only roughly geographical at best) and will preferably be prepared to show as large a section as feasible on a single diagram. A drawing about 4 feet square is about as large as can be handled satisfactorily. Where a series of diagrams is necessary to show the complete layout, they should be designed for ready cross reference and preferably arranged so that they can be mounted, as on a large wall, to form connecting sections of a large over-all diagram. A circuit diagram may ordinarily be made complete where the number of facilities does not exceed about 30 in any section. Where a greater number of facilities exist in a single cross-section, as in the case of large cables, a supplementary record, in book form, may be desirable. Circuit diagrams should be prepared to permit ready posting and reposting of circuit assignments. One satisfactory arrangement for accomplishing this purpose involves a tracing on which the facilities are drawn on the back with the numbering of facilities and posting of circuits assigned to them on the front of the tracing. This permits erasure of circuit designations without disturbing facility symbols. If the time lag between issuance of orders and actual execution of circuit order changes is short, it will usually be satisfactory to post the new layout on the diagram prints used by the circuit assignment group at the time the orders are issued. If the time lag promises to be considerable, it may be necessary during the interim to show both old and new layouts, such as by striking out the old assignment instead of erasing it. The latter arrangement will be particularly desirable if there is a change in operating personnel, such as from day to night shift. At a minimum, the circuit diagrams should show:

(*a*) Length and kind of wire, including gauge.

(*b*) Pair numbers available and designation of line.

(*c*) Carrier systems established.

(*d*) Ownership of facilities, such as civil or Army.

(*e*) Circuit designation (name and number) of telephone and telegraph circuits assigned to various facilities.

(*5*) *Circuit Record Cards.*

(*a*) A circuit record card should be made up by the circuit assignment office for each telephone circuit, for each carrier system, and for each telegraph circuit. The forms shown in figures 11-36 and 11-37 may be used for all types of voice-frequency telephone circuits and for telegraph circuits respectively.

(*b*) The cards should be prepared before a circuit order is issued. In the field, the centrals and repeater stations will need the data on the cards to complete the circuit order. These cards are also needed for maintenance of the circuits. For further information, see paragraph 1142 and TM 11–2022.

(*6*) *Circuit Assignment Index.* An index or record of each trunk circuit and carrier system channel should be made up for each central and repeater station. This can be made by the circuit assignment office for the initial installation but probably will be maintained by local wire chiefs thereafter. It should show the line wire and entrance cable assignments, voice-frequency ringers, composite sets, and

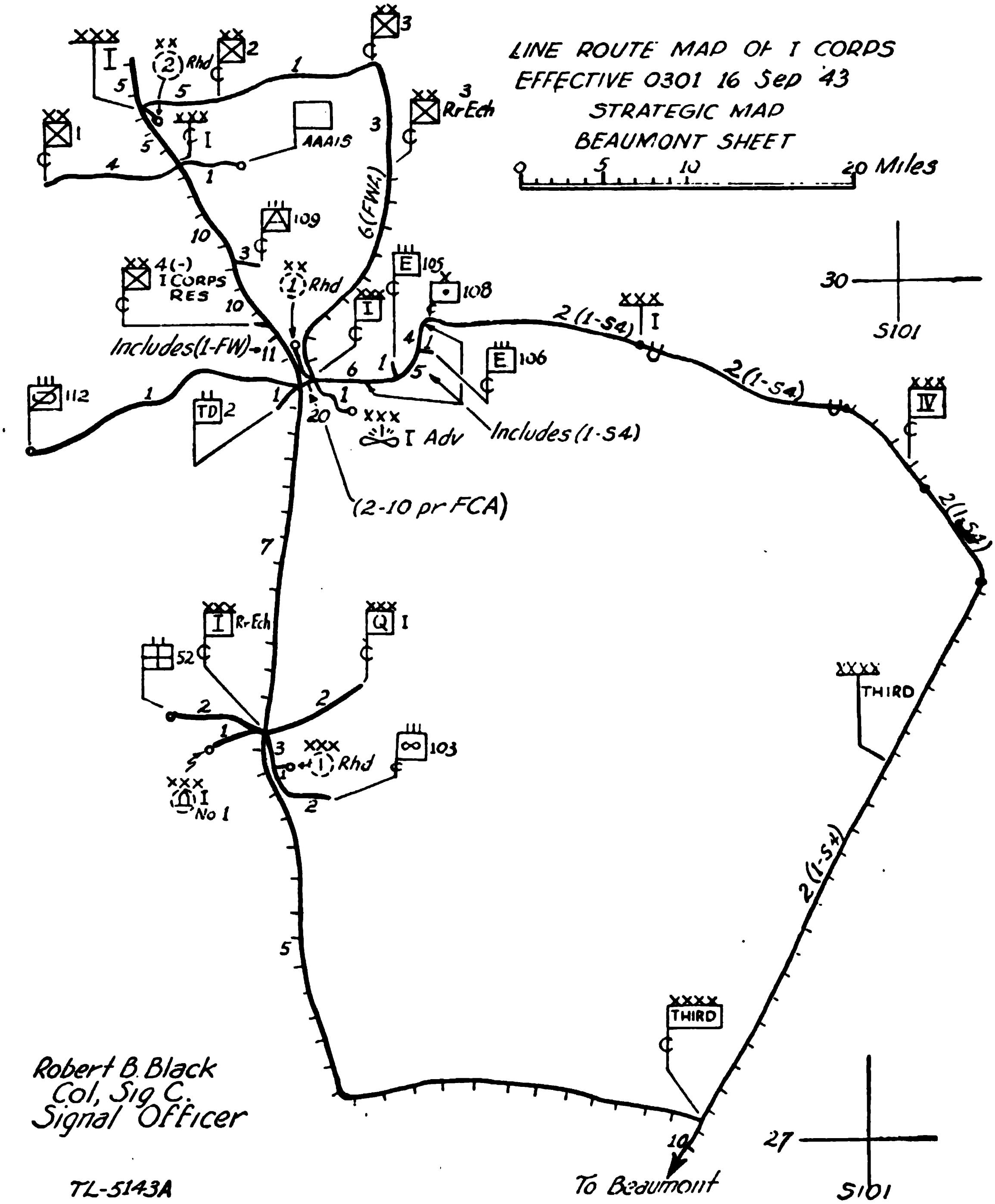


Figure 11-33. Line route map.

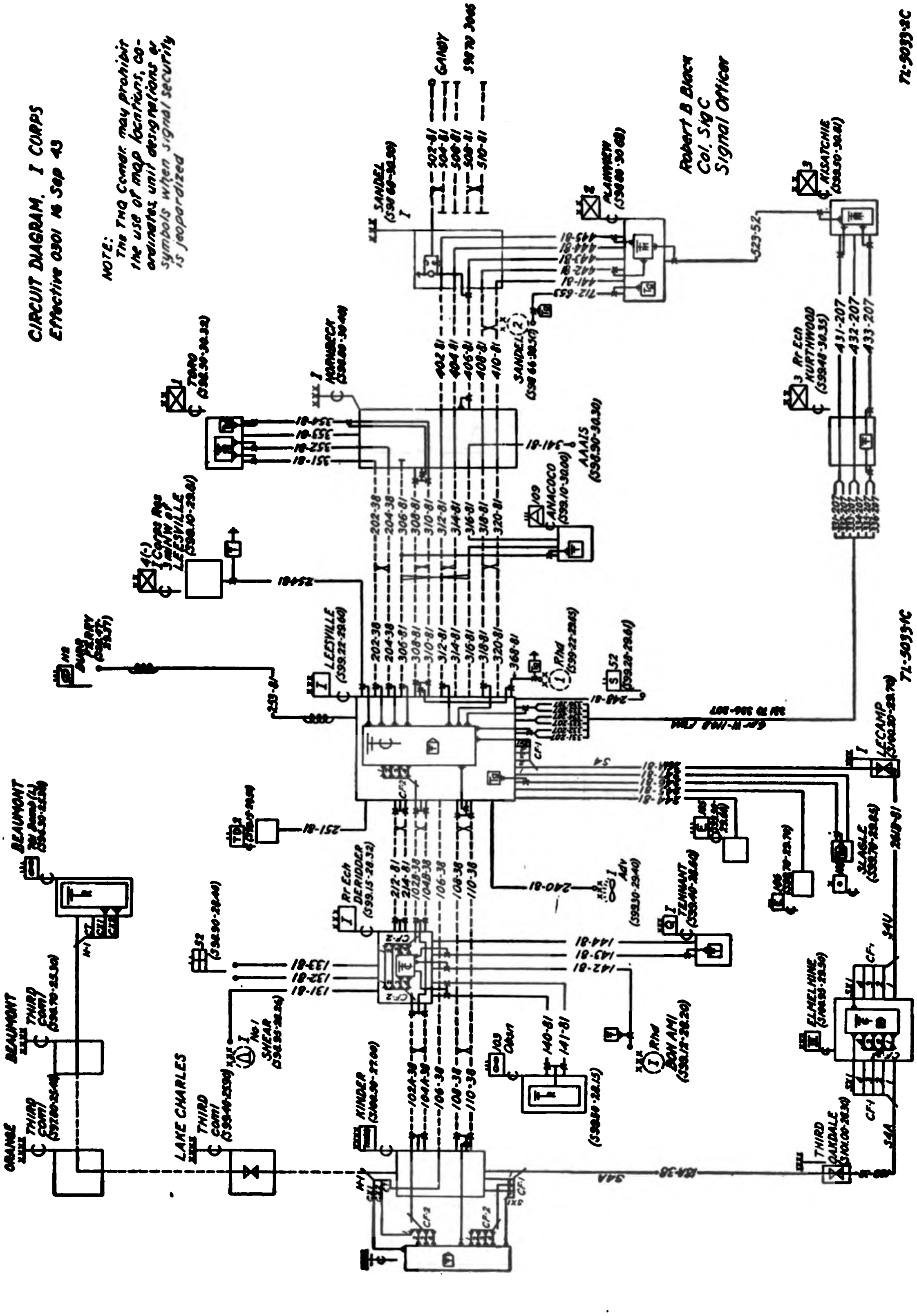
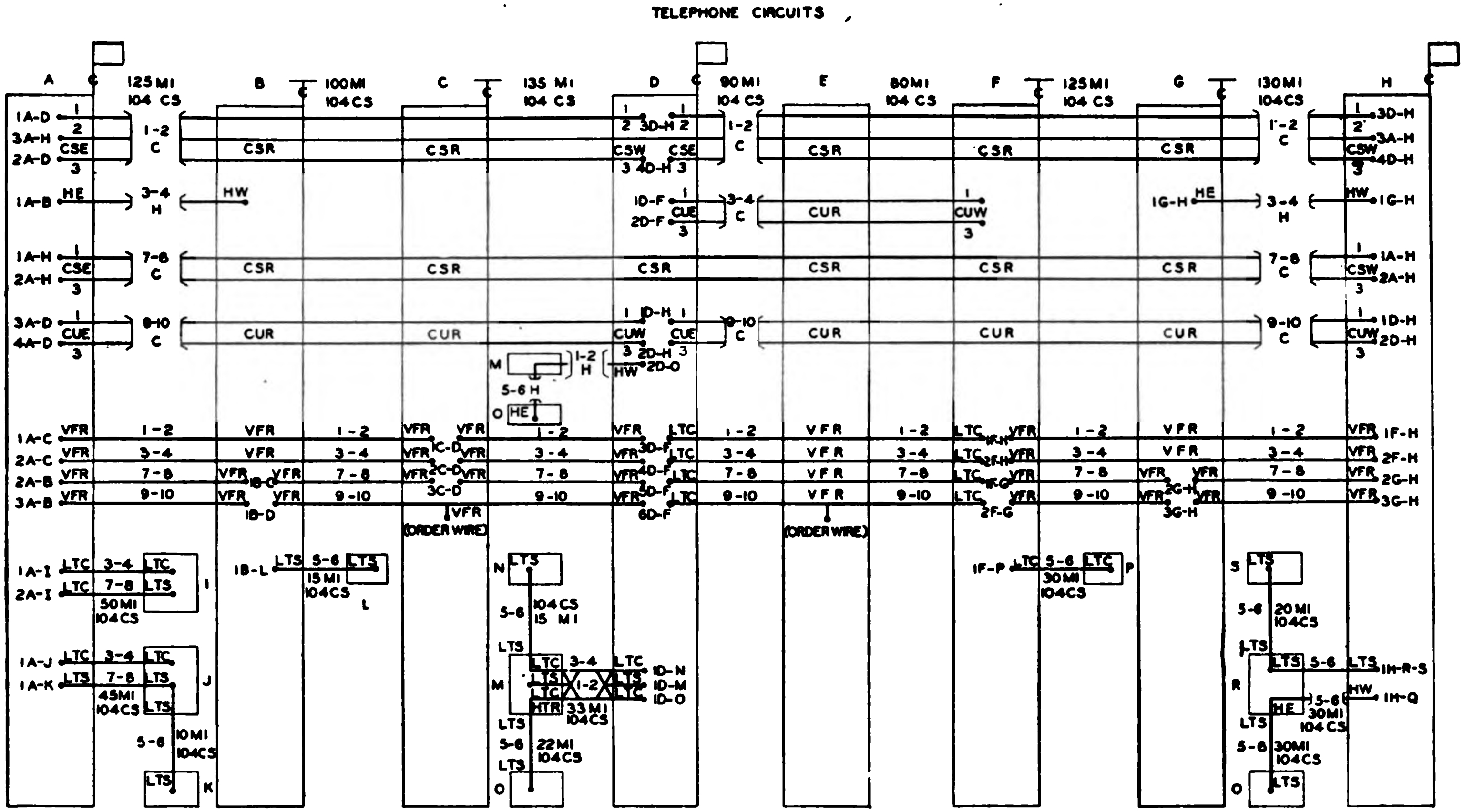


Figure 11-34. Circuit diagram.



NOTES:

1. PIN POSITIONS ABOVE LINE, 1-2, INDICATE V.F. TELEPHONE AND D-C TELEGRAPH WIRE CIRCUITS.
2. PIN POSITIONS IN LINE,)1-2 (, INDICATE CARRIER CHANNELS, TYPE C OR H, ON ASSOCIATED PAIRS.
3. X INDICATES PHANTOM LINE.
4. EACH CARRIER SYSTEM SHOULD BE NAMED AND NUMBERED. THIS CHART SHOWS THE FOLLOWING SYSTEMS:

TYPE C SYSTEMS	TYPE H SYSTEMS	V-F CARRIER TELEG. SYSTEMS
A-D NO. 1	A-B NO. 1	A-H NO. 1
A-D NO. 2	D-O NO. 1	A-D NO. 1
A-H NO. 1	G-H NO. 1	D-H NO. 1
D-H NO. 1	F-P NO. 1	D-F NO. 1
D-H NO. 2	H-R NO. 1	F-P NO. 1
D-F NO. 1		

5. ABBREVIATIONS FOR USE ON CIRCUIT RECORDS

TYPE OF EQUIPMENT		
CUE	C CARRIER, EAST TERMINAL,	CU ALLOCATION
CSE	C CARRIER, EAST TERMINAL,	CS ALLOCATION
CUW	C CARRIER, WEST TERMINAL,	CU ALLOCATION
CSW	C CARRIER, WEST TERMINAL,	CS ALLOCATION
CSR	C CARRIER, REPEATER	CS ALLOCATION
CUR	C CARRIER, REPEATER	CU ALLOCATION
HE	H CARRIER, EAST TERMINAL	
HW	H CARRIER, WEST TERMINAL	
HR	H CARRIER, REPEATER	
VFR	VOICE-FREQUENCY REPEATER	
LTS	LINE TERMINATING AND SIMPLEX PANEL	
LTC	LINE TERMINATING AND COMPOSITE PANEL	

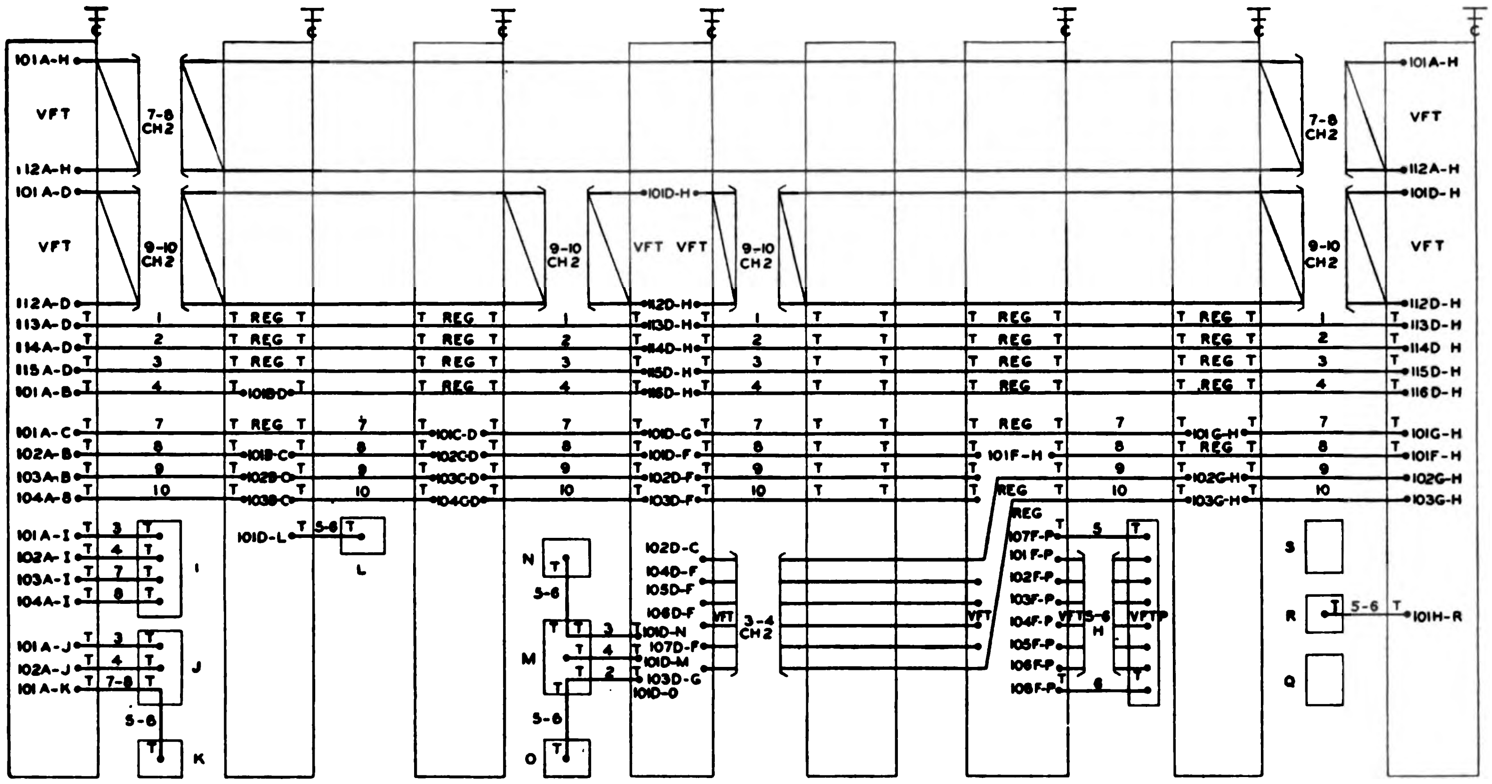
5 (CONTINUED)

TYPE OF EQUIPMENT	
VFT	VOICE-FREQUENCY CARRIER, TELEGRAPH TERMINAL
VFC	VOICE-FREQUENCY CARRIER TELEGRAPH CHANNEL TERMINAL
B	VOICE-FREQUENCY RINGER
CTR	C CARRIER TRANSFER SET
HTR	H CARRIER TRANSFER SET
BRG	BRIDGING CIRCUIT ON A VOICE REPEATER
T	D-C TELEGRAPH REPEATER
REG	D-C REGENERATIVE TELEGRAPH REPEATER
TT	TELETYPEWRITER STATION

TL 53205-S

Figure 11-35. *Circuit layout chart* *(continued on opposite page).*

TELEGRAPH CIRCUITS



NOTES:

1. PIN POSITIONS ABOVE LINE, 1-2, INDICATE V.F. TELEPHONE AND D-C TELEGRAPH WIRE CIRCUITS.
2. PIN POSITIONS IN LINE, 1-2, INDICATE CARRIER CHANNELS, TYPE C OR H, ON ASSOCIATED PAIRS.
3. I INDICATES PHANTOM LINE
4. EACH CARRIER SYSTEM SHOULD BE NAMED AND NUMBERED. THIS CHART SHOWS THE FOLLOWING SYSTEMS:

TYPE C SYSTEMS	TYPE H SYSTEMS	V-F CARRIER TELEG. SYSTEMS
A-D NO.1	A-B NO.1	A-H NO.1
A-D NO.2	D-O NO.1	A-D NO.1
A-H NO.1	G-H NO.1	D-H NO.1
D-H NO.1	F-P NO.1	D-F NO.1
D-H NO.2	H-R NO.1	F-P NO.1
D-F NO.1		

5. ABBREVIATIONS FOR USE ON CIRCUIT RECORDS

	TYPE OF EQUIPMENT
CUE	C CARRIER, EAST TERMINAL, CU ALLOCATION
CSE	C CARRIER, EAST TERMINAL, CS ALLOCATION
CUW	C CARRIER, WEST TERMINAL, CU ALLOCATION
CSW	C CARRIER, WEST TERMINAL, CS ALLOCATION
CSR	C CARRIER, REPEATER CS ALLOCATION
CUR	C CARRIER, REPEATER CU ALLOCATION
HE	H CARRIER, EAST TERMINAL
HW	H CARRIER, WEST TERMINAL
HR	H CARRIER, REPEATER
VFR	VOICE-FREQUENCY REPEATER
LTS	LINE TERMINATING AND SIMPLEX PANEL
LTC	LINE TERMINATING AND COMPOSITE PANEL

5. (CONTINUED)

	TYPE OF EQUIPMENT
VFT	VOICE-FREQUENCY CARRIER TELEGRAPH TERMINAL
VFC	VOICE-FREQUENCY CARRIER TELEGRAPH CHANNEL TERMINAL
B	VOICE-FREQUENCY RINGER
CTR	C CARRIER TRANSFER SET
HTR	H CARRIER TRANSFER SET
BRG	BRIDGING CIRCUIT ON A VOICE REPEATER
T	D-C TELEGRAPH REPEATER
REG	D-C REGENERATIVE TELEGRAPH REPEATER
TT	TELETYPEWRITER STATION

TL 53206-S

Figure 11-35. Circuit layout chart (continued).

switchboard location of each channel. This record (office diagram) will be required for quickly locating the equipment to permit testing in case of trouble.

CIRCUIT RECORD - TELEPHONE

DATE 27 April 1944

CIRCUIT OR #1a (EAST) C (WEST) NET LOSS 6 db

CARRIER SYSTEM (EAST) (WEST)

CONTROL OFFICE TYPE

OFFICE	EQUIP.	TOWARD EAST: V.F. REPEATER AMP GAIN	ATT.	BAL.	OUT-PUT	TERM.	TOWARD WEST: V.F. REPEATER AMP GAIN	ATT.	BAL.	OUT-PUT	TERM.	C CARR. PADS: TRSO.	REC.
a	VFR	20.5	0		-2	2W	33.5	17.5		+10	2W		
B	VFR	33	5.0		+10	2W	30	0		+7.5	2W		
C	VFR	33.5	17.5		+10	2W	21	2.5		-2	2W		

FROM	TO	SYSTEM OR LINE	CHAN. OR WIRES	GAUGE & TYPE	LENGTH MILES	ASSOCIATED CONNECTED EQUIPMENT
a						C1E, B
	B	a-B	1-2	104 C1	125	C1R
B						C1R
	C	B-C	1-2	104 C1	100	C1R, B

Pair 1-2 composited from a & C

TL 54963

Figure 11-36. Telephone circuit record card.

b. Distribution and Maintenance of Records.

(*1*) The distribution and maintenance of records should be limited to actual need, with due regard to security requirements.

(2) The essential records for area offices are the line route maps and circuit diagrams for their particular area, the equipment record for each central and repeater station, and the circuit record cards for each trunk circuit in the area.

(*3*) The wire chief at each central and repeater station will require an equipment record of his office showing the chief items of equipment that are used in trunk circuits, a circuit record card for each through or terminating trunk circuit, and a circuit diagram for that part of the system for which he is responsible. The last, for use in trouble clearing, should show junctions, etc. He will also require and keep up to date the circuit assignment index.

(*4*) The best rule that can be given for issuance of new circuit diagrams is to do it as often as necessary, that is, when major changes occur or minor changes accumulate.

(*5*) An economical procedure is to require the area offices to post ordinary changes on their circuit diagrams, leaving it up to them to request new copies when needed, either because too many changes have accumulated or because their records are wearing out.

(*6*) Circuit record cards should be distributed to every location that will have work to do in connection with establishing or maintaining the circuit, including terminal centrals, intermediate centrals, and repeater stations. The cards should accompany the circuit order that establishes the circuit or they can be sent later in case of telegraphic circuit orders.

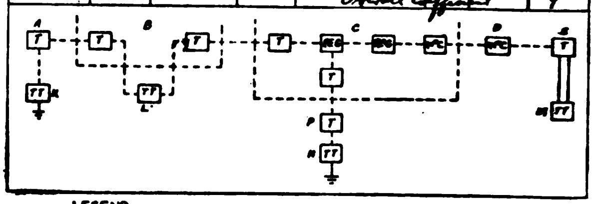
CIRCUIT RECORD - TELEGRAPH

CIRCUIT 101-(A-E-P) DATE [illegible]

SPEED [illegible] HALF DUPLEX ☑ FULL DUPLEX ☐

CONTROL OFFICE C

FROM: STATION OR OFFICE	TYPE OF EQUIP	TO: STATION OR OFFICE	TYPE OF EQUIP	LINE OR CARRIER SYSTEM	PIN OR CARRIER CHANNEL	SIZE WIRE	LENGTH	COEFFICIENT
		Section A-C						
K	M11 [illegible]	A	J	K-A	5-6	[illegible]	3	2
A	J	B	J	A-B	3	[illegible]	75	10
B	J	C	J	B-C	4	[illegible]	50	
J	MNBT	D	[illegible]	J-D	1-2	[illegible]	1	0
					Overall Coefficient			12
		Section C-M						
C	VFJ	D	VFC	CD#1	CH 5		200	3
D	VFJ	E	J	D-E	5-6	[illegible]	40	7
E	J	M	MNBT				0	0
					Overall Coefficient			10
		Section C-N						
C	J	P	J	C-P	7-8	[illegible]	50	7
P	J	N	MNBT	P-N	1-2	[illegible]	5	2
					Overall Coefficient			9



LEGEND
TT = TELETYPEWRITER
T = D-C TELEGRAPH REPEATER
REG = D-C REGENERATIVE TELEGRAPH REPEATER
VFC = VOICE-FREQUENCY CARRIER TELEGRAPH

TL 54962

Figure 11-37. Telegraph circuit record card.

1142. COMPUTATIONS FOR RECORD CARD, VOICE-FREQUENCY REPEATERED CIRCUIT.

a. This paragraph describes a method which can be used to obtain the data required to fill out a record card (fig. 11-36) for a circuit using packaged voice-frequency repeaters. The required information consists of the amplifier gain, the attenuator loss, and the repeater output level for each repeater on the circuit. The column BAL is provided on the record card for recording the value of the balance between the line and the network, as measured in accordance with the procedures given in manuals on the repeater.

b. Transmission level diagrams based on information given in chapter 5 and illustrated in figure 11-38 will indicate the transmission levels into and out of the repeater and the required gain of the repeater, for each direction of transmission. This information, together with the input and output equipment losses, can be used to determine the required amplifier gain and attenuator loss. An example of the factors involved in making the amplifier and attenuator adjustments is shown in figure 11-39. The input and output equipment losses, the magnitude of which depends upon the types of connecting lines, are shown in figures 11-40 and 11-41. Equipment losses for 4-wire circuits are given in figure 11-42.

c. An example of the computations involved in repeater adjustments is shown in figure 11-43. It is assumed that the repeaters are used on an 080 copper-steel open wire line. The computations are made in the following manner:

(*1*) Prepare a level diagram (chs. 5 and 12) such as that shown in figure 11-38.

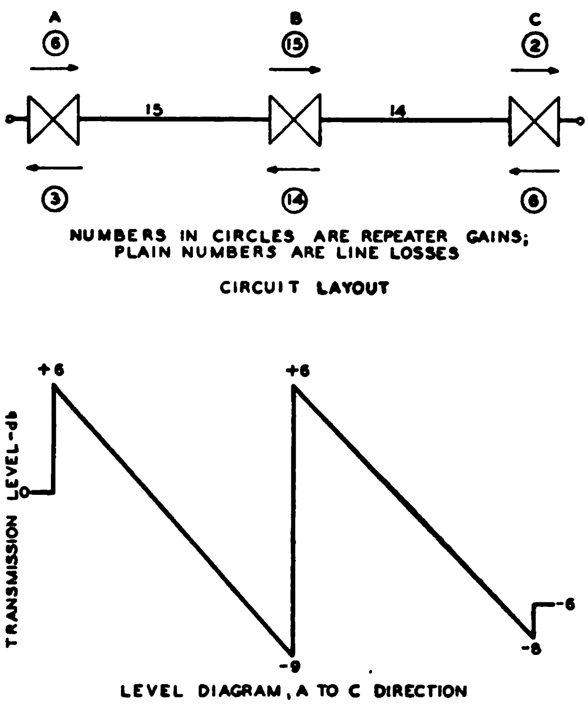


Figure 11-38. Level diagram for a voice-frequency circuit and repeater.

(*2*) Compute an attenuator loss such that the transmission level at the amplifier input (fig. 11-39) will be as close as possible to –23 db after taking into account the input equipment loss and the transmission level at the repeater input, as read from the level diagram. The attenuator is adjustable in 2.5 db

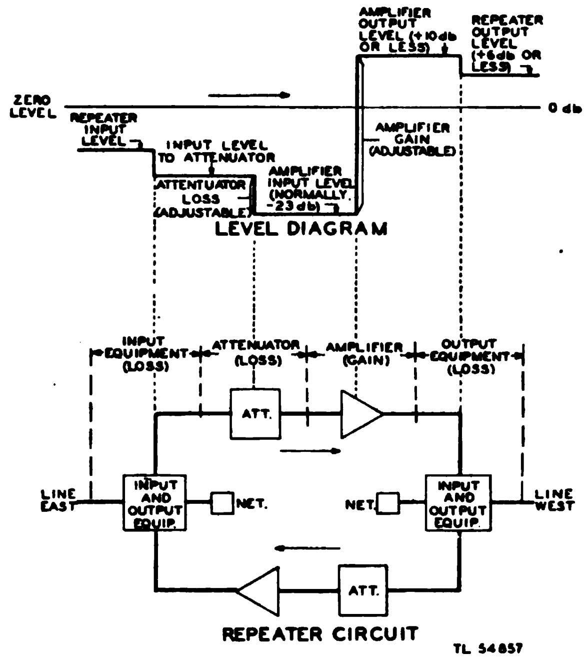


Figure 11-39. Two-wire voice-frequency repeater circuit and level diagram.

steps from 0 to 17.5 db, so in general it will not be possible to adjust exactly to –23 db. The transmission level at the amplifier input should be computed for the attenuator setting used.

(*3*) Compute the level at the amplifier output (fig. 11-39). This is equal to the transmission level at the repeater output, as read from the level diagram, plus the output equipment loss.

(*4*) Compute the amplifier gain by subtracting the transmission level at the amplifier input from that at the amplifier output.

d. The computations given in subparagraph c above cover only one direction of transmission, A to C. Similar computations are required for the opposite direction of transmission, C to A.

e. The procedure for 4-wire circuits is essentially the same as that described for 2-wire circuits.

Type of circuit	*Side or phantom*	*Equipment losses (db)* [a]	
		Input	*Output*
165 Copper	Side	6.0	4.5
165 Copper	Phantom	6.3	4.5
128 Copper	Side	6.0	4.5
128 Copper	Phantom	6.3	4.5
104 Copper	Side	6.0	4.5
104 Copper	Phantom	6.3	4.5
080 Copper	Side	6.2	4.4
080 Copper	Phantom	6.4	4.5
165 C-S 40%	Side	6.5	4.4
165 C-S 40%	Phantom	6.4	4.6
128 C-S 40%	Side	6.9	4.2
128 C-S 40%	Phantom	6.7	4.4
104 C-S 40%	Side	6.9	4.1
104 C-S 40%	Phantom	6.8	4.3
080 C-S 40%	Side	7.5	3.9
080 C-S 40%	Phantom	7.4	4.1
128 C-S 30%	Side	6.9	4.1
128 C-S 30%	Phantom	6.8	4.3
104 C-S 30%	Side	7.5	3.9
104 C-S 30%	Phantom	7.3	4.2
109 GS	Side	8.9	3.8
109 GS	Phantom	8.8	3.9
083 GS	Side	7.7	3.7
083 GS	Phantom	7.8	3.9
Switchboard side of terminal repeater		5.5	5.0

[a] The losses are for 1,000 cycles and 600-ohm measuring sets. Figures apply to any spacing of wires which may be found, since impedance variations from this cause are small (ch.5).

Figure 11-40. Equipment loss data for packaged voice-frequency repeaters on open wire circuits.

Type of circuit	*Loading system* [a]	*Equipment loss (db)* [b]	
		Input	*Output*
Paper-insulated cable			
16 ga. side	6000-88-50	5.0	4.2
16 ga. phantom	6000-88-50	6.0	4.4
19 ga. side	6000-88-50	5.0	4.2
19 ga. phantom	6000-88-50	6.0	4.4
16 ga. side	6000-172-63	6.2	4.1
16 ga. phantom	6000-172-63	6.0	4.3
19 ga. side	6000-172-63	6.2	4.1
19 ga. phantom	6000-172-63	6.0	4.3
16 ga. side	6000-44-25	6.0	4.4
16 ga. phantom	6000-44-25	4.9	4.6
19 ga. side	6000-44-25	6.1	4.3
19 ga. phantom	6000-44-25	5.9	4.6
16 ga. side	3000-88-50	6.2	4.1
16 ga. phantom	3000-88-50	6.1	4.2
19 ga. side	3000-88-50	6.2	4.1
19 ga. phantom	3000-88-50	6.1	4.2
16 ga. side	Nonloaded	10.8	3.5
19 ga. side	Nonloaded	10.7	3.5
Rubber-insulated wire and cable			
Wire W-143	Nonloaded	10.9	3.3
Wire W-143	3300-44	7.5	4.3
Wire W-143	3300-88	6.1	4.2
Cable Assembly CC-358-( )	1320-6	6.1	4.6
Switchboard side of terminal repeater		5.5	5.0

[a] The first number is the coil spacing in feet, the second is the inductance of the side circuit loading coil in millihenries, and the third, when present, is the inductance of the phantom loading coil in millihenries.

[b] The losses are for 1,000 cycles and 600-ohm measuring sets.

Figure 11-41. Equipment loss data for packaged voice-frequency repeaters on 2-wire cable circuits.

Type of circuit	*Loading system* [a]	*Equipment loss (db)* [b]	
		Input	*Output*
19 ga. side	6000-88-50	2.4	1.0
19 ga. phantom	6000-88-50	2.4	1.0
19 ga. side	6000-172-63	2.4	1.0
19 ga. phantom	6000-172-63	2.4	1.0
19 ga. side	6000-172-63	2.4	1.0
19 ga. phantom	6000-172-63	2.4	1.0
19 ga. side	Nonloaded	5.9	1.0
Switchboard side of terminal repeater		5.5	5.0

[a] The first number is the coil spacing in feet, the second is the inductance of the side circuit loading coil in millihenries, and the third, when present, is the inductance of the phantom loading coil in millihenries.

[b] The losses are for 1,000 cycles and 600-ohm measuring sets.

Figure 11-42. Equipment loss data for packaged voice-frequency repeaters on 4-wire cable circuits.

Item	*Transmission levels, losses, and gains*	*Values obtained from*	*Repeater location (fig. 11-38)*		
			A	*B*	*C*
1	Level at repeater input	Figure 11-38	0	−9	−8
2	Input equipment loss	Figure 11-40	5.5	7.5	7.5
3	Attenuator loss	Computed	17.5	7.5	7.5
4	Level at amplifier input	Computed (item 1 − item 2 − item 3)	−23	−24	−23
5	Level at repeater output	Figure 11-38	+6	+6	−6
6	Output equipment loss	Figure 11-40	3.9	3.9	5
7	Level at amplifier output	Computed (item 5 + item 6)	9.9	9.9	−1
8	Amplifier gain	Computed (item 7 − item 4)	32 9	33.9	22

Figure 11-43. Illustration of computations of attenuator loss, amplifier gain, and amplifier output.

Section IX. CIRCUIT ASSIGNMENT WORK

1143. GENERAL.

a. The problems of making circuit assignments for both radio and wire circuits in a theater of operations are somewhat similar. Circuits in the fixed plant, such as long distance telephone trunks and radio circuits, may be assigned by the theater of operations signal staff as indicated in figure 11-1. Circuits extending beyond the fixed plant into the tactical zone may be controlled from theater headquarters. The circuit assignment work described in the following paragraphs applies particularly to the long distance telephone and radio circuit assignments made by the staff for the fixed plant. However some of the suggestions may have application in the assignment of tactical circuits.

b. The work of preparing and issuing trunk circuit orders is called trunk circuit assignment work. The organization responsible for the initial system circuit layout should continue to operate as a centralized assignment organization for the day to day circuit changes, unless otherwise specified.

c. Each long distance wire or radio trunk circuit added, changed, or discontinued will require a circuit order authorizing the work. It should be issued to each location which will have work to do in connection with the order or which will be involved in maintaining the circuit. Written orders are desirable for record purposes, but it may be necessary at times to transmit them by telephone or teletypewriter with subsequent confirmation by a written order. A circuit order assigns the facilities that are to be used to make up a trunk circuit. A pair, a phantom, a carrier channel, a simplex, or a composite channel are called facilities.

d. Because of the various types of long distance wire circuit facilities and terminal equipment, circuit assignment work is frequently complicated and must be planned and carried out with extreme care. There may be 25 or more circuit orders per week in a given active theater of operations, depending upon its size. Many of the orders will require rapid and accurate planning and execution.

e. Radio circuit changes may not be as numerous as in the wire service but will require similar distribution of circuit orders to the locations involved in changes.

1144. CENTRALIZED CIRCUIT ASSIGNMENT OFFICES.

a. General. In the proper handling of circuit assignment work, centralized circuit assignment offices are necessary. The one for wire service probably will be in the wire engineering group and the one for the radio service probably will be in the radio group. However, control for a base section area may be delegated to base sections, if desirable. The assignment office, in the wire service, functions to plan the work required to accomplish the desired circuit changes, and to coordinate it within the various organizations involved. The office in the radio service coordinates call sign and frequency assignments. Responsibility for prompt execution of the plans normally is delegated to a particular office known as the control office, and designated by the centralized assignment office (par. 1105).

b. Wire Service; Requirements. In order to acaccomplish the work required of a centralized circuit assignment office in the wire service, the basic requirements are:

(*1*) Skilled and careful personnel, aware of the importance of this work.

(*2*) Records of facilities and equipment available or in prospect, and of the current use of existing facilities and equipment.

(*3*) Requirements for circuit changes.

(*4*) Knowledge of the field personnel who will be engaged in the actual work, particularly with regard to their qualifications for doing such work.

(*5*) Authority to issue, and means of issuing circuit orders for necessary changes.

(*6*) Means for receiving reports of completion on circuit orders issued.

(*7*) Systematic designation of facilities and circuits.

c. Wire Service; Personnel. The personnel requirements for an assignment office in the wire service are:

(*1*) Engineers with ability to plan and direct the work and whose duties include:

(*a*) Proper design of circuits and circuit changes to meet allowable transmission losses in the most economical manner with minimum lost circuit time in making circuit changes.

(*b*) Prompt investigation of all difficulties encountered in new or existing circuit layouts and issuance of adequate instructions for applying suitable remedial measures.

(*2*) Clerical personnel to:

(*a*) Prepare and maintain records.

(*b*) Prepare and issue authorized circuit orders and circuit record cards.

d. Radio Service. The personnel assigned to this work should be engineers or others with a thorough understanding of radio communication. They must have authority and means for issuing circuit orders for necessary changes.

e. Records. In assuming control of an existing record layout, a review as to its adequacy and accuracy should be made. Where record layouts are to be newly established, careful work is required to provide a satisfactory record. Improving the records is a continuous process, requiring constant alertness to detect errors, conscientious reporting of errors found, and a routine for such reporting. The records listed in paragraph 1141 are essential for wire circuit assignment offices.

1145. LONG DISTANCE WIRE CIRCUIT ORDERS; GENERAL.

a. Circuit orders for long distance wire trunks may be issued in different forms and convey various information.

b. Planning of these trunk circuit orders requires skill and ingenuity in order to devise a smoothly working arrangement for making a required set of circuit changes in proper sequence. The objective is to give adequate, concise, and precise instructions.

c. In the ordinary case, particularly at the start, the assignment office is likely to be continually pressed to set up more or different circuits. This will require careful scheduling and coordination so that, as far as possible, the more urgently needed circuits are established first, and future changes can be scheduled with a fair degree of assurance that the schedule can be met. In addition to ordinary circuit changes, temporary changes may have to be made quickly to minimize the effects of line trouble or to meet a temporary increase in traffic to a particular office. Wire chiefs on their own initiative may make temporary patches to replace a section of a trunk that is in trouble.

1146. CIRCUIT ORDER DETAILS.

a. Introduction to Order. The introduction to a trunk circuit order should show pertinent information as follows:

(*1*) Date and place of issuance, serial number, and the person who has authorized it to be issued.

(*2*) Purposes for which the order is issued. This normally consists of statements summarizing the changes covered, including such items as circuits added, discontinued, or changed; facilities or equipment released from service (as when they are to be removed); and the establishing of a new central or signal center or the moving of an existing one.

(*3*) Conditions under which the changes are to be made, including such items as:

(*a*) New facilities or equipment required for completion of the order, showing the time at which they are expected to be available (and preferably under what order they are being installed). The places involved can correct their records from circuit orders.

(*b*) Coordination with other circuit orders, such as, *assumes circuit order CO 259 in effect.*

(*c*) Time when order is to be completed, as on a specific date, as soon as possible, etc.

(*d*) Assignment of responsibility for supervising the execution of the changes, usually one of the following arrangements:

1. Circuit control offices.[4] (If there are several separate and distinct changes on one order, the control office on each individual circuit involved controls the work on that circuit.)

2. Circuit control office of the principal circuits involved (if there are several changes most of which involve the one control office.)

3. The office that will have to execute all of the changes. (If a new entrance cable is being installed and many circuits have to be transferred from their existing entrance facilities to the new cable, thus involving various control offices.)

(*e*) Completion tests required, if different from the standard tests.

(*f*) Completion reports required, if different from the regular reports. (In case of special urgency, telegraph or telephone report may be required.)

(*g*) Special conditions, such as, *circuits involved may be taken out of service only between 2400 and 0500 hours.*

(*h*) An index or list of items, especially in the case of large orders. Such a list may be used conveniently for assigning supervision and indicating completion reports as required.

b. Body of Order. The body of the circuit order can be prepared in memorandum form, written in a systematic manner. It should indicate the end of groups of related changes, commonly called steps, that is, the points at which work can be stopped without leaving any circuits out of service, and should show an item number for each change. The style preferably should permit transmission by teletypewriter, facsimile, or even by telephone. It can list a moderate number of related changes or a large number of independent changes. Where a large number of similar changes are required, time can often be saved

[4] The importance of establishing a control point in European international telephony was recognized at the Budapest plenary meeting of the CCIF (International Consultative Committee on Telephony) in September 1934 at which the following rule was recommended: "One of the stations through which a circuit passes is responsible for satisfactory transmission on that circuit. This station is called the *control station;* it is chosen by agreement between the technical departments of the Administrations and operating companies involved. Unless otherwise arranged between the technical departments interested, the control station will be one of the terminal stations of the circuit."

by tabulating the changes, that is, describe the change once and list the circuits and facilities involved. The order should be a natural arrangement to consist of the information the engineer would normally write out in planning an order, working either directly from records or, in a complicated case, from a work diagram, to describe the changes. This narrative form of order places reliance on the assumption that the centrals, repeater stations, and signal centers have circuit record cards for each existing circuit entering or passing through their office, and receive cards with the circuit order for each new or rearranged circuit. There is considerable opportunity for use of abbreviations. A sample circuit order and a sample completion report shown in figures 11-44 and 11-45, respectively, illustrate the application of many of the above items.

```
FROM        LAYT WIRE DIV. FHQ271500A
TO          CENTRL CITY WIRE CHIEF FAC
            WIRE OFFICER, 3063RD SIG REGT
            PLANT BRANCH WESTERN BASE SECTION
            C30 L/C ATLANTIS     ATTN LINES OFFICER
            3 COY, 91ST L/C SIGNALS
            HUDSON WIRE CHIEF
L.D. CIRCUIT ORDER NO. 627
27 APRIL 1944
PURPOSE     DISCONTINUE SERVICE SNAPPY /KINGSTON/ TO LOOKOUT START
            SERVICE SNAPPY /KINGSTON/ TO TOPPER
REQUIREMENTS  NEW PAIR HUDSON - TOPPER, HUDSON WIRE CHIEF PROVIDES.
              REMOVE PAIR CENTRAL CITY-LOOKOUT, SIGNAL OFFICER WBS
              RECOVERS.
SUPERVISION  CENTRAL CITY WIRE CHIEF SUPERVISES THESE CHANGES WHICH
               ARE TO BE COMPLETED FORTHWITH.
DETAILS
          1. DISCONTINUE SNAPPY /KINGSTON/ - LOOKOUT SPEECH CIRCUIT
             L OF C62 FROM PR 24 CENTRAL CITY - KINGSTON U G CABLE
             LOCAL FACILITIES KINGSTON - SNAPPY ARE REUSED BY ITEM 4.
             LOCAL FACILITIES CENTRAL CITY - LOOKOUT TO BE REMOVED.
          2,3 REROUTE SNAPPY / KINGSTON/ - FLINT SPEECH CIRCUIT
             L OF C 67 AND S PLUS D, L OF C 73 THEREON FROM PR 13
             CENTRAL CITY - HUDSON U G CABLE PR 29/30 HUDSON-
             KINGSTON U G CABLE TO PR 24 CENTRAL CITY - KINGSTON U G
             CABLE CLEARED BY ITEM 1. ASSUMES LD CO246 IN EFFECT
          4. ADD L OF C 51, SNAPPY /KINGSTON/ - TOPPER SPEECH
              CIRCUIT ON PR 29/30 HUDSON - KINGSTON U G CABLE
             AT KINGSTON REUSE LOCAL FACILITIES RELEASED BY ITEM 1
             AT HUDSON PROVIDE NEW LOCAL FACILITIES.
          5. LEAVE IDLE PR 13 CENTRAL CITY - HUDSON U G CABLE
BT 271500A
AP E                                                   TL 53207-S
```

Figure 11-44. Sample circuit order.

```
TO      WIRE DIV. FHQ
        WIRE OFF 3063 SIG REGT
        C30 L/C ATLANTIS: ATTENTION LINES OFFICER
        PLANT BRANCH WESTERN BS
        HUDSON WIRE CHIEF
FROM    CENTRAL CITY WIRE CHIEF
COMPLETION REPORT TOLL CIRCUIT ORDER NO. 627 27 APRIL 1944
     1. LD CIRCUIT ORDER 627 COMPLETED WITHOUT EXCEPTIONS 26/4/44 2100
     2. ALL OFFICES CONCERNED HAVE BEEN NOTIFIED
CE 290610A
AR                                                     TL 53208-S
```

Figure 11-45. Sample completion report.

c. Special Circuit Orders. Special circuit orders may be desirable, such as a preliminary order to prepare for later changes, subdivision of a large order into parts, or a supplement to the original order covering changes in plan. The supplement should cancel the items in the original order which are incorrect or no longer required, and then list the changes. Extensive corrections are very difficult to handle. In each of these special cases the various parts of the order carry the one serial number as *CO 140A, or CO 140A supplement No. 1,* to show its relation to the original order *CO 140.*

d. Distribution of Orders. Distribution of circuit orders and cards should be direct to all concerned and not via lines of organization. Wherever possible, circuit orders should be originally delivered in written form. When greater speed is required, transmission of orders by teletypewriter is the first choice. The teletypewriter test wire network which generally exists along the main routes can be used for the distribution of circuit orders. Oral orders are the last choice and should be confirmed promptly by written orders and circuit record cards to avoid errors and omissions in records. The circuit assignment office should keep a record of the distribution made on all orders and cards issued.

e. Filing of Circuit Orders and Cards.

(*1*) The circuit assignment office should maintain a complete file of all circuit orders (with useful work sheets) and circuit record cards issued, transferring cards to a dead file when they are superseded. It is frequently convenient to refer to these dead cards in planning later changes or reviewing former layouts.

(*2*) Area offices, centrals, repeater stations, and signal centers need to maintain only an active card file, destroying superseded cards when the superseding change is completed. Circuit orders need be retained only until they are completed or for a short period, such as one month, after completion.

1147. CIRCUIT ORDERS FOR PACKAGED CARRIER EQUIPMENT.

a. The general plan can be applied to trunk circuits using packaged carrier equipment. However, some differences in detail will be required. TM 11–2022 and TM 11–2037 give complete details of the circuit order information required for use with packaged carrier equipment.

b. It is desirable to send a complete set of the various forms to each place involved in a change of circuit layout. When this is not practicable the equivalent information should be sent by teletypewriter or telephoned.

Section X. INSTALLATION

1148. GENERAL.

This section gives a general outline of the practices applicable to the installation of telephones, teletypewriters, centrals, signal centers, and carrier equipment. The information relates chiefly to fixed plant installations and mobile equipments. References are given to the appropriate technical manuals that apply to the different types of installations.

1149. TELEPHONE STATION INSTALLATION.

a. General. The methods, wire, miscellaneous material, and tools used in placing telephone and teletypewriter wires outside and inside of buildings, and for placing the telephones, are described in detail in TM 11–474 and FM 24–20. Placing cable outside and inside of buildings is discussed in section VII.

b. Installation of Drop Wires.

(*1*) *Wiring Practices.* Commercial practice is followed in the methods of terminating drop wires on poles and buildings. Drop wires are used in spans between poles, from pole to building, from open wire to telephone protector, and from cable terminal to telephone protector. A variety of fixtures such as drive hooks, clamps, drive anchors, toggle bolts, knobs, and insulator supports are available. Clearance from objects that may damage the wire covering by abrasion is important. Suitable clearance is necessary above objects such as tracks, roadways, and traveled pathways. Separation from power wires in crossings, parallels, and joint use must be observed. Requirements on clearances are given in TM 11–474.

(*2*) *Types of Drop Wire.*

(*a*) Wire W–50, twisted pair, solid No. 14 B&S gauge hard drawn copper separately insulated with rubber compound and asphalt-impregnated weatherproof braid with a tracer thread in the braid of one wire.

(*b*) Wire W–108, two conductors, solid No. 17 B&S gauge bronze or copper-clad steel, separately insulated with rubber compound on each wire but both wires encased in the same outer covering which is asphalt-impregnated braid with a tracer ridge on the compound of one conductor.

(*c*) Wire W–108–A, is a modification of Wire W–108 in having solid No. 18 B&S gauge conductors; otherwise the same as Wire W–108.

(*d*) Commercial parallel drop wires, designated BP, TP, BR, or TR (Western Electric Company designations). The BP (same as W–108) and TP (same as W–108–A) are for normal runs, and BR and TR, which have heavier braid and heavier rubber insulation on the individual conductors, are for drops subject to slight abrasion against foliage or branches.

c. Telephone Station Wiring.

(*1*) *General.* The practices for wiring inside of buildings to connect the outside wire to the protectors and from there to the telephones, are similar to those of the commercial telephone companies and are shown in detail in TM 11–474.

(*2*) *Wiring Practices.* If the point of entrance is subject to choice, it should be located to obtain minimum length of inside wire and in such a manner that the inside wiring can be protected from ordinary mechanical and moisture damage. Sections of the wire likely to be subject to damage should be wrapped with friction tape. Wiring should usually be run clear of the floor and fastened about every 3 feet with wiring nails or cleats, or be supported in drive rings. Drive rings permit greater flexibility, as four to six pairs can be strung through the same rings. On semi-permanent installations, splices should be soldered or made with sleeves. The installation time per telephone will average approximately 0.75 man hour under ordinary conditions.

(3) *Telephone Location.* In locating a telephone, the installer should be guided by the wishes of the using personnel, but should have a few fundamental requirements in mind and endeavor to fit these in with the wishes of the user. These requirements are: a location where the bell will be clearly heard by the user; a dry location; separation from metallic substances such as radiator or sink; sufficient light at all times, particularly for dial telephones; accessibility for inspection and repair; and avoidance of excessive vibration. Backboards should be used where bell boxes or wall telephones are to be mounted on masonry, solid metal, metal lath, or metal sheath walls, and on rough, uneven, or damp surfaces.

(4) *Protector Location.* Electrical protection of telephones is discussed in chapter 10. If a suitable location for the protectors cannot be found inside the building, they may be placed outside if located where it is well sheltered from rain and snow. Inside protectors may be mounted on any substantial surfaces or on a backboard if the surface is rough or damp. They may be mounted on ceilings. On walls they should be mounted with the fuses vertical. Outside use requires a special mounting for certain types of protectors.

(5) *Protector Grounding.* This subject is covered in chapter 10.

(6) *Types of Station Wire.*

(a) Wire W–117, twisted pair, solid No. 22 B&S gauge tinned soft copper, separately insulated with a rubber compound and green cotton braid. Supersedes Wire W–33.

(b) Wire W-118, 3-conductor, solid No. 22 B&S gauge tinned soft copper, separately insulated with rubber compound and green cotton braid, with red thread in one braid and a yellow thread in a second and no tracer in the third.

(c) WPB (War Production Board) special wire, a commercial product, twisted pair solid No. 22 B&S gauge, tinned soft copper, separately insulated with rubber compound and with a single brown cotton braid covering both conductors, giving the appearance of a single wire, with a raised ridge as tracer on the rubber compound of one wire. It is a permissible substitute for Wire W–117.

(d) Wire W–143 or Wire W–110–B, described in chapters 5 and 9, may be used in damp locations.

(e) Duct wire, twisted pair, solid No. 22 B&S gauge tinned soft copper, separately insulated with rubber compound and a tight-wrapped paper jacket impregnated with a sealing, waterproof compound. It should not be used where subject to abrasion. It has no Signal Corps code number or equivalent.

(f) Bridle wire, Wire W–69–A, a description of this wire is described in paragraph 1151e.

(g) GN station wire, a Bell System commercial-type wire, twisted pair, solid No. 22 B&S gauge tinned copper, separately insulated with rubber compound, covered with cotton braid, with a red tracer thread in the braid of one. It is obtainable in either brown or ivory and offers an inconspicuous installation against colored backgrounds. It can be used in damp but not wet locations. Under most conditions GN wire may be substituted for either inside or bridle wire.

d. Installation Order Routine.

(1) *Necessity.* A routine to systematize the installation of telephones and teletypewriters may be needed at locations where more than four or five installers will be working at one time. In any case, an order routine can assist in orderly handling of the installation work, plant records, switchboard marking, and directory work. It also can be used in processing requests for the installation, change, or termination of wire service such as local telephone or teletypewriter stations. The functions involved in the origin and completion of an installation order for a telephone, are: origination of service request; approval; assignment of facilities; central office cross-connection work; installation and test; property record work; switchboard marking; and directory work.

(2) *Adaptability.* The routine can be varied to meet different conditions, such as for those cases where civilian facilities are required. In using civil plant, the civilian telephone authority, civilian installers and civilian wire chiefs will be involved, in addition to the Army personnel, in completing service orders. Some of the functions listed in the sub-

paragraph above may be combined in the smaller areas.

(3) *Forms.* A form, with at least three copies, will be desirable, which will indicate the facilities to be used, and the address of the telephone location.

(4) *Distribution.* One copy should be held by the approval authority and two should be forwarded to the assignment clerk. The latter should enter the cable pair and switchboard assignments on both copies. One should go to the wire chief who performs the work of connecting the loop at the switchboard and who forwards his copy to the chief operator after he has tested the loop with the installer. The chief operator should post the directory record and return the copy to the approval authority. The second, or work copy, should be forwarded by the assignment clerk to the telephone installer. The installer should call the wire chief for test upon completion of his work and indicate the amount and type of equipment used and forward his copy to the wire chief. The wire chief should record pertinent information, such as the type of equipment used, on a new line record card for the installation, and then forward this copy to the property clerk who makes his records therefrom and files the order. Variations and modifications may be found desirable to fit conditions not covered in the above routine.

e. Installation Records.

(1) *Switchboard Assignment Records.* It may be desirable to maintain local records at each central which will show the quantities of line and trunk equipments that are available, particularly at the larger switchboards, so that assignments can be made correctly in connection with service growth.

(2) *Line Record Cards.* Line record cards are individual for each local loop, as shown in figure 11-46 and in TM 11-473. Information they carry is necessary in connection with maintenance work. Suitable columns for trouble records permit one set of cards to be used for both assignment and trouble clearing purposes. The line record cards should be filed numerically in a suitable way, convenient to the trouble clerk.

(3) *Trunk Circuit Record Cards.* Trunk circuit record cards are individual for each telephone and telegraph trunk or point-to-point circuit that enters the central. These are shown in figures 11-36 and 11-37.

(4) *Cable Records.* Where lead-covered, paper-insulated cable, or other multipair cables are installed for the entrance cables to the centrals, for local loop distribution plant, or

W. D., A. G. O. Form No. 11-145
(Old W. D., S. C. Form No. 1156
which may continue in use)
12 June 1944

LINE RECORD CARD

(File take-outs in dead file; do not destroy)
(USE PENCIL ONLY)

TEL. No. 1st PARTY	RING No.	CLASS OF SERVICE	DATE INSTALLED	ACCESS TO TRUNKS?
NAME OR OFFICIAL POS.		STREET ADDRESS		BLDG. No.
AUTHORITY FOR INSTALLATION				LOOP RES. OF LINE OHMS
TEL. No. 2D PARTY	RING No.	CLASS OF SERVICE	DATE INSTALLED	ACCESS TO TRUNKS?
NAME OR OFFICIAL POS.		STREET ADDRESS		BLDG. No.
AUTHORITY FOR INSTALLATION				LOOP RES. OF LINE OHMS

	TELEPHONE		BOX CODE	STAND CODE	EXTEN. CODE	ARRESTER		CABLE	PAIR	CABLE	PAIR	TERM.	PINS	MULT.
	MFR.	W. OR D.				MFR.	CODE							
1st PARTY														GRP. OR PANEL
2D PARTY														TERM. OR JACK

TROUBLE RECORD (USE INK OR TYPEWRITER)

REPORTED				TEST SHOWED	TROUBLE FOUND	CLEARED		
DATE	HOUR	BY—	TROUBLE			DATE	HOUR	BY—
	A P						A P	
	A P						A P	
	A P						A P	
	A P						A P	
	A P						A P	
	A P						A P	

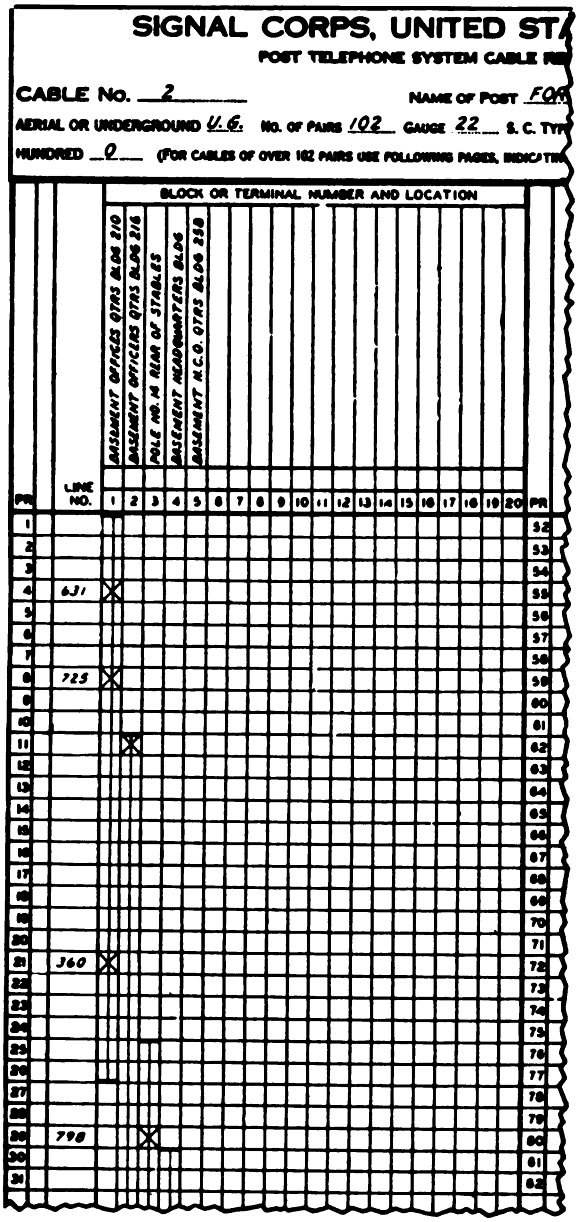
(OVER)

16—26330-2

TL 54923

Figure 11-46. Line record card, Signal Corps Form 1156.

for long distance trunks, cable records are required to show the individual pair assignments. A cable record is shown in figure 11-47 and in TM 11–473.



SIGNAL CORPS, UNITED ST

POST TELEPHONE SYSTEM CABLE RE

CABLE No. 2 NAME OF POST FOR

AERIAL OR UNDERGROUND U.G. NO. OF PAIRS 102 GAUGE 22 S. C. TYP

HUNDRED 0 (FOR CABLES OF OVER 102 PAIRS USE FOLLOWING PAGES, INDICATI

BLOCK OR TERMINAL NUMBER AND LOCATION

PR		LINE NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	PR
			BASEMENT OFFICERS QTRS BLDG 210	BASEMENT OFFICERS QTRS BLDG 216	POLE NO. 14 REAR OF STABLES	BASEMENT HEADQUARTERS BLDG	BASEMENT N.C.O. QTRS BLDG 258																
1																							52
2																							53
3																							54
4		631	X																				55
5																							56
6																							57
7																							58
8		725	X																				59
9																							60
10																							61
11				X																			62
12																							63
13																							64
14																							65
15																							66
16																							67
17																							68
18																							69
19																							70
20																							71
21		360	X																				72
22																							73
23																							74
24																							75
25																							76
26																							77
27																							78
28																							79
29		798			X																		80
30																							81
31																							82

TL-7470

Figure 11-47. Cable record, Signal Corps Form 1160.

1150. TELEPHONE CENTRAL INSTALLATION.

a. References. Several technical manuals include useful information on installing centrals, telephones, teletypewriters, and the associated equipment. These are: TM 11–353, TM 11–457, TM 11–458, TM 11–471, TM 11–473, TM 11–474, TM 11–487, TM 11–2001, TM 11–2022, TM 11–2037, and FM 24–20.

b. Installation of Tactical Centrals. Instructions for installaton of tactical switchboards and telephone central office sets are given in the technical manuals that are furnished with them. The work is relatively simple because the switchboards and associated equipment are designed for rapid installation with a minimum of effort and skill. Figure 11-48 shows an installation of two Telephone Central Office Sets TC–4 and figure 11–49 shows an installation of two Telephone Central Office Sets TC–1.

Figure 11-48. Installation of two Telephone Central Office Sets TC-4.

Figure 11-49. Installation of two Telephone Central Office Sets TC-1.

c. Installation of Fixed Plant Telephone Centrals.

(*1*) *General.* The major features of fixed plant telephone central installation work are described in TM 11–471. These features are:

placing the equipment; constructing the cable rack; running, lacing, stripping, butting, splicing, and forming switchboard cable; skinning and soldering cable conductors; installing and testing the power plant; installing the wire chief's cabinet; and adequate marking of the equipment by stenciling. The work is summarized in the following subparagraphs.

(2) *Common Battery Multiple Switchboards.* Commercial multiple switchboards require extensive cabling between the switchboard sections, and between the switchboard and the relay racks and distributing frame. Power plant wiring is also required. The cabling, on all but one commercial-type multiple switchboard, requires forming, attaching, and soldering of the multiple cable conductors to the multiple jacks and distributing frame by the installers on the job. The exception is the Western Electric Company No. 12 switchboard, in which the multiple cable is attached to the multiple jacks and terminal blocks at the factory. The power wiring always is done completely on the job. Commercial switchboard cables are of several types, numbers of conductors, and wire gauges. ASF catalog Sig 5 lists a considerable number of switchboard cables of various make-ups and sizes. Power wires are made in sizes from small rubber-covered solid conductor wire to the large stranded wires. Wire and switchboard cable is furnished by the Army Communications Service in proper quantities and sizes to fit the requirements of each installation.

(3) *Location of Central.* Factors to consider in selecting a suitable location for a central include: nearness to the center of the area served; availability of necessary space; fire hazards; floor strength; roof strength; door or window size to permit entry of equipment units; water supply; sanitary conveniences; heat; light; electric power availability; dampness; building vibration; disturbing noise; exposure to bomb damage requiring shielding of windows; and protection from bursting water pipes. It may be necessary to provide supplementary strengthening of the floor, walls, or roof.

(4) *Location of Switchboard.* Factors to consider in placing a telephone switchboard include: clearance of not less than 6 feet between keyshelf and wall; 3 feet from rear of board to wall; not less than 2 feet from wall at fixed end of board; door clearance to avoid striking board; space for added positions in case of growth; and light. Low type switchboards should not have their backs towards windows as the light will shine directly in the face of the operators and make it difficult to see lighted switchboard lamps. Backs of high switchboards should be toward the windows. Direct light from a window or skylight should not fall on the face or keyshelf of a lamp signal switchboard. Strong light makes it difficult for the switchboard operators to see whether the lamp signals are on or off. If such a location cannot be avoided, suitable blinds should be used to control the light.

(5) *Location Of Associated Equipment.* Chapter 2 gives a typical layout of a telephone central. Distributing frame clearance should be not less than 40 inches from the face of protectors to the wall; not less than 40 inches from the face of the terminal strips to the wall or nearest obstruction; and not less than 1 foot from the permanent end to the wall. Sufficient space on the other end for growth to the ultimate size should be allowed. Where wall-type distributing frames are used, the protectors should be mounted as near the cable entrance as possible. Relay racks, where required, preferably should be installed approximately 40 inches from, and parallel to, the terminal strip side of the distributing frame. Cabling between the distributing frame, the switchboard, and the relay racks and power plant preferably should be run overhead.

(6) *Typical Installation.* Figure 11-50 il-

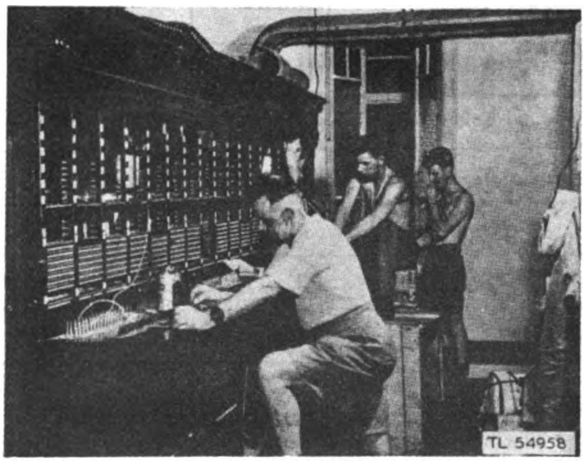


Figure 11-50. Installation of commercial-type multiple switchboard.

lustrates a fixed plant commercial-type multiple switchboard in the process of installation. Figure 11-51 illustrates the installation of a main distributing frame.

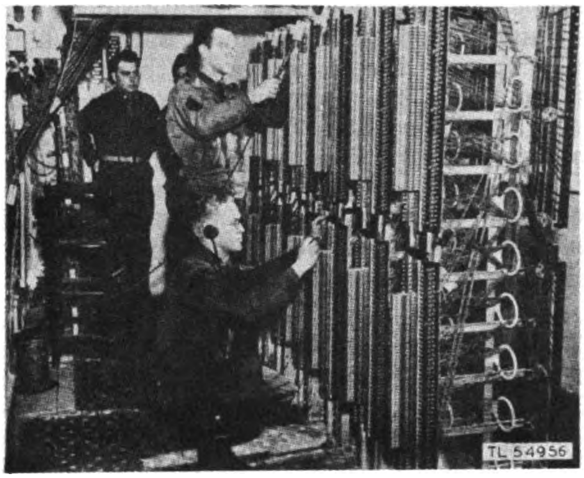


Figure 11-51. Installation of main distribution frame for a commercial-type multiple switchboard.

d. Fixed Plant Centrals; Installation Intervals and Man-hours.

(*1*) *General.* The interval for the installation of commercial switchboards and associated equipment in buildings will depend on the number of positions, the number of installers, the experience of the installers, and whether the work is done by one, two, or three shifts per day. Inexperienced installers will increase the intervals considerably.

(*2*) *Installation Intervals.* Installing intervals are given in figure 11-52 for commercial switchboard installations, based on working a seven day week. Intervals can be reduced about one half if two shifts are used and about two thirds if three shifts are used. The intervals are based on an installing force of normal size. The use of more men will lessen the intervals but crowding limits the practicable size of the force. The interval required to put a switchboard into service can be shortened by deferring such work as cable lacing, stenciling, etc., until after the service begins. The intervals given are based on the assumption that no delays occur because of material shortages, and are for the completion of the entire job, except in the figures on the rush basis, in which case it is assumed that as much work as possible would be deferred until service begins.

(*3*) *Installation Man-hours.* The man-hours of work required to complete the installation of a multiple telephone central can be estimated by using time factors for a few major items of work, as shown in figure 11-53.

(*4*) *Example of Use of Man-hour Data.* An example of the use of the man hour data for a switchboard of eight operating positions, one end position, one test position, (total 10 positions), 1,000 lines, power plant, chief operator's cabinet, wire chief's cabinet, and repair clerk's desk, is given in figure 11-54.

No. of positions (incl. end and trouble pos.)	*Normal installing force (men; including supervisor)*	*Interval with normal force working 56 hours per week per man (weeks)*			*Interval on rush basis (days)* [a]
		1 shift	*2 shifts*	*3 shifts*	
3	4	4 to 5	2 to 2½	1½ to 1¾	5
4	4½	4½ to 5½	2¼ to 2¾	1½ to 1¾	6
5	5½	5 to 6	2½ to 3	1¾ to 2	7
10	8	7¼ to 8¾	3¾ to 4½	2½ to 3	9
15	10	8½ to 10¼	4¼ to 5¼	3 to 3½	11
20	11½	9½ to 11½	4¾ to 5¾	3¼ to 3¾	13
25	13½	10½ to 12½	5¼ to 6¼	3½ to 4¼	15

[a] The interval on a rush basis assumes a 3-shift work schedule, with as many installers on each shift as is practicable, and deferring as much work as possible such as stenciling, etc., until after service begins.

Figure 11-52. Installation intervals for commercial type multiple telephone centrals.

Work items	*Man-hour factor*[a]	*Multiplier*
New office		
Basic allowance[b] (jobs with 1 to 5 positions)	30	Job
Basic allowance[b] (jobs with more than 5 positions)	130	Job
To line-up switchboard (jobs with more than 8 total positions only)	50	Job
Operating positions	40	Positions
End position (blank position)	10	Positions
Trouble or test position	20	Positions
Switchboard face equipment	0.019	Lines
Lines	1.7	Lines
Chief operator's cabinet	25	Cabinet
Repair service desk	25	Desk
Wire chief's cabinet	25	Cabinet
Power plant (jobs with 1 to 8 positions)	100	Job
Power plant (jobs with more than 8 positions)	200	Job
Adding equipment to existing switchboard.		
Basic allowance[b]	30	Job
Positions	40	Positions
Line circuits added	1.2	Lines
Added multiple	0.019	Lines times appearances
Extending the multiple in an existing switchboard.		
Basic allowance[b]	20	Positions
Lines extended	0.13	Lines
Line appearances added	0.019	Lines times appearances added

[a] Add 20 percent to the computed hours for abnormal job conditions. This gives the productive hours. Add another 20 percent to the productive hours, to cover supervision, material handling, record work, janitor work, etc.

[b] This time is allowed for organizing the job.

Figure 11-53. Telephone switchboard installation man-hour data.

Item	*Man-hours*
Basic allowance	130
To line-up switchboard	50
Operating positions 8 x 40	320
End position	10
Test position	20
Switchboard face equipment 1,000 x 10 x 0.019	190
Lines 1,000 x 1.70	1,700
Chief operator's cabinet	25
Repair service desk	25
Wire chief's cabinet	25
Power plant	200
	2,695
20% for abnormal job conditions	539
TOTAL productive labor	3,234
20% for supervision, clerical, etc.	649
TOTAL	3,883

Figure 11-54. Example of use of man-hour data.

1151. CARRIER EQUIPMENT INSTALLATION.

a. Spiral-four Equipment. TM 11–2001 contains detailed instructions for the installation of the carrier equipment used with spiral-four cable. Any one station on a single system has only a small amount of equipment, which is easily arranged. However, when more than one system is being used, or when a single system is to be placed alongside other equipment, a logical floor plan should be established. The main considerations are adequate passage ways, working space, and convenient wiring and interconnecting layouts. It is usually desirable to locate the telephone equipments together and the telegraph equipments together, to avoid congestion when it is necessary to have work in progress about each group of equipment. Cabling between the units and to the power equipment, outside plant, etc. should be overhead when possible. Wire W–69–A (subpar. e below) is provided with the equipment for use in making interconnections.

b. Packaged Carrier Equipment. TM 11–2022 and TM 11–2037 contain detailed instructions for the installation of packaged carrier equipment. Figures 11-55 and 11-56 show a typical packaged carrier equipment installation. The following information must be furnished the installer: line layout chart; circuit diagram; circuit record cards for both telephone and telegraph trunks; floor plan layout; list of

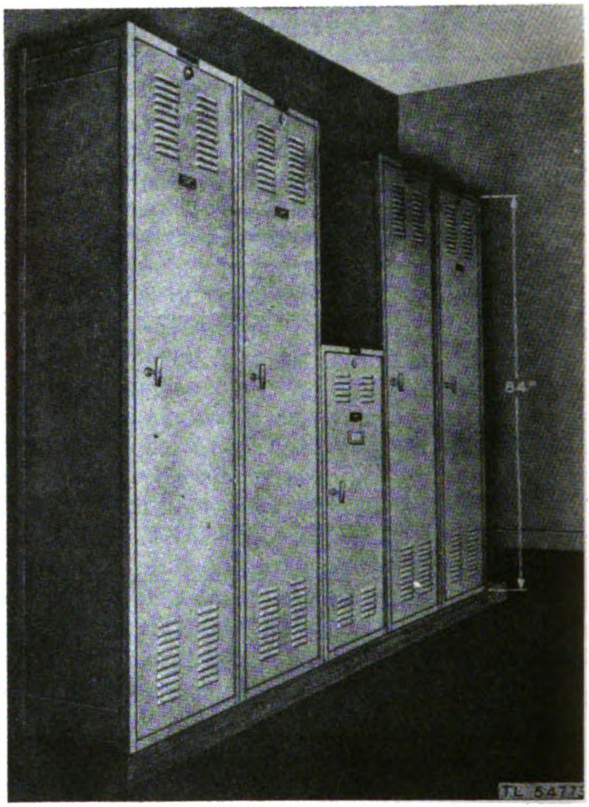


Figure 11-55. Packaged carrier equipment installation.

trunk assignments; equipment list of packages furnished; office wiring diagram; and equipment wiring record. Immediate steps should be taken by the installer to obtain any of the data that may be lacking. If the information cannot be obtained, the installer should refer to TM 11–2022 and to the technical manuals furnished with the individual units of equipment and endeavor to work out the needed information. The equipment cabinets are open at the bottom and are placed on timbers. Cable-runs along the floor connect the lines of cabinets. A method of constructing the cable runway and cabinet supporting timbers is shown in figure 11-57. Panels of the same type preferably should be grouped together; for example, all line terminating and simplex panels should be mounted adjacent to each other. Each unit is wired for several optional wiring arrangements, each option being for a particular set of conditions. The manuals furnished with the equipment describe in detail the connections required for each option. A list of connecnection tables, figures, etc. (corresponding to the options) should be made up by the installer

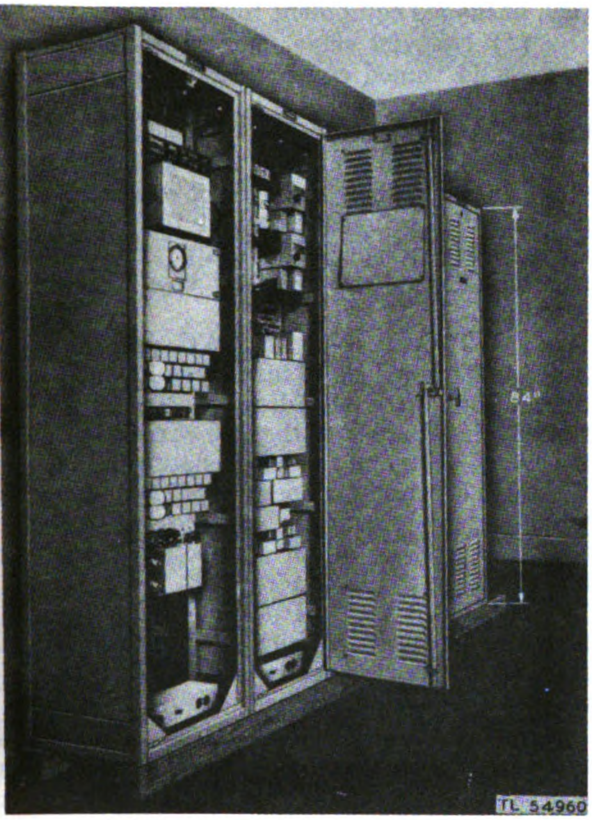


Figure 11-56. Packaged carrier equipment installation.

in advance. After setting up the equipment the wiring is run, including power wiring, but fuses should not be placed until testing is to begin. Cross connections to other cabinets should be made through the open bottom. Wiring from entrance cable or protectors is direct to the equipment. Initial local tests of each equipment unit are necesary, after which circuit and system line-up tests and telegraph circuit transmission measurements can be made.

c. Packaged Carrier Cross-connections.

(*1*) To establish a long distance telephone trunk circuit or a telegraph circuit certain cross-connections must be made between various equipments. In small offices where all of the equipment can be placed in one line of bays, the separation between all the terminals in the office is small and the labor of running wires from terminal to terminal is small. Saving on this labor does not justify a distributing frame. In a large office the amount of labor required to run wires from terminal to terminal could be large. To reduce this labor, it may be desirable to have a distributing frame with permanent wire from there to the equipment for certain of the circuits. This will not, how-

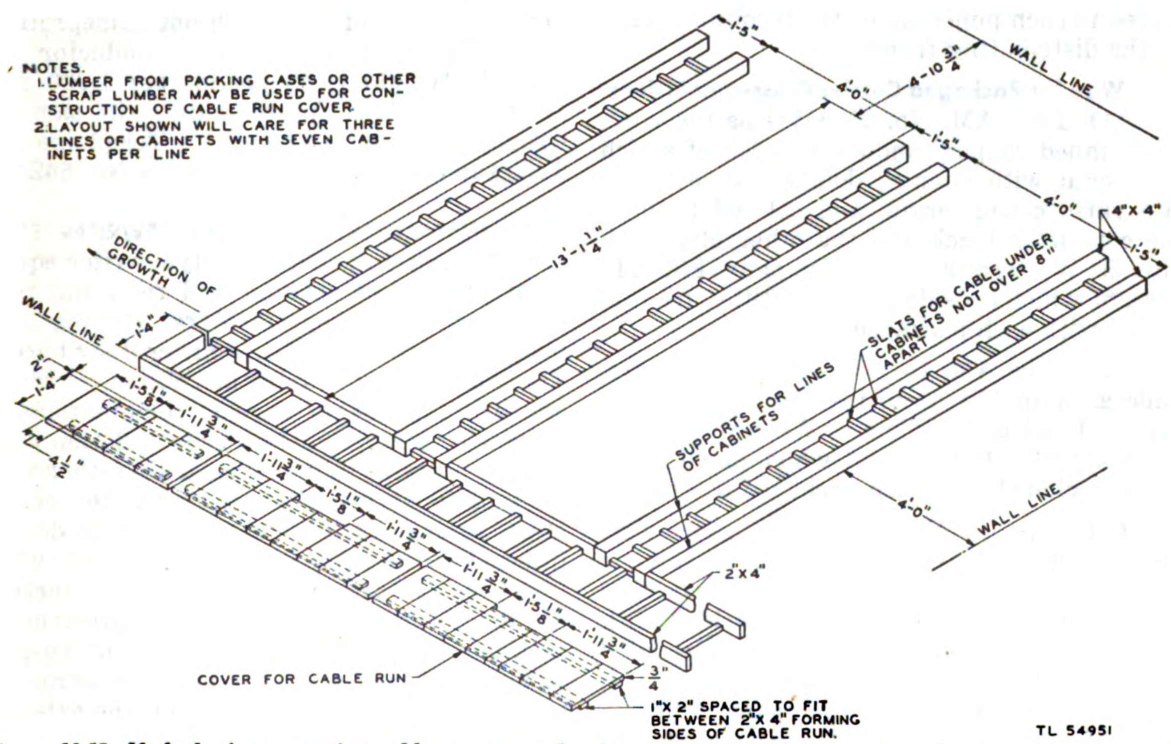


Figure 11-57. Method of constructing cable runway and cabinet supporting timbers for packaged carrier equipment.

ever, reduce the number of wiring changes required for a circuit change.

(2) For example, on a type C carrier terminal there are three distinct possibilities for consideration as to what circuits to bring out to a frame, to facilitate the making of circuit changes or assignments. One is to bring out a small group (8 wires) which permits reassigning channels and telegraph composite legs only, if the channels are 2-wire. Bringing out 42 more wires to the frame permits changing any of the three channels from a 2-wire to a 4-wire termination or vice versa, at the frame. Bringing out 18 others permits the voice frequency circuit on which the carrier is superposed to be connected to any voice-frequency repeater or other equipment, at the frame. The cross-connection blocks can be either of the following: vacant terminals on an existing frame in the office; protection and distributing frame X-61823G (packaged unit); or a separate distributing frame of the type usually furnished with telephone switchboards. Although it is convenient to have all the wires that are involved in circuit changes brought out to a distributing frame, there are certain disadvantages. These are that fewer men can work on changes at one time and that exact records must be maintained as to what is connected to each punching of the terminal blocks on the distributing frame.

d. Wire for Packaged Carrier Cross-connections.

(1) Type AM, No. 20 AWG paired wire, solid tinned copper conductors, each of which is covered with enamel, double cellulose acetate yarn, cotton braid, and colored lacquer, one conductor black and the other black-red. This is Western Electric Company P368247 wire, of which considerable quantities are furnished with each packaged equipment.

(2) Type AM, No. 20 AWG single wire, same as item (1) as to insulation but single wire, colored green. This is Western Electric Company P368403 wire, of which about 2,500 feet is included with each packaged test board.

(3) Type P, No. 22 AWG single wire, solid tinned copper conductors each of which is covered with enamel, double cellulose acetate yarn, single cotton and lacquer, shielded with No. 36 AWG tinned wire braid, and insulated with paper tape and slate colored cotton braid. This is Western Electric Company P368446 wire, of which about 100 feet is included in each packaged equipment for use in strapping.

(4) No. 720 cable, No. 22 AWG paired wire, solid tinned copper conductors, each of which is covered with a rubber jacket, a braided copper shield, crepe paper tape, and an external slate cotton braid, with a longitudinal ridge on the rubber insulator of one conductor as identification means. About 100 feet is included with each packaged equipment, for connections from line wires to type C carrier equipment.

(5) Type P, No. 22 AWG paired wire, same as item (3) as to insulation of each conductor, but with shielding of No. 36 AWG tinned wire braid over the two wires. One wire is colored slate and the other slate-red. This is Western Electric Company P357170 wire, of which a small quantity is included in each packaged equipment for connecting telegraph terminals to telephone terminals.

(6) No. 8 AWG bare copper wire. A small amount of this wire is included in each packaged equipment for use in making ground connections between packaged equipment units.

e. Wire for Spiral-four Cross-connections (Wire W–69–A). Wire W–69–A is twisted pair cross-connecting wire for use outdoors or in humid places. Two No. 20 solid conductors of soft, tinned copper have insulation of rubber and weatherproofed, though not flameproofed, braid. The braid covers each conductor and over-all. Weight is 13 pounds per 1,000 feet. Wire W–69–A is approximately the same as Graybar duct wire, American Telephone and Telegraph Company Specification No. 6423.

1152. INSTALLATION OF TELETYPEWRITER SETS.

a. General. In general, teletypewriter equipment consists of sending and receiving page teletypewriters, reperforators (typing and nontyping), and transmitter-distributors. These units require table or cabinet mounting and are supplied in various combinations to form teletypewriter sets. The installation work usually pertains to installing a set rather than an individual piece of teletypewriter equipment. In general it is not necessary to do any internal wiring in a teletypewriter unit when installing the set. Sets arranged for tactical use are designed for rapid installation using jack and plug connections and binding-post terminals. Fixed plant equipment is arranged much like commercial equipment, the external connections generally requiring soldering or attachment to terminals; and the wiring is therefore done in a semipermanent manner. When installing teletypewriter equipment, every effort should be made to provide adequate lighting and dry and warm operating conditions. At ambient temperatures below 40° F, the temperature under the teletypewriter cover should be raised artificially, otherwise lubricants and lubrication intervals other than standard, will be required. A location not exposed to the weather is required to protect the paper and tape used for recording teletypewriter messages. TM 11–353 may be referred to for general information on the installation of teletypewriter equipment. The types of drop wire and station wire used for telephone stations may be used for teletypewriter stations.

b. Fixed Plant Installations. In fixed plant, the teletypewriter tables or cabinets, afford a mounting which conserves space and provides access to the wiring of the equipment for maintenance. Space not occupied by the teletypewriter apparatus is often used for rectifiers, a terminal and jack box for making external connections, and table cord connections. External connections consist of power wiring for the teleypewriter motor, and wire connections for the sending and receiving signaling circuits. Motor wiring should conform to standard power-wiring methods, and common fusing with lighting circuits should be avoided when practicable. Typical fixed plant teletypewriter sets are shown in chapter 3.

c. Tactical Installations. Tactical teletypewriter equipments are transported in wood chests. A portion of the chest often serves as a table when the equipment is in service. Installation connections, including power supply and signaling circuits, are made without the use of other than simple tools. Chapter 3 shows a typical tactical teletypewriter set in which the installation work consists essentially of connecting the components of the set by means of cords and plugs.

d. Installation Order Routine. The installation order routine for teletypewriter set installation can be similar to that given for telephones in paragraph 1149d.

e. Installation Records.

(1) *Telegraph Equipment, Assignment Records.* It is desirable to maintain local records to show the quantities of telegraph equipment and teletypewriter equipment that are available so that assignments can be made correctly in connection with service growth and replacements.

(2) *Designation Cards.* Sample cards for maintaining records of line assignments for packaged equipment are shown in TM 11–2037. These are attached to the equipment units by inserting in card holders or otherwise fastening them. This same general designation plan is applicable to tactical equipments. Figure 11-58 shows typical designation cards for a v-f carrier telegraph channel terminal and a v-f carrier telegraph cabinet (packaged equipment).

V.F. TELEG. SYSTEM ____________

CONNECTED LINE EQUIP.

SEND LINE LEVEL PAD ____________

CHANNEL NO. ____________

CIRCUIT ____________

DC EXT. SW ____________

CONNECTED DC EXT. EQUIP.:

TTY STATION AND EQUIP.:

GRD OR METALLIC RETURN

TYPE OF DC EXT. OPERATION

B-402130

TL 53209-S

V.F. CARRIER TELEGRAPH CAB. NO. ____________

SYSTEM ____________

CONNECTED LINE EQUIP. ____________

CH ______ CKT ____________

CH ______ CKT ____________

CH ______ CKT ____________

B-402131

TL 53210-S

Figure 11-58. Typical designation cards for v-f packaged carrier telegraph equipment.

1153. TELETYPEWRITER CENTRAL INSTALLATION.

A teletypewriter manual switching central, sometimes called teletypewriter exchange (TWX), consists of teletypewriter switchboards which provide means for interconnecting stations for 2-way communication and a means of interconnecting switchboard trunks and station lines. A teletypewriter central may be installed in or near a signal center. Teletypewriter switchboards may be Switchboard BD–100 (10 lines), or the British 15-line or 40-line teleprinter switchboards. Switchboard BD–100 should not be installed for tandem operation with the British switchboards because the types of transmission used do not permit interoperation. When installing Switchboard BD–100, it is essential to secure a low-resistance ground connection. When the switchboard is installed in a signal center, the external wiring should be made on a semipermanent basis and the same considerations given to securing a good ground connection. The switchboard line relays should be lined up for the proper bias adjustment prior to starting service. If the rectifier furnished with the switchboard is not to be used, the local power supply must be adequate for meeting the operating requirements of the switchboard. Refer to TM 11–358 for detailed information on Switchboard BD–100. The rectifier power supply furnished with the telegraph central office switchboard will supply up to three boards. Improvised arrangements which permit installing a group of five switchboards are described in chapter 3. Group operation of five boards might be required in a teletypewriter central operated in conjunction with a large signal center.

1154. TELEGRAPH AND TELETYPEWRITER EQUIPMENT INSTALLATION.

a. References. A number of technical manuals include useful information on installing telegraph line transmission equipment, teletypewriter signal center equipment, teletypewriter centrals, and teletypewriter stations. The more important manuals, some of which also give information on systems, are: TM 11–353, TM 11–354, TM 11–358, TM 11–487, TM 11–2001, TM 11–2022, TM 11–2037, and TM 11–2207.

b. Telegraph Line Transmission Equipment. Telegraph line transmission equipment for wire circuits generally includes voice-frequency carrier telegraph equipment for long-haul circuits, d-c telegraph repeaters for the shorter circuits, and d-c regenerative telegraph repeaters for multisection circuits. In addition, voice-frequency carrier telegraph equipment may be installed for use on single-tone and 2-tone multichannel radio teletype systems. To facilitate the use of tools and test sets and to organize maintenance forces, it will be preferable to locate the telegraph and telephone line transmission equipment in the same room. In many cases, fixed plant telegraph equipment will be packaged, the installation of which is discussed in paragraph 1151 and in TM 11–2022 and TM 11–2037. A method of constructing cable runs with cabinet-supporting timbers is shown in figure 11-57. TM 11–2001 contains detailed information for installing spiral-four cable carrier systems using telephone and telegraph terminal equipment. A floor plan layout should be prepared prior to installation and it is recommended that carrier telegraph equipment be installed in a group and d-c repeater equipment in another group. Tactical telegraph equipment may also be used in fixed plant installations, and in such cases it will be preferable to install the equipment in a semipermanent manner.

c. Signal Center Installation.

(*1*) *General.* The installation of teletypewriter equipment in a fixed plant signal center involves the selection of a suitable location and the arrangement of equipment for efficient flow of telegraph messages inward and outward.

(*2*) *Location of Center.* The following factors enter into the selection of a signal center: availability of necessary space, proximity to wire and cable routes and to headquarters, fire hazards, floor and roof strength, water supply, sanitary conveniences, heat, light, electric power availability, dampness, building vibration, exposure to bomb damage requiring shielding of windows, and protection from bursting water pipes. It may be necessary to provide supplementary strengthening of floor, walls, or roof. The ability to conceal the location of the signal center may be important under some circumstances.

(*3*) *Equipment Layout.* The layout of the equipment and the associated furniture will vary; it should, however, be based on the flow of messages, with minimum travel of personnel in the movement of an outgoing message from receipt to transmission, and of an incoming message from receipt to delivery. Equipment should be located so that there is ample access for maintenance; at least 40 inches is desirable between equipment and adjacent obstructions such as walls, columns, or other equipment. Space for orderly growth should be provided where feasible. Cabling between units ordinarily will be overhead on suitable cable racks, which can be made of wood or steel. A floor plan layout should be prepared before installing teletypewriter equipment in a signal center. In addition to the location of the equipment, this plan should show power wiring with power outlets, and signaling circuits to the associated telegraph line transmission equipment, the radio transmitters, and the radio receivers, together with monitoring and control circuits as required. It is preferable to locate the telegraph line transmission equipment in or near the operating room. Line transmission equipment will usually consist of v-f carrier telegraph terminals and d-c telegraph repeater equipment. The d-c signaling circuits between the operating room and the telegraph line transmission equipment are generally not composited or simplexed. Adequate telephone facilities must be provided for order wire and control purposes. The d-c circuits should be carried through loop Switchboards SB–6/GG, sometimes called jack panels, to permit reassignment of the teletypewriter sets in the operating room as required by service conditions. TM 11–2207 describes the installation of radioteletype code room and signal centers.

d. General Plan for Signal Center Radio Equipment.

(*1*) The principles discussed below should be followed where feasible in selecting sites for radio equipment associated with the signal center. In the discussion which follows, reference should be made to figure 11-59. Reference should also be made to FM 24–18.

(*2*) The radio transmitters, particularly the long-haul, high-powered, h-f types, should be located from 2 to 10 miles from the signal center. This avoids interference with the radio receiving equipment; it also minimizes the likelihood of disclosing the exact position of the signal center, by either radio direction finding or aerial reconnaissance. The technical requisites for antenna siting are discussed in chapter 6. It is good practice, where feasible, to divide the transmitters into two groups to minimize the likelihood of having service disrupted by enemy action. Siting considerations may require separate locations for h-f and v-h-f transmitters or receivers. Excessive dispersal of individual transmitters is undesirable because of the problem of guarding them.

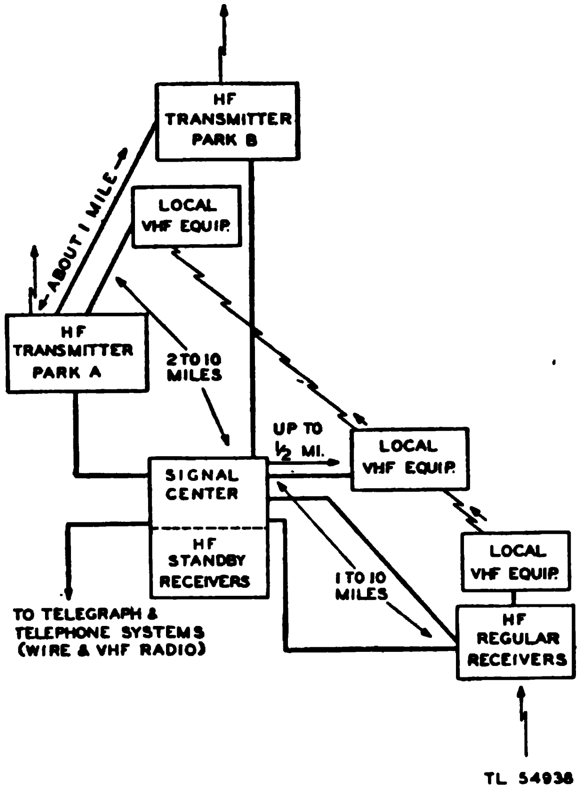


Figure 11-59. Relative locations of signal center and associated radio transmitters and receivers.

(*3*) It is desirable to have independent wire routes to each transmitter park, each capable of handling the traffic through all transmitters, with a supplementary wire route of about half that capacity between the two parks. By providing suitable terminal blocks at the ends of the wire circuits, they can be rerouted in case one of the main routes is lost. In determining the number of wires in each route, provision should be made for one or more wire telephone circuits for intercommunication between the signal center and the radio attendants. Information covering the layout of radio parks is given in chapter 6.

(*4*) The receivers for regular use should likewise be located at a distance from the signal center, principally to avoid the man-made noise usually encountered at places where there is considerable activity. These receivers are preferably placed in the opposite direction from the transmitter to obtain maximum freedom from interference. The distance from the signal center will vary from 1 to 10 miles, as governed by available sites which are satisfactory from a technical standpoint, as discussed in chapter 6.

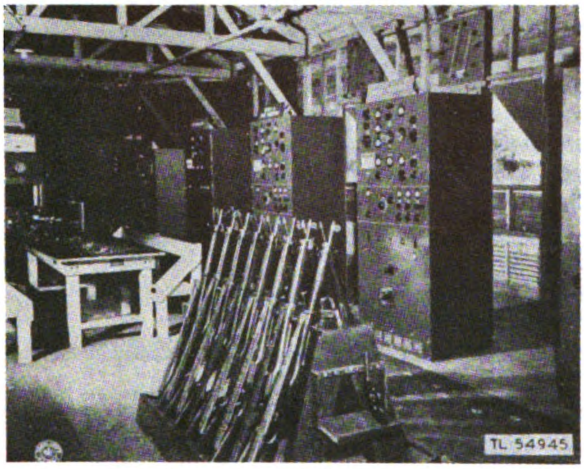


Figure 11-60. Fixed plant radio transmitting station, (showing three Radio Transmitters BC-339 in the right center).

(5) Duplicate radio receiving equipment for standby service can usually be located within or adjacent to the signal center, since the antenna systems for this service are usually much less extensive and conspicuous than transmitting antennas.

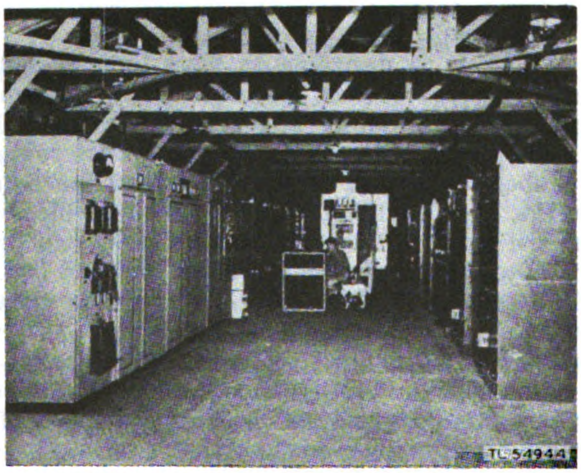


Figure 11-61. Fixed plant radio transmitting station.

(6) For interconnecting the signal center with both transmitter and receivers, buried cable is ideal. Where this is not practicable, aerial lead-covered or rubber-covered

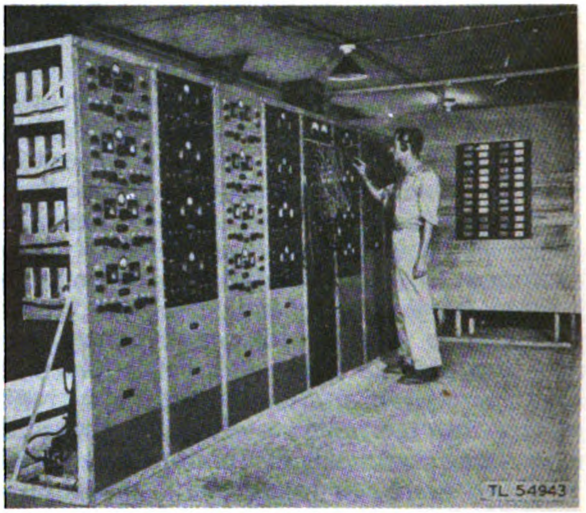


Figure 11-62. Fixed plant radio receiving station, (showing Hammarlund super-pro receivers in the foreground and National HRO receivers, with their associated spare coil sets on the wall, at the right).

cable, open wire, or long range tactical wire can be used.

(7) Under circumstances where the wire circuits are unreliable or alternate routes are not feasible, multichannel v-h-f radio links between the signal center and the remote radio transmitters and receivers can be used effectively. Either wire or v-h-f radio may be used for regular operation, with the other serving as a standby, depending on local circumstances.

e. Radio Station Layout. The physical layout of different radio stations will vary considerably, depending on local conditions and other factors. Figures 11-60, 11-61, 11-62, and 11-63 show photographs of portions of a few fixed

Figure 11-63. Fixed plant radio receiving station, (showing single side band receiver Western Electric Company D-99945 in left foreground).

ant military radio station installations. They ow orderly layout with sufficient room for intenance. A floor plan for a 10-kw radio nsmitter station is shown in figure 11-64.

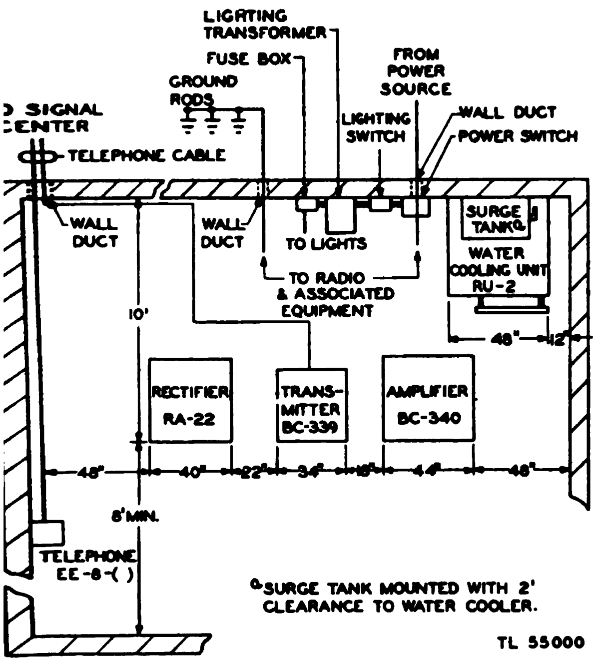


Figure 11-64. Floor plan requirements and equipment arrangement for 10-kw radio transmitter.

1155. MOBILE INSTALLATIONS.

a. General.

(*1*) Mobile arrangements of telephone centrals, teletypewriter centrals, carrier terminal sets, and multichannel radio terminal or relay sets can be provided for tactical conditions where the equipment may have to be moved frequently and where the vehicles or mobile shelters are available. There are no Signal Corps standards of this type available except for the Telephone Central Office Set TC–2. The information and drawings contained in this paragraph are intended to serve as a guide for making such arrangements. For this purpose, the sets can be mounted in standard Army semitrailers or shelters.

(*2*) The first consideration in making such an arrangement is to determine the inside dimensions of the available truck, semitrailer, or shelter. Consideration should be given to the head room and a check should be made to see that there are no inside projections or offsets in the floor which will interfere with the layout of the equipment. In arranging the equipment, care should be taken to see that there is ample space for items such as the operators' chairs in the front of a switchboard, and aisle space in the rear of switchboards and around the frames, power, and testing equipment for maintenance. In case there is more space available than is needed for operation and maintenance, the equipment should be located so that the unused space can be used to store the power equipment and packing cases when the outfit is being moved. Where it is necessary to add windows in semitrailers or shelters or if blackout restrictions preclude windows for light and air, consideration should be given to adding forced convection unit heating equipment and the necessary lighting outlets at the same time. TM 11–2525 describes the Miller utility heater model OG–31–A which is a portable unit suitable for heating trailers and shelters.

(*3*) Minimum lighting requirements have been shown on some of the floor plans. Care should be taken in locating the lighting outlets and windows to see that the amount of light provided on the face and keyshelf of a switchboard is not of high intensity, which would make it difficult for the operator to see the lamp signals.

(*4*) The equipment which is to remain in place should be securely fastened to the floor. In most cases it may be necessary to supply supplementary bracing from the top of the switchboards or frames to the ceiling or side walls to prevent tipping when the outfit is being moved. It may also prove desirable to secure the operators' chairs to the floor. The procedure for fastening the components of Telephone Central Office Set TC–2 by either lag screws, bolts and nuts, or toggle bolts to the shelter, as described in Changes 2 to TM 11–340 (15 April 1944), may be used in other arrangements. Other methods of fastening equipment, which may be employed in the mobile installations, are described in HQ, AAF, Technical Order No. 03-1-39, Instructions for Operation and Maintenance of Cargo Tie-Down Equipment. These methods, which are used in securing cargo in Army cargo planes, make use of two tiedown rods, a beam, and a jack.

(*5*) When motor vehicles are used for transportation of mobile installations, consideration should be given to the possibility of deep-water fording. The waterproofing of such

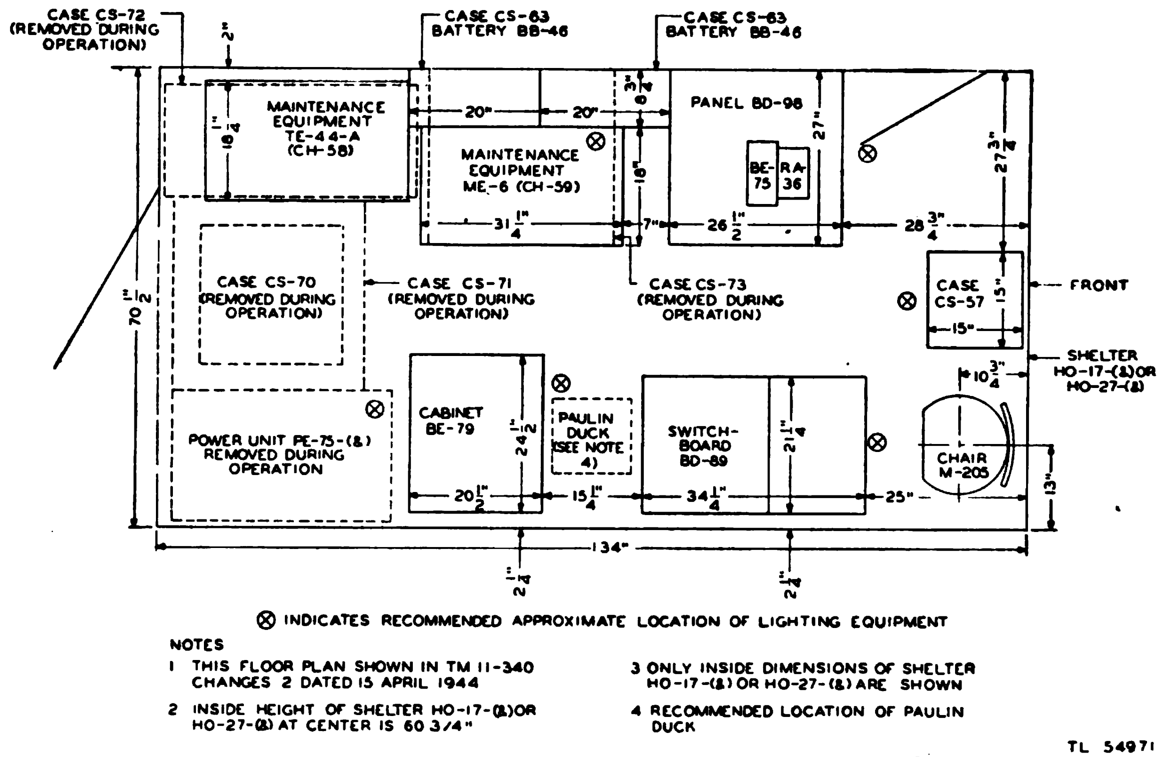


Figure 11-65. Floor plan of one-position Telephone Central Office Set TC-2 in Shelter HO-17-( ) or HO-27-( ).

vehicles for this purpose is described in TM 9–2853. These arrangements, in general, provide breather pipes and exhaust extensions to a point above the expected water level.

b. Mobile Telephone Centrals.

(*1*) *General.* Mobile telephone central arrangements are included for a 1-or 2-position switchboard mounted in a Shelter HO–17–( ) or HO–27–( ) or a semitrailer, and for a 4-position switchboard in a semitrailer. Arrangements similar to these have already been used in the theaters of operations.

(*2*) *One- or 2-position Telephone Switchboard.*

(*a*) The arrangements for mounting a 1- or 2-position switchboard using Telephone Central Office Set TC–2 in Shelter HO–17–( ) or HO–27–( ) are described in Changes 2 to TM 11–340 (15 April 1944). Shelters HO–17–( ) and HO–27–( ) are identical, except that shielding is provided in Shelter HO–17–( ). When available, Shelter HO–27–( ) should be used for the Telephone Central Office Set TC–2.

(*b*) The bare floor plan showing the complete installation of all items in Shelter HO–17–( ) or HO–27–( ) for a 1-position Telephone Central Office Set TC–2 is shown in figure 11-65. For a 2-position switchboard, another floor plan arrangement in Shelter HO–17–( ) or HO–27–( ) is shown in fiure 11-66. This figure also shows the arrangement of equipment in a Trailer, Cargo, 1-ton, which is required in addition to the shelter for transporting some of the equipment. In both of these cases the Shelter is transported in Truck, Cargo, 2½-ton, 6 x 6.

(*c*) An arrangement for mounting a 2-position Telephone Central Office Set TC–2 in a semitrailer, is shown in figure 11-67. This arrangement is not described in TM 11–340. This plan requires the use of a Semitrailer, Van, 3-ton (6-ton gross) and has sufficient room for storing the unfastened equipment when the outfit is being moved.

(*3*) *Four-position Telephone Switchboard.*

(*a*) Arrangements for a 4-position installation of Telephone Central Office Set TC–10 are shown in figures 11-68 and 11-69. Similar arrangements no doubt could be used with the Telephone Central Office Sets TC–1 and TC–20 but are not included.

(*b*) The two floor plans shown are

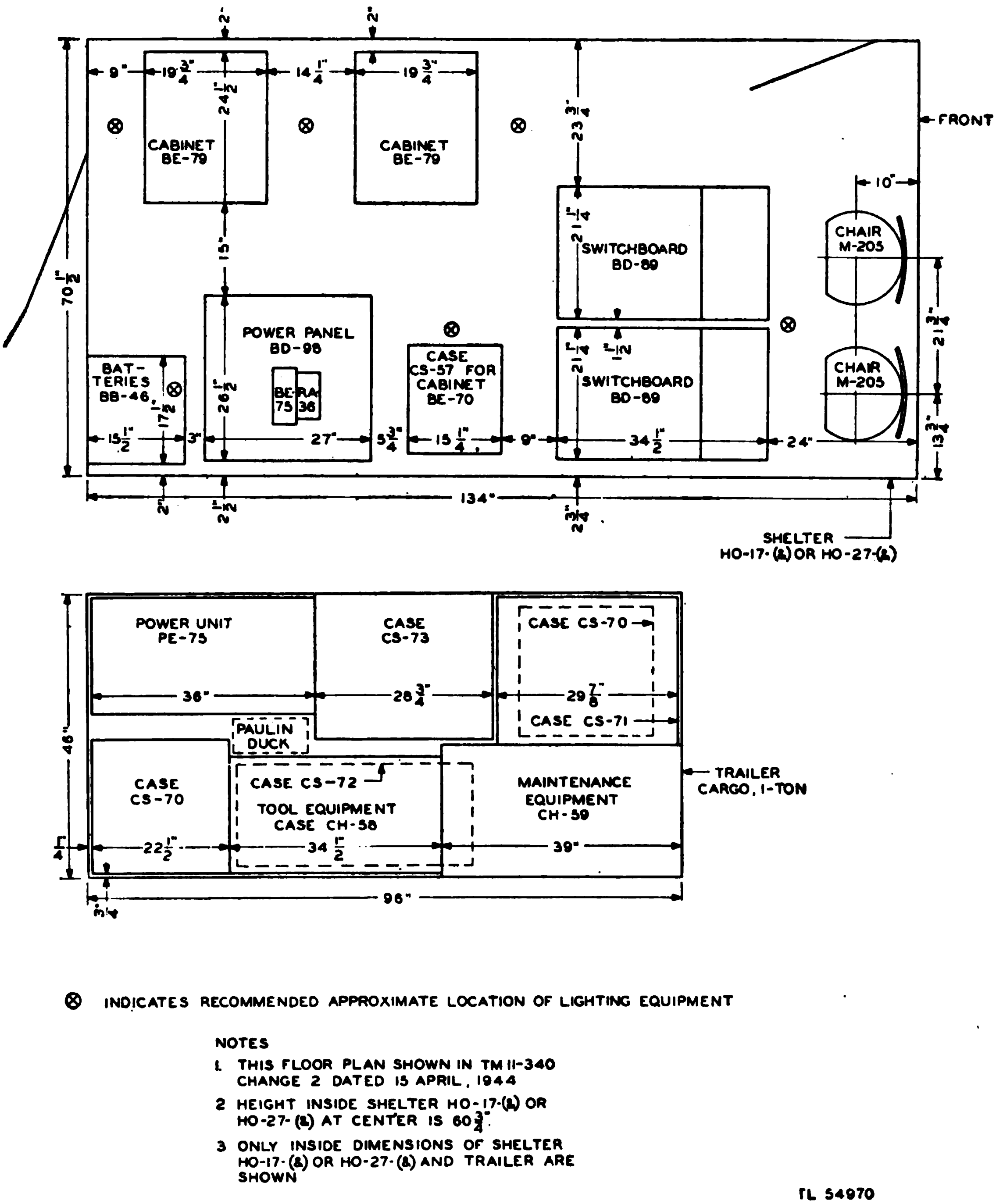


Figure 11-66. Floor plan of 2-position Telephone Central Office Set TC-2 in Shelter HO-17-( ) or HO-27-( ) and trailer.

suitable for the most commonly available semi-trailers. Figure 11-68 assumes the use of a Semitrailer, Van, 3-ton (6-ton gross). Figure 11-69 assumes the use of a Semitrailer, Van, 6-ton (10-ton gross). The latter is preferable since the operators' space is more liberal, and there is room for transporting the two engine alternators and the empty packing cases when the outfit is being moved. The plan in figure 11-68 shows the proposed location of some of

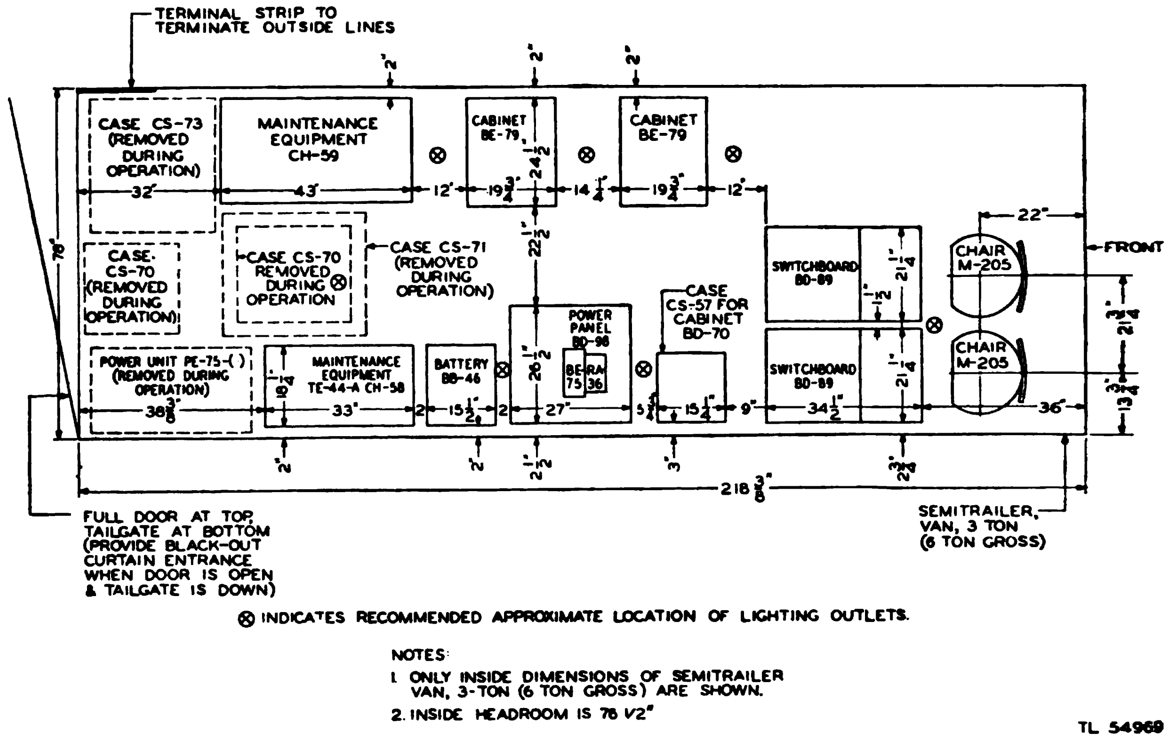


Figure 11-67. Floor plan of 2-position Telephone Central Office Set TC-2 in Semitrailer, Van, 3-ton (6-ton gross).

the empty packing cases in the semitrailer with the remainder located in a Trailer, Cargo, 1-ton, when the outfit is being moved.

(*c*) Because head room is somewhat restricted in the two arrangements for the TC–10, it is recommended that the cable racks be omitted and the cables be attached to the ceiling or side walls in any suitable manner.

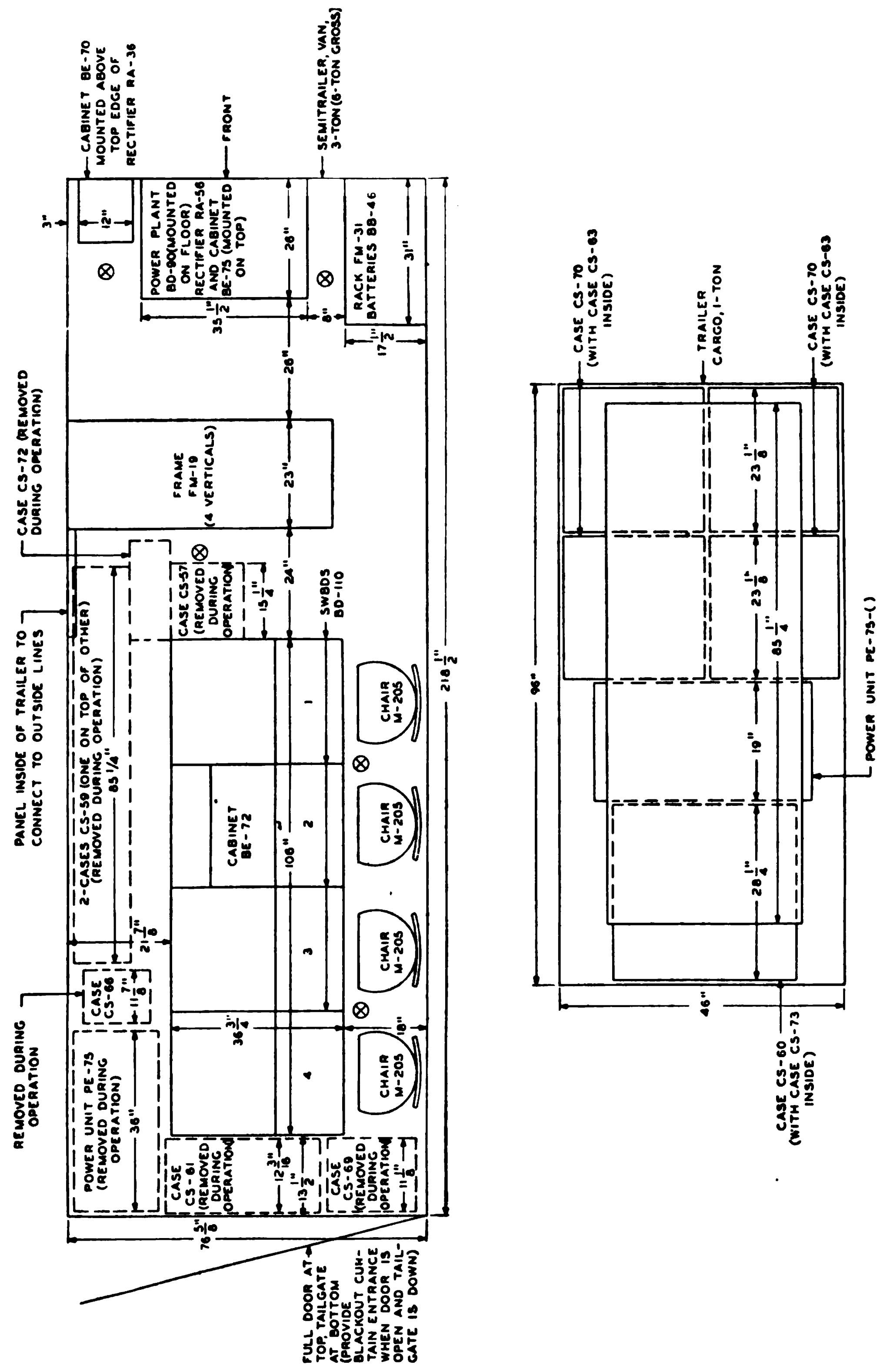
c. Mobile Spiral-four Carrier Terminals.

(*1*) An arrangement for mounting the three carrier telephone and three carrier telegraph terminals of three spiral-four carrier systems in a Semitrailer, Van, 6-ton (10-ton gross) is shown in figure 11-70. Each group, composed of a Telephone Terminal Set TC–21, Telegraph Terminal Set TC–22, and two Ringer Sets TC–24, is arranged to operate as an individual terminal on one spiral-four cable. When mounting three of these complete terminal sets in a semitrailer, duplication of all items of equipment contained in the TC–21, TC–22, and TC–24 sets is not necessary. The arrangement shows the essential units required for the proper operation and maintenance of three separate spiral-four terminals.

(*2*) A typical floor plan arrangement suggested in figure 11-70, shows the equipment located in such a manner that the cords, which are a part of the equipment, will reach the associated apparatus, except in the case of the Teletypewriter TG–7–( ), for which it will be necessary to furnish longer cords in order to connect the TG–7–( ) to each CF–2–B.

(*3*) In order to save space, two Ringing Equipments EE–101–A are mounted one above the other. It is suggested that a rack or shelf be built to hold the six ringers that are provided. A shelf above the ringer rack is also suggested in order to provide space for mounting the two Rectifiers RA–83–A. This shelf can also be used as a writing shelf and as a place to keep the miscellaneous testing and maintenance equipment when the unit is in operation.

(*4*) In fastening the carrier terminal carrying cases in the semitrailer, they should be placed tight against the sides and bolted to the floor. In addition, an arrangement similar to that used in Operations Center AN/TTQ-1 (TM 11-438) can be used for fastening the carrying cases to the sides of the semi-



⊗ INDICATES RECOMMENDED APPROXIMATE LOCATION OF LIGHTING OUTLETS

NOTES:
1. ONLY INSIDE DIMENSIONS OF SEMI-TRAILER AND TRAILER ARE SHOWN
2 HEADROOM OF SEMITRAILER IS 76 1/2".

TL 54967

Figure 11-68. Floor plan of 4-position Telephone Central Office Set TC-10 in Semitrailer, Van, 3-ton (6-ton gross) and Trailer, Cargo, 1-ton.

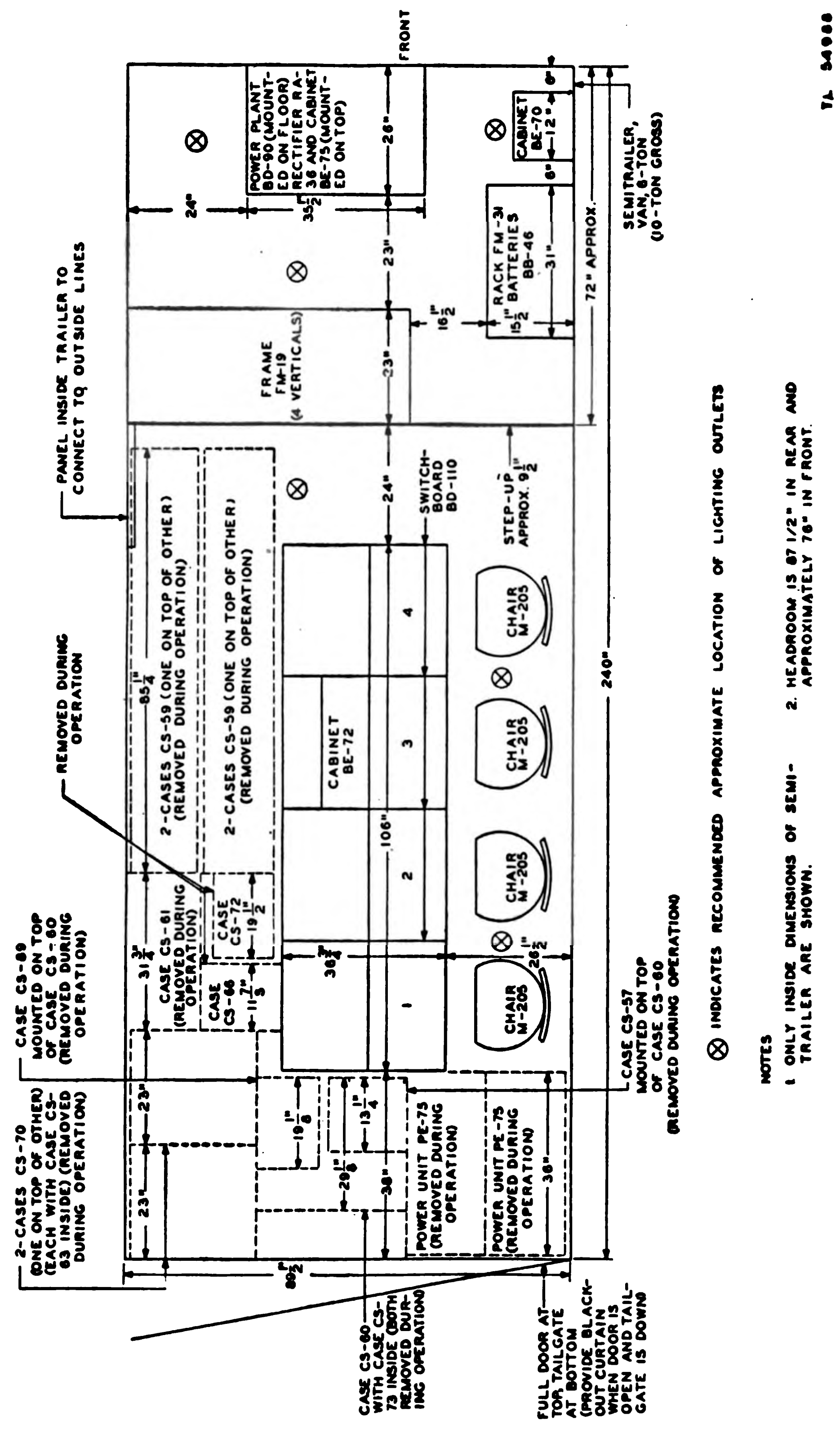
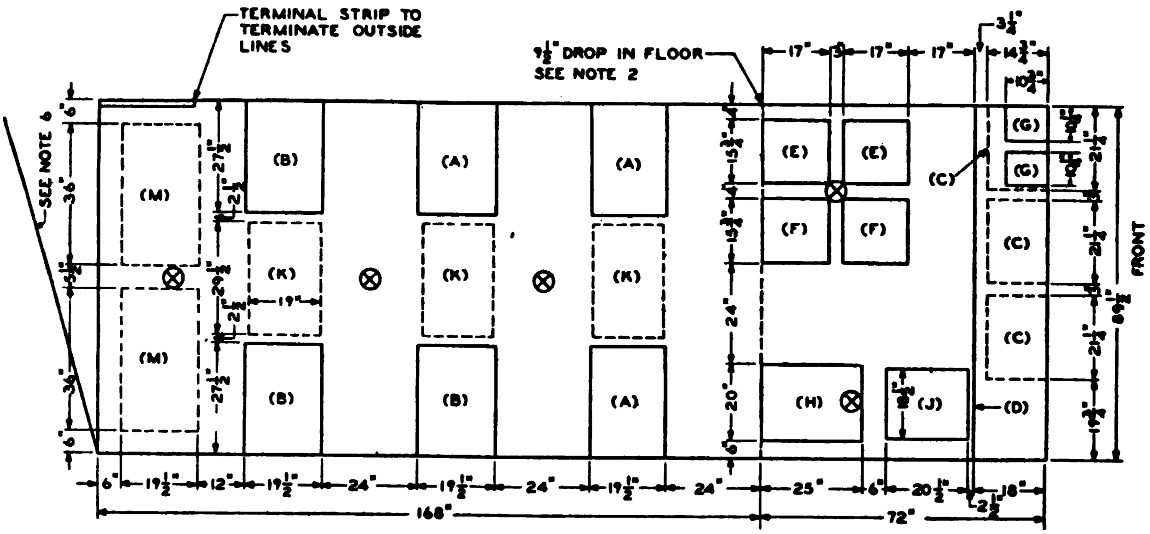


Figure 11-69. Floor plan of 4-position Telephone Central Office Set TC-10 in Semitrailer Van, 6-ton (10-ton gross).



CODE:

(A) - CARRIER TELEPHONE TERMINAL CF-1-A
(B) - CARRIER TELEGRAPH TERMINAL CF-2-B.
(C) - RINGING EQUIPMENT EE-101-A (VOICE FREQUENCY), MOUNTED TWO HIGH ON RACK UNDER SHELF (D). EACH EE-101-A CONTAINS TWO RINGERS.
(D) - SHELF OVER RINGING EQUIPMENT, SIZE 18" X 89 1/2" AND 30" FROM FLOOR
(E) - CASE CS-111 CONTAINING TWO BATTERIES BB-55 CONNECTED IN SERIES.
(F) - CASE CS-111 CONTAINING TWO BATTERIES BB-55 CONNECTED IN SERIES.
(G) - RECTIFIER RA-83-A FOR CHARGING BATTERIES BB-55, TWO RECTIFIERS MOUNTED ON SHELF (D).
(H) - TELETYPEWRITER TG-7-( ) MOUNTED ON COVER OF CHEST CH-50-A.
(J) - CHEST CH-62-A, USED AS SEAT.
(K) - CHEST BC-5, TWO FOR TELEPHONE PARTS, ONE FOR MECHANICAL PARTS AND MISC. HARDWARE, ETC. REMOVED DURING OPERATION.
(M) - PE-75-( ) POWER UNIT, ONE REGULAR AND ONE EMERGENCY, REMOVED DURING OPERATION.
⊗ - INDICATES RECOMMENDED APPROXIMATE LOCATION OF LIGHTING OUTLETS.

NOTES:

1. ONLY INSIDE DIMENSIONS OF SEMITRAILER, VAN, 6-TON (10-TON GROSS) ARE SHOWN.
2. INSIDE HEADROOM IS 78" IN THE FRONT AND 87 1/2" IN THE REAR.
3. CONNECT THE TWO 12V BATTERY UNITS (E) IN PARALLEL TO SUPPLY THE SIX RINGING EQUIPMENTS EE-101-A (12 RINGERS).
4. CONNECT THE TWO 12V BATTERY UNITS (F) IN PARALLEL TO SUPPLY THE THREE CF-1-A TERMINALS.
5. IT IS RECOMMENDED THAT THE FRONT OF THE TERMINALS FACE TOWARDS THE FRONT OF THE SEMI-TRAILER, VAN.
6. FULL DOOR AT TOP, TAILGATE AT BOTTOM. (PROVIDE BLACK-OUT CURTAIN ENTRANCE WHEN DOOR IS OPEN AND TAILGATE IS DOWN).

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Figure 11-70. Floor plan of spiral-four carrier terminals in Semitrailer, Van, 6-ton (10-ton gross).

trailer. In order to mount the carrier terminal carrying cases in this manner, it is necessary to remove the front and rear covers of the terminals, and leave them off at all times. Where dust or moisture is excessive during transportation, a canvas cover should be provided for both the front and rear of the terminals.

(*5*) Since the six Ringing Equipments EE–101–A are mounted on a rack or shelf, it is necessary to omit the covers when fastening them to the rack. If a rack is employed such that the first layer of three Ringing Equipments EE–101–A is set on the floor, it may be necessary to provide a narrow foot guard to protect them.

(*6*) In order to eliminate the need for several storage batteries, it is recommended that two 12-volt battery units be connected in parallel to serve as the emergency battery for the three Telephone Terminals CF–1–A, and two more units similarly connected, for supplying the six Ringing Equipments EE–101–A. Since an emergency Power Unit PE–75–( ) is carried in the semitrailer, the emergency storage batteries required can be carried as removable equipment.

(*7*) In cases where it is found necessary to run cables along the floor, wooden protecting ducts should be provided.

(*8*) The Teletypewriter TG–7–( )

should be provided for lining up the carrier telegraph circuits and to provide for general testing and maintenance of the equipment.

(9) Two Rectifiers RA–83–A, one regular and one emergency should be provided.

d. Mobile Teletypewriter Centrals.

(1) A floor plan for a mobile teletypewriter central arrangement is shown in figure 11-71 for two Switchboards BD–100 and a teletypewriter station in a shelter. In addition to the switchboards and teletypewriters, a line unit with power supplies, and one Repeater TG–30 are provided. There is not sufficient space for more than two teletypewriters; one of these can be used by the switchboard operator for operating the two switchboards and the other for use on a switchboard line that terminates in the shelter.

(2) The equipment mounted in Shelter HO–17–( ) or HO–27–( ) (fig. 11-71), consists of one Switchboard BD–100, one Teletypewriter Set EE–98–A, one Repeater TG–30, spare Power Unit PE–75–D, and one Telegraph Central Office Set TC–3 (one position). Components of these sets include ground rods, running spares, major tools, rectifier power units, and teletypewriters with accessories and supplies. Field wire may be used to interconnect equipments which are not furnished with cords. Circuits operated on a simplex (simultaneous telephone and telegraph) basis are derived from simplex coils located with the telephone line terminating equipment. This floor plan layout shows the location for two gas-engine power units. When the outfit is being moved, care should be taken to insure that the power units and chests, which are not permanently secured to the floor, are temporarily fastened in some manner so that no damage is done to the equipment while being transported (subpar. a (4) above). If terrain is such that the weight of the equipment in shelters is excessive, then the two power units can be placed in a separate truck.

e. Mobile Multichannel Radio Terminal or Relay Arrangements.

(1) A mobile installation of the components of two Radio Terminal Sets AN/TRC–3

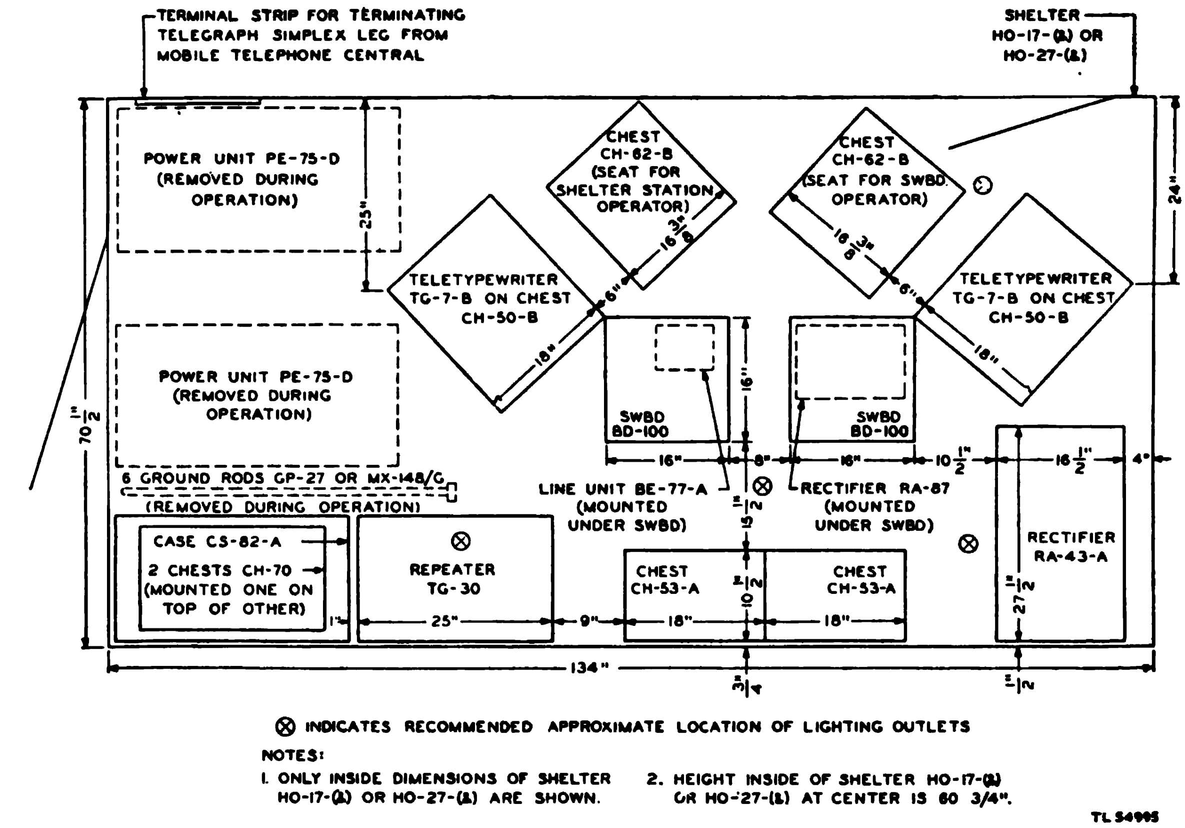

Figure 11-71. Floor plan of mobile teletypewriter central in Shelter HO-17-( ) or HO-27-( ).

and three Radio Relay Sets AN/TRC-4 has been used in one theater. This equipment, mounted in eight Trucks, Weapons carrier, ¾-ton, 4 x 4 and eight Trailers, Cargo, Amphibian, ¼-ton can be used to provide a complete 100-mile system consisting of two terminals and three relays. Five of the individual truck-trailer combinations can also be used as radio terminals (subpar. (2) below) which may be used alone or in conjunction with the mobile spiral-four equipment described in subparagraph c above. The same radio equipment can also be mounted in eight Trailers, Cargo, 1-ton in place of the above truck-trailer combinations.

(2) The two Radio Terminal Sets AN/TRC-3 and three Radio Relay Sets AN/TRC-4 are broken into their component parts, thus providing 13 Radio Transmitters T-14/TRC-1 and 13 Radio Receivers R-19/TRC-1 and an adequate number of antennas, power units, maintenance equipments, etc. to operate these transmitters and receivers, when distributed throughout the truck-trailer combination, as described in subparagraphs (3) to (5) below.

(3) Two each of the transmitters, receivers, antenna systems, and power units are installed in each of five truck-trailer combinations. Figure 11-72 shows the arrangement of the major components, which mount in the truck. Only two Power Units PE-75-( ) are used with each station and these are carried in the associated trailer. The arrangement of the power equipment in the trailer has not been shown but space is available to carry the necessary gasoline, oil, water, and personal equipment. The floor space in the bottom of the trailer is about 38 x 72 inches.

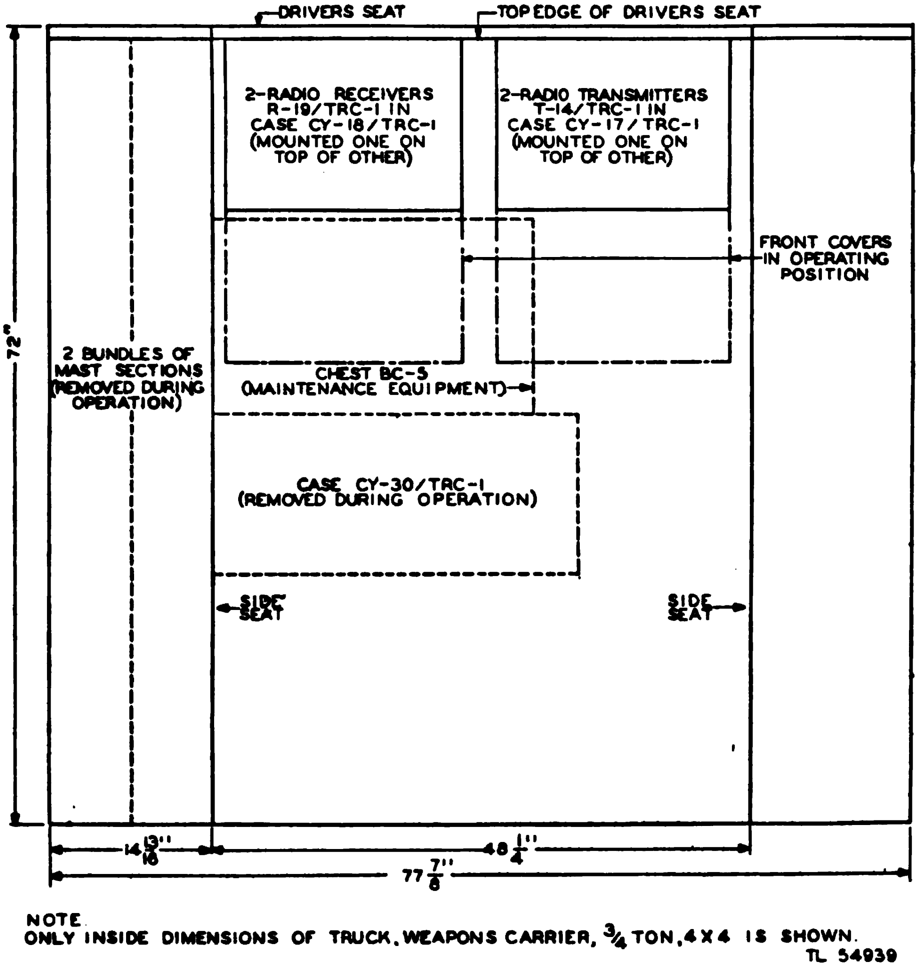

Figure 11-72. Typical AN/TRC-3, AN/TRC-4 mobile set-up.

(4) Each of the remaining three truck-trailer combinations is equipped with one transmitter, one receiver, two antenna systems, and two power units.

(5) The five truck-trailer combinations described in subparagraph (3) above serve as a terminal station having an operating transmitter, an operating receiver, and a spare of each. For a radio relay station, one truck-trailer combination, described in subparagraph (3) above and one truck-trailer combination described in subparagraph (4) above are required.

(6) In order to make the five truck-trailer combinations, described in subparagraph (3), independently operable, it is necessary to divide the maintenance equipment so that each will have the items and amounts of maintenance equipment which are a part of Radio Terminal Set AN/TRC–3. The maintenance equipment provided with the two radio terminal and the three radio relay sets is contained in two Chests BC–5 for the AN/TRC–3 (one for each) and six Chests BC–5 for the AN/TRC–4 (two for each). The material is removed from the two chests of each AN/-TRC–4 and those items which are normally a part of the chest of each AN/TRC–3 are put in one of the chests and the remaining items are put in the other chest. Five AN/-TRC–3 maintenance equipments will then be available for use in the five truck-trailer combinations described in subparagraph (3) above and the excess items in the three spare chests can be used with the three truck-trailer combinations, containing only a single transmitter and receiver, described in subparagraph (4) above.

(7) In order to conserve space, all of the Cases CY–29/TRC–1 and all except eight of the Cases CY–30/TRC–1, which contain the antenna mast sections and other antenna parts, are discarded and their contents are distributed among the eight truck-trailer combinations as required. The mast sections are carried on the side seats, and the remainder of the antenna equipment is carried on the floor, and in the one Case CY–30/TRC–1 which is in each of the trucks. In order to provide more room in the Cases CY–30/TRC–1 which are retained, the element racks are removed. The Cords CD–800, which are normally stored in Case CY–30/TRC–1 are placed in the rear pocket of the truck.

Section XI. MAINTENANCE

1156. GENERAL.

a. Necessity. Maintenance is required to prevent or correct the undesirable effects of wear and dirt, damage from the elements such as storms and moisture, and damage from friendly or enemy action. Maintenance also includes day-to-day rearrangements and changes, such as placing cross-connections for telephone installation and trunk circuit orders. The work can be classified broadly as preventive maintenance, corrective maintenance, and service order work. Maintenance varies in character according to whether it involves telephone and teletypewriter switchboards, local loops and telephones, test rooms, teletypewriter and telegraph equipments, station sets, repeater stations, radio stations, long distance lines, and power plants. All maintenance work requires personnel with specialized training.

b. Maintenance Instructions. Maintenance work is based largely on the experience and training of the maintenance personnel. However, it is desirable to have written instructions available covering certain features of the work, as a source of information and for periodic review. This section gives a general outline of the maintenance procedures. Maintenance instructions are given in TM 11–473, TM 11–353, TM 11–2037, and manuals provided with various types of equipment. It is sometimes advisable to supplement the information in the technical manuals with written instructions covering routine work items, particularly when the work involves more than one organization. Reference can be made to FM 24–20, and TM 11–473 for methods, routines, and forms to be used in maintenance.

c. Maintenance Supplies. Suitable tools and testing equipment (par. 1167) are essential, as are adequate stocks of spare parts and materials. Recovery and prompt repair of equipment at supply depots is desirable. Information concerning tool, test, and maintenance equipments may be obtained from TM 11–487.

1157. PREVENTIVE MAINTENANCE.

a. General. This is work done to detect conditions which may cause trouble and to correct them before they have a chance to affect service. Illustrations are: tree trimming before limbs touch wires; routine inspection of the entire station installation when a visit is made to clear a case of a trouble; testing all cord circuits of a switchboard to see that they give correct supervisory signals; periodic line-up of repeaters on a circuit; and patrol of wire lines by crews equipped to correct minor troubles. Important factors in maintenance are cleanliness of equipment, care in the use of tools and in handling equipment, and accuracy in making adjustments. Effectively used, preventive maintenance will contribute greatly to good service with economical use of facilities and personnel.

b. Effect of Construction and Installation Work. Service interruptions will be minimized if the planning anticipates and eliminates potential sources of trouble. For example, the location of a line where it may be washed out under flood conditions is an invitation to trouble. Careless work when installing local lines and equipment can be the cause of trouble at a later date. A pole line failure may be traceable to insufficient depth of setting of a pole or anchor, or to insufficient ground clearance in a span at a point where it becomes necessary to divert traffic from the highway.

c. Initial Tests. It is desirable to make tests of the components of any communication installation before placing it in service, that is, cut-over tests, to assure that they will function properly. This work can be performed by the personnel that is to be responsible for maintenance, thus familiarizing them with the equipment and its maintenance. A check list of work items, called a *cut-over program*, made in advance will be helpful.

d. Periodic Line Inspections. Line troubles may be minimized through periodic inspections by patrol crews to repair minor defects and report major ones. Progressive deterioration of supporting structures or the introduction of new hazards along the route can be detected. For example, an anchor may be found to have pulled up; insulated wires and cables, where laid on the ground, may become exposed to grass fires in dry seasons, which can be avoided by burning the grass under control; etc.

e. Periodic Equipment Tests and Inspections. Periodic tests, sometimes called *routine tests*, should be made on many items of equipment, in centrals and carrier stations. The necessary tests for carrier equipment are stated in the technical manuals that accompany the equipment. Tests that take trunk circuits out of service should be scheduled by the control office. Preventive maintenance testing is scheduled work which requires: provision of a list of work items to be performed; a suggested frequency such as daily, weekly or monthly, at which they should be performed; instructions as to how each should be performed; and forms for recording the tests and the trouble detected. Practices for some types of switchboards are available in Bell System Practices which can be obtained through Army Communications Service. Special instructions may have to be prepared locally for special types of equipment. The routine instructions should cover: tests for the correct operation of such items as alarm circuits, emergency ringing and power supplies, and trunk and cord circuits; inspections to determine items such as the level and specific gravity of storage battery electrolyte, and the state of wear on switchboard cords and plugs; and, work items such as apparatus cleaning and the polishing of switchboard plugs.

f. Apparatus Cleaning. Equipment trouble can be caused by dust and dirt which can come from outside a central or be generated within the office. The entrance of external dirt can be reduced by preventing the free intake of outside dirt-laden air. Air filters, if available, aid in preventing this. Precautions can be taken to minimize internally generated dust and dirt by preventing unnecessary travel of personnel through an office. Accumulated dust and dirt can be removed by cloth (very lightly dampened with water if desired) or a vacuum cleaner.

g. Switchboard Cord Repair. Switchboard cords that become worn or frayed are repaired either while attached to the switchboard cord shelf or after their removal from the switchboard. On busy switchboards it may be desirable to replace the cords and then repair them, to avoid interference with operators. Cord repair tools and methods are described in TM 11–473.

h. Teletypewriters. Teletypewriter maintenance should consist of systematic periodic inspections, lubrication, and adjustment. The inspections and readjustments as required should reveal and correct faults before serious equipment damage or interruption to service occurs. By keeping the equipment clean and free from dust and by proper lubrication, not in excess, it is possible to prevent a very large number of failures and consequently reduce the amount of corrective maintenance to a minimum. Preventive maintenance may be executed without great loss of operating time and should not materially tie up traffic. Operating personnel should cooperate with maintenance personnel by keeping the equipment clean and by reporting any abnormal operating condition.

1158. CORRECTIVE MAINTENANCE.

This is the work of testing and clearing troubles after they have started to affect service. These troubles are predominantly those which are reported by the service users, but also include those detected by operators or maintenance men. Corrective maintenance will probably take more of the maintenance force's time than preventive maintenance. Paragraphs 1164 and 1166 describe trouble testing and clearing.

1159. SERVICE ORDER WORK.

This is the work of placing cross-connections for local loops and trunks, between incoming line or cable pairs and the office equipment in centrals, and the testing of new installations in conjunction with the telephone installers. It constitutes a considerable percentage of the total work in the larger centrals, when installing and changing location of telephones is active. Work occasioned by rearrangement of voice-frequency and carrier long distance circuits, also falls in this category.

1160. MAINTENANCE OBJECTIVES AND PERSONNEL REQUIREMENTS.

a. Training. Men specially trained for the maintenance work to which they are assigned are essential. Training does not stop when the training course ends but is a continuing process to which officers and other supervisory personnel must contribute effectively from day to day in the theater in order to render good communications service.

b. Telephone and Teletypewriter Station Maintenance. Some station troubles will take ½ hour to find and clear, others three times that long or longer. The nature of the trouble will have an important bearing on the time required to clear it. An average to expect of the repair force is about 1 hour per trouble, if travel time is not excessive. With temporary open wire or field wire used extensively for the station loops, one repairman per 100 or less telephones probably will be needed. More permanent wire or cable plant will reduce this considerably. Six to 10 teletypewriter stations may require one maintenance man. Field wire can be expected to have 15 or more troubles per 100 miles of wire per week. Open wire lines will probably have 5 or more troubles per 100 pair miles per week. Lead-covered underground cable may have more than 2 sheath troubles per 100 sheath miles per month, and aerial cable possibly as high as 12 sheath troubles per 100 sheath miles per month. The trouble expectancy figures quoted are on plant not exposed beyond ordinary noncombat conditions and can be expected to be much greater where activity is greater. A local area with only three or four repairmen does not require a supervisor for the local loop maintenance since the men can be directed by the wire chief. Larger groups of men probably will require a group supervisor. In an installation of six or more switchboard positions serving several hundred telephones, the full time of one tester probably will be required to test and handle the trouble work.

c. Long Distance Line Maintenance.

(*1*) Long distance lines may need to be maintained by patrol crews, each responsible for a short section of line, in the order of 5 to 10 miles long. The length of section will depend on the importance of the line and the nature of the territory traversed. The number of wires on an open wire line may not always indicate the importance of the line because a few wires may carry many communication channels if carrier equipment is used. The crews should be on call 24 hours per day. A terminal circuit 10 miles long which is interrupted 5 percent of the day might be considered tolerable. A circuit consisting of 10 such sections would be considered highly unsatisfactory since the circuit might be working only 60 percent of the day. A suggested standard for open wire lines of the order of 100 miles in length should be that each section between 10-mile test points is free from interruptions for at least 99 percent of the time. Interruptions must be kept to less than 1 hour in every 4 days per 10-mile test section to achieve this result. This standard can be achieved by attention to preventive maintenance, by the instantaneous readiness of linemen, vehicles, and supplies at the terminals and at every test point, and by the provision of telephone communication between the terminals and the test points concerned. For 1,000-mile lines, a better standard should be achieved. Long line preventive maintenance may require wholesale cutting of tree branches; permanent diversion of the route when break-downs are found to recur at certain points because of traffiic or enemy action; and the elimination of incipient troubles by frequent patrol of the route, for example, at dawn, midday, and late afternoon. The lineman should be prepared to climb on his vehicle, knowing that all necessary testing equipment and supplies for permanent and temporary repairs are already there.

(*2*) Priority may be required covering the maintenance and restoral of important operation circuits, including rerouting if the circuit is out of service for longer than some definite period.

d. Maintenance of Centrals. Multiple switchboards should have a wire chief in charge to supervise the switchboard maintenance and the test room operation where both local as well as long distance line testing is performed. If the central is not too large he may also direct the local telephone and teletypewriter station maintenance, the installation of telephones and teletypewriters, and the carrier equipment maintenance. Large centrals may require three separate supervisors, one for the switchboard and test room, another for the carrier equipment, and a third to supervise the installation and maintenance of telephones and teletypewriters. Telephone and teletypewriter maintenance supervised separately from their installation is a further possibility, justifiable only in unusually large and active situations. Single-position local switchboards can often be maintained by the same force that maintains the associated larger office.

e. Carrier and Repeater Station Maintenance. The outlying repeater or carrier stations may require 24-hour coverage, particularly if engine-driven generators are installed, or if the installation is large. In any case, attendance at least during day and evening hours probably will be necessary to operate the gas engine power plant, to assist in locating line trouble, and to maintain the telephone, telegraph, and carrier equipment that may be there. A small office may combine this work under one small group of men. In large offices it may be necessary to have one group for the line testing, another for equipment maintenance, and a third to operate the power plant.

f. Dispatching Installers and Repairmen.

(*1*) It is generally preferable to dispatch all of the installers and repairmen for a local area from one central point. Such an area may consist of one central or several in a group and assumes that travel time will not be excessive to reach the average telephone or teletypewriter station in the area.

(*2*) It is preferable to dispatch from a test cabinet, which has voltmeter testing facilities and local lines between the switchboard and the test cabinet, in order to test lines and to assist the outside men in their work. Where a test cabinet is not provided, a 506B cordless PBX, or a simple wiring plan (ch. 2) with pickup keys at the telephones, can be used to terminate the local lines from the switchboards.

1161. TROUBLE REPORTING, GENERAL.

a. Trouble Sources. Trouble that develops in a communication system is detected by the service users, the operators, or the maintenance force, and trouble reports from each of these three sources takes a different course through the maintenance organization. The methods suggested for handling the trouble reports are described in paragraphs 1162 and 1163.

b. Instructions to Service Users. Telephone directories should instruct service users how to report trouble. Instruction cards at teletypewriter stations should carry similar instructions. These instructions should specify that trouble be reported through the operators to someone assigned to take such reports. This person can be the operator or the chief operator at small centrals, or a clerk at larger centrals.

1162. TROUBLE RECORDING.

a. General. Service users' trouble reports can be recorded and handled as follows:

(*1*) At small centrals and in the light traffic hours at large centrals, the calls can be answered by the operator or chief operator as described in paragraph 1108k.

(*2*) At large centrals or when the volume of reports warrants, a repair service clerk can be located at a table where the trouble reporting trunks from the switchboard terminate. The original record by the repair clerk should be on a daily trouble report, shown in figure 11-73. Immediate transcription should be

Exchange.................... DAILY TROUBLE REPORT *Telephone Teleprinter Date................

Serial No.	[illegible]				[illegible]		CLEARED		
	Time	By	Circuit	Trouble	To	Time	Trouble Found	Time	By

* Cross out one. .... Chief Operator

TL [illegible]

Figure 11-73. Daily trouble report.

made to the line record card (fig. 11-46) for the line involved in the trouble. This card is then used by the wire chief or test deskman in handling the work of clearing the trouble. These cards should be filed numerically in a tray convenient for use by the repair service clerk. After the trouble is cleared and the wire chief or deskman has entered the trouble record on the line card, it is returned to the repair service clerk. This clerk then completes the entry of the trouble found on the daily trouble report and returns the card back to file. The daily report is useful for subsequent analysis and control.

b. Long Distance Trunk Trouble.

(*1*) *General.* Each wire chief should have in file a circuit record card such as shown in figure 11-36 for each long distance telephone trunk and one like figure 11-37 for each telegraph trunk. These can be printed on the reverse side, as shown in figure 11-74, so that trouble reports and subsequent action can be entered on them.

DATE	TIME	NATURE OF TROUBLE	REPORTED TO	CLEARED				REMARKS
				DATE	TIME	FOUND	BY	

TL [illegible]

Figure 11-74. Telephone and telegraph trunk circuit trouble record.

(*2*) *Telephone Trunk Trouble.* In general, circuits that are kept busy do not require as frequent routine test, since a busy circuit obviously indicates that it is not in trouble. Circuits that have been handling considerable traffic and suddenly become idle should always be tested at the first opportunity by the switchboard operator. In addition, daily or more frequent tests of all telephone trunks, both long and short, are advisable, and should be made in periods of light traffic. Both operators making tests should report the out-of-order trunk on trouble tickets (fig. 11-6) and make it busy by means of signal plugs, rather than by cord circuit plugs that might open the circuit and interfere with testing. When an operator encounters trouble on a circuit at other times than while testing, the case should be referred to the chief operator who should test the circuit with the distant chief operator; if it proves to be faulty it should be reported by ticket and made busy as outlined above.

(*3*) *Teletypewriter Trunk Trouble.* Teletypewriter trunk troubles, encountered by service users or operators, that are referred to the teletypewriter chief operator should be recorded on a trouble ticket (fig. 11-6-B), which should be forwarded to the teletypewriter maintenance man. Subsequently the record of the trouble found can be entered on the ticket, which should be returned to the chief operator for his information. If the indications are that the trouble is in the outside plant, the teletypewriter maintenance man should refer the trouble to the wire chief.

c. Preventive Maintenance Trouble. Trouble detected while performing the daily, weekly, or monthly routine tests on equipment should be recorded on a test record to show the date, units tested, trouble encountered, trouble found, frequency of the test, and the identity of the tester. This record can be a sheet, designed to record the routine tests made on various equipments.

d. Telephone Switchboard Trouble. Switchboard troubles detected by the operators should be reported to the chief operator. These should include trouble on local loops and telephones, switchboard lamps, jacks, keys, cords, plugs, hand generators, head and chest sets, clocks, chairs, etc. The chief operator should verify the trouble and refer it to the wire chief by trouble ticket (fig. 11-6-B). The wire chief should enter the trouble found on the trouble ticket, which should then be returned to the chief operator for his information.

e. Teletypewriter Switchboard Trouble. Switchboard troubles detected by the operators should be reported to the officer in charge. Trouble may occur on station lines or trunk lines in the form of unsatisfactory transmission, requiring the test and control board attendant to make a check of the condition of the line facilities. Line transmission tests (line-up tests) are made from the switchboard. A trouble ticket should be made out by the officer in charge and forwarded to the wire chief for action.

f. Line and Cable Failures. The simultaneous appearance of several line signals, or several troubles on long distance lines, may indicate a line or cable failure which should be reported promptly by the chief operator to the wire chief and then to the maintenance officer in charge of outside plant maintenance. The line record cards for all of the loops or trunks involved in a cable failure should be passed to the test deskman, and after the trouble is cleared, a suitable record of the trouble can be made on the cards.

g. Power Failures. Failure of the power supply for telephone, telegraph, or radio operation, if from civilian or other distant source, will require prompt verbal report to the responsible authority. The time the trouble occurs and the clearing time should be entered on the wire chief's log.

1163. PERIODIC SUMMARY OF TROUBLE REPORTS.

a. When operations in a new system have reached a settled stage, it may be found desirable to summarize reported trouble weekly or monthly for analysis. The size of the maintenance force in relation to the number of troubles can be studied for possible improvement. The trouble summaries for different locations can be related to the number of units of plant involved, to show the troubles per unit of plant. This permits comparison of trouble conditions at different locations. For this purpose, analysis sheets can be prepared with suitable column headings to summarize the troubles under several general headings. Such a record is illustrated in figure 11-75.

b. For local loop and telephone troubles, a similar record can be used, in which the column headings can be: date, name of switchboard, station bell, station telephone, station protector, station wiring, drop wire, line wire, cable, and terminal. For this summarization, one line across the page can be used for each day; entries can be made by strokes and added up by weeks with a blank space between the weekly summary and the first day's entry for the following week.

1164. TESTING AND CLEARING TROUBLE.

a. General. Methods for testing and clearing trouble vary with the size and type of plant. For example, a one-position telephone central may permit one man or a small group of men, to do all the maintenance work at the central and also on the local loops and telephones, whereas a large central with many telephones, carrier equipment, and considerable telegraph equipment, may require specialized groups for the maintenance of the switchboard separate from the carrier equipment, etc. Switchboard testing is described in TM 11–473. The tests that can be made with various test sets and testboards are described in the technical manuals or instruction books which describe the test sets. It is important that suitable test sets be supplied at each switchboard. These sets are described briefly in TM 11–487.

b. Complete Line or Cable Failure. When a complete line or cable failure is indicated, the wire chief should determine the approximate location of the trouble and dispatch an outside plant maintenance man to ascertain the nature of the trouble and to endeavor to make prompt repair. This is particularly desirable in locations where lead-covered paper-insulated cable is involved, because a sheath crack may occur which will cause a few lines to be affected at that moment, but which may rapidly develop into a complete failure affecting all lines in the cable. Prompt action may prevent the trouble from causing a complete failure.

c. In Small Centrals. To clear local switchboard line and telephone trouble in small centrals, the repairman may do his own testing with the assistance which the switchboard operators can give, such as ringing and talking. To test trunk trouble, in addition to a telephone set, he should be provided with a voltohmmeter such as Test Set TS–26/TSM, to test for grounds, shorts, crosses, and opens. Knowledge and use of a Wheatstone bridge also will be desirable for the location of faults.

d. In Large Centrals.

(*1*) *Local Loop and Telephone Trouble.* It is desirable to assign a testdesk man whose duty will be to test and analyze the local trouble reported by service users. The tests will disclose whether the trouble is at the telephone, in the loop, or in the central. Voltmeter tests only are required in this work. Upon receipt of the trouble ticket or the line record card, the testdesk man will test the loop from his test cabinet with his voltmeter. Local telephone loops do not appear in test and control boards. Therefore, provision usually is made at one position of fixed plant multiple switchboards for a test cord connected to the wire chief's test cabinet. An order circuit is connected to the switchboard operator's set at this position, over which the testdesk man can direct this operator to put the test cord in any desired line jack. At small installations (perhaps six positions or less of switchboard) and in tactical switchboards such as Telephone Central Office Sets TC–1 and TC–10, it is usual for the tester to remove the heat coils of the loop at the main distributing frame and insert a test shoe, or attach test clips, with cords connecting to the test cabinet, by means of which tests can be made outward toward the telephone as well as inward toward the switchboard.

(*2*) *Long Distance Line Trouble.* In the larger centrals, it is usual to assign a testboard man to test and analyze troubles on long distance lines. The testboards provided for this work include a Wheatstone bridge. The localization of line trouble at a distance re-

WEEKLY REPORT OF LINE & EQUIPMENT TROUBLE

E.B.S.
AREA

APHQ Controlled Carrier Systems or Circuits
Out of Service for Periods of 3 Hours or More. Week of 0001 hours 30 Aug to 2400 hours 5 Sept.

Fault Control Ticket	DATE	CARRIER SYSTEM or CIRCUITS AFFECTED	DESCRIPTION OF TROUBLE	LOCATION	1 Toll Open Wire	2 Toll Cable	3 Local Cable or Wire	4 Repeater	5 Carrier Terminals	6 Ringers	7 Relay Equipment	8 Machines	9 Dist. Frame & Wiring	10 Power Failure	11 Undetermined	HOURS OUT OF SERVICE
		Troubles in this Area														
356	8/31	System #3 CF-1-A Bone - Bizerta	Pole broken by Military Vehicle-Wires Crossed	6 Km. E. Mateur	X											6 1/2
		Troubles in other Areas														
101	9/5	Algiers-Bizerta L.D. #1	Adjusted relay in Ringer	Algiers						X						3 1/4
				Total												
										Total all Troubles						

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Figure 11-75. Periodic report of line and equipment troubles.

quires bridge measurements because voltmeter tests are inadequate. The long distance lines usually are looped through jacks in these testboards for convenience. The testboard man, upon receipt of a trunk trouble ticket, will monitor on the trunk to make sure no one is talking before he opens the circuit for test. If the trunk is idle he will put up a test cord in the line circuit jacks and test the trunk by means of the test equipment that is provided for the purpose. If the trunk is in service he will have it made busy at both ends before making tests. Preliminary analysis tests can be made by voltmeter but exact locations of trouble on outside plant require a Wheatstone bridge. Troubles in the centrals are located by using a voltmeter.

(*3*) *Carrier Equipment Trouble.* If a preliminary test made by a testdesk man indicates that trouble exists in the carrier equipment, the case usually should be referred to the carrier equipment maintenance man. Major troubles on tactical carrier units may require replacement of the defective component and its return to a repair depot. Fixed plant type packaged equipment should not require return of units to the repair depot for most troubles encountered.

(*4*) *Switchboard Trouble.* Telephone central maintenance usually divides into preventive (routine) testing on a regularly recurring schedule basis and trouble clearing as a result of trouble reports. Both functions are carried on by the same group. If the switchboard is large, the preventive maintenance work may be assigned to one person, and the trouble clearing to others. Test Set TS–190/U, which is a telephone receiver with suitable cords and cord termination, is the chief testing device used in switchboard trouble clearing. At the multiple switchboards, circuits are numerous enough to justify a current flow test set, such as Test Set I–181, for measuring the current flowing through relays. A file of schematic and wiring diagrams for maintenance use should be kept for all circuits in an office. Figure 11-76 indicates the type of information necessary for use in testing and adjusting switchboard relays.

e. Teletypewriter Circuit Trouble.

(*1*) *General.* Unsatisfactory operation of teletypewriter circuits, resulting in defective transmission of signals, may arise from any of the following troubles: abnormal line conditions, improper line-up or adjustments of line transmission equipment, or improper adjustment of station teletypewriter equipment. Checks of the transmission quality may be made by use of teletypewriters and signal distortion test sets as covered in chapter 12. General maintenance information for teletypewriter equipments is given in TM 11–353. Detailed information regarding trouble location methods and maintenance procedures for individual equipments will be found in the technical manuals or instruction books furnished with the equipment.

(*2*) *Testing Procedures.*

(*a*) In general, the first objective is to locate the trouble either in line or local extension conductors or in centrals or station equipments. On a direct point-to-point circuit this is generally not difficult. However, on a circuit composed of a number of sections in tandem, with or without branch circuits from the main line circuit, it will often be necessary to send test signals in one or both directions over the complete circuit from one or more points. By observing these test signals on monitoring teletypewriters at the various offices, it should be possible to determine where the trouble condition exists.

(*b*) After the trouble has been located in a particular section, office, or station it may be necessary to make some general tests specifically to locate and clear the trouble. Tests which may be made are: voltmeter tests of line and local circuits, polar relay tests, margin measurements, and motor speed check of station teletypewriter. Chapter 12 gives data for making teletypewriter margin measurements. Failure to obtain a supervisory signal may be due to burned-out lamps, or the contacts of the signaling relays may require cleaning. The proper speed for the operators' teletypewriter motors should be maintained.

f. Teletypewriter Trouble.

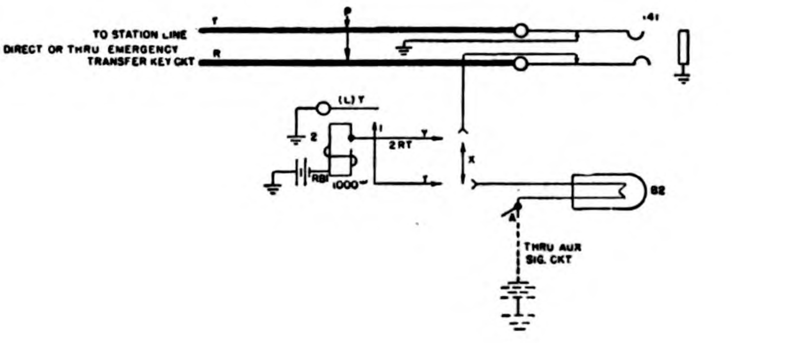
(*1*) Corrective maintenance is necessary before teletypewriter equipment is returned to service after it has failed to operate satisfactorily, and may require in some cases the use of new parts or complete overhaul. The necessity of taking teletypewriters out of service for repairs may cause traffic delays. Therefore every effort should be made to reduce the necessity of corrective maintenance to a minimum. Corrective maintenance should be per-

CIRCUIT REQUIREMENTS
551A OR 551B STATION LINE CIRCUIT (STA L)

APPARATUS		MECH. REQ			CIRCUIT PREPARATION				TEST SET PREP	SEE TEST NOTE NO	DIRECT CURRENT FLOW REQ.					REMARKS
							TEST CLIP DATA									
DESIG	CODE	B.S.P FIG.	CONT. PRESS	ARM TRVL	SEQ SW POS	BLOCK	CONN. BAT	CONN. GRD.			TEST WDG.	TEST FOR	AFTER SOAK MA	TEST MA	READJ MA	
RELAYS																
L ◆	E5	I	L	15				RT (L)	GRD	2		O		8.4	8	INSERT REAR PLUG IN JACK
								RT (L)	GRD			R		2.8	3	. . . . .
L ◆	A5	D						2RT (L)	GRD	2		O		8.4	8	. . . . .
								2RT (L)	GRD			R		2.6	2.8	. . . . .

CKT ISS NO 1 2 3 4 5

TEST NOTES:
1. ◆ INDICATES THAT THERE IS MORE THAN ONE RELAY WITH THE SAME DESIGNATION.
2. PRIOR TO ISSUE 6-D, TEST VALUE WAS 9 MA.



TL-7590

Figure 11-76. Relay circuit requirement table as found on circuit drawings.

formed in a repair shop where tools and test equipment are available. It is recommended that maintenance personnel who are trained in corrective maintenance be sent to the operating station to inspect the faulty apparatus and decide if the repairs should be made at the station or in the shop.

(*2*) To maintain service while repairs are being made, the maintenance shop should have spare machines in working order which can be used to replace any machine used in the area. It is not anticipated that maintenance shop spare equipment will be sufficient to cover combat losses. A machine which cannot be readily made to continue in service should be replaced by a spare machine.

g. Telegraph and Equipment Maintenance.

(*1*) Maintenance work should be done with a minimum effect upon service and complete spare equipment units or components of units should be installed when trouble cannot be cleared at once. Apparatus covers, especially relay covers, should be kept in place, and dust accumulation inside covers should be removed with a clean cloth before replacing. Cleanliness in the care of contacts on keys, jacks, and relays will reduce service interruptions. Caution should be exercised in soldering (TM 11–2037). The control office[5] is responsible for satisfactory operation of circuits under its control and in general, supervises the maintenance of equipment connected to these circuits.

(*2*) Demountable polar relays in telegraph and teletypewriter equipment should be tested and adjusted in standard polar relay test sets when available. A periodic maintenance schedule may be established for check testing the relays and, if necessary, adjusting them. The frequency with which the relays should be checked will depend upon the amount of time they are actually functioning while in the circuit. This frequency of test may vary from about one week for busy equipment to several months for infrequently used equip-

[5] The importance of establishing a control point in European international telephony was recognized at the Budapest plenary meeting of the CCIF (International Consultative Committee on Telephony) in September 1934 at which the following rule was recommended: "One of the stations through which a circuit passes is responsible for satisfactory transmission on that circuit. This station is called the *control station;* it is chosen by agreement between the technical departments of the Administrations and operating companies involved. Unless otherwise arranged between the technical departments interested, the control station will be one of the terminal stations of the circuit."

ment. Spare relays, properly adjusted, should be available at all times for replacement purposes.

1165. POWER PLANT MAINTENANCE.

a. General. This paragraph discusses the maintenance of engine-generator sets, storage batteries, rectifiers, and ringing generators. Other matters pertaining to power supplies are covered in chapter 7. Some power equipments require daily or more frequent inspection. Further information on maintenance is contained in TM 11–430, TM 11–473, and in information furnished with the equipment.

b. Engine-driven Generator Sets. Information on the maintenance of gasoline engines used with generators is given in chapter 7. The information for the maintenance of diesel engines similarly used is given in the manuals provided with the engines. Each diesel engine model is intended to be lubricated by, and operated on, certain grades of oil. Because it is not always possible to obtain the suitable grades of oil, the engines are frequently run on and lubricated with improper grades with resultant maintenance difficulties, and comparatively short life.

c. Storage Batteries.

(*1*) These may be either the enclosed or open type. The open type probably will be encountered only in civil plants. All storage batteries generate explosive gas, and care must be exercised to prevent igniting this gas by sparks, including those from static, or nearby flame. Distilled water should be used in replacing that which evaporates. The use of impure water may be unavoidable but it should be recognized that the life of the battery may be shortened thereby. Improper charging rates will adversely affect the plates in a manner readily apparent in open type batteries but difficult to observe in enclosed types. Charging rates should be adjusted so that the specific gravity of individual cells, when properly filled, is maintained according to instructions provided with the particular battery. New batteries, when shipped dry, require the addition of electrolyte and always require preliminary charging before placing them in service. This may take 24 hours or more. The acid is corrosive to most metals, wood, and clothing and, if spilled, can be neutralized by a strong soda and water solution, (½ pound of soda per gallon of water).

(*2*) Individual cell voltage readings should be taken after a full charge. Different cells may show different voltage readings. The allowable limit of variation from the average for the string of cells, is 0.05 volts for large and 0.10 volts for smaller cells. These voltage readings preferably should be taken while the cells are on charge at the maximum charging rate used on the battery. A voltmeter with a 3-volt scale is desirable.

(*3*) Several methods of charging batteries for particular centrals are available and will be determined when the job is engineered. The charging method has considerable bearing on the life of the battery. The recent designs of power plant which use regulated tube rectifiers require little attention and result in long battery life.

d. Rectifiers.

(*1*) In general, the maintenance required for rectifiers may be confined to a few items, such as the replacement of tubes, rectifying discs, fuses, and electrolytic capacitors.

(*2*) In the case of Tungar or other tube type rectifiers, the replacement of tubes, which have burned out or otherwise become inactive, will be required. With the disc type rectifiers, whether selenium or copper oxide, their disc assemblies will usually have to be replaced when the particular rectifier output indicates its voltage has fallen off about 20 percent of its rated value, unless specific application dictates earlier replacement.

(*3*) When a rectifier equipped with electrolytic capacitors is stored or otherwise left idle for considerable periods of time, it will be necessary, in order to maintain the electrolytic film on such capacitors, to connect the rectifier to a source of alternating current for ½ hour every 18 months of such idleness. In addition, experience indicates the electrolytic capacitors, will have to be replaced every few years, the period depending on the type of capacitor and the conditions to which it has been subjected.

(*4*) Reference to the various technical manuals, or to specific instructions which may be furnished with a particular rectifier, should be made to insure that additional or special maintenance instructions are not overlooked.

e. Ringing Generators. The types of ringing generators used by the Signal Corps include reed-type Interrupter PE–250–( ) (Telering), pole-changer Interrupter PE–248–

( ), static-type Ringer TA-13/TT (Subcycle), and various types of motor-generator ringing machines. The reed-type and pole-changer interrupters, which have electrical contacts, require attention frequently. Their contacts pit, burn, and may become dirty. Contact springs may require adjustment. The speed of vibration is important and can be checked with a frequency meter, if available. The output voltage is controlled by the amount of swing of the vibrator arms which can be adjusted. Increase of swing increases the output voltage. Ringer TA-13/TT has no moving parts, is less subject to failure, and requires no periodic attention. Motor-generator ringing machines require attention daily to see that oil cups are properly filled, that the machine is not overheating, that the collector rings and armature contact surface are clean, that the brushes are seated properly, and that the machine is free from dust and excessive oil.

1166. RADIO MAINTENANCE.

a. Preventive Maintenance. Some of this work is performed while the equipment is on the air and some during normal shutdown periods. It is limited to inspection by the using unit, cleaning and lubrication of parts, tightening of assemblies, minor adjustments, etc. The inspection, visual and by feeling, detects overheating by temperature or by discoloration and corrosion; it also locates fungus growth and need for dusting or cleaning. Lubrication includes that of parts such as gear trains, shafts, guide motors, etc. Tightening of connections, knobs, and assemblies affected by vibration and use, is required periodically. Adjustments normally are very limited, generally of an emergency nature when required to keep the equipment in service. The technical manuals and instructions supplied with each type of equipment give detailed instructions on preventive maintenance, as well as moistureproofing and fungiproofing requirements and methods. Section XII also gives information on these subjects.

b. Corrective Maintenance.

(1) *General.* This work divides between the using echelons and the higher echelons of repair. Using-echelon maintenance generally is limited to replacement of plug-in parts, except for fixed plant equipment where more extensive repairs may be performed within the skill of the station personnel and the facilities of the station. Higher echelon repairs include those of limited nature which are performed by the mobile third echelon shop and personnel; and complete reconditioning at fourth and fifth echelon shops. The important consideration is to assure that the repair echelons are equipped with the essential tools, test sets, and technical and repair manuals; and have proper personnel to do the specialized work involved. Also, that the repair parts authorized by the Signal Supply Catalogues SIG 7, SIG 8, and SIG 10 are available in the depots and are issued to the indicated repair echelons.

(2) *Test and Repair Procedure.*

(a) *General.* Test and repair on equipment in place should follow a logical procedure. The methods divide into five parts which are: physical inspection; electrical test; section-by-section test; repair and replacement of parts; final inspection; and test run.

(b) *Physical Inspection.* Physical inspection uses sight, smell, hearing, and touch. The sense of smell detects overheated or burning insulation. Hearing detects failures which cause humming, sputtering, or crackling sounds. Glass tubes can be checked by sight for burnouts. Sight also can locate wiring damage, insulation breakdown, and loose connections. Metal tubes can be checked for burnout by touching envelopes after the set has been warmed up for use. If these tests fail, the next step is to make electrical tests.

(c) *Electrical Tests.* Radio equipment usually can be sectionalized in making electrical tests. The testing procedure should provide for section-by-section tests in order to locate faults quickly. The first test should be made on the power supply equipment (battery, dynamotor, or vibrator). Then the cordage should be examined for defects. Fuses should be next in order. Blown fuses should not be replaced until the cause of failure has been located and cleared. The current should be checked for normal flow. If the power supply is satisfactory, the tubes should be tested one by one in a tester. Tubes that show an open filament or heater on the tube tester can be checked by inspection or with an ohmmeter. Burned out tubes should not be replaced until possible set troubles have been located, so that new tubes will not be burned out from the same cause that ruined the removed tube. Faulty tubes should be replaced, however voltmeter and resistance tests should be made on the equipment because the failure may be due to the tube or improper voltage. Sockets should be inspected for corrosion on the under side. If the set still fails, section-by-section tests should be made.

(*d*) *Section-by-section Tests.* Section-by-section tests include voltage, current, resistance, and dynamic tests. The voltage tests are made with all tubes in operation and normal power applied. Resistance tests are made with the power off. Caution should be exercised in testing so that personnel will not be burned by the high voltages that may be encountered. Measurements are made at points specified in the instructions provided with the equipment. Readings that differ from the maintenance data for the set indicate defects. The current tests can be omitted unless the other tests fail to locate the trouble. However, they are very important in checking transmitters. When testing sets with expensive tubes it is advisable to make the resistance tests first. The dynamic tests (signal tracing), are made section-by-section through the equipment.

(*e*) *Repair and Replacement, Final Inspection, and Test Run.* Inspection should be made after repairs or replacement of parts, to be certain that a good job has been done, that soldering is good, and that assembly is correct. A final test run should then be made which will be sufficiently long to assure that the sets will stand up in service, and then they should be checked for correct calibration.

1167. MAINTENANCE TOOLS AND TEST SETS.

a. For Telephone Maintenance.

(*1*) *Tools.* Tool equipments, or maintenance equipments which may include some tools, are furnished as components of certain of the telephone equipment, such as switchboards, central office sets, etc. These equipments do not include the small pocket tools (pliers, screwdriver, etc.) of Tool Equipment TE–5, usually employed in maintenance of centrals and telephones. These are supplied separately in accordance with the Tables of Equipment.

(*2*) *Test Sets.* Telephone EE–8–( ) can be used as a general utility test set in practically all line and telephone maintenance work. Telephone Unit EE–105 should be used by line repairmen who work on lines with carrier, because it can be bridged on a carrier circuit without interference whereas Telephone EE–8–( ) cannot. If the repairman takes care of small satellite common battery or magneto centrals, the small portable Test Sets TS–26/TSM and TS–27/TSM are useful. Suitable test cabinets for local testing and test and control boards for long distance line testing are available. Switchboard maintenance requires Test Set I–181 for adjusting relays. Test sets are covered in more detail in TM 11–487.

b. For Telegraph and Teletypewriter Maintenance.

(*1*) *Tools.* Tool Equipments TE–50–( ) contain tools and expendable material for the use of teletypewriter repairmen in the maintenance of teletypewriter equipment in the field, in addition to Tool Equipment TE-5 mentioned in subparagraph a above.

(*2*) *Test Sets.* Two forms of test sets are required especially for telegraph and teletypewriter purposes. These are polar relay test sets and signal distortion test sets. Test Set I–193–A (the polar relay test set) and Test Sets TS–2/TG, DXD–1 and DXD–4 (the signal distortion test sets) are generally used in the field; these are discussed in chapter 3. Neutral flat-type relays in telegraph equipments are adjusted and maintained in the same manner as in telephone equipments.

c. Tools and Tests Sets for Radio Maintenance.

(*1*) *Tools.* Tool Equipment TE–5 (subparagraph a above) is issued to all required personnel in all echelons. Tool Equipment TE–41–( ) contains an assortment of tools and supplies for 2nd echelon radio and radar maintenance. Tool Equipment TE–113, the individual repairman's kit for radio and radar repair, is issued to each radio repairman of the 3rd or higher echelons, and may be issued to each radar repairman of the 2nd or higher echelons. Tool Equipment TE–114, the basic radio and radar repair kit, is issued to each repair unit of the 3rd or higher echelons. TE–113 and TE–114 contain various small hand tools for repair work.

(*2*) *Test Sets.* Test Equipment IE–9–C is used for radio repair by the 3rd and 4th echelons and contains: analyzers, frequency meter sets, signal generators, dynamotor test set, tube tester, ammeters, voltohmmeter, etc. Various other test equipments, described in TM 11–487, are provided in repair shops and by service groups, for use on particular types of radio sets. A 3rd echelon mobile radio repair shop is shown in figure 11-77.

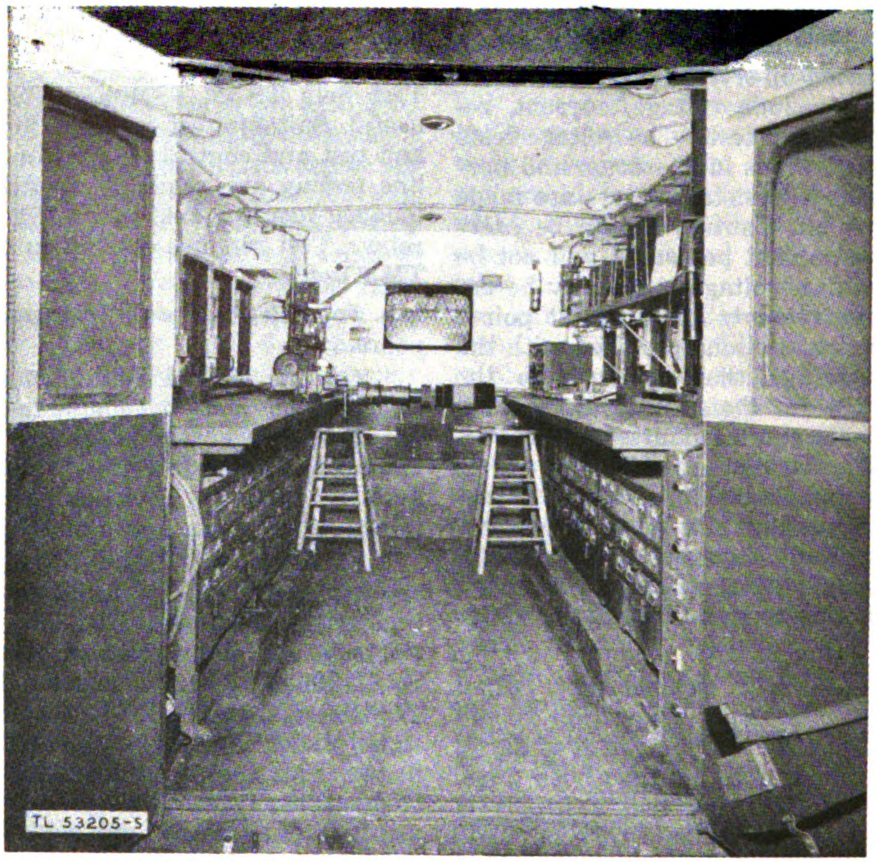


Figure 11-77. Mobile radio repair shop.

Section XII. EFFECTS OF CLIMATE

1168. POSSIBLE WORLD-WIDE USAGE.

Equipment to be used in any part of the world is subject to wide ranges of temperature, pressure, and humidity; to water damage in shipment and use; and to fungus growth in the tropics. The problems of fungus and humidity are discussed in TB SIG 13, Moistureproofing and Fungiproofing Signal Corps Equipment, and TB SIG 72, Tropical Maintenance of Ground Signal Equipment. TB SIG 66, Winter Maintenance of Signal Equipments, discusses the problems of cold-climate usage.

1169. TEMPERATURE EFFECTS.

a. Equipment in transit to various parts of the world may be exposed to temperatures between −40°F and +150°F. Equipment in operation ordinarily will not be exposed to temperatures of such extreme range. The effects of temperature on dry batteries, storage batteries, and rectifiers of the dry disc type are discussed in chapter 7.

b. Low temperatures may affect the operation of certain equipment seriously. Dry batteries become inoperative at temperatures between −10°F and −20°F but they regain their normal characteristics when they again reach normal temperature. At 0°F charged storage batteries lose capacity in the order of 50 percent, but without damage to the cells otherwise. At this low temperature discharged storage batteries may be permanently damaged. Counter emf cells are subject to freezing at temperatures of 15°F or lower; if enclosed and heated by lamp, vents are required to allow escape of the explosive gas they generate when activated by current flow through them. Rubber becomes brittle at low temperatures, but ordinarily this has no effect on maintenance conditions. Freezing of rotating bearings, shafts, and gears is the most troublesome feature of cold climate operation if these parts are not properly lubricated for cold operation.

c. High temperatures create more problems in maintenance than low temperatures. Prolonged temperatures of 150°F will cause rubber spring studs in relays to lose their shape when under pressure, which affects the adjustment and operation of the relay considerably. The increase in resistance of windings of relays in the order of 15 percent may affect the operating characteristics. Paper and mica capacitors which are potted in wax or asphaltic compounds may be impaired permanently. Resistors of the fixed carbon type are subject to excessive changes in value at higher temperatures. Rectifiers of the copper oxide disc type age more rapidly when ambient temperatures are high. It is found that rectifiers of the selenium disc type deteriorate rapidly in storage in tropical areas when high temperatures and high humidity are combined. Reports indicate that satisfactory operation is obtained if they are kept in use. Dry batteries deteriorate rapidly in shipment or storage in hot climates if not protected. Use of refrigerated space for shipment and storage has been helpful. Some use has been made of sealed containers for dry batteries. Caution should be exercised in opening these containers since explosive gas may be generated by the batteries in them.

1170. WETTING, HUMIDITY, AND RELATED EFFECTS.

a. While all equipment for use in the tropics must be capable of functioning efficiently under the temperature ranges encountered, high temperatures alone are not the source of the greatest difficulties. Wetting by salt water or salt spray in landing operations and in temporary storage causes much damage. Continuous damp warm air causes breakdown of wire insulation, warping, swelling, disintegration of insulating materials, corrosion of ferrous parts, contact corrosion, collapse of woodwork, and troubles caused by fungus growth.

b. Ordinary insulations consisting of silk, acetate yarn, or cotton alone, commonly used for telephone equipment, even though wax-impregnated, are not adequate. Unimpregnated textiles absorb moisture, which greatly reduces their effectiveness as insulators. An enamel coating on the wire under the textiles is indispensable. A cellulose acetate coating over the outer layer of textiles is superior to wax impregnation from the standpoint of fungus growth. Wax, especially beeswax, quickly becomes covered with fungus growth (mildew) which, if allowed to remain, in time will destroy the outer layers of insulation.

c. Fungus growth often will reduce insulation resistance to such an extent that service is interrupted. Under favorable tropical conditions it may form in a day or two on the edges of insulators in spring pileups of relays, keys, and jacks, thereby causing short circuits. Experience indicates that once such growth begins, even though the insulator is immediately and thoroughly dried, growth will continue more rapidly as soon as the high humidity reappears.

d. Insects create maintenance problems. Spiders build webs everywhere in the tropics, including the wiring of switchboards and station equipment and in the petticoats of line wire insulators. Even lizards have been known to enter equipment and short-circuit main bus bars. Termites eat up wooden structures and some types of insulation.

e. Tropical wind storms sometimes carry large quantities of dust which causes considerable difficulty by getting into equipment and causing contact and insulation trouble.

1171. MOISTUREPROOFING AND FUNGIPROOFING.

a. TB SIG 13 and TB SIG 72 describe moistureproofing and fungiproofing treatment adopted for Signal Corps equipment which provides reasonable protection against fungus growth, insects, corrosion, salt spray, and moisture. The treatment is intended for field application as well as in the factory and uses a moisture-resistant and fungi-resistant varnish applied with a spray gun and brush.

b. The method of application in the field briefly is:

(*1*) Make all repairs and adjustments necessary for the proper operation of the equipment.

(*2*) Disassemble the equipment partially and strip it as far as necessary to reach inaccessible parts.

(*3*) Clean all parts thoroughly of dirt, dust, rust, fungi, etc., and cover air capacitors, relay contacts, open switches, etc., with masking tape.

(*4*) Dry equipment thoroughly to dispel moisture which the circuit elements have absorbed. (Drying with infra-red lamps or in drying ovens heated by light bulbs or gasoline burner are suggested. In general, 2 or 3 hours at a temperature not exceeding 140°F is required.)

(*5*) Spray all circuit elements with three coats of Lacquer, Fungus-resistant, Specification No. 71–2202 (stock No. 6G1005.3), or equal. Ten minutes in the heating oven is suggested between the first and second coats. Return to the heating oven after spraying is complete, turning off the heat and allowing the oven and contents to cool. Air drying is practicable but takes 20 to 30 minutes longer.

(*6*) Touch up with a brush the points missed by the spray.

(*7*) Reassemble the equipment.

(*8*) Retest and readjust the equipment, realign radio sets, and mark all sets to show that they have received treatments.

c. Moisture and Fungus-proofing Equipment MK–2/GSM has been developed for use by repair units in the field. This kit contains equipment and materials required for treatment of signal equipment by third echelon and higher repair units. The kit contains infra-red lamps, lamp sockets, mounting brackets, switches, and a control thermostat to be used in moisture removal treatment. The spray gun provided is hand-operated.

1172. OTHER PREVENTIVE AND REMEDIAL MEASURES.

a. Hot-air Blowing. The use of hot-air blowers frequently may be necessary, depending on the equipment involved and the severity of the moisture conditions encountered. If available, portable 4- or 5-kw fan-type convection heaters are useful. Heaters as large as these usually operate on 230-volt ac, 60-cycle, single-phase power. They have been successfully used to dry out telephone central equipment which has been submerged. Infra-red and ordinary lamps also may be used for drying equipment. Ordinary fans may be used to circulate the air that is heated by the lamps. Troubles in switchboard cables or forms caused by wire insulation leakage, heating, or breakdown from moisture may require opening up by cutting away the cable sheath or outer covering so that warm dry air can be blown through the core. Apparatus that can be removed can be dried in ventilated areas in which the temperature does not exceed 140°F.

b. Heated Enclosures. For enclosed equipment, the use of a heating unit in the form of a resistor or lamp will frequently be found helpful. Sufficient heat to raise the temperature within the enclosure 5° to 10° F above the normal temperature will be adequate. It is recommended that, if practicable, enclosed heaters be used to effect reduction of humidity troubles wherever preventive action is needed. Sometimes, however, enclosed heaters will create temperature gradients within the apparatus such that objectionable condensation of moisture will still persist. Proper physical location of heating units and fans may be important.

c. Screens and Enclosures. Where trouble is experienced with insects, all ventilating louvers or openings in enclosures not already provided with screens should be screened, preferably with copper or other nonferrous material, with a mesh equivalent to 16 mesh, if it is at all practicable. Dustproof enclosures are desirable to protect equipment where dust is a source of trouble. If enclosures are used, temperature rise of equipment enclosed should be considered so that damage from overheating will not occur.

d. Termites. Protection against termites is difficult. Inside of buildings protection can consist of pans of oil in which the legs of equipment panels are placed. This prevents access to the structure except through the liquid.

CHAPTER 12

TRANSMISSION YARDSTICKS

1201. PURPOSE.

This chapter explains some of the terms and basic ideas on transmission which are used in chapters 1 to 11. Other terms and ideas have been explained at the points in the text where they were first used, when it seemed more appropriate to do so. Chapter 12 should therefore be considered primarily as an auxiliary to the rest of this manual.

1202. POWER RANGES IN COMMUNICATION SYSTEMS.

In a 60-cycle power system, most of the power generated is delivered to the users. In a telephone or a voice-frequency telegraph system, where the frequencies are higher and the wires smaller, most of the electrical power at the start of the circuit does not reach the user (the listener at the other end of the circuit), but is unavoidably lost en route. In a radio circuit this is true to a greater degree than in nonrepeatered wire lines. The power taken from the receiving antenna may be only a billionth or a trillionth of that delivered to the transmitting antenna[1].

1203. THE DECIBEL (db).

a. With the great range of powers discussed in the preceding paragraph, it is convenient to measure relative power on a scale which avoids very large or very small numbers. This is done by expressing *power ratios* on a logarithmic scale. The unit value of this scale is the *decibel* (commonly abbreviated *db*)[2].

b. The number of decibels corresponding to a given power ratio is 10 times the logarithm of the power ratio. Thus, for any values of power, P_1 and P_2

$$\text{db} = 10 \log \frac{P_1}{P_2}$$

where *log* is the logarithm to the base 10, found in ordinary logarithm tables.

db	*Power ratio* (P_1/P_2)
0	1
10	10
20	100
30	1000
−10	0.1
−20	0.01
−30	0.001
−120	1 trillionth
10n	10^n

db	*Power ratio* (P_1/P_2) (*approximate*)
5	3.2
15	32
25	320
35	3200
−5	0.32
−15	0.032
−25	0.0032
−35	0.00032

db	*Power ratio* (P_1/P_2) (*approximate*)
1	1.25
2	1.6
3	2
4	2.5
5	3.2
6	4
7	5
8	6.3
9	8
10	10

db	*Power ratio* (P_1/P_2) (*approximate*)
−1	0.8
−2	0.63
−3	0.5
−4	0.4
−5	0.32
−6	0.25
−7	0.2
−8	0.16
−9	0.125
−10	0.1

Figure 12-1. Relation between db and power ratio.

c. Figure 12-1 is a table of db and the corresponding power ratios. Figure 12-2 expresses the relation graphically. *Adding* db corresponds to multiplying power ratios. Thus from figure 12-1, the power ratio corresponding to 36 db, or 30 + 6 db, is 1000 x 4 = 4000.

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[1] The volume of received speech in the listener's ear, however, is not much different from that which he would have if he were a few feet away from the talker. This result is achieved by the use of amplifiers. Two types of amplifier are in common use: the vacuum tube amplifier and the ordinary carbon button type of telephone transmitter.

[2] The decibel is practically universally used in the United States, and has been standardized by the International Advisory Committee on Long Distance Telephony and other organizations.

d. As one example, in a well designed telephone circuit the electrical power at the receiving end of the circuit is not less than about one thousandth of that of the electrical power at the start of the circuit. From figure 12-1 we see that the db corresponding to this power ratio of one thousandth is −30 db. The ratio of input to output powers in this case is 1,000, and from the figure the db corresponding to this ratio is +30 db.

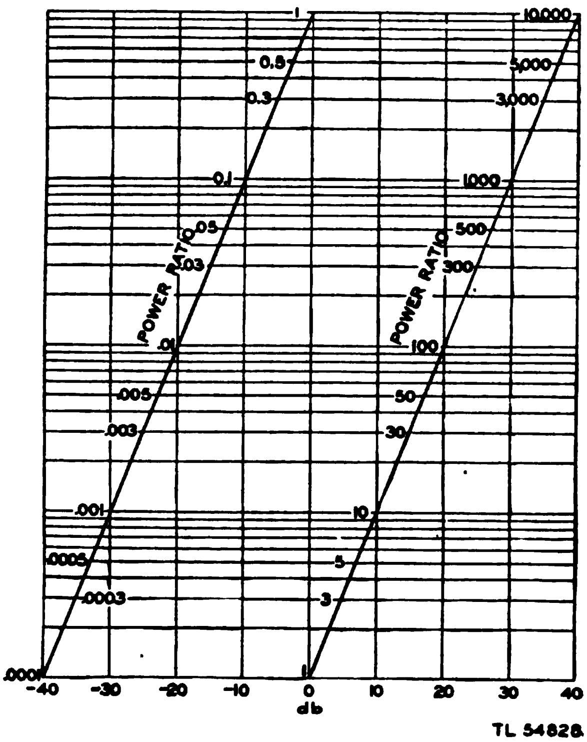

Figure 12-2. Relation between power ratio and db.

e. As shown in figure 12-1, changing the sign of a given number of db from plus to minus, or vice versa, is equivalent to taking the reciprocal of the corresponding power ratio. This also may be stated as

$$\text{db} = 10 \log \frac{P_1}{P_2} = -10 \log \frac{P_2}{P_1}$$

This is a convenient relationship to remember when using ordinary logarithm tables since it is somewhat simpler to employ the logarithms of numbers larger than unity. This is also useful in relation to the determination of gains or losses when P_1 and P_2 apply to the input and output powers of a network which may contain either gain or loss.

f. The db is a useful unit for another reason. One db corresponds to about the smallest change in sound power that a careful observer can detect when the sound is at a medium loudness level. A person's senses detect changes in terms of ratios, much more nearly than they detect the absolute amount of the change. For example, when a person is riding on a train and the speed increases from 1 mile per hour to 11 miles per hour, he readily notices the difference; however, if the speed increases from 60 to 70 miles per hour, the change is much less noticeable. The absolute increase in speed is the same in both cases but the percentage change is much larger in the first instance and therefore the change is more noticeable. This principle also applies to a person's hearing and some of his other senses. Thus, it is appropriate to measure changes in telephone power in terms of the db, which is a unit corresponding to a fixed percentage change in power.

g. Relations between db and current or voltage ratios are given in paragraph 1207. The neper, another unit value for power ratios, is described in paragraph 1208.

1204. USE OF THE db IN EXPRESSING TRANSMISSION LOSSES AND GAINS.

a. The transmission loss of a circuit, or of a part of a circuit, is the db corresponding to the ratio of *input* to *output* powers. Thus, if the input power is greater than the output power the circuit has a positive transmission loss. If, on the other hand, a part of a circuit has an amplifier in it, such that the output power is greater than the input power, then this circuit element has a negative transmission loss, or a positive transmission gain. This gain is measured by the db corresponding to the ratio of *output* to *input* power.

b. Very often when designing a circuit it is necessary to find the transmission loss resulting from connecting together a number of component parts. The use of the db is convenient in making this calculation, because the total transmission loss in db is merely the sum of the losses in the individual parts[3]. For example, a circuit may run from a supply depot to corps headquarters, then to division headquarters, and then to a local command post. If the loss

[3] When the impedances of the individual parts are matched to each other.

rom the supply depot to corps headquarters s 6 db, that from corps headquarters to division headquarters is 6 db, and that from division headquarters to the local command post s 12 db, then the total loss from supply depot o command post is obtained by merely adding hese numbers and is therefore 24 db.

c. As another example, the power received from one mile of very wet Wire W–110–B is only about 50 percent of the power put in at the sending end. This 50 percent is reduced another 50 percent in the second mile and the resulting 25 percent is reduced another 50 percent in the third mile and so on. By the end of about 10 miles only 0.1 percent is left. Obviously multiplying 50 percent by 50 percent 10 times in order to determine the loss of 10 miles of wire is an awkward method. The use of the db gets rid of this awkwardness. As seen from the above table, when the output power is half of the input power, the corresponding transmission loss is 3 db. In the case in question this is for 1 mile. The transmission loss for 10 miles can be obtained by adding up the 10 individual losses or, in other words, by multiplying the loss per mile by 10. The resultant loss is 10 x 3 = 30 db.

d. In adding together the transmission losses and gains of parts of a circuit which contains amplification, it is important to keep correct account of plus and minus signs. To do this, the transmission through each element of the circuit can be expressed in terms of loss, a gain being counted as a negative loss. For example, if a circuit has a transmitting repeater with 6-db gain; a line section with 20-db loss; an intermediate repeater with 19-db gain; another line section with 20-db loss; and a receiving repeater with 9-db gain: then the over-all loss (net loss) of the circuit is $-6+20-19+20-9=6$ db. An alternative method is to express the transmission through each element of the circuit in terms of gain, and to count each loss as a negative gain. The important thing is to adopt one system for use throughout the problem, and not to mix losses and gains indiscriminately.

e. The db is commonly used to express losses in transmission lines used in radio circuits, such as a line connecting the radio transmitter with its antenna. It can also be used to express losses in the radio path proper, when sufficient data are available. Other examples of the use of the db in radio are in chapter 6.

1205. STANDARD TESTING POWER.

It will be noticed that the above discussion has been about power ratios, not absolute powers. A decibel is a measure of power ratio. When telephone circuits are set up and tested, it is common to use a standard testing power of 1 milliwatt (one thousandth of a watt). Testing powers received at various parts of the circuit are then measured in terms of db referred to this standard testing power. The db referred to a milliwatt is abbreviated *dbm.* Thus 1 milliwatt is 0 dbm; 100 milliwatts are +20 dbm; 0.01 milliwatt is −20 dbm, etc[4]. When a circuit is lined up, a standard source of 1 milliwatt testing power is connected to the sending end of the circuit (commonly the sending switchboard), and the received powers at various points are compared with the received powers which would be expected from the design of the circuit. Thus in a circuit consisting of 10 miles of very wet Wire W–110–B, the received testing power would be about −30 dbm. If an amplifier with 20-db gain were connected at the receiving end of this wire, the received power at the output of this amplifier would be $-30+20=-10$ dbm.

1206. TRANSMISSION LEVEL AND NET LOSS.

a. In laying out circuits, it is often convenient to consider the relative power level at a given point, referred to the start of the circuit (transmitting switchboard). The start of the circuit is conveniently designated as *zero transmission level.* If the loss from the start of the circuit to a point X is 15 db, then the transmission level at X is −15 db. If there is a gain of 10 db from the start of the circuit to a point Y, then the transmission level at Y is +10 db. Transmission level diagrams are often convenient in engineering telephone circuits, because there are lower and upper transmission levels beyond which it is not safe to go. An example of such a diagram is given in figure 12-3.

b. If the transmission level at the receiving end of circuit is −L, then the net loss of the circuit (sum of losses minus sum of gains) is evidently L.

[4] In the past, power levels in radio transmitters and receivers have sometimes been rated in terms of db referred to a power of 6 milliwatts instead of 1 milliwatt; and this reference point has sometimes been called *zero level* in radio instruction books. This usage is not recommended.

c. The net losses in the two directions of transmission over a given circuit are usually but not necessarily the same. The net loss may vary with frequency and with the amount of transmitted power. If no statement about these items is included, the frequency is usually taken as 1,000 cycles, and the power as 1 milliwatt, at the transmitting switchboard.

d. For a length of circuit such as a repeater section the loss will, in general, be different at different frequencies in the transmitted frequency band. When these differences are large they are usually reduced by *equalization*. A network placed in the circuit in order to equalize the transmission losses at various frequencies is known as an *equalizer*.

1207. RELATION BETWEEN db AND VOLTAGE OR CURRENT RATIOS.

In practice it is often convenient to measure the voltage or current at a given point, rather than to measure the power at this point directly. *If the impedances at two points in a circuit are equal,* the ratio of the powers at these two points equals the square of the ratio of the corresponding currents, or the square of the ratio of the corresponding voltages. Thus if the power, current, and voltage at one point are respectively P_1, I_1, and V_1 and the corresponding quantities at the other point are P_2, I_2, and V_2,

$$\frac{P_1}{P_2}=\frac{(I_1)^2}{(I_2)^2}=\frac{(V_1)^2}{(V_2)^2}.$$

Referring to the definition of a decibel given above,

$$\text{db}=10\log\frac{P_1}{P_2},$$

it is seen that $\text{db}=10\log\dfrac{(I_1)^2}{(I_2)^2}$

$$\text{or db}=20\log\frac{I_1}{I_2}=20\log\frac{V_1}{V_2}.$$

Thus it is seen that *where the impedances at the two points are equal,* the db are equal to 20 times the logarithm of the ratio of currents at the two points, or 20 times the logarithm of the ratio of voltages at these two points. The db is, however, fundamentally a measure of power ratio. Figure 12-4 is a table of db and the corresponding voltage or current ratios in the case where the impedances are equal. Where the impedances at the two points are unequal, the db can be obtained by using power ratios. Adding db corresponds to multiplying current ratios or voltage ratios. Thus from figure 12-4, the current ratio corresponding to 36 db, or 30 + 6 db, is 32 × 2 = 64.

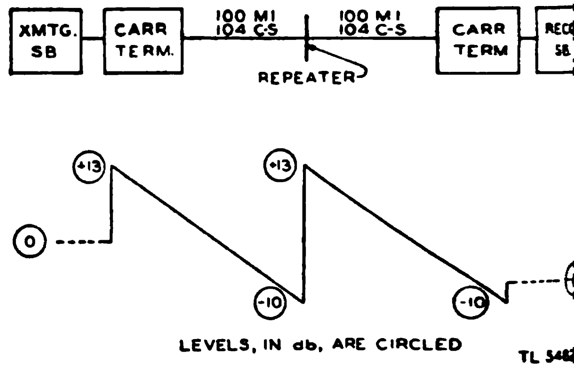

Figure 12-3. Sample transmission level diagram.

1208. THE NEPER.

An alternative unit of power ratio, which is sometimes used in Europe, and also in mathematical investigations, is the *neper*. To convert nepers to db, multiply nepers by 8.7. This conversion factor may be of use in converting European figures of transmission loss, etc., to values in db. Mathematically, the neper is defined by

$$\text{nepers}=\frac{1}{2}\log_e\frac{P_1}{P_2}$$

where P_1 and P_2 are two powers and $e=2.718$ is the base of the Naperian system of logarithms.

1209. MEASUREMENT OF POWER IN TRANSMITTED SPEECH; THE VOLUME UNIT (VU).

It is sometimes necessary to measure the power in the speech currents on a telephone circuit. Speech power is not steady like that from a testing oscillator, but varies from moment to moment. Hence a special technique and a special measuring instrument are needed for measuring speech power. The instrument designed for this purpose is known as a *volume indicator*. It consists essentially of a meter used as an indicating device and certain controls for changing its sensitivity. Its impedance is high enough to permit bridging across ordinary telephone circuits with negligible loss, and its frequency characteristic is approximately flat from about 50 to 10,000 cycles. The meter, known as the *vu meter*, is arranged to have a particular dynamic characteristic (speed of response to a suddenly applied voltage), which approximates the performance of the human ear. When electrical speech currents are fed into a vu meter, the meter needle will move about in response to the speech currents; the characteristics of speech are such that the motion of the needle will approximately follow a certain pattern with peaks and valleys in the deflection. The average of the three highest peaks per 10 seconds, disregarding occasional extreme peaks, is taken as the indication of the meter needle. The scale of vu is a db scale, such that a 1,000-cycle sine wave testing power of 1 milliwatt (0 dbm) reads 0 vu on the volume indicator[5]. Details are given in Bell System Practice Section E47.153. Zero vu corresponds approximately to the power fed into a telephone line when a loud talker talks into an Army local battery telephone set connected to the line, or to the power obtained from a telephone when Army personnel talk over radio circuits to planes in flight.

1210. CROSSTALK.

On account of the relatively high frequencies used in telephone communication and in telegraph communication other than d-c telegraph, there is a marked tendency for the transmission currents to stray from their appointed path and for part of the transmission to appear in other circuits. This phenomenon is known as crosstalk. Crosstalk is measured in the same terms as those used for transmission[6]. Thus, if there is a power P_A at a point A on a circuit and a resulting power P_B at a point B in another circuit, due to crosstalk from the first circuit, then the crosstalk loss from A to B, in db, equals $10 \log \frac{P_A}{P_B}$. It will be observed that crosstalk loss, like transmission loss, relates to power ratio and not to absolute powers. Crosstalk is discussed further in chapter 5.

db	*Approximate current ratio or voltage ratio*	*db*	*Approximate current ratio or voltage ratio*
0	1	1	1.12
5	1.78	2	1.25
10	3.2	3	1.41
15	5.6	4	1.58
20	10	5	1.78
25	17.8	6	2.0
30	32	7	2.25
−10	0.32	8	2.5
−20	0.1	9	2.8
−30	0.032	10	3.2
−120	0.000001	−1	0.9
20n	10^n	−2	0.8
		−3	0.7
6	2	−4	0.63
12	4	−5	0.56
18	8	−6	0.5
24	16	−7	0.45
−6	0.5	−8	0.4
−12	0.25	−9	0.36
−18	0.125	−10	0.32
−24	0.063		

Figure 12-4. Relation between db and current ratio or voltage ratio, where impedances are equal.

1211. NOISE.

a. Measurement of Noise. Noise is also measured on a db scale. This applies both to noises in electrical circuits and to acoustical noises. Electrical circuit noises are referred to a zero or reference power of 1 micromicrowatt (90 db below 1 milliwatt). If a 1,000-cycle power of this small amount is fed into an ordinary telephone set, a listener in a quiet room can barely hear the resulting sound. Telephone instruments do not have the same efficiency at all frequencies, and this is also true for the human ear. Since telephone receivers are usually most efficient in the speech-frequency band in the neighborhood of 1,000 cycles, a micromicrowatt at frequencies other than 1,000 cycles will not be as audible in a telephone set as a micromicrowatt at 1,000 cycles; and equal electrical noise powers at different frequencies

[5] In former volume indicators the reference point of the db scale was known as *reference volume;* this corresponded to a 1,000-cycle sine wave calibrating power of + 8 dbm (about 6 milliwatts).

[6] Crosstalk loss is also sometimes expressed in terms of crosstalk units. The scale of crosstalk units is such that 1 million crosstalk units equals 0-db crosstalk loss; 1,000 crosstalk units equals 60-db crosstalk loss; 1 crosstalk unit equals 120-db crosstalk loss, etc. In circuits of equal impedance, the crosstalk unit expresses the current in the disturbed circuit as millionths of the disturbing current.

will not have the same interfering effect. Noises in electrical circuits (circuit noises) are commonly measured by means of noise meters, of which the Western Electric Company 2B noise measuring set (fig. 12-5) (stock No.

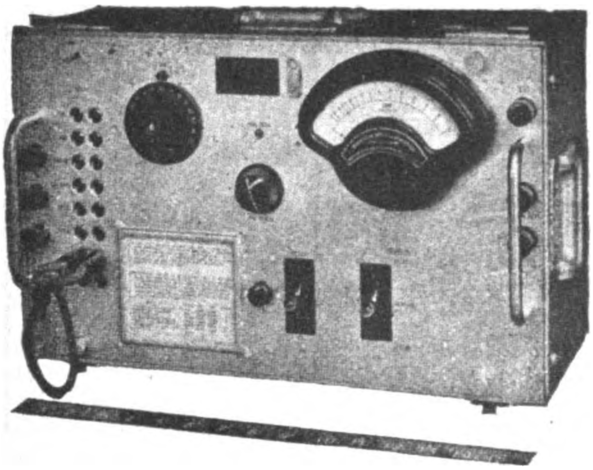

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Figure 12-5. Western Electric Company 2B Noise Measuring Set.

3F4265) is most common. In these noise meters the different interfering effects of different frequencies are taken care of by a frequency-weighting network which is incorporated in the noise meter. The noise meter is calibrated at 1,000 cycles, in terms of the above mentioned reference power of 1 micromicrowatt (90 db below 1 milliwatt). Noise meters have a db scale. One micromicrowatt at 1,000 cycles reads 0 db on the noise meter, and is called *reference noise* (*RN*). A noise 35 db greater than this is written 35 dbRN. The meter needle of the noise meter has a dynamic characteristic which is approximately the same as that of the vu meter and which therefore corresponds approximately to the performance of the human ear.

b. Addition of Noises.

(*1*) If two circuit noises combine or add, for example, the noises at a circuit terminal which originate in two repeater sections; it is approximately correct to add the noise *powers*. It is *not* correct to add the db values. For example, two noises, of 30 and 36 dbRN, do not give a resultant noise of 66 dbRN; the resultant noise is 37 dbRN, as can be seen by using the information in paragraph 1203 to convert each noise into the corresponding power ratio referred to reference noise. Since 30 db corresponds to a power ratio of 1,000, the first noise power is 1,000 times the reference; similarly the second noise power is 4,000 times the reference; the sum of these powers is 5,000 times the reference, and the corresponding db value is (par. 1203) 37 db above reference noise.

(*2*) The following is a short-cut method of adding two noise powers, or other powers, expressed in db above a common reference point. Take the difference between the two db values; in the following table find the number corresponding to that difference, and add it to the larger db value.

Difference:	0	0.5	1	1.5	2	3	4	5	6
Add:	3	2.8	2.5	2.3	2.1	1.8	1.5	1.2	1.0

Difference:	7	8	9	10	11	13	16	20
Add:	0.8	0.6	0.5	0.4	0.3	0.2	0.1	0.0

For example, to add noises of 30 and 36 dbRN: the db difference is 6, hence from the table 1.0 should be added to the larger one (36 dbRN), giving the result: 37 dbRN.

(*3*) Several noises may be added by repeated applications of this process. If the noises are all equal, the following table may be used; the db value specified is added to the db value of one noise.

No. of equal noises:	2	3	4	5	6	7	8	9	10	100
db to be added:	3	4.8	6	7	7.8	8.4	9	9.5	10	20

For example, if a circuit has five repeater sections and if the noise at the terminal from each repeater section is 28 dbRN, the total noise at the terminal is $28 + 7 = 35$ dbRN.

c. Signal-to-noise Ratio.

(*1*) Many circuits have receiving amplifiers with gain which is adjustable over a fairly wide range of values. This is particularly true of radio circuits, especially those with automatic volume control. In such circuits the ratio of the received signal to the received noise often is more significant than the absolute value of either the signal or the noise, as a criterion of the understandability of the received telephone message. This signal-to-noise ratio is often expressed in db. The signal-to-noise ratio in db is thus the db corresponding to the ratio of signal power to noise power.

(2) In the literature various ways of expressing the signal-to-noise ratio have been used, particularly in radio circuits. In such circuits it is wise to use the term *speech-to-noise ratio* to indicate the ratio of speech power to noise power, when both are measured by the same kind of meter. In radio circuits it is generally inconvenient to measure the speech power at radio frequencies since this is contained in sidebands which are generally weaker than the carrier which is present at the same time. In this case the radio carrier and the radio noise may be measured, and the ratio of the two preferably called the *carrier-to-noise ratio*; or, alternatively, the speech-to-noise ratio, for a known talker volume, can be measured at the radio receiver output. The relation between the speech-to-noise ratio and the carrier-to-noise ratio depends on the degree to which the talker modulates the transmitter, and thus depends on the type of radio transmitter and how it is used. For example, it is difficult to talk loudly enough to fully modulate some handy-talkie sets. As another example, in a multichannel radio system such as radio sets AN/TRC–3 and AN/TRC–4 combined with 4-channel carrier terminal equipment, the degree to which a given single talker can safely modulate the transmitter is necessarily less than that which a comparable single-channel system can use. Again, there is no universal method of measuring radio noise and different methods may yield different numerical values for the same noise. The net result is that quoted values of radio signal-to-noise ratio need interpretation before using them in systems engineering. A standard method of measuring signal-to-noise ratio of a radio receiver (equipment noise only) is to connect to its input a standard signal generator, and to measure the output of the radio receiver (for example, by using a vacuum-tube voltmeter), first with both the signal carrier and the modulation on (30 percent modulation at 400 cycles) and then with only the carrier on. The ratio of the two measurements is taken as the signal-to-noise ratio of the receiver for the particular test conditions.

d. Noise Requirements. It has been found that when telephone speech and noise are both measured by means of a noise meter, and when the noise is typical power induction or is uniformly distributed over an ordinary telephone channel, a signal-to-noise ratio (more accurately, speech-to-noise ratio) of 6 db is about as poor as can be used for marginal understandability, and a ratio of about 13 db is as small as should be permitted as an engineering basis for laying out telephone circuits. On many Army landline circuits the average talker volume at the terminals of Telephone EE–8–( ) is thought to be about -5 vu. If speech volume is measured on a Western Electric Company 2B noise measuring set (unmodified) it will not read as high as it will when measured on a vu meter because the noise meter contains a frequency weighting network while the vu meter is flat over the voice-frequency range. This reduction in reading has been determined to be about 8 db. Therefore, by comparing the reference points of the noise meter scale and the volume indicator scale, it follows that this average volume of -5 vu will be a noise meter reading of $-5 + 90$ (subpar. a above) $-8 = 77$ dbRN. If this speech is transmitted over a 30 db point-to-point circuit, the speech at the receiving end will read $77 - 30 = 47$ dbRN. In order to provide a speech-to-noise ratio of 13 db, the noise at the receiving end must be $47 - 13 = 34$ dbRN. Assume, instead of a point-to-point circuit, the 30 db is made up of a 6 db sending loop, three 6 db via trunks (long distance circuits suitable for switched connections as shown in chapter 2), and a 6 db receiving loop. Then, as in the case of the 30 db point-to-point circuit the noise at the end of the receiving loop must be 34 dbRN to obtain a 13 db speech-to-noise ratio. Assume that the noise on the receiving loop is negligible, and that the noise on the last via trunk is attenuated 6 db before it reaches the telephone at the end of the receiving loop. Also assume that the noise which reaches the receiving loop from other parts of the circuit may be neglected, because it is attenuated more and will therefore be small in comparison with the noise on the last via trunk. Then the noise on the last via trunk, as measured at its junction with the receiving loop, should not exceed $34 + 6 = 40$ dbRN. In practice, in order to allow some margin for below-average talkers, long distance tactical wire circuits are designed for 35 dbRN, instead of 40 dbRN, whenever practicable. In commercial cable or carrier circuits the noise requirement is 29 dbRN at the receiving toll switchboard (commonly the −9-db transmission level); this does not compare directly with the values for Signal Corps Circuits, since Signal Corps and commercial arrangements for building up via circuits are different.

1212. NOISE IN THE AIR.

Acoustical noises are also measured on a db scale. Such noises and other sounds are measured by means of an instrument called a *sound-level meter*. This consists of a microphone, a calibrated amplifier with frequency networks corresponding to the way in which the ear appreciates loudness of single frequencies at different loudness levels, and an indicating meter like that used in circuit-noise meters. Sounds are measured in terms of the power per square centimeter in the sound wave. They are measured in terms of db above a power of density of 10^{-16} watts per square centimeter at 1,000 cycles. This extremely small power density is just audible in the ear of a person with somewhat better than average hearing acuity, who is situated in a place which has no other sound than the 1,000-cycle tone in question. It is called *reference sound level*. The range of acoustic noises and other sounds which is encountered in practice is extremely wide; and therefore, the db scale is particularly useful in measuring them. Figure 12-6, which is abstracted from one of many such tables which have appeared in the literature, gives an approximate idea of the sound levels in db for certain common noises and other sounds.

Source or description of noise	*Approximate sound level (db)*
Threshold of painful sound	135
Airplane (observer outdoors, 20 feet from propeller)	120
Riveter, 35 feet away	105
Elevated electric railway, 20 feet away	95
Very noisy street, New York or Chicago	85
Very busy traffic, London	80
Ordinary conversation, 4 feet away	70
Rather quiet New York City residential street, afternoon	65
Quiet automobile, 25-50 feet away	55
Quiet suburban street, London, evening no traffic	35
Average whisper, 5 feet away	25
Rustle of leaves in gentle breeze	15
Threshold of hearing for acute ear	0

Figure 12-6. Sound levels.

1213. RADIO R AND S SCALES.

a. In ear reception of radio signals, the following scales are in general use to express the listeners' judgment of the signal strength, *S*, and readability, *R*, of the message.

S1—Barely perceptible	R1—Unreadable
S2—Weak	R2—Readable now and then
S3—Fairly good	R3—Readable with difficulty
S4—Good	R4—Readable
S5—Very good	R5—Perfectly readable

In earlier versions of these scales the numbers ran up to 10.

b. Some radio receivers have *S meters*, to give an indication of signal strength, from 1 to 5. The higher the number, the greater the signal strength; otherwise the numerical values have no precise meaning. The S meter scales on different types of set, even from the same manufacturer, generally will not agree.

1214. RADIO FIELD INTENSITY.

a. The field intensity, or field strength, of a radio wave is measured in microvolts per meter, or in db referred to one microvolt per meter. It is the voltage gradient, or space rate of change of voltage, of the wave. It has both a magnitude and a direction. This direction is that of the lines of electrostatic force at the point in question. A short, straight antenna placed in this direction will pick up more voltage from the wave than if placed in any other direction. The wave is said to be *polarized* in the direction of the electrostatic force lines. Thus if the electrostatic force lines are horizontal, the wave is horizontally polarized; if they are vertical, the wave is vertically polarized[7].

b. Assume a dipole antenna (a straight antenna broken at its center to permit connection to apparatus) of length L meters in a radio field of E microvolts per meter, is placed in the direction to collect maximum voltage from the field. Also assume it is remote from other objects, and is connected to a radio receiver whose input impedance matches that of the dipole through a transmission line with negligible loss. Then if the length of the antenna is short compared to a half wave-length of the radio wave in question, the voltage across the receiver input is 0.25 LE microvolts; if the antenna length is a half wave-length, the voltage across the receiver input is 0.32 LE. Since the free-space wave-length in meters

[7] Sometimes the term *vertical polarization* is used to mean any polarization which is not horizontal.

times the frequency in megacycles equals 300, it will be found that at a frequency of about 48 megacycles the voltage (in microvolts) across the receiver input with the above half-wave dipole setup is numerically equal to the field intensity (in microvolts per meter). The impedance of a half-wave dipole remote from other objects is about 73 ohms resistance.

1215. ANTENNA EFFECTIVE HEIGHT AND ANTENNA GAIN.

a. The effective height of an antenna is the ratio of the *open-circuit* voltage at its terminals, when it is used as a receiving antenna, to the field intensity near the antenna producing this voltage. The effective height of a short grounded vertical antenna, on ground waves, is about half its physical length.

b. The gain of an antenna, with respect to a reference antenna and in a given direction, is the ratio of the power which must be supplied to the reference antenna to the power which must be supplied to the given antenna, when each radiates the same field in the given direction. The gain may be expressed in terms of power ratio or in db. The reference antenna must be specified. It need not be a physically realizable antenna; an easily computable ideal antenna, such as a half-wave dipole in free space, is a good reference antenna. The transmitting gain of an antenna is the same as its receiving gain, for the same direction and polarization of the radio field relative to the antenna.

1216. IMPEDANCE MATCHING.

a. Characteristic Impedance. The impedance of a uniform line (more accurately, its characteristic impedance) is the impedance obtained when the line is very long (mathematically, when it is of infinite length). A general idea of the meaning of characteristic impedance may be obtained from figure 12-7 in which

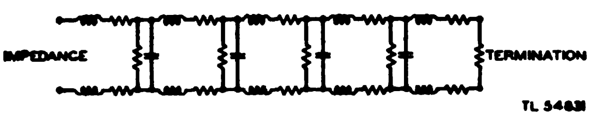


Figure 12-7. Schematic of wire line.

the line is represented as being made up of a large number of series and shunt impedance elements. For a line with a large number of these elements, that is, a very long line, it is apparent that the current sent into the line will be affected very little by the value of the terminating impedance at the distant end. For example, if the line has an attenuation of 20 db, even if it is open-circuited or short-circuited at the far end, the impedance at the sending end will not differ from characteristic impedance by more than two percent.

b. Impedance Mismatch.

(*1*) In communication systems a circuit is seldom, if ever, entirely uniform. The telephone or telegraph stations at the terminals differ in impedance characteristics from the lines to which they are connected. On switched connections the loops and trunks are generally of different construction and differ in impedance. Likewise, the trunk may be made up of different types of lines which also differ in impedance. There are, however, connections in which the same type of line is used throughout the entire circuit between telephone terminals, such as some point-to-point circuits, connections through small tactical switchboards where the entire wire plant may be of one type such as Wire W-110–B, or loop-to-loop connections through the larger switchboards.

(*2*) When lines or apparatus of unlike impedances are connected together in a communication system the transmission between telephones can be affected in the following ways unless corrective measures are applied.

(*a*) Transmission losses may be introduced because of reflections (par. 1217).

(*b*) Telephone repeater balance may be impaired (par. 1218).

(*c*) Sidetone at the telephones may be increased (par. 1219).

(*d*) Crosstalk may be increased. The effect, on crosstalk, of connecting together lines of different impedances is explained in chapter 5.

(*e*) Standing waves may be produced on radio transmission lines (par. 1217i and j); and the operation of radio transmitters may be affected (par. 1217h).

1217. REFLECTION LOSS.

a. It is a characteristic of wave motion that in passing from one medium to another a certain part of the energy propagated by the wave is reflected. For example, light-waves striking a pane of glass or some other denser medium are in part transmitted and in part reflected. The amount of energy reflected depends upon the physical properties of the media through which the wave passes; the greater the dissimilarity, the greater the reflection. Similarly, in communication circuits, wherever there are dissimilarities in the transmission media, that is, differences in impedances of the various parts of a circuit, part of the electrical wave will be reflected toward the source and the remainder will be transmitted toward its destination. In the case where sending and receiving impedances have the same phase angle, the reflection loss is equal to the ratio (expressed in db) of the delivered power with an ideal matching transformer inserted between these impedances to the delivered power without inserting the transformer. A more general definition of reflection loss is given below in subparagraph f.

b. In a simple circuit, consisting of a line connecting two telephones such as shown in figure 12-8, the major part of the total trans-

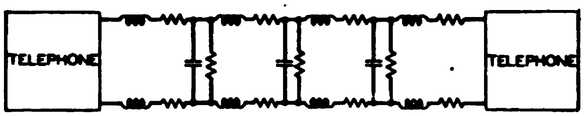


Figure 12-8. Simple telephone circuit.

mission loss between the telephones is generally the attenuation of the line. In addition, since the impedance of the telephone is different from the impedance of the line there are reflecting effects, generally small, where each set is connected to the line. Furthermore, if the line is composed of long sections of different types of wire, such as open wire and field wire, there is a reflection loss at each junction, and the total reflection loss in the line equals the sum of the reflection losses at each junction. The reflection loss is not large unless there are considerable differences in magnitude or phase angle of the impedances, as illustrated in figure 12-9. Figure 12-10 gives values of reflection loss versus the ratios of the magnitudes of the two impedances and their difference in phase angle.

c. When a very short section of line is inserted into a line of another type, the total loss due to reflections at the ends of the short length is materially smaller than would be obtained if the inserted section were long. In a voice-frequency cable circuit, this would be true if the attenuation of the short length were 1 db or less; further illustrations are given in chapter 5. In an open wire radio transmission line, this would be true if the line were substantially shorter than a quarter wave.

Lines	Impedance (ohms) at 1,000 cycles		Reflection loss (db)
	Z	R-jX	
Wire W-110-B (wet) and 080 C-S	$405\angle 42^\circ$ $930\angle 31^\circ$	300-j270 791-j481	0.7
Wire W-110-B (wet) and 109 GS	$405\angle 42^\circ$ $1390\angle 27^\circ$	300-j270 1230-j630	1.5
Spiral-four (CC-358-( )) and 080 C-S	$485\angle 12^\circ$ $930\angle 31^\circ$	475-j105 791-j481	0.4

Figure 12-9. Reflection losses between dissimilar lines.

d. Where reflection losses are large it is the usual practice in commercial wire telephone circuits to connect circuits of unequal impedances by means of a suitable inequality ratio repeating coil. By this means the magnitudes, but not the phase angles, of the two impedances may be made equal. Other methods of impedance matching, sometimes used in radio work, are quarter-wave line sections, transmission lines of tapered cross-section, and vacuum-tube impedance-transforming devices.

e. If a source of power has an internal impedance $Z_1 = R_1 + jX_1$ and is connected to a load $Z_2 = R_2 + jX_2$, maximum power is delivered to the load when the resistances R_1 and R_2 are equal and the reactances X_1 and X_2 are of equal magnitude and of opposite phase. However, from the standpoint of controlling effects on telephone repeater balance, crosstalk, or sidetone, it is better to make the two reactances equal in both phase and magnitude, and to make the two resistances equal. In wire lines, particularly repeatered circuits, effects on repeater balance, crosstalk, and sidetone are generally more important than adjusting impedances to obtain maximum delivered power.

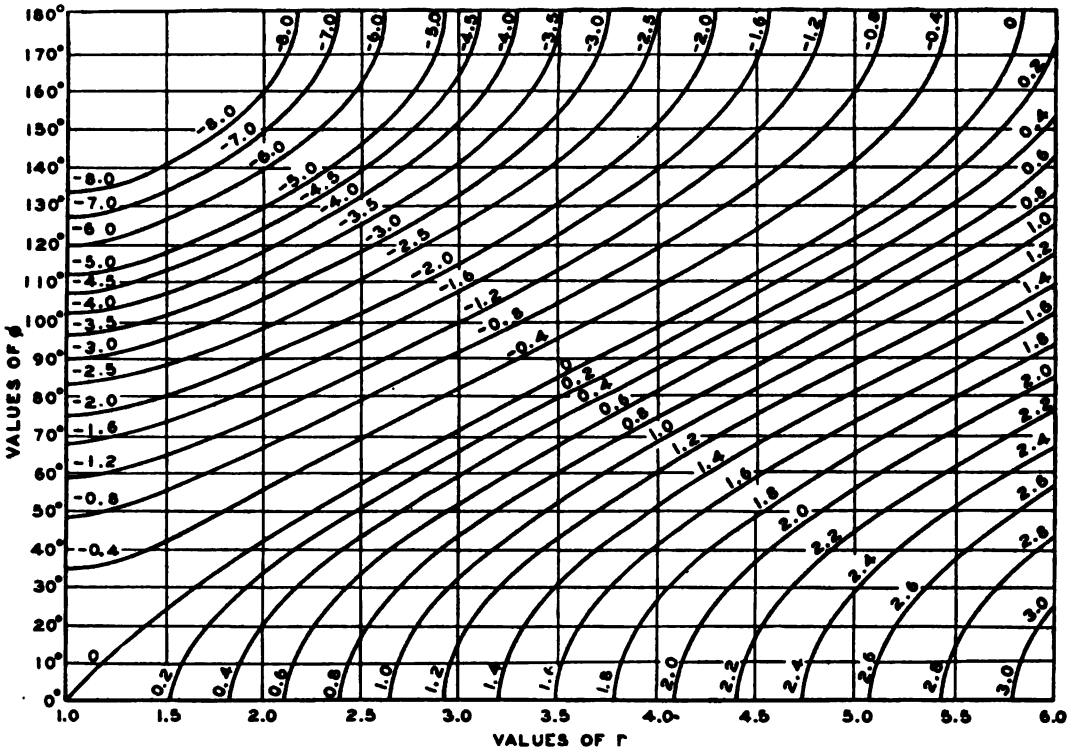
f. The reflection loss, in db, at the junction of two impedances Z_1 and Z_2, has been customarily defined by the formula

$$L = 20 \log \left| \frac{Z_1+Z_2}{2\sqrt{Z_1Z_2}} \right|$$

Here Z_1 and Z_2 have both magnitude and phase, and must be added with due regard to phase[a].

[a] One way of doing this is to use the equivalent formula

$$L = 10 \log \frac{(R_1+R_2)^2+(X_1+X_2)^2}{4\sqrt{(R_1^2+X_1^2)(R_2^2+X_2^2)}}$$



NOTES: VALUES OF THE REFLECTION LOSS FOR ANY TWO IMPEDANCES Z_X AND Z_Y ARE HERE GIVEN AS A FUNCTION OF THE RATIO $\frac{Z_X}{Z_Y} = r\angle\phi$ WHERE r IS THE RATIO OF THE MAGNITUDES AND ϕ IS THE DIFFERENCE BETWEEN THE ANGLES OF THE TWO IMPEDANCES. THE RATIO IS ALWAYS TO BE TAKEN BY DIVIDING THE LARGER IMPEDANCE BY THE SMALLER, THAT IS, SO THAT r WILL NOT BE LESS THAN UNITY. IT IS IMMATERIAL WHETHER ϕ IS POSITIVE OR NEGATIVE.

NEGATIVE VALUES OF REFLECTION LOSSES ARE REFLECTION GAINS.

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Figure 12-10. Reflection losses; decibels.

(The | | sign indicates the numerical or absolute value of the quantity within it.) The reflection loss depends on both the magnitudes and phases of the two impedances. When one impedance has a positive reactance (inductive) and the other has a negative reactance (capacitive), a reflection gain is sometimes obtained. In general, a reflection gain is obtained when maximum power is delivered.

g. Reflections are a matter of concern in the design of radio circuits, since it is often desired to transfer the maximum proportion of power from transmitter to antenna, or from antenna to receiver.

h. Large reflection gains are obtainable when connecting radio transmitters or receivers to certain types of antennas, such as short whips, whose impedance is mostly reactive. Adjusting the reactance of the radio set to cancel that of the antenna circuit is sometimes called tuning or resonating the antenna. Some radio transmitters, such as those designed to operate only with whips which are short compared to a quarter wave, have built-in tuning circuits suitable for obtaining the needed reflection gain only when used with the particular type of antenna for which they were designed[9].

i. Assume that there is a transmission line between the radio transmitter and antenna, and the impedances of the line and the transmitter are equal, but the antenna impedance is different from this. Then, as the electrical wave from the radio transmitter (called the incident wave) is transmitted over the line it meets a reflected wave returning from the antenna end of the line. The resultant wave, formed as the incident and reflected waves combine in and out of phase, is called a *standing wave*. If a volt-

[9] When a radio transmitter is operated with an antenna materially different from that for which it is designed, there may be danger of improperly loading it, thereby drawing excessive plate current from the output tube.

meter is bridged across the line and is moved along the line, the ratio of maximum to minimum voltmeter readings is called the *standing wave ratio.* When the standing wave ratio is unity, there are no reflections. Let Z_1 and Z_2 be the impedances of the line and antenna respectively. When the phase angles of Z_1 and Z_2 are equal, the standing wave ratio equals Z_1/Z_2 (customarily the larger impedance is used as the numerator). Another measure of the magnitude of the standing wave is the reflection coefficient r.

$$r=\frac{Z_1-Z_2}{Z_1+Z_2}$$

The reflection coefficient is the ratio of the reflected current to the current which would have been transmitted into the antenna if its impedance had been equal to the line impedance. From this formula it is evident that when the line impedance is equal to the antenna impedance the reflection coefficient is zero and there is no reflected wave. The reflection coefficient is used in wire transmission as well (par. 1218d). The relation between reflection coefficient, r, and standing wave ratio, S, is as follows for the case of a line of negligible attenuation:

$$S=\frac{1+|r|}{1-|r|}$$

For example, if a line of about 350-ohms impedance is connected to a dipole antenna of about 70-ohms impedance, the reflection coefficient, r, is 2/3, and the standing wave ratio, S, is 5. Reference may be made to TM 11–314.

j. Large standing wave ratios are accompanied by voltage and current peaks on a radio transmission line. They may cause breakdown of insulation on a line from transmitter to antenna; introduce higher losses if nonlinear effects such as corona are involved; or produce unwanted radiation. On the antenna proper, however, standing waves are a benefit in many cases, when the antenna is designed to make use of them to increase the radiation in desired directions.

1218. REPEATER BALANCE.

a. Since a vacuum-tube amplifier permits transmission in one direction only, it is common practice in 2-wire telephone circuits to use two amplifiers to make up a repeater, one to provide amplification in one direction and the other to provide amplification in the opposite direction. If these amplifiers were merely connected together, each amplifier input to the other output, the circuit would *sing* or *howl.* A circuit which will permit such amplifiers to be used on a 2-wire line without establishing a singing path between the two amplifiers is shown in figure 12-11.

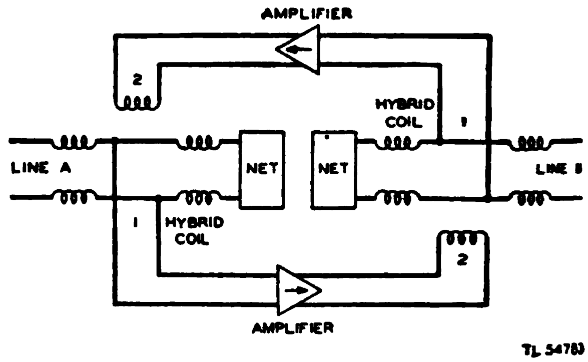


Figure 12-11. 22-type repeater.

b. The action of the hybrid coil is similar to that of the Wheatstone bridge; that is, when a voltage is applied across a particular pair of terminals, no current will flow through an impedance connected across the two other terminals of the bridge if certain well-known conditions regarding the ratios of the impedances of the four arms of the bridge are satisfied. Referring to figure 12-11, if a voltage is impressed on terminal number 2 no current will flow in terminal number 1 if the impedances of the line and network are identical. The greater the difference between the impedances of line and network, the greater will be the amount of current which flows in terminal number 1 and the greater will be the tendency of the repeater to sing. Further discussion of the use of hybrid coils in repeatered circuits is given in TM 11–457 and TM 11–475.

c. Since perfection cannot be attained even in the most carefully designed telephone circuits, there is always some transmission across the hybrid coil; consequently the amount of amplification which can be provided by a repeater without singing is limited. The sum of the gains of the two amplifiers must always be less than the sum of the losses across the two hybrid coils in order to prevent *singing.* In practice, to allow for variations in the circuit, a margin is provided between total loss and total gain.

d. The *return loss* between two impedances is a measure of the similarity between the impedances; these might be the line and network impedances, or the impedances of two types of line. It is expressed in db and equals 20 times the logarithm of the reciprocal of the numerical value of the reflection coefficient (par. 1217i), namely, return loss

$$R = 20 \log \left| \frac{Z_1 + Z_2}{Z_1 - Z_2} \right|$$

The loss across an ordinary hybrid coil is about 6 db greater than the return loss.

e. Since speech transmission through a repeater must be practically uniform over the band of frequencies used for speech transmission, about 200 to 2,800 cycles, it can be seen that transmission loss across the hybrid coil must be sufficiently great at all frequencies in this band to prevent singing at any one of them. Filters usually are employed to prevent singing at frequencies outside the speech-transmission band.

f. It is obvious that good balance usually cannot be obtained by matching the line impedance at a single frequency by means of a simple network consisting of a resistor and a capacitor or inductor. Excellent balance between line and network could, of course, be obtained by duplicating in the network each element of the line, but this is an impractical solution. In practice, fixed networks are used or variable networks are provided which can be adjusted in the field to match approximately the characteristic impedance of the types of lines in common use. The networks are furnished as part of the repeater.

g. To obtain good balance between a line and a network, the line must be reasonably uniform. Where apparatus is placed between the hybrid coil and the line, duplicate apparatus is usually placed between the hybrid coil and the network. A line irregularity which is distant from the repeater is less important than one which is close to the repeater. If a repeater section is composed of two dissimilar lengths of line in tandem, L_1 and L_2 of characteristic impedance Z_1 and Z_2, and if the repeater connected to L_1 matches Z_1 and the repeater connected to L_2 matches Z_2 then the return loss at the junction of L_1 and L_2 is R, as given by the formula in subparagraph d above, but the return loss at the repeater connected to L_1, is R + 2A, where A is the attenuation of L_1. This can be seen by noting that a current starting at the repeater would traverse L_1, be partially reflected at the junction of L_1 and L_2, and traverse L_1 again before the reflection reached the repeater.

h. Where a given repeater is connected to a circuit whose impedance is quite irregular or unstable, or to circuits of different impedances (terminal repeater), a compromise network (resistance plus capacitance) is ordinarily used, and the repeater gain must be restricted.

i. Sometimes a 21-type repeater is used. As shown in figure 12-12 this type of repeater

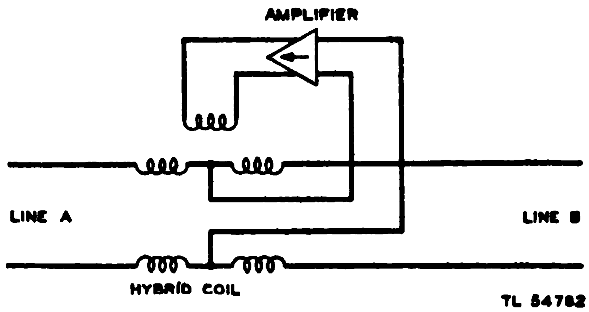


Figure 12-12. 21-type repeater.

contains one amplifier, one hybrid coil, and no balancing networks; freedom from singing is obtained by the impedance balance between the lines on the two sides of the repeater. In figure 12-12, a current coming from line A will divide equally between the amplifier input and output circuits if the amplifier output and input impedances are such as to balance the hybrid coil; none will go directly to line B. The amplifier input current will, however, be amplified; and if the impedances of lines A and B are equal, the amplified current will flow equally in them, none of it returning to the amplifier input. The current in line B is the useful current. The current returned to line A propagates toward the original source as an echo. If lines A and B have unequal impedances, some of the amplifier output current will return to its input; if the inequality is great enough at some frequency, the repeater will sing. Transmission from line B to line A takes place in the same manner as described above for line A to line B.

1219. SIDETONE.

a. In the antisidetone circuits of the most commonly-used telephones, the transmission loss in the sidetone path between the micro-

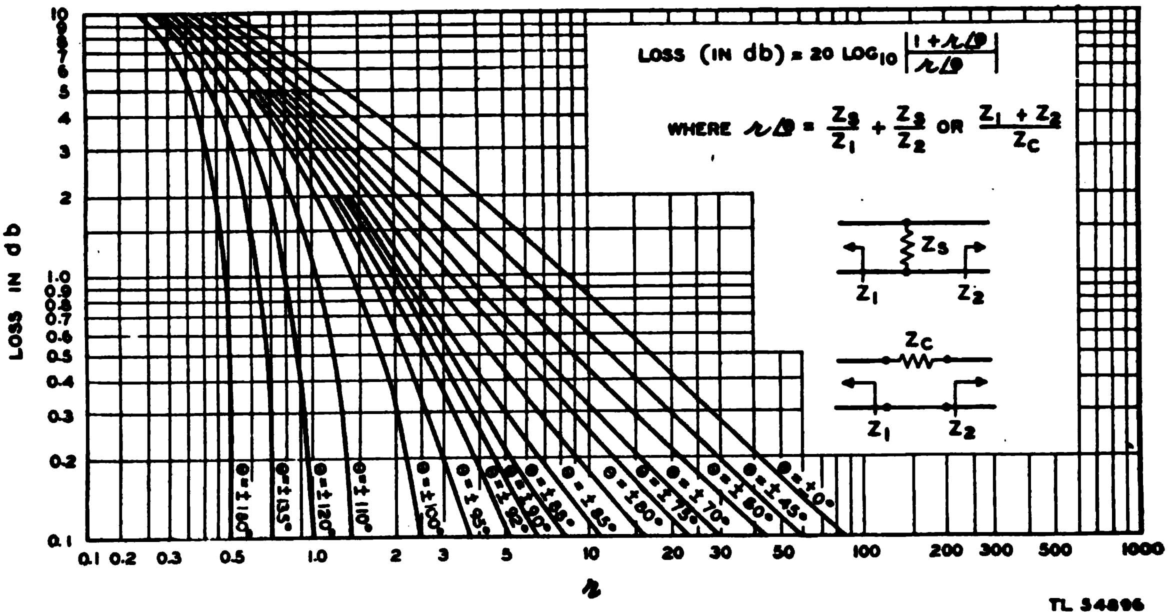


Figure 12-13. Insertion loss caused by a bridged impedance or by an inserted series impedance.

phone and the receiver depends upon the similarity between the impedances of the balancing network in the telephone circuit and of the line. The balancing network of the antisidetone telephone is usually designed to match the impedance of the line with which it is mostly used. In the case of Telephone EE–8–( ), the balancing network roughly matches Wire W–110–B. Descriptions of various types of antisidetone telephones are given in TM 11–333, TM 11–457, and TM 11–458.

b. Transmission loss in the sidetone path adds to the user's comfort when talking and also has a tendency to cause him to talk louder. When listening, it also improves receiving efficiency by reducing the room noise picked up by the microphone and transmitted through the sidetone path to the receiver. Since the singing path in the telephone includes the transmission loss in the acoustic path from the receiver to the microphone, which is comparatively high, the probability that the telephone will sing is usually remote.

c. When the telephone loop has a loss of 5 db or more, the impedance of the trunk beyond has little effect on the sidetone in the telephone.

1220. INSERTION LOSS.

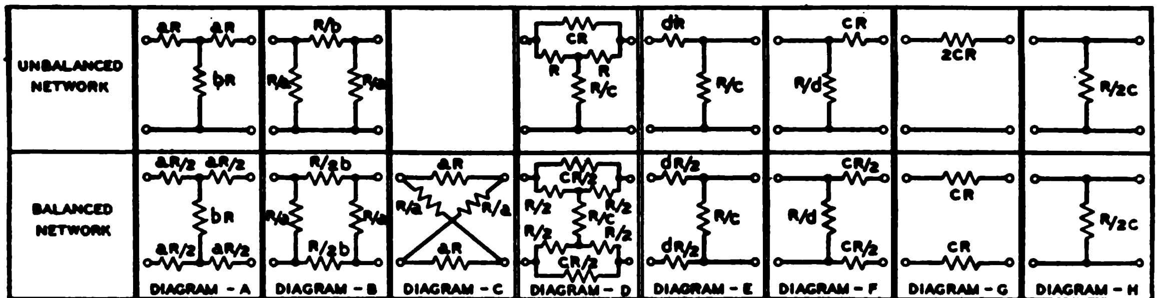
a. Assume a generator with an internal impedance Z_1 connected to a load Z_2 causes a current I_1 to flow. Also, when there is inserted between Z_1 and Z_2 any network; which may consist of resistors, capacitors, inductances, transmission lines, or combinations of these; the resulting current is I_2. Then the insertion loss of the network, between the impedances Z_1 and Z_2 is 20 log I_1/I_2, in db. The insertion loss includes both the transmission loss in the network and the reflections. A common special case is the loss caused by bridging one or more telephones across a line.

b. Figure 12-13 gives the insertion loss due to inserting a series or bridged impedance between two known impedances Z_1 and Z_2. For example, Z_1 might be the impedance looking west at a point on an east-west line and Z_2 the impedance looking east. The loss is given as a function of the impedance ratios in magnitude and phase. As a numerical example, suppose

$Z_1 = 600 + j0$, $Z_2 = 400 + j0$, and

$Z_s = 1{,}000 + j1{,}000 = 1{,}410\underline{/45°}$

then $r\underline{/\theta} = \dfrac{1{,}410\underline{/45°}}{600} + \dfrac{1{,}410\underline{/45°}}{400} = 5.9\underline{/45°}$, and from figure 12-13, the loss due to shunting Z_s across the junction of Z_1 and Z_2 is 1 db. From figure 12-13 it is seen that for a given absolute magnitude of the impedance ratio, the loss becomes smaller as the phase difference θ increases. If a number of equal impedances (such as a number of telephones) are bridged at the same



INSERTION LOSS db	A: a	A: b	B: 1/b	B: 1/a	C: a	C: 1/a	D: c	D: 1/c	E: d	E: 1/c	F: c	F: 1/d	G: 2c	H: 1/2c
0.1	0.00576	86.9	0.0115	174	0.00576	174	0.0116	86.4	0.0114	86.4	0.0116	87.4	0.0232	43.2
0.2	0.0115	43.4	0.0230	86.9	0.0115	86.9	0.0233	42.9	0.0228	42.9	0.0233	43.9	0.0466	21.5
0.3	0.0173	28.9	0.0345	57.9	0.0173	57.9	0.0351	28.5	0.0346	28.5	0.0351	29.5	0.0703	14.2
0.4	0.0230	21.7	0.0461	43.4	0.0230	43.4	0.0471	21.2	0.0450	21.2	0.0471	22.2	0.0943	10.6
0.5	0.0288	17.4	0.0576	34.8	0.0288	34.8	0.0593	16.9	0.0559	16.9	0.0593	17.9	0.119	8.44
0.6	0.0345	14.5	0.0691	29.0	0.0345	29.0	0.0715	14.0	0.0667	14.0	0.0715	15.0	0.143	6.99
0.7	0.0403	12.4	0.0807	24.8	0.0403	24.8	0.0839	11.9	0.0774	11.9	0.0839	12.9	0.168	5.96
0.8	0.0460	10.8	0.0922	21.7	0.0460	21.7	0.0965	10.4	0.0880	10.4	0.0965	11.4	0.193	5.18
0.9	0.0518	9.63	0.104	19.3	0.0518	19.3	0.109	9.16	0.0984	9.16	0.109	10.2	0.218	4.58
1.	0.0575	8.67	0.115	17.4	0.0575	17.4	0.122	8.20	0.109	8.20	0.122	9.20	0.244	4.10
2.	0.115	4.30	0.232	8.72	0.115	8.72	0.269	3.86	0.206	3.86	0.259	4.86	0.518	1.93
3.	0.171	2.84	0.352	5.85	0.171	5.85	0.413	2.42	0.292	2.42	0.413	3.42	0.825	1.21
4.	0.226	2.10	0.477	4.42	0.226	4.42	0.585	1.71	0.369	1.71	0.585	2.71	1.17	0.855
5.	0.280	1.64	0.608	3.57	0.280	3.57	0.778	1.28	0.438	1.28	0.778	2.28	1.56	0.642
6	0.332	1.34	0.747	3.01	0.332	3.01	0.995	1.00	0.499	1.00	0.995	2.00	1.99	0.502
7.	0.382	1.12	0.896	2.61	0.382	2.61	1.24	0.807	0.553	0.807	1.24	1.81	2.48	0.404
8.	0.431	0.946	1.06	2.32	0.431	2.32	1.51	0.661	0.602	0.661	1.51	1.66	3.02	0.331
9.	0.476	0.812	1.23	2.10	0.476	2.10	1.82	0.550	0.645	0.550	1.82	1.55	3.64	0.275
10.	0.519	0.703	1.42	1.92	0.519	1.92	2.16	0.462	0.684	0.462	2.16	1.46	4.32	0.231
20.	0.818	0.202	4.95	1.22	0.818	1.22	9.00	0.111	0.900	0.111	9.00	1.11	18.0	0.0556
30.	0.939	0.0633	15.6	1.07	0.939	1.07	30.6	0.0327	0.968	0.0327	30.6	1.03	61.2	0.0163
40.	0.980	0.0200	50.0	1.02	0.980	1.02	99.0	0.0101	0.990	0.0101	99.0	1.01	198.	0.00505
50.	0.994	0.00632	158	1.01	0.994	1.01	315.	0.00317	0.997	0.00317	315	1.00	630.	0.00159
60.	0.998	0.00200	500	1.00	0.998	1.00	999.	0.00100	0.999	0.00100	999	1.00	2000	0.000501

* THE CHARACTERISTIC IMPEDANCE OF THE NETWORKS IN DIAGRAMS A TO D IS R OHMS

TL 54836

Figure 12-14. Resistance networks causing stated losses when inserted between two resistors of R ohms each.

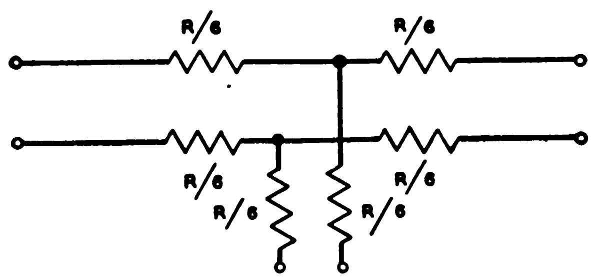
point the value of a single one of the impedances can be divided by the number of impedances, before entering the chart.

c. Figure 12-14 gives insertion loss of several types of resistance networks which might be used to intentionally insert loss when it is needed. The choice between different types of networks depends on their suitability to the particular problem, and on the available resistors.

d. Figure 12-15 shows a 3-way pad which can be used to connect three circuits of impedance R + j0 together with 6-db loss between any two circuits, and with no reflections produced in the circuits.

1221. IMPORTANT FACTORS IN TELEGRAPH TRANSMISSION.

a. Telegraphy uses codes in which characters are represented by combinations of two conditions of variable duration. One condition is called *marking* and the other *spacing*, these corresponding respectively at the transmitter to the closed and open positions of a key. Marks and spaces are represented, for example, by positive and negative currents, by current-on and current-off, tone-on and tone-off



TL 54925

Figure 12-15. Three-way 6-db pad.

as in radio with ear reception, or by alternating currents of two different frequencies. The relative positions in time of the transitions from one condition to the other indicate the intelligence in the message, the values of the currents during steady-state marking and spacing conditions being of secondary importance. This applies particularly to relay or similar reception, either wire or radio. Any over-all uniform shift or delay in transit is unimportant.

b. With point-to-point radio transmission and ear reception, however, where interfering currents, that is noise, may tend to override the signals, the most important consideration is the maintenance of a satisfactory value of signaling current in comparison with the interference. If a satisfactory signal-to-noise ratio is maintained, the signals can be understood since there is usually nothing in the radio transmission system to cause any material change in the relative timing of the transitions.

1222. TELEGRAPH SIGNAL DISTORTION.

a. It is usual to express the over-all transmission impairment of telegraph signals in terms of the time displacement of the transitions from their proper positions. This is given in percent of the duration of a unit signal element of the code. Such displacement of a transition is referred to as distortion. Time distortion should be clearly distinguished from distortion of the signal wave-shape, which may or may not cause time distortion of the transitions. Where signals are repeated into a local circuit by a receiving relay, the time distortion is a complete over-all measure of the transmission impairment. Time distortion is occasioned by a combination of such factors as wave-shape distortion, attenuation, interference, and variations in voltages and adjustment of relays. For satisfactory operation the distortion should not reach an amount which would result in ambiguous or incorrect interpretation of the received signals.

b. In the case of manual telegraphy, this distortion has been expressed, for a particular marking or spacing impulse, as the algebraic sum of the displacements of the two transitions determining the beginning and ending of the impulse. In other words, this is the lengthening or shortening of the pulse expressed in percent of a perfect unit pulse, the lengthening of marks being considered positive and their shortening negative.

c. Teletypewriter operation requires a different manner of specifying distortion, as will be clear from an examination of a teletypewriter signal. Such a signal, as indicated by figure 12-16, consists of a start pulse of unit length, a selecting period five time-units in length, and a stop pulse. In general any one of the five elements of the selecting period may be either marking or spacing. When such a signal is transmitted to a teletypewriter, by a

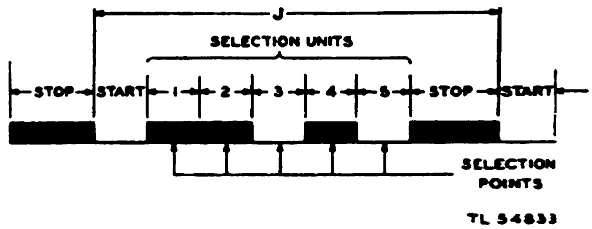


Figure 12-16. Teletypewriter character "J"; undistorted.

receiving relay for instance, the beginning of the start pulse causes the selective mechanism of the receiving machine to commence rotation; it will then rotate in substantial synchronism with the sender for a revolution, until brought to rest by the stop latch. At the midpoint of each of the five selection units or pulses, an examination of the received signal is made and, accordingly as the armature of the receiving relay is resting on marking or spacing, mechanical parts will be positioned so that one particular character and no other will be typed.

d. In case any particular transition of the selecting group is displaced in either direction by 50 percent or more of a selection unit, a wrong selection will inevitably be made. Figure 12-17 depicts a character with such a distortion of pulse 2. Since each selection point

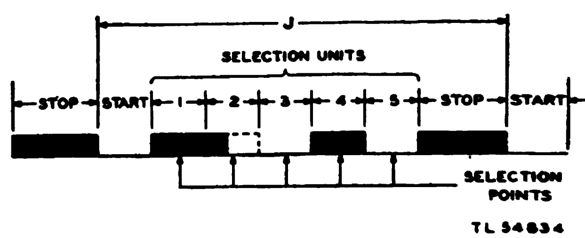


Figure 12-17. Teletypewriter character "J"; with over 50 percent distortion of pulse 2.

is timed with respect to the beginning of the start pulse, the displacement of the various transitions from their proper position relative to the beginning of the start pulse is of significance, rather than the total lengthening or shortening of any particular unit pulse, as in manual telegraphy. In the foregoing explanation an ideal receiving device was assumed; actual teletypewriters do not perform the selecting functions instantaneously exactly at the midpoints of the five intervals, consequently the distortion tolerance is generally between plus or minus 35 and plus or minus 40 percent.

e. Telegraph distortion may be conveniently divided into three different components. The first of these is *bias,* which means that some asymmetrical condition, such as voltage unbalance, improper relay adjustment, or change in received signal strength, has caused all marks to be either too long or too short. The bias of a circuit may be checked by transmitting *reversals,* that is, a steady stream of unit marks and spaces, or repeated space-bar teletypewriter signals. The latter requires special treatment since the marking and spacing intervals are unequal.

f. The second kind of distortion is called *characteristic,* for the reason that it depends upon the electrical and mechanical characteristics of the circuit and the particular signal combination which is being transmitted. This form of distortion is caused mainly by typical imperfections in the signal wave-shape impressed upon the receiving relay, occasioned, for example, by the effect of a low-pass filter with comparatively low cut-off in a d-c telegraph circuit.

g. The remaining type of distortion is called *fortuitous,* this being a random effect due to interference from other communication facilities and from power systems, chatter of relay contacts, etc.

1223. TELEGRAPH TRANSMISSION COEFFICIENTS.

a. Introduction. Various types and lengths of telegraph line sections and extension circuits differ in the amount of signal distortion which they cause. Furthermore, the performance of a given section or other part of a network varies from time to time because of changes in weather conditions, adjustments, etc. To predict the transmission capabilities accurately is difficult, but a system of transmission ratings, called coefficients, has been established which will be useful in planning. In this rating system, each part of a network is assigned a numerical coefficient in accordance with the impairment of transmission which it produces, the higher the number the greater the impairment. The coefficients for the parts of a proposed layout are added to obtain the over-all coefficient, which will indicate whether or not the circuit can be expected to operate satisfactorily.

b. Over-all Performance of Circuits.

(*1*) In a complete telegraph circuit, even one of comparatively simple make-up, the total distortion is made up of contributions from a considerable number of sources. It rarely happens that practically all contributing factors will combine in the most unfavorable manner, that is, so as to cause the maximum distortion which is possible due to direct addition of all increments. To evaluate the transmission quality, measurements can be made from which the rate of occurrence of errors or false characters may be predicted for various types of circuits.

(*2*) It has been found that, with either teletypewriter or Morse-code reception, signals with total distortion of less than about 35 percent are not likely to cause an error.

(*3*) Although a high degree of stability is desirable in operation of telegraph circuits, it is not practicable to design them so that they will operate perfectly at all times, particularly with long and complicated layouts. If any over-all connection, as a matter of long-time average does not produce more than one error in 1,500 characters, the service will be considered high-grade for Signal Corps purposes in the theater of operations. A circuit at the border line of this limit might operate with very few errors for a number of days and then have fairly frequent errors over a period of several minutes to an hour. In some cases layouts with a higher percentage of errors will be considered satisfactory. To meet the requirements, the rear-area fixed communications should be designed to provide as good operating performance as practicable to allow for the probable poorer performance of the forward-area facilities. If the occurrence of errors interferes seriously with handling traffic, steps should then be taken to improve transmission if practicable, as, for instance, by readjustment, by direct substitution of other facilities, or by a change in the circuit layout.

c. Prediction of Performance of Networks.

(*1*) The basic idea in the establishment of coefficients for use in network planning is that increments of distortion from different sources generally combine at random, the most probable resultant total value being equal to the square root of the sum of the squares. A convenient approximation in determining whether the distortion limit will be exceeded is to add the squares rather than the first power of the distortions. Accordingly, coefficients are made proportional to the square of a representative value of distortion for the particular section in question. From observations of distortion or from the corresponding coefficient, it is possible to predict with reasonable accuracy the probable rate of occurrence of errors for a single link or for several links in tandem.

(*2*) As stated above, an average rate of occurrence of one error in 1,500 characters in Signal Corps teletypewriter operation is believed to be satisfactory for usual service requirements. In the system of coefficients (ch. 3), this corresponds to an over-all coefficient of 15. If the requirements are more lenient, a limit of 18 or 20 corresponding to one error in about 300 characters could be used. It will be appreciated that the higher the over-all coefficient, the more frequent will be the occurrence of periods of material duration during which the circuit will not be usable, so that the service will be inferior and more maintenance effort may be required.

(*3*) In using the coefficients, a layout diagram is first drawn and a coefficient is selected for each part of the transmission circuit. Then a computation is made of the over-all coefficient from each terminal station to every other terminal station, including those at the end of each branch. If any such over-all figure exceeds the established limit, it will then be necessary either to substitute better transmission facilities or divide the path into parts by the insertion of one or more regenerative repeaters. Since such a repeater reforms and retimes the signals, it is then necessary only to compute the over-all coefficient from each terminal to a regenerative repeater and from one regenerative repeater to another to see whether or not the limit is exceeded.

d. Bell System Coefficients. The coefficients which have been established for circuits used in Bell System service are generally lower in value than those given in chapter 3 because these circuits are generally set up to give higher quality transmission. For instance, a carrier telegraph section is assigned a value of 1.5 in a representative case. D-c polar and polarential line circuits have values ranging from about 2 for the most favorable case up to about 6 for extreme conditions, the average being about 3.5. Local loop circuits are generally in cable and are treated individually to improve the signal wave-shape, and these have coefficients ranging from 0.2 for short loops to about 2 for 35-mile loops. The limiting over-all coefficient is set at 10 because the service requirements for commercial use are generally high.

1224. TELEGRAPH TRANSMISSION MEASUREMENT.

a. It is generally practicable to measure the total distortion of teletypewriter signals in the field, and this is valuable as it furnishes a direct indication of the grade of transmission. Determination of the characteristic and fortuitous components of distortion separately is not generally practicable, but in many cases a check is made of the important factor of bias during certain lining-up procedures, and it is advantageous to make such checks in case of transmission difficulties.

b. Bias is a variable factor and generally may be minimized by proper adjustment of relays and operating currents. One method of checking bias is to apply repeated teletypewriter space-bar signals at one end of the circuit and observe the received signals in a local circuit at the other end. These received signals are measured with a bias-measuring circuit arranged so that its meter needle vibrates about zero when receiving unbiased space-bar signals. Another method involves the same kind of test but uses, for the test signals, a series of equal marks and spaces known as telegraph reversals. Reversals will not be retransmitted properly by a regenerative repeater. Space-bar signals will be regenerated, thereby removing the bias. Accordingly when such tests are made through regenerative repeaters the bias will be checked only in that part of the circuit beyond the last regenerative repeater.

1225. MEASUREMENT BY TELETYPEWRITER.

a. The orientation range finder provided on teletypewriters may be used conveniently to give an indication of total distortion. For best results machines should be in good adjustment and care taken in making the observations. The finder and its scale are shown by figure 12-18. The scale is graduated in percent of a unit dot length and the range finder arm may be moved from 0 to 120 on the scale. Adjustment of this finder causes the selection points (fig. 12–16) to be shifted with respect to the beginning of the start pulse and when the shift is sufficiently great, errors will be made by the teletypewriter. The range over which the finder may be moved without errors being typed is reduced by any distortion of the incoming signals.

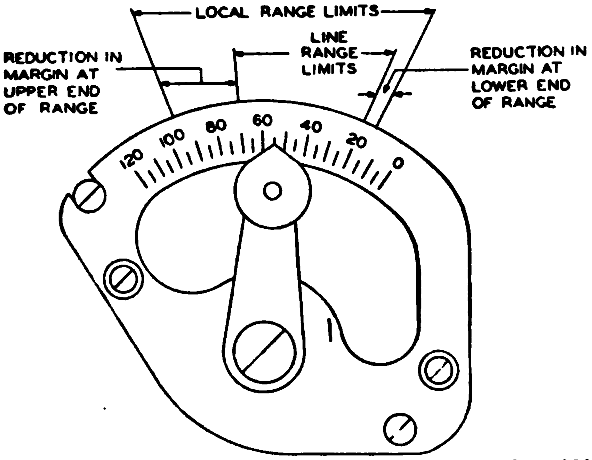


Figure 12-18. Teletypewriter orientation range finder.

b. In determining the range, the range finder is first moved towards one end of the scale until errors appear in the copy and then moved back slowly until no error occurs in one or two lines of page printing. Similarly, the range finder is moved towards the other end of the scale until errors occur and then moved back slowly until there are no errors. The difference between the two scale readings at the points where errors disappear is the *orientation range.*

c. Representative orientation ranges for different degrees of signal distortion for well-adjusted teletypewriters are as follows:

Distortion	*Orientation range*
Very little	80
Moderate	60–70
Average	50
Large	Less than 40

d. Representative orientation ranges with practically perfect signals and a teletypewriter in good condition are 10-90 and 15-95 on the scale. In general, best operating results will be obtained when the finder arm of the receiving teletypewriter is set at the middle of the local range. It is often not practicable to make a determination in the field of this setting and in such cases an arbitrary setting of about 55 is used.

e. Practically perfect signals for orientation tests are supplied by a properly adjusted transmitter-distributor or a signal-distortion test set. Keyboard signals may also be used where better methods are not available. Since keyboards usually have noticeable distortion, a satisfactory local test with these signals is a range of 70 or more.

f. The differences between limits determined by local test and the corresponding limits obtained when receiving signals over a line, give directly the reduction in margins due to signal distortion. These reductions, as illustrated in figure 12-18 are a direct measure of the total signal distortion.

g. Signal bias affects one limit more than the other; marking bias reduces the upper limit, spacing bias raises the lower limit. Characteristic and fortuitous distortions cause reductions in the margin at both limits with miscellaneous signals.

h. Correct teletypewriter motor speed is important in maintaining the operating margins and a check of speed should always be made before measuring ranges. The speed should be checked with a tuning fork of the proper type. A two percent variation from the correct value will result in 12 percent distortion at the end of the fifth pulse. Therefore, the speed should be kept within one percent of the correct value.

i. Tests may be made of the distortion tolerance of teletypewriters (or teletypewriters in combination with line circuits) by applying predistorted signals. Signal distortion test sets are arranged to supply miscellaneous teletypewriter signals having both marking and spacing bias adjustable from zero to about 40 percent or more. Well adjusted teletypewriters should type correctly when the signals from the test are biased by as much as plus or minus 35 percent in a local test circuit[10]. With line sections between the test set and the teletypewriter, the tolerance should not be less than plus or minus 15 percent for highgrade army service.

[10] A circuit including the sending and receiving elements of the teletypewriter and a suitable resistor which, with a normal voltage of 115 volts, will provide a normal operating current of 60 milliamperes. The local test circuit is sometimes included in the teletypewriter.

APPENDIX

LIST OF PUBLICATIONS

Field manuals	*Title*
FM 11-5	Mission, Functions and Signal Communication in General
FM 11-21	Signal Operations in the Theater of Operations (*when published*)
FM 11-22	Signal Operations in the Corps and Army
FM 24-5	Signal Communication
FM 24-8	Combined Teletypewriter (Teleprinter Procedure)
FM 24-10	Combined Radiotelegraph (W/T) Procedure)
FM 24-14	Teletypewriter Switching and Relay Procedure
FM 24-18	Radio Communication
FM 24-20	Field Wire Systems
FM 24-75	Telephone Switchboard Operating Procedure
FM 55-50	Military Railroads and the Military Railway Service
FM 55-55	Railway-Operating Battalion

Technical manuals	*Title*
TM 9-2853	Preparation of Ordnance Matériel for Deep Water Fording
TM 11-200	Radio Sets SCR-AF-283, SCR-AG-183, SCR-AH-183, SCR-AJ-183, SCR-AK-183, SCR-AL-183, SCR-AN-183, SCR-AL-283, and SCR-AN-283
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TM 11-355	Telegraph Terminal CF-2-A (Carrier)
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TM 11-600	Radio Sets SCR-508-(*), and SCR-528-(*), and SCR-538-(*)
TM 11-601	Radio Sets SCR-808-A and SCR-828-A
TM 11-602	Radio Set AN/MRC-1
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TM 11-619	Radio Set SCR-619 (*when published*)
TM 11-620	Radio Set SCR-608-A and SCR-628-A
TM 11-630	Preliminary Instructions for Radio Set SCR-506-A
TM 11-637	Radio Set AN/VRC-3
TM 11-755	Grounds, Grounding Procedure, and Protective Devices for Wire Communication Equipment
TM 11-801	Power Amplifier BC-340-G and Water Cooling Unit RU-2-A
TM 11-802	Radio Transmitters Wilcox Types 96-200A and 96-200B
TM 11-803	Radio Transmitters Wilcox Types 96C and 96C3; Rectifier Unit, Wilcox Type 36A; Modulator Unit, Wilcox Type 50A
TM 11-813	Radio Transmitter BC-610-E and Associated Equipment
TM 11-816	Radio Transmitting Equipment RC-263
TM 11-820	Radio Transmitter T-4/FRC, Radio Transmitter T-5/FRC, Power Rectifier PP-1/FRC, Modulator MD-1/FRC, Switch Panel SA-2/FRC, Oscillator O-2/FRC, Amplifier AM-2/FRC
TM 11-821	Radio Transmitter (Press Wireless Type PW-15) (*when published*)
TM 11-828	Radio Transmitter BC-365-F and Remote Control Unit RM-10-F
TM 11-829	Radio Set AN/VRC-4 and Transmitter Type TS-25-3 and Receiver Types RS-25-3 and RS-25-4
TM 11-832	Radio Transmitting Equipment, Single Sideband (Western Electric Co. Type D-156000) (*when published*)
TM 11-834	Radio Transmitter PW-981-A, 2.5 kw
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TM 11-836	Radio Transmitter BC-339-A, -B, -C, -D, -E, -F, -G, -H, -J, -K, and -L (*when published*)
TM 11-853	Radio Receiver (Wilcox Types CW and F3) and Receiver Bay (Wilcox Type 113A) (*when published*)
TM 11-895	Radio Set SCR-593-A and SCR-593-C
TM 11-866	Radio Receivers BC-779-B, BC-794-B, and BC-1004-C and Power Supply Units RA-74-C, RA-84-B, and RA-94-A
TM 11-868	Radio Receiver 128-AY
TM 11-872A	Diversity Receiving Equipment AN/FRR-3A
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TM 11-900	Power Units PE-75-C through PE-75-T
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TM 11-914	Power Unit PE-201-A
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TM 11-967	Power Transfer Panel CN-22/F
TM 11-1055	6 kw R. F. Amplifier PA-1A, Rectifier RA-1A, and Antenna Tuning Unit A1-1A
TM 11-2001	Complete 100-mile Spiral-Four Carrier System
TM 11-2002	Substitute Telephone Central Office Equipment
TM 11-2003	Carrier Hybrid CF-7
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TM 11-2005	Repeater Set TC-19 (Intermediate)
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TM 11-2009	Telegraph Terminal CF-6 (Carrier)
TM 11-2020	Line Terminating and Simplex Panel (Packaged Equipment)
TM 11-2021	Voice-Frequency Ringer (Packaged Equipment) (*when published*)
TM 11-2022	Application of Packaged Equipment to Open-Wire Lines
TM 11-2023	Installation Instructions for Type C Carrier Telephone (Packaged Equipment) (Moisture-Resistant)
TM 11-2026	Type C Carrier Telephone (Packaged Equipment) (Moisture-Resistant) (*when published*)
TM 11-2027	Installation Instructions for Voice-Frequency Telephone Repeaters (Packaged Equipment) (Moisture Resistant)
TM 11-2028	Voice-Frequency Telephone Repeaters (Packaged Equipment) (Moisture-Resistant) (*when published*)
TM 11-2029	Voice-Frequency Carrier Telegraph (Packaged Equipment) (*when published*)
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TM 11-2038	Installation Instructions for Type H Carrier Telephone (Packaged Equipment)
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TM 11-2203	Teletypewriter Set AN/TGC-1
TM 11-2204	Dual Diversity Receiving Equipment (Wilcox Type CW3-D)
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TM 11-2206	Telegraph Terminal Set AN/TCC-1, Telegraph Terminal TH-1/TCC-1, and Filter F-2/GG

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TM 11-2208	Test Set TS-2/TG
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TM 11-2211	133A1 Teletypewriter Table and Associated Printer Apparatus
TM 11-2214	133A2 Teletypewriter Subscriber Set and Associated Equipment
TM 11-2215	Teletypewriters TT-5/FG and TT-6/FG
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TM 11-2217	Distortion Test Set (4TDXD1/DTS) (*when published*)
TM 11-2220	Reperforator Transmitters TG-26-A and TG-27-A
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TM 11-2256	Limiter Amplifier Type 3BLH and Speaker Type 6AL
TM 11-2257	Power Units, Fahnsteel Nos. 1161 and 1152
TM 11-2510	Master Power Meter Panel
TM 11-2513	Test Set I-193-A
TM 11-2515	Diversity Receiving Combining Equipment
TM 11-2601	Radio Set AN/TRC-1, Radio Terminal Set AN/TRC-3, Radio Relay Set AN/TRC-4, and Amplifier Equipment AN/TRA-1
TM 11-2603	Radio Set AN/TRC-2
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TM 11-2614	Assembling and Erecting 30-Foot Gin-Pole-Type Trylon Ladder Towers
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TB SIG 13	Moistureproofing and Fungiproofing Signal Corps Equipment
TB SIG 28	Instructions for Treatment of Teletypewriter Paper Rolls
TB SIG 37	Grounding Requirements and Procedure Applicable to Wire Communication and Associated Electrical Apparatus
TB SIG 52	Connection and Line-Up Procedure for Switchboards BD-100 Interconnected with Other Teletypewriter Equipment By Wire Lines and By Carrier Telegraph Equipment
TB SIG 61	Uses of Adapter Plug U-4/GT
TB SIG 66	Winter Maintenance of Signal Equipment
TB SIG 67	Laying Field Cable Under Water
TB SIG 72	Tropical Maintenance of Ground Signal Equipment
TB SIG 73	Open-Wire Transpositions
TB SIG 78	Instructions for Initial Line-Up and Check of Levels in Standard Multichannel Radio Communication System
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WAR DEPARTMENT ORDER NO. 52262; 6,300; 25 APRIL 1945.