

Military Teletypewriter Systems of World War II

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THE TELETYPEWRITER was a vital communications tool of World War II. Secret teletypewriter communications to permit close and efficient coordination between all echelons, from comparatively small tactical units to the highest military and diplomatic leaders, were handled with accuracy and dispatch on a very efficient basis. Wire and radio teletypewriter networks, extending over land and sea were used intensively by our armed forces and Government officials for handling the stupendous tactical, supply, and administrative problems, as well as the affairs of state, brought about by the war. These teletypewriter communications became a reality as a result of the development since late 1941 of improved teletypewriter cipher arrangements and of means to permit dependable teletypewriter operation, not only over short-haul radio and military wire-line networks, but also over transoceanic and other long-haul radio circuits.

This paper reviews the evolution of military teletypewriter communications since 1941 and briefly describes some of the important systems that were developed during the war by Bell Telephone System engineers for the armed forces.

Telegraph Communication Systems as of 1940-41

COMMERCIAL WIRE-LINE SYSTEMS IN THE UNITED STATES

Immediately prior to the Pearl Harbor attack the large amount of commercial and the relatively small amount of military telegraph communications within the United States were handled mostly over wire lines. Teletypewriter, rather than manual keying methods, were used in the majority of these communications.

Through successive improvements made in teletypewriter apparatus¹ and in the d-c^{2,3} and carrier telegraph^{4,5} line facilities since World War I, it was practicable to send several teletypewriter messages simultaneously over long wire-line circuits at speeds of 60 words per minute and higher.

The Western Union Telegraph Company and Postal Telegraph Company utilized teletypewriters for communications between their local offices and main distributing centers in each city. These companies passed their intercity public message and their large customers' leased circuit traffic over carrier and d-c telegraph channels generally using either synchronized time-division multiplex telegraph methods⁶ or variations of this method,^{7,8} thereby obtaining very efficient use of the line facilities. With synchronized time-division multiplex, commutating devices provide a means whereby two or more messages are sent over a single telegraph channel.

The Bell Telephone System furnished teletypewriter exchange (TWX)^{9,10,11} and private line manual Morse and teletypewriter^{11,12} services, providing direct communication between two or more stations in each customer's connection or network, as is done in telephone service. With direct connections the sender's message is recorded at all customers' offices in the network as soon as the message is sent.

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The Bell Telephone System and telegraph companies also furnished private-line switched teletypewriter service on a leased network basis^{11,13,14} to some of the large users of teletypewriter service. This form of service permits a very rapid handling of messages and a high traffic-carrying capacity of the intercity trunks used in the network.

OVERSEAS TELEGRAPH SYSTEMS

Prior to the war telegraphic communications between the continental United States and foreign countries were handled by radio and submarine cable. Traffic was handled on an efficient basis over high-speed submarine cables¹⁵ using the synchronized time division system.¹⁶ The long-haul radio links employed international Morse code methods generally using perforated tape sending and dot-dash inked tape receiving.¹⁷ With this tape method it is necessary to read the receiving tape and translate the information manually into typed messages. Teletypewriter methods^{18,19} were applied only to a minor extent over long-haul radio because of transmission difficulties.

SYSTEMS USED BY THE NAVY

The Navy operated a rather extensive network between shore stations, between ships and between ships and shore. Practically all of the Navy traffic was handled by manual international Morse code telegraphy. The Navy had not adopted the teletypewriter although to care for large traffic over their main communication routes they used the perforated-tape-sending and inked-tape-receiving method of transmitting international Morse code signals. Skilled operators and reasonably good radio paths were required and the latter were not always available. It was, of course, necessary to transcribe manually incoming dot-dash messages at the receiving end of the circuit

SYSTEMS CONSIDERED BY THE ARMY

Because of restrictions imposed by peacetime conditions the Army used only a relatively small amount of wire-line teletypewriter communications facilities within the United States. These condi-

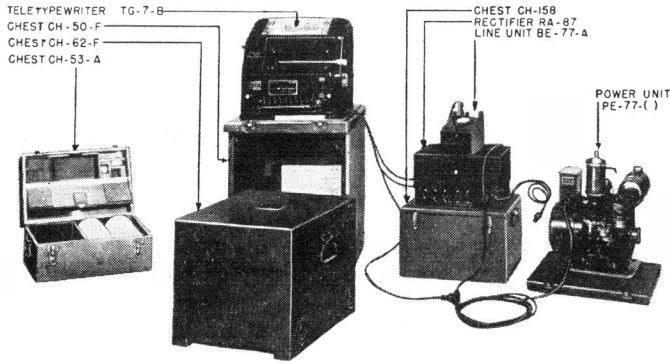


Figure 1(a). Teletypewriter set, EE-97-A

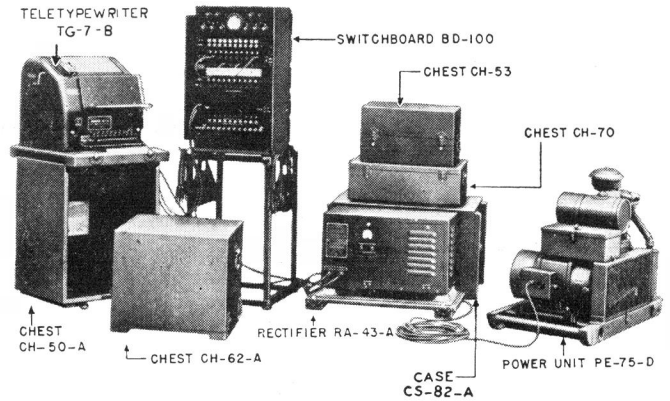


Figure 3(a). Telegraph central office set TC-3

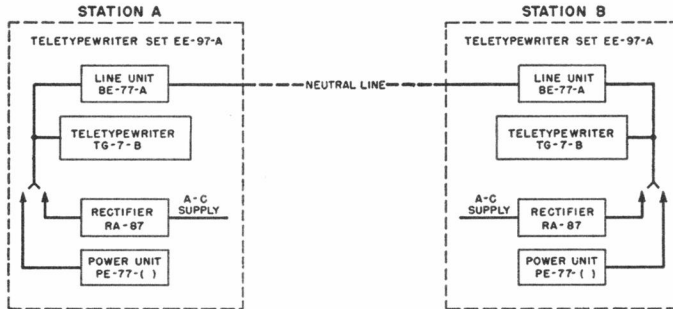


Figure 1(b). Application of teletypewriter set, EE-97-A

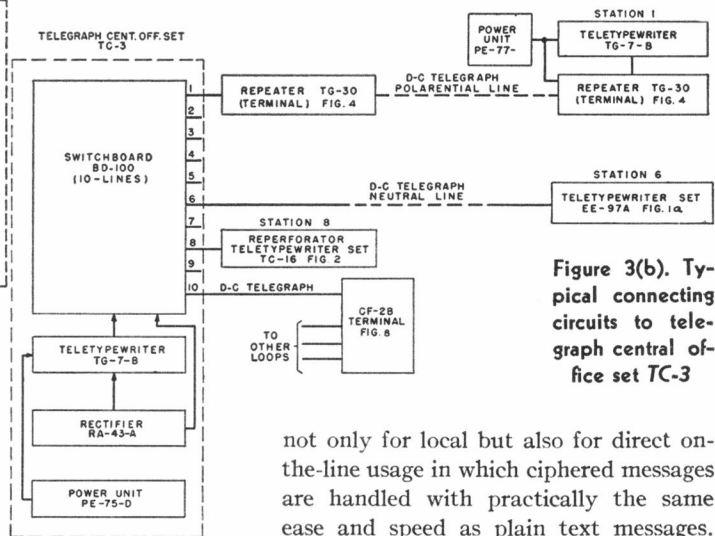


Figure 3(b). Typical connecting circuits to telegraph central office set TC-3

tions made it very difficult for the Signal Corps to do more than consider potential communication networks for war purposes. At the beginning of World War II the Signal Corps had worked out comprehensive plans for handling wire-line telegraph and teletypewriter communications. Work had been done in co-operation with the Teletype Corporation engineers and other groups toward the development and production of portable military teletypewriter equipment. The trend at that time indicated, however, the use of slow manual Morse methods and not teletypewriters over radio.

Evolution and Advantages of Cipher Teletypewriter Systems for Military and Diplomatic Communications

During World War I Bell Telephone System engineers recognized the advantages of the teletypewriter as a particu-

larly suitable means of providing military and diplomatic communications. Indeed it was during this period that they developed the method of locally enciphering and deciphering teletypewriter signals.²⁰⁻²⁴

With the advent of World War II it was natural for the Bell Telephone Laboratories and Teletype Corporation engineers to advocate the use of ciphered teletypewriter arrangements in military and diplomatic communications. With close co-operation of the Army, modernized teletypewriter enciphering and deciphering arrangements were quickly developed

not only for local but also for direct on-the-line usage in which ciphered messages are handled with practically the same ease and speed as plain text messages. The Army started to apply both arrangements soon after Pearl Harbor.

Teletypewriter cipher communication methods have the outstanding advantages of secrecy, dependability, ease of training operators, speed in handling messages, and of accurate and efficient use of the transmission medium. Ordinary telegraphy, coded words of speech and other cipher systems do not have all of these advantages. The advantages of cipher teletypewriter communications were generally recognized by the War and Navy Departments and by the other departments of the Government and their use over both wire and radio networks rapidly became the backbone method of military communication during World War II, especially where long distance communications were involved and where conference connections were desired.

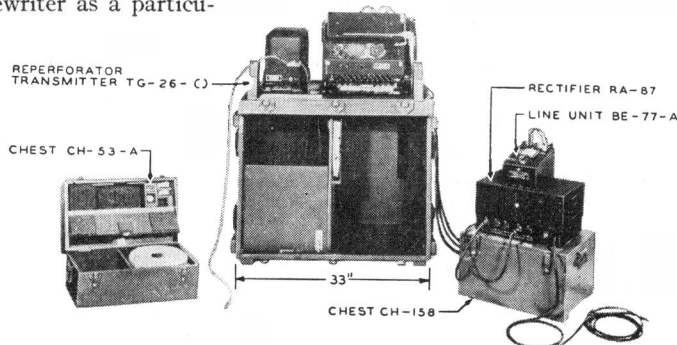


Figure 2. Re-perforator teletypewriter set TC-16

-C and Carrier Telegraph Systems for Wire Lines Used in World War II

It was recognized at the outset of World War II that military wire-line telegraph systems must be capable of withstanding extreme and widely fluctuating tempera-

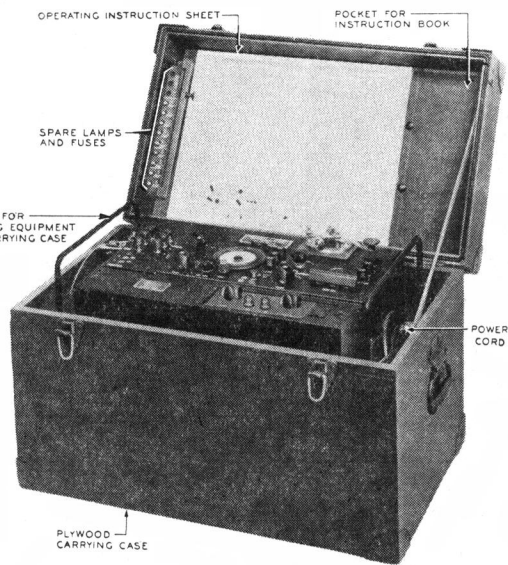


Figure 4 (left).
Telegraph repeater
TG-30
(Terminal)

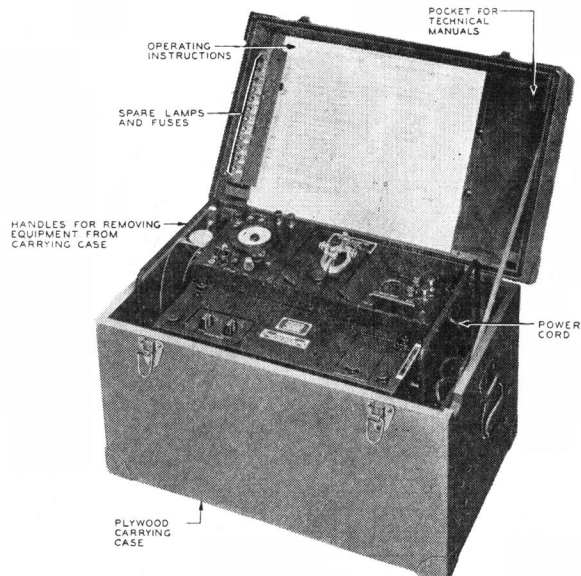


Figure 5. Tele-
graph repeater
TG-31 (Inter-
mediate)

ture and humidity conditions, must be sufficiently rugged for transportation at least into and through the theatres of operation if not in combat areas, must be capable of operating from a-c sources of power supply whose voltage and frequency fluctuate considerably, and must be capable of being set up for operation in a very short time and of operating over long periods with a minimum amount of maintenance. These engineering problems were quickly and successfully solved and during 1942 some of the first military wire-line telegraph systems were delivered to the Army. Constant progress was made after that date and the armed forces were well supplied with up-to-date military d-c telegraph and wire-line carrier telegraph equipments for handling their teletypewriter and other telegraphic communications. The engineering problems were attacked and solved, having in mind that all of the components used in these military teletypewriter communication circuits had to fit into and be a part of a complete working system, each component forming a link in a chain. The approach is sometimes called the "system's viewpoint" and is the method which is followed in planning and engineering American TWX and private line teletypewriter networks.

MILITARY D-C TELEGRAPH ARRANGEMENTS

In the military d-c telegraph field some of the important units, used by our armed forces to handle teletypewriter communications in the theatres of operation, made by various manufacturers, are:

*Teletypewriter Set EE-97-A**. This set includes a page-receiving and keyboard-

*These sets were developed by Signal Corps Laboratories. They were manufactured by various contractors and made use of teletypewriter apparatus furnished by Teletype Corporation.

sending teletypewriter, coded *TG-7-B*, which is arranged for operation at 60 or 66 words per minute. It also includes line unit *BE-77* and power equipment. Figure 1(a) shows teletypewriter set *EE-97-A* and Figure 1(b) is an illustration of how it was used over short wire-lines. It is used also in carrier telegraph and radio teletypewriter networks.

*Reperforator Teletypewriter Set TC-16**. This set includes reperforator transmitter *TG-26-A*, line unit *BE-77-A* and a power supply unit. Reperforator transmitter *TG-26-A*, perforates and types messages on a tape from a local keyboard or from line signals and sends signals from tape run through the transmitter at either 60 or 66 words per minute. Reperforator teletypewriter set *TC-16* was connected in the same general manner as teletypewriter set *EE-97-A* to d-c telegraph wire-line circuits, and to carrier and radio teletypewriter circuits. Figure 2 is an illustration of this set.

*Telegraph Central Office Set TC-3**. This set includes a 10-line teletypewriter switchboard, coded *BD-100*, a *TG-7-B* operator's teletypewriter and power supply equipment. The *BD-100* switchboard provides a means of interconnecting wire-line and radio teletypewriter circuits manually for either point-to-point or conference connections. Two or more *BD-100* switchboards were operated together to increase capacity. Figure 3(a) shows the telegraph central office set *TC-3* and Figure 3(b) is a schematic of a typical network including other tactical equipments.

Repeater TG-30, Repeater TG-31, and Repeater Package X-61824A. The *TG-30* and *TG-31* repeaters are combat types and the *X-61824A* package is a fixed plant type. All of these repeaters operate on a polar-intential³ transmission basis. The *TG-30* and *X-61824A* provide means of operating teletypewriters over simplex Army field wire up to 50 miles; by interposing a *TG-31* at the middle of such a circuit, operation up to 80 miles was possible. These repeaters could be used also on simplex and composite bases over cable and over much longer links of open wire. Figure 4 shows a *TG-30* and Figure 5 a *TG-31* repeater. Each cabinet includes a power rectifier for operation from a-c power.

Figure 6 shows an *X-61824A* repeater package cabinet housing two repeaters with their associated power rectifiers.

Regenerative Repeater Package, X-66031A. This repeater provides a means of reconstructing teletypewriter signals after they have been badly distorted as a result of transmission over a telegraph circuit that is operated near its limit of transmission capability, thereby permitting a considerable extension of transmission range. Figure 7 shows a cabinet housing two of these repeaters.

MILITARY MULTICHANNEL CARRIER TELEGRAPH WIRE-LINE SYSTEMS

The Army used two classes of multichannel carrier telegraph wire-line terminals in the theatres of operation, tactical and fixed plant. The tactical terminals, known as the *CF-2* and *CF-6* types, were used with the spiral-4 cable and also with Army field wire, with open-wire lines, and with commercial cable. The Army also used them with portable frequency-modulation radio sets to pro-

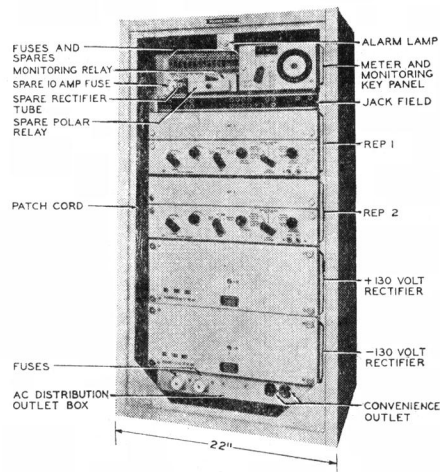


Figure 6. Telegraph repeater package,
X-61824A (Terminal)

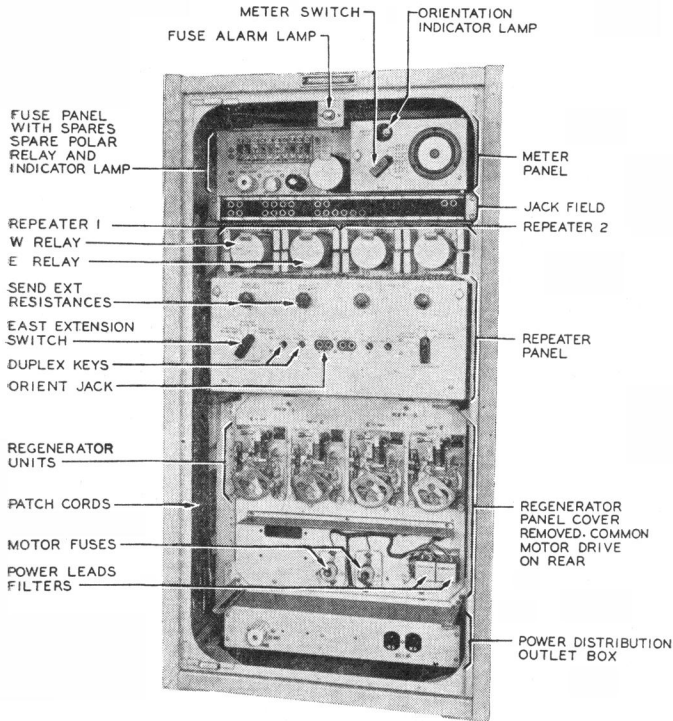


Figure 7 (above). Regenerative repeater package X-66031A

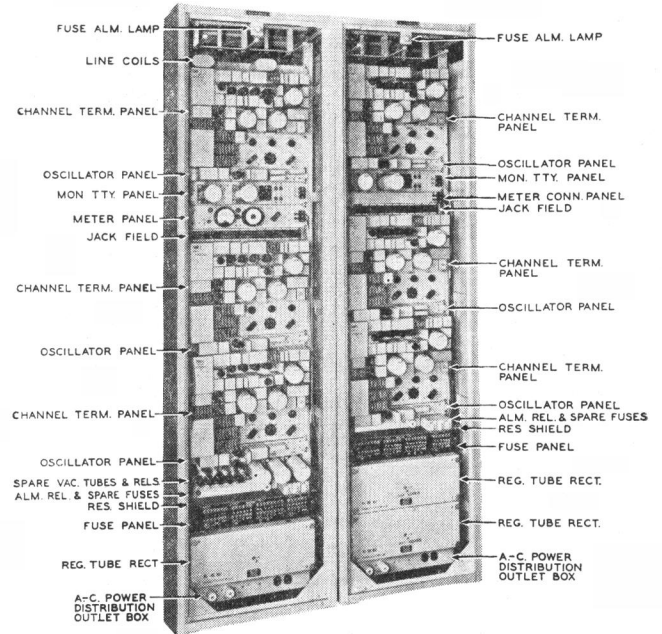


Figure 9. Fixed plant military voice frequency carrier telegraph terminal X-61822

Figure 8. Military voice frequency carrier telegraph terminals

View showing physical comparison

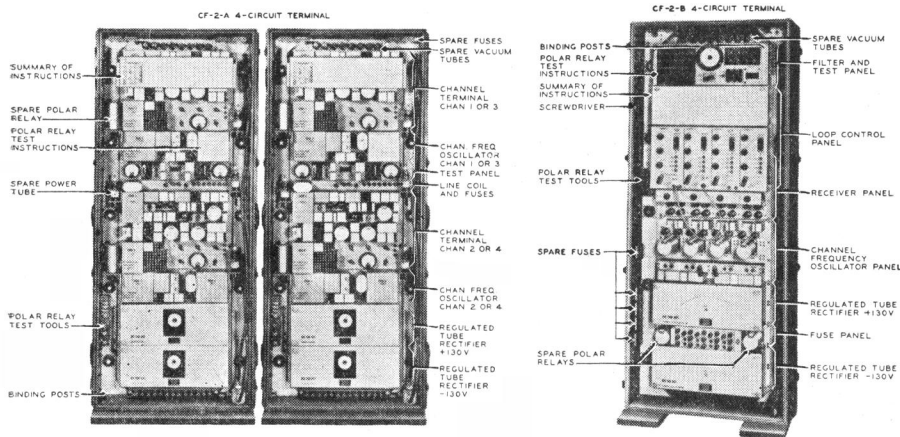


Figure 10. Teletypewriter networks in European theatre of operations, January 1945

vide multichannel teletypewriter circuits. There are two types of *CF-2* terminals; these are coded *CF-2-A* and *CF-2-B*.²⁵ Either type provides four 2-way teletypewriter circuits over a 2-wire circuit that is suitable for telephone. By supplementing either of these terminals with *CF-6-A*, a total of six 2-way teletypewriter circuits was provided over a 2-wire circuit. Where 4-wire telephone facilities were available, the number of teletypewriter channels could be doubled by using twice as much terminal equipment. The *CF-2-A* terminal was superseded by the *CF-2-B*, which is one-half the size and is about 55 per cent as heavy. Figure 8 shows a comparison in size and appearance of the *CF-2-A* and *CF-2-B* terminals.

In addition to the *CF-2* and *CF-6* types

of carrier telegraph terminals, a so-called "packaged carrier telegraph system terminal" was provided for fixed plant use by the Signal Corps. This equipment makes use of the same apparatus components as those used in the *CF-2-A* but the over-all assembly is quite different both physically and electrically, as the packaged equipment was called upon to meet somewhat different service requirements than the tactical equipment. The package terminal is arranged for operation over a 4-wire telephone circuit and either 6 or 12 2-way teletypewriter circuits could be obtained over such a circuit, depending upon the amount of equipment used. Figure 9 shows the complete equipment of a 6-circuit terminal. For 12 circuits an additional pair of cabinets was required.

Figure 10 illustrates the scope of the "fixed plant" teletypewriter networks in the European theatre of operations during January 1945; the tactical circuits in the forward areas are not included. The carrier and d-c telegraph equipments described previously were used in this network. The long-haul radio equipments are those described later in this paper.

Radio Teletypewriter Systems Used in World War II

The radio teletypewriter communication networks used by Government officials and the armed forces included a number of different systems which may be divided broadly into two general classes, short-haul and long-haul systems. The former class was generally used over relatively short distances up to about 200 miles with the maximum distance between radio repeater points not in excess of about 40 miles; the latter over long stretches of water or over difficult terrain where intermediate radio repeater points were impracticable. Each teletypewriter channel in these systems handled traffic at a normal rate of 60 words per minute and sometimes at higher speeds.

SHORT-HAUL RADIO TELETYPEWRITER SYSTEMS

Short-haul radio teletypewriter systems that were developed by the Bell Laboratories during the war for the Army and Navy made use of telephone-type radio sets operated on either an amplitude or frequency modulation basis. Toward the end of the war it was also possible to establish radio teletypewriter communication links in the ultra high-frequency radio range by applying these short-haul radio teletypewriter systems to one or more of the channels in multichannel pulse modulation radio systems.²⁶ Certain of the short-haul radio teletypewriter systems were installed on a fixed plant basis and others were used on a combat basis.

An example of a fixed plant system is the Navy "carrier control system—model UN." This is a 1-way system capable of transmitting as many as 36 individual teletypewriter messages simultaneously. It was, and is still used mainly for interconnecting a naval headquarters control station and nearby stations where a number of long-haul radio circuits terminate. Figure 11 shows the over-all layout of a typical small sized installation and Figure 12 shows schematically the various service options and channel frequency allocations. The naval headquarters control station is located several

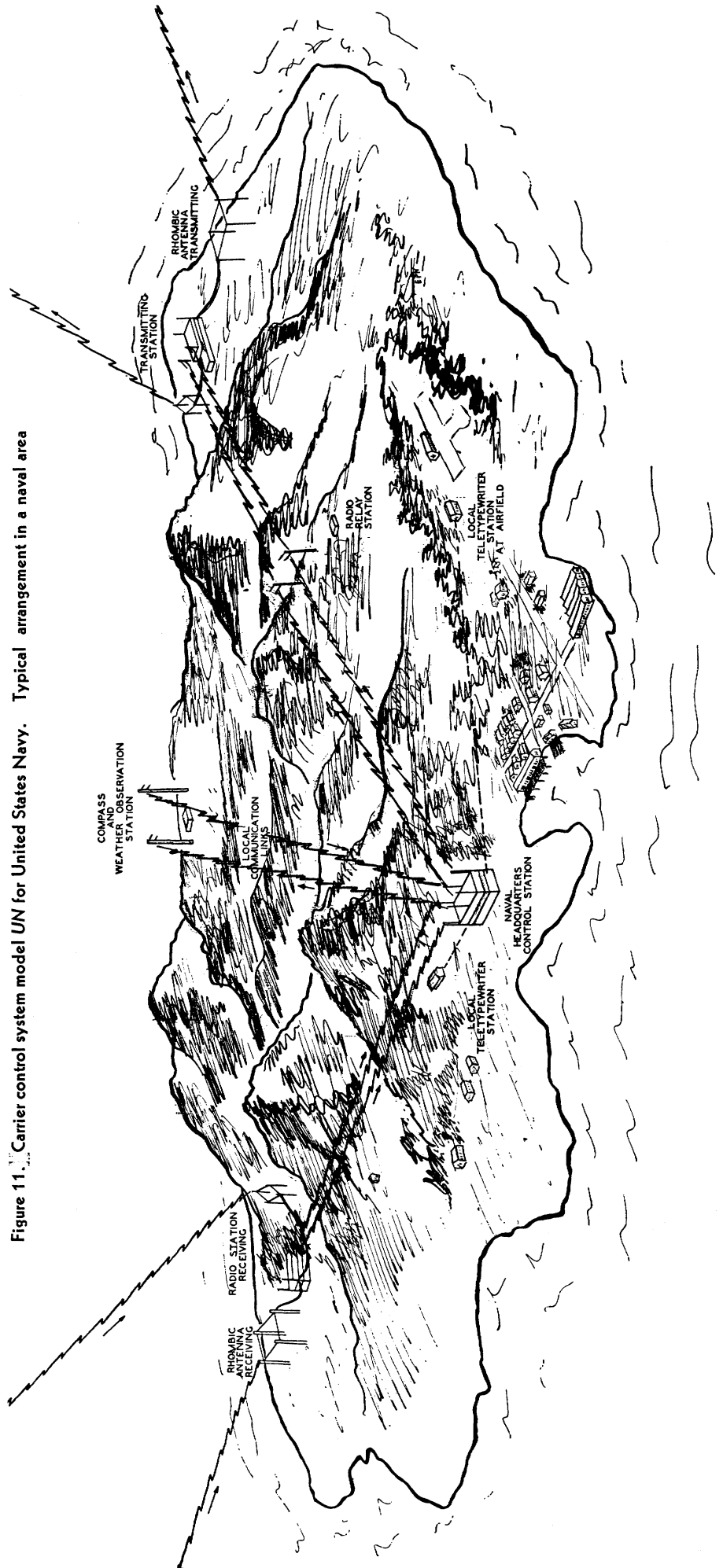


Figure 11. Carrier control system model UN for United States Navy. Typical arrangement in a naval area

miles from either of the long-haul radio stations which are separated from each other by several miles to avoid mutual interference. Originally intended as a fall-back system for emergency use in cases of failure of wire lines, the model *UN* system is being used satisfactorily in the Hawaiian Islands, and in the Washington, Panama, San Diego, San Francisco, Seattle, San Juan, and other areas in regular service. Bell Laboratories engineers designed the radio transmitters, receivers, and carrier equipment in this system, and also co-operated in the field in connection with their installation and adjustment. A somewhat similar system, coded *42B1*, was also developed for the Army. It came into use during the war to interconnect terminals of long-haul radio teletypewriter links and Army signal centers, such as between the radio station at Fort Myer, Va., and the telegraph central office—WAR—in Washington.

A portable short-haul multichannel teletypewriter system, which is known as

the Navy "portable carrier control system—model *UF*," provides four teletypewriter channels in each direction over a 2-way radio link. The equipment may be landed readily on a beach and requires only a few minutes to set up for service. Figure 13 shows a schematic of a typical setup of the equipment of the model *UF* system. The line terminals and radio line terminal, shown in Figure 13, were ordinarily used in conjunction with a portable amplitude or frequency modulation *VHF*-type radio set for termination of a point-to-point multichannel radio teletypewriter circuit. The capacity of the system is four 2-way teletypewriter circuits, each operating at 60 words per minute.

LONG-HAUL RADIO TELETYPEWRITER SYSTEMS

The transmission of teletypewriter pulses over long-haul high-frequency radio was not accomplished, as might be supposed, merely by connecting the tele-

typewriter machines to radio facilities that were in use prior to the war. The prewar radio systems did not contain the features to overcome the effects of signal fading and other natural and man-made disturbances required for good teletypewriter service. The wide experience of Bell Telephone System engineers in the design of electronic circuits and in the development of land-line teletypewriter and radio telephone systems proved to be of great value in their efforts to surmount these transmission difficulties. With the co-operation of the Army and the Navy, the required features were developed during the early part of the war and applied to long-haul high-frequency radio to permit teletypewriter machines to receive enciphered radio teletypewriter messages with only an occasional error.

In the conventional single-channel long-haul radio telegraph system in general use before the war, the radio transmitter was keyed by manual or automatic methods using the international Morse code. With this method, the sending key controls the output of the radio transmitter; when the key is closed energy at a particular radio frequency is transmitted and when the key is open the transmitter is cut off. Reception of these signals is possible using a tunable amplitude-modulation radio receiver similar to those in homes. The listener reads the interrupted "tone" signals as "dots" or "dashes," or they are automatically recorded on a tape.

If the transmitting telegraph key is replaced by the sending circuit of a teletypewriter and a simple rectifier is interposed between the output of the radio receiver and the receiving teletypewriter, it is possible under favorable conditions to receive good teletypewriter copy. Frequently, however, the arrangement will be unsuitable.

In the single-channel long-haul *AN/FGC-1* system, shown in Figure 14 and developed during 1942,²⁷ a new device, known as a frequency shift keyer, is actuated by the open and close pulses produced by the sending teletypewriter apparatus. The keyer causes the radio transmitter to emit radio power at a particular frequency for teletypewriter open pulses and a slightly different frequency but the same power for the close pulses. In order to minimize some of the transmission difficulties experienced in many long-haul radio paths, such as the tendency for a radio wave to fade out at a particular spot but to be noted at another point close by, two separate antennas and two radio receivers are used, as shown in Figure 14. This is known as space diver-

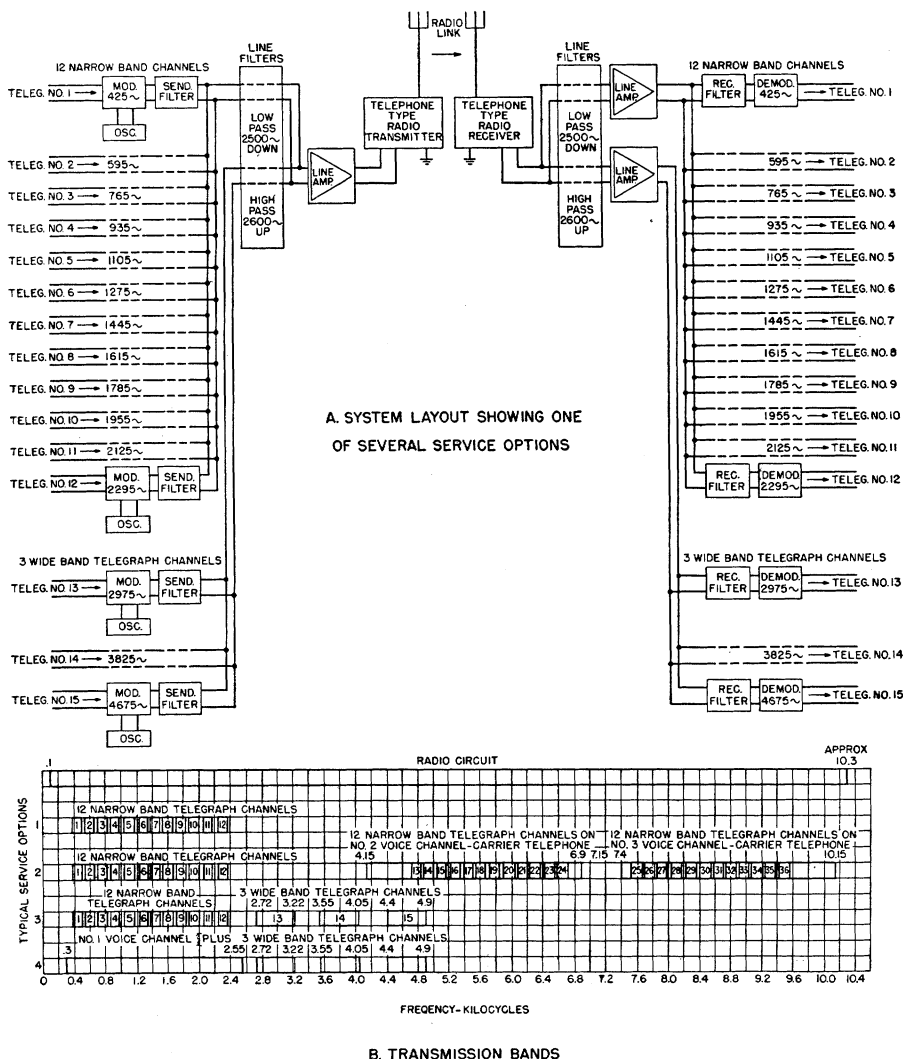
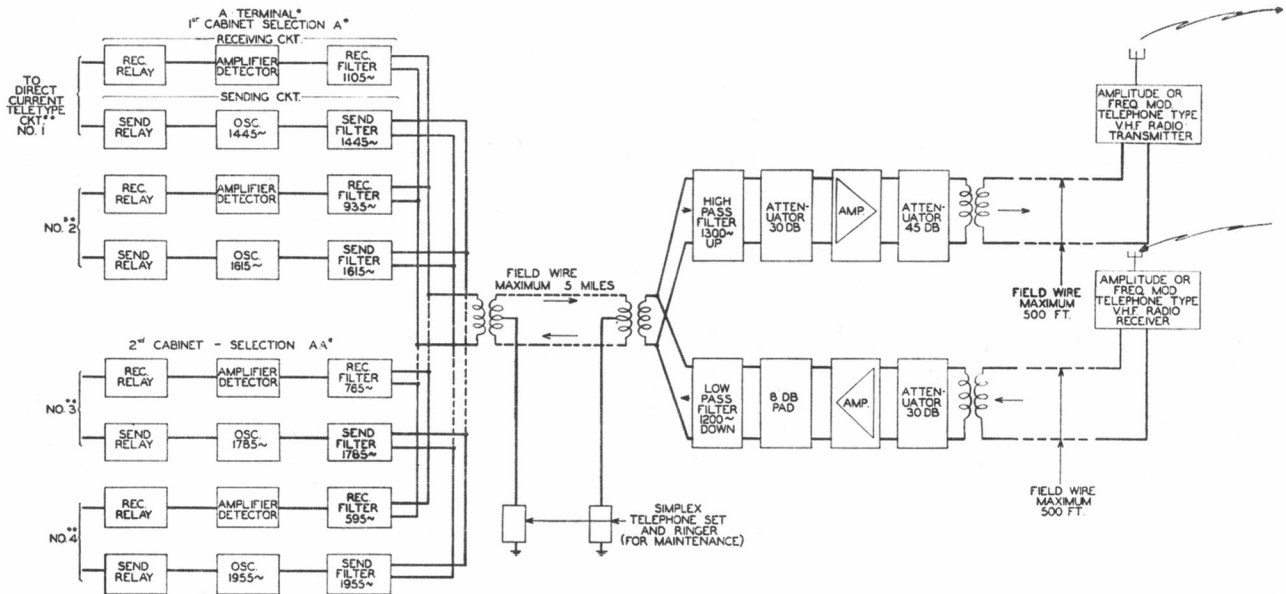


Figure 12. Carrier control system, model *UN*, for United States Navy

Typical system layout and transmission bands

LINE TERMINAL - UG

RADIO LINE TERMINAL - UH



* SWITCHES IN THE CABINET PERMIT SELECTION A, AA, B OR BB WHICH DETERMINES THE SENDING AND RECEIVING AUDIO FREQUENCIES. AT TERMINAL A THESE FREQUENCIES ARE AS SHOWN. AT TERMINAL B THEY ARE THE CONVERSE.

* A SERVICE SWITCH IN EACH CIRCUIT PROVIDES OTHER SERVICE OPTIONS INCLUDING A DIRECT CONNECTION TO A HF RADIO TRANSMITTER OR TO A LONG-HAUL HF RADIO RECEIVER.

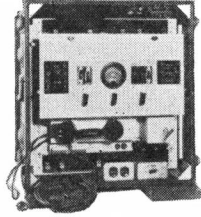
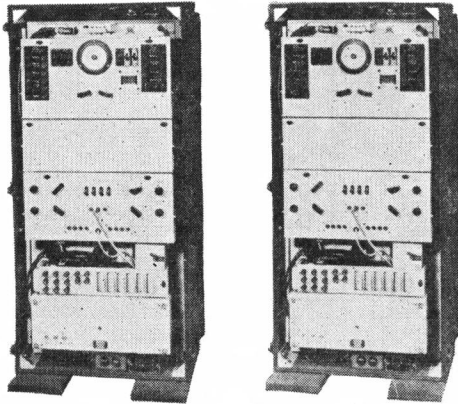


Figure 13. Carrier control system, model UF, for United States Navy

sity reception and, with antennas spaced a few wave lengths apart, fading out of the received signals is extremely unlikely to occur at both receiving points at the same time.¹⁷

Except during fading, when one radio receiver may become virtually inactive, each receiver delivers to the teletypewriter system a current of a particular audio-frequency when a teletypewriter open pulse is received and a current of a different audio-frequency when a teletypewriter close pulse is received.

Each channel of the teletypewriter terminal equipment includes a wide-band filter, a fast-acting current limiter, the input-output characteristic of which is shown in Figure 15, a filter and a detector S for the reception of teletypewriter open signals, and similar equipment for the reception of close signals. The output circuits of the two channels in the terminal will appropriately combine these signals

to operate a polar relay, which, in turn, delivers d-c signals to the receiving teletypewriter apparatus.

By having the limiters in the receiving equipment continuously energized by the

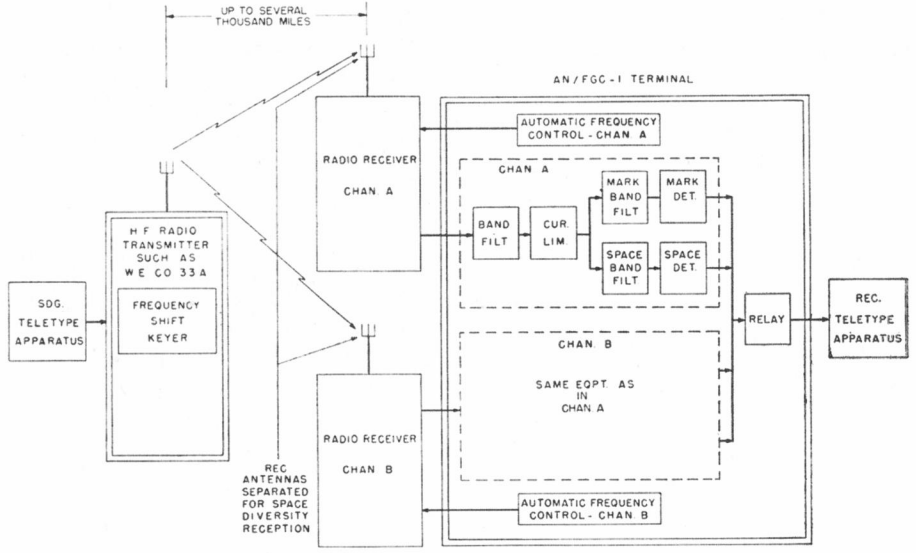


Figure 14. Single channel frequency shift long-haul radio teletypewriter link using AN/FGC-1 terminal equipment

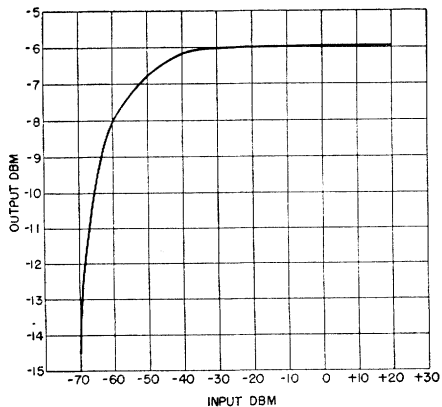


Figure 15. Current limiter characteristic

frequency shift constant power radio transmitter, the effects of noise are overcome to a much greater degree than in the on-off keying method. When combined with space diversity reception the resultant system was found to be highly reliable. Often, when the tones are indistinguishable to the ear because of noise, the receiving teletypewriter continues to operate without errors.

The equipments comprising the *AN/FGC-1* system are arranged for rapid installation and, although somewhat large, were transported by airplane into advance points to meet urgent needs.

An alternative, but quite similar system to the one developed for the Army, and known as the *AN/FGC-1A* was designed and made available for use by the Navy at their large well-established shore station installations. Many of these are now being operated over routes such as Washington—Honolulu, San Francisco—Honolulu and Washington—Balboa.

In addition to the need for the single-channel long-haul *AN/FGC-1* system, during 1942 the Army also had a very urgent need for a high traffic-carrying capacity long-haul radio system to handle their written communication between Washington and major overseas headquarters. To care for this demand Bell Telephone System engineers devised a highly satisfactory long-haul multichannel radio teletypewriter system²⁸ making use of available single side-band twin-channel radio telephone^{29,30} and carrier telegraph equipments together with additional components, such as fast-acting current limiters (Figure 15), that were needed to make the system suitable for reception of teletypewriter signals. The radio transmitters and receivers used in this system are the suppressed-carrier twin-sideband types that have been in use during the last several years in Bell Telephone System overseas telephone service. The multichannel carrier telegraph equip-

ment is an adaptation of the type used extensively in Bell Telephone System carrier telegraph wire networks. By applying the carrier telegraph multichannel frequencies to one sideband of this system in such manner that two separate and distinct audio-frequency tones are supplied for each teletypewriter channel during the close-circuit condition and two other tones during the open-circuit condition, frequency diversity operation is provided. The use of two frequencies for each signal condition minimizes the effects of signal fading in a manner similar to space diversity operation described previously. Figure 16 shows schematically one terminal of this system.

The first of these systems was provided within a few weeks after it was requested and successful operation was obtained between Washington and London using one sideband of the existing radio telephone system to provide three simultaneous teletypewriter circuits in each direction. The capacity of this system was later doubled. The Army operated a number of these multichannel transoceanic links for many months in a highly successful manner between such points as Washington—London and San Francisco—Aus-

tralia. The Navy obtained also a number of these systems for use over their main global communication routes, such as that between Washington and Honolulu. A common military application of this system included six telegraph channels applied to one of the sidebands of the twin-channel radio telephone system with the other sideband available for telephone. When used in this manner the system had a teletypewriter traffic-carrying capacity of about 5,000 100-word messages per day in each direction.

As a result of the phenomenal success of the *AN/FGC* type systems from the outset, both the Army and Navy became very much interested in obtaining smaller and lighter weight frequency shift keying systems. Small size equipments were particularly important to both services in connection with their contemplated large-scale use of long-haul radio teletypewriter circuits between points in rear areas and advanced bases and between shore stations and ships. As a result of this interest, during 1944 the Bell Telephone Laboratories undertook the design of smaller equipments. One of these was a new receiving equipment for use with a pair of amplitude-modulation radio receivers, designated Navy "model *FRF*

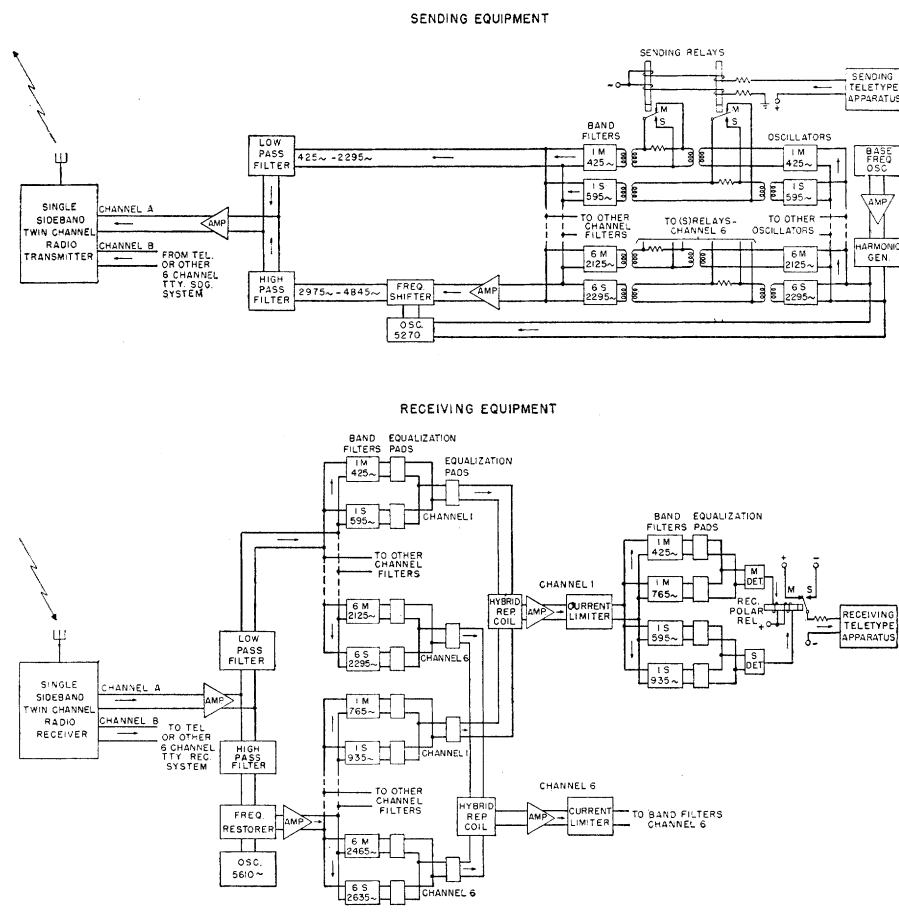


Figure 16. Multichannel radio teletypewriter system or single sideband twin-channel radiotelephone

frequency shift receiver converter equipment."

Field tests made by the Navy of an engineering model of this new equipment indicated that it performed better than the *AN/FGC-1* type though much smaller and lighter. More recently a large number of these equipments have been delivered to the Navy for use at both shore and ship stations. Figure 17 shows a physical comparison between the radio telegraph terminal equipment, *AN/FGC-1*, and the model *FRF* frequency shift receiver converter equipment.

The Bell Telephone Laboratories also developed frequency shift applique equipment for use with the truck-borne radio set *SCR-399-A* which was the Army's tactical work-horse among radio sets. This applique, designated radio teletypewriter equipment *AN/TRA-7*, permits the radio equipment to send teletypewriter signals on a frequency shift basis and to receive these signals on a dual space diversity basis. In addition to permitting 2-way or full duplex teletypewriter service, the *AN/TRA-7* equipment contains features to permit a new form of service, known as one-way reversible. With this service a to-and-fro teletypewriter communication can be carried on between two distant points using the same radio frequency assignment on an alternate basis for both directions of transmission. Figure 18 shows the arrangement of the *AN/TRA-7* equipment and other components comprising the complete radio sending and

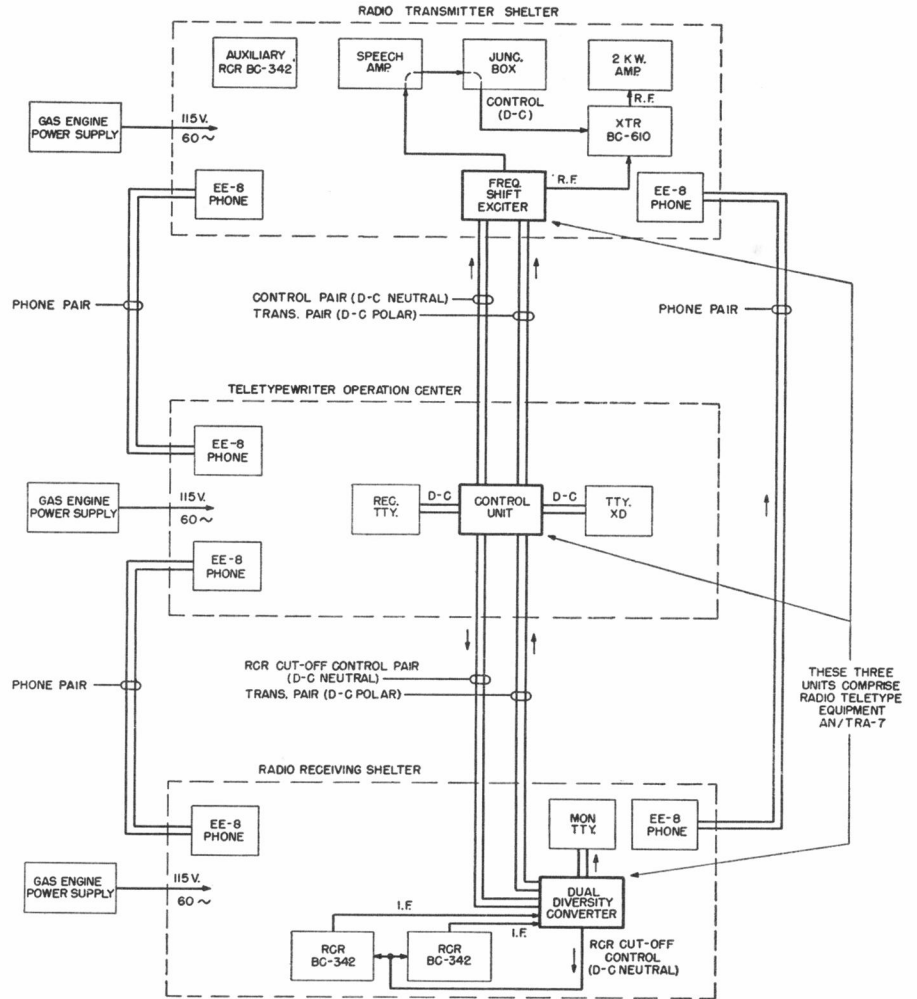


Figure 18. Assembly of frequency shift radio equipment (radio teletypewriter equipment *AN/TRA-7*) with teletypewriter apparatus and radio set *SCR-399-A* to provide signal corps radio set *AN/MRC-2*

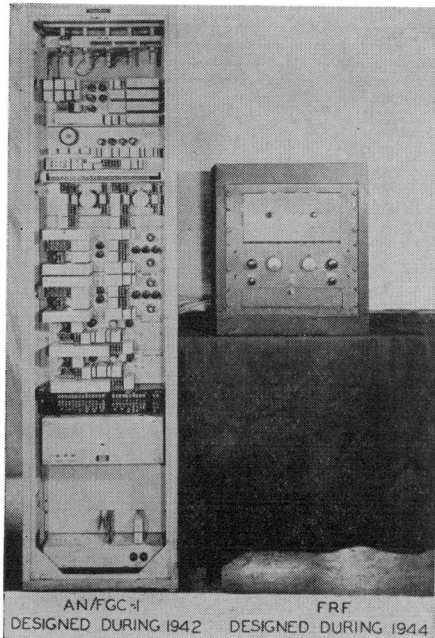


Figure 17. Single channel dual space diversity radio teletypewriter receiving equipments

receiving equipments and teletypewriter operating center. This complete assembly of three shelters has been designated as radio set *AN/MRC-2* by the Army. The frequency shift exciter, the control unit, and the dual diversity converter comprise radio teletype equipment *AN/TRA-7*. Figure 19 shows an experimental model of the frequency shift exciter. The converter equipment, shown in Figure 17, is quite similar to the Army converter being provided in the *AN/TRA-7* equipment. The control unit, not shown, is housed in a cabinet approximately the size of the exciter.

As indicated on the map, Figure 20, these radio teletypewriter communication systems were very extensive and handled a large part of the total message traffic over many routes. For example, a large network, using the *AN/FGC-1* system, extended from southeastern United States to the West Indies, to the eastern tip of South America, thence across the Atlantic to Africa. Others linked up India, China, New Guinea, and Australia

and numerous islands in the Pacific Ocean, Honolulu, and the west coast of the United States. Another *AN/FGC-1* system extended northward and eastward to Newfoundland, Labrador, Greenland, Iceland, the Azores, the United Kingdom, Russia, and Italy.

Looking at the matter broadly, it may be said that the long-haul radio teletype-

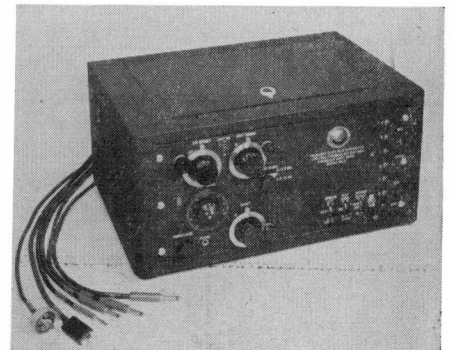


Figure 19. Frequency shift exciter, O-39(-)TRA-7 for use with radio set, *SCR-399-A*

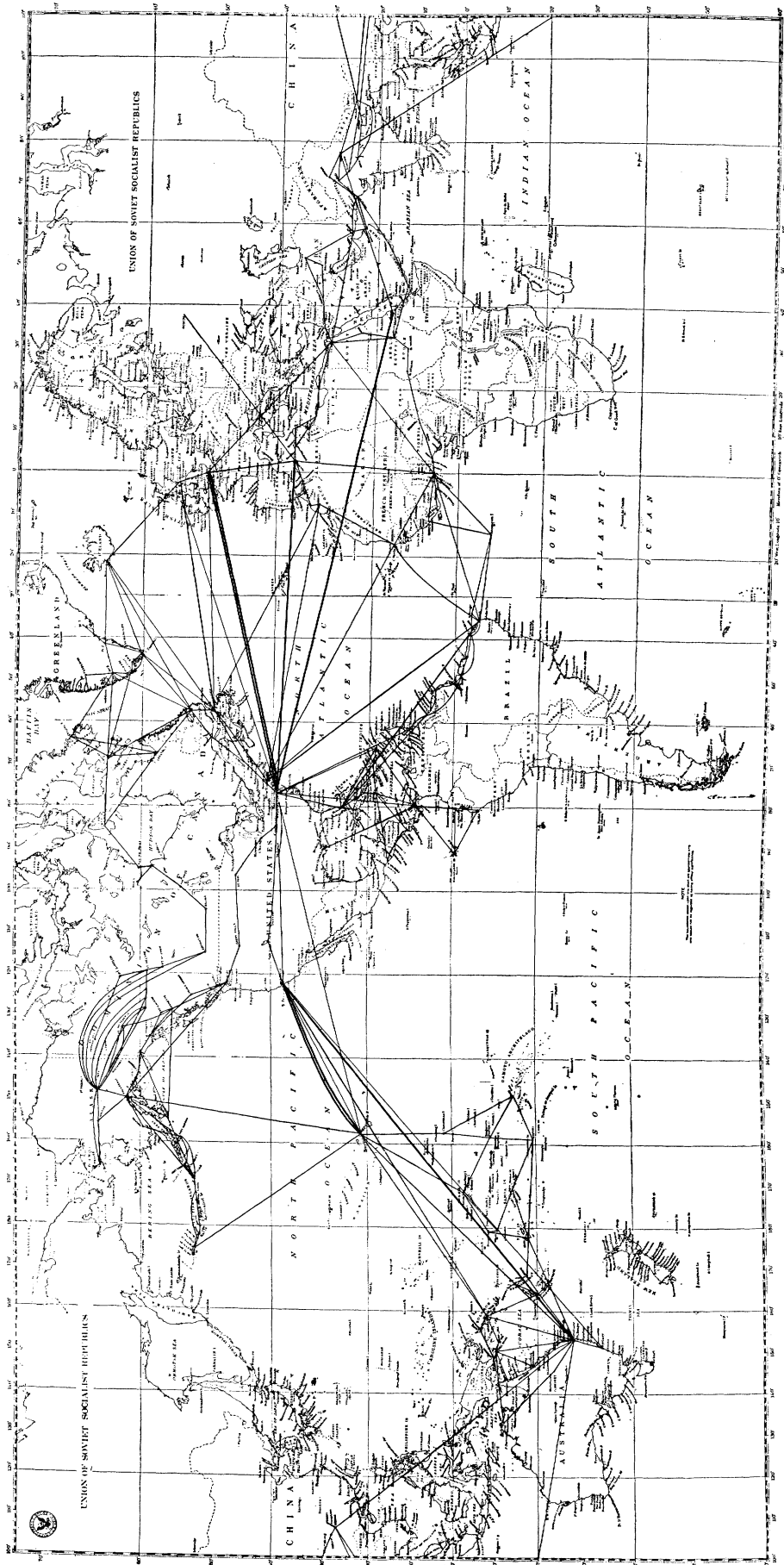


Figure 20. Long-haul military radio teletypewriter circuits during 1944

Legend: — Multichannel System
 - - - Frequency Shift Single Channel System

writer systems provided outstandingly reliable, rapid and secret communication facilities which were found by the armed forces and Government officials to be much better suited for providing extensive military communication networks than alternative arrangements. Although each teletypewriter channel usually operated at a rate of only 60 words per minute, whereas some automatic Morse channels operate at much higher speeds, experience demonstrated that as much or more traffic could be handled each day over a single teletypewriter channel as over a single high-speed automatic Morse circuit. This is possible because the new method of transmission is so superior that the teletypewriter traffic flows at a uniform rate hour after hour with few if any interruptions and enciphering and deciphering may be automatic and instantaneous. This is in contrast to Morse methods which require interpreting and typing the received messages.

The successful application of teletypewriters to long-haul radio links permitted the establishment and successful operation of extensive military teletypewriter networks. This is because the long-haul radio links could be operated in the same manner as the short-haul radio links and wire-line circuits with which they were associated. Thus, by the help of teletypewriter tape relay methods, in which messages were stored in perforated tape form and these used to control transmitters on other circuits, teletypewriter networks extending over land and sea and including long-haul radio facilities and American private-line networks, were operated as an integrated military communication system including connections, as required, with certain stations of the TWX system. Results were successful far beyond previous accomplishments in overseas transmission of written communications via radio or other means, and perhaps beyond expectations. Favorable and enthusiastic reports were received on the use of these facilities. Our military leaders and government officials depended upon them for communications, including scheduled conferences in which groups separated by thousands of miles passed communications back and forth practically instantaneously.

The following quotations from President Roosevelt's speech to the Congress on March 1, 1945, regarding the Yalta conference indicates the importance of radiotelegraph in handling the communications while en route to and from Yalta and during the conference there. Both Morse and teletypewriter methods were employed.

"Far away as I was, I was kept constantly informed of affairs in the United States. The modern miracle of rapid communication has made this world very small; and we must always bear that in mind, when we think or speak of international relations. I received a steady stream of messages from Washington, and except where radio silence was necessary for security purposes, I could continuously send messages any place in the world. And, of course, in a grave emergency, we could even have risked breaking the security rule."

Future Outlook

Radio teletypewriter methods not only provide direct reading, no delay, point-to-point overseas communications, but also make possible the radio broadcasting of information from a single station to many others and for conferences to be held, including two or more groups of conferees located on various continents and at sea, all communications being on a secret basis. Radio provides means for communication to moving units, and a new radio teletypewriter service to motor cars, airplanes, and other similar vehicles, using special radio transmission features to secure dependability, now is also technically possible. It would therefore seem certain that the radio teletypewriter communication methods developed during the war will be of prime importance in the future because of their efficient use of the radio spectrum, now so restricted, and the advantages of secrecy, speed, and reliability.

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No Discussion