

ARMY SERVICE FORCES  
 SIGNAL CORPS ENGINEERING LABORATORIES  
 COLES SIGNAL LABORATORY  
 RED BANK, NEW JERSEY

11 October 1945

REPORT OF WIRE EQUIPMENT COMMITTEE

- I. STATEMENT OF PROBLEM. It is the objective of this committee to outline a program for the development of facilities for transmission of telephone and telegraph signals and other forms of intelligence over wire lines in the Army communication network. In this connection, there is a further requirement that the signals transmitted over the wire lines shall be capable of retransmission by other transmission mediums, particularly radio without additional complicated equipment or operating procedures. The following general types of equipment and facilities are required for solution of this problem.
- A. Wires and cables to serve as a transmission medium.
  - B. Equipment and tools for installation and maintenance of the wire lines.
  - C. Station equipment for conversion of intelligence to and from electrical energy.
  - D. Switching equipment suitable for interconnecting all similar communication channels.
  - E. Transmission equipment for greater utilization of the transmission medium.
- II. ADVANCES DURING WORLD WAR II. During the time between the opening of the European war in 1939 and the United States' entry in 1941, many significant developments were made in the Army wire communications equipment. The exploitation of mobile warfare by the Germans with the greatly increased distances for which communications were required placed great emphasis on the need for better transmission. During this period, all presently available carrier telephone and telegraph equipment, spiral-four cable, the two-wire Repeater EE-89, and the four-wire Repeater KE-99 were developed. Improved construction methods such as rapid pole line construction and the development of the cable plow were also consummated, but were never generally accepted for use in the field. Subsequent to the United States' entry in the war, no general advance in the art of wire communication was made, most of the effort being expended in a search for substitutes for critical materials, improvement of the performance of the equipment by changes in mechanical and electrical design, and the moisture and fungiproofing of equipment for use in the tropics. Prior to the cessation of hostilities, a number of new

projects were authorized, some of which are approaching completion such as high speed coils, lightweight field wire, a new field switchboard, and a lightweight teletypewriter. Other projects have more recently been authorized, and no significant progress has been made to date. These projects are included in the general discussion of required research and development outlined in other parts of this report.

### III. PRESENT STATUS.

A. General. There are a good many items which comprise the list of wire communication equipments. Many of these are adapted from the commercial field with little or no change in design, either because of War Department policy, lack of development funds or lack of time to prosecute development. This has resulted in some equipment being extremely heavy and bulky for military use, particularly when man-packed or used by parachute troops, and has aggravated the supply problem because of the necessity for using non-interchangeable parts made by different manufacturers for the same piece of equipment when expansion of the sources of supply became necessary in wartime. In addition, a great many wire equipments of various designs and makes were bought for use in the fixed plant. All this equipment was handled by the same supply organizations and as a result, the number of parts which were kept in stock was enormous. It is believed that this trend has been recognized and in the future, development of equipment which is suitable for both fixed plant and tactical use will be made wherever possible. Discussion of the present status of the various classes of wire communications equipment follows.

#### B. Wire and Cable.

1. The major standard items of equipment are as follows:
  - a. Wire W-130-( ), lightweight assault wire for forward use.
  - b. Wire W-110-B, general purpose field wire.
  - c. Wire W-143, long distance field wire.
  - d. Cable Assembly CC-358, spiral-four cable.
  - e. Cable WC-534 and WC-535, five and ten-pair cable used as an entrance cable for field wire lines at command posts, and other concentrations.
2. The development of lightweight field Wires WD-1( )/TT and WD-14( )/TT is rapidly approaching completion. These wires employ new insulating and protective materials and have the range of present field wire with about 2/3 of the strength and 1/3 of the weight.

3. It is significant that all wires listed are suitable only for voice-frequency transmission, except spiral-four cable which is satisfactory for transmission of frequencies up to 16 kc or 4 or 5 voice channels.

C. Transmission Equipment.

1. The following major items of equipment are now standard in this category:

- a. Carrier telephone and telegraph equipment of the CF series. This equipment provides four telephone channels for transmission over spiral-four cable on a four-wire basis or over open-wire lines on a two-wire basis and is capable of utilizing any voice channel to derive six carrier telegraph channels.
- b. Repeater EE-89, two-wire, battery operated, 21-type voice repeater for field lines.
- c. Repeater EE-99, four-wire battery operated, voice repeater for field lines.
- d. Repeater TP-14, two-wire battery or power operated, 22-type repeater for general use.
- e. Telegraph Terminal TI-1( )/TCC-1, equipment which provides one carrier telegraph channel in the middle of any voice channel while retaining the use of the latter.
- f. Telephone TP-9, telephone set with vacuum tube amplifiers for both talking and listening use on extended field lines for point-to-point communication.

2. It is significant that a maximum of four voice channels can be placed on field facilities with these equipments. Voice-frequency communication is still used exclusively in the lower echelons.

D. Line Equipment. A large number of items are included in this class of equipment including: reels, reel units, cable hangers, poles, pole hardware, crossarms, insulators, linemen's personal equipment, etc. For tactical line construction in forward areas, Axle RL-27 and Reel Units RL-26 and RL-31 are the main items of equipment used. Field wire is extensively used for ties. In pole line construction, the methods and equipment used for rural telephone lines in this country, such as Class 9 poles and Truck K-44 pole setting equipment, are still in use by the Army. Trucks K-43 and K-44 are still listed as standard items on Tables of Equipment. However, experience in the European Theater indicated that these trucks were not satisfactory, either as a motor vehicle or as a piece of Signal Corps equipment. At the close of the war in that theater, one Field Army had discarded both vehicles referred to in favor of the standard 2-1/2 ton, 6 x 6. Rapid pole line and multi-airline construction methods using structural timber have been used to a limited extent. Plow-in methods using Plow LC-61 or a modified plow, were

employed largely on an experimental scale. However, it is felt that there is a very definite opportunity for development in this respect. Overall trunk line construction equipment remains too bulky and heavy, and trunk line construction methods are cumbersome and far too slow.

### E. Telephone Switchboards and Station Equipment.

#### 1. Telephone Switchboards.

a. All present standard telephone switchboards are of the manual type. The major telephone central office sets and switchboards now standard are listed below:

- (1) Telephone Central Office Set TC-10. Major component Switchboard BD-110. Capacity a maximum of 6 positions with 4 trunks, 60 common battery and 30 magneto lines per position. Used at Army and Army Group.
- (2) Telephone Central Office Set TC-2. Major component Switchboard BD-89. Capacity a maximum of 2 positions (non-multiple) with 40 common battery, 20 magneto lines and 4 trunks per position. Used at Corps, (This set was recently replaced by Telephone Central Office Set AN/TC-3. Main component Switchboard BD-120. Capacity of 3 positions with 30 common battery and 30 magneto lines and 8 trunks per position.)
- (3) Telephone Central Office Set TC-4. Major component Switchboard BD-96. Capacity one position with 40 magneto lines. Used at Division.
- (4) Telephone Central Office Set TC-12. Major component Switchboard BD-91. Capacity one position with 20 magneto lines. Used in echelons below Division and in AAF units.
- (5) Switchboards BD-71 and BD-72. Six or 12 line monocord field switchboards used at Regiment and Battalion levels.
- (6) Switchboard SB-18/GT. Very small, emergency, six line field switchboard, using Adapter Plug U-4/GT as line unit. Telephone EE-8 is used as the operator's set.

b. It will be noted that there are four different types of the larger telephone central office sets. Most of these types are made by at least three different manufacturers. Component parts of the switchboard made by one manufacturer are rarely interchangeable with those made by another. As a result, the component parts of all manufacturers must be

kept in stock separately. It will also be noted that the heavy, bulky field Switchboards BD-71 and BD-72 were designed about revamped World War I switchboard units in what was thought to be an economy move at the time because of the large stock on hand. Fortunately this board will soon be replaced by Switchboard SB-22/PT, an eight-line lightweight field switchboard of the patent cord type which is less than 1/2 of the weight of the present switchboard.

## 2. Telephone Station Sets.

a. The major items of equipment now standard and in use in this category follow.

- (1) Telephone EK-8, standard field set with leather or canvas case, capable of being operated on either local battery or common battery lines, employs Handset TS-9 and derives power from two Batteries BA-30.
- (2) Telephone IP-3, this telephone is similar to Telephone EK-8 except that it uses Handset TS-10, sound-powered type.
- (3) Telephone TP-6, a standard commercial desk telephone, with certain minor changes to make it adaptable for Army use.

b. The performance of this category of equipment has been generally satisfactory, except that the handsets in general do not fit well under the M-1 battle helmet.

F. Telegraph Switchboards and Station Equipment. One of the major advances in wire communications during this war was the greatly expanded use of the teletypewriter for communications. The speed, accuracy, and dependability of this type of communication by any method of transmission has been a very important factor in the efficiency of communication systems.

1. Telegraph Switchboard Equipment. Telegraph Central Office Set TC-3 with its major component Switchboard BD-100 was generally and widely used in the field. The switchboard operates on a neutral basis with 10 line capacity. Three switchboards may be operated together to give a total capacity of 30 lines.

2. Telegraph Station Equipment. Items of equipment in this category which are now standard follow.

a. Telegraph Set TG-5, a small, manually operated, telegraph set for transmission of international Morse code. With the advent of the teletypewriter, the use of this set has greatly declined.

b. Teletypewriter Sets EE-97-A and EE-98-A. Principal component Teletypewriter TG-7-( ). This is the Teletype Corp. #15 Printer with standard keyboard adapted for Army use. It is very generally used in all echelons from Division upward and in fixed plant.

c. Teletypewriter Set EE-102. Principal component teletypewriter TG-37-( ). This equipment is similar to the TG-7-( ) except that a meteorological keyboard is employed.

d. Reperforator Teletypewriter Set TG-16. Principal component Reperforator Transmitter TG-26-( ). This component consists of two units, the printer reperforator for preparing the tape either by local keyboard operation or from received line signals, and a transmitter-distributor for transmitting the prepared message over the line. Used quite extensively in the fixed plant at teletypewriter centers and to a limited extent at Army Headquarters and higher echelons, although not authorized equipment.

e. Repeater Set TG-18. Major component Repeater TG-30. Polar-entential type d-c terminal telegraph repeater for extending teletypewriter operating range on field and open-wire lines and also to interconnect U. S. and British telegraph equipments.

f. Repeater Set TG-19. Major component Repeater TG-31. Polar-entential type d-c intermediate telegraph repeater for long field and open-wire lines. May be operated on attended or unattended basis.

**IV. CURRENT TRENDS OF DEVELOPMENT.** Developments now in progress were initiated when the emphasis was placed on the Pacific War and reflect the lessons learned in that war. In general, emphasis is placed on lightening of equipment because of the necessity for man-packing much of the equipment used in this theater. As might be expected, there has been no call for new or radical departures from present communication systems since the introduction of such methods in an already satisfactory system in the middle of a war would be difficult, if not impossible. Description of the developments now being prosecuted follows.

A. High Speed Coils. The desire to eliminate the clumsy, cumbersome, reels and reel units required in laying out field lines resulted in the initiation of the development of high speed coils. A high speed coil consists of a precision layer-wound coil of field wire inclosed in a lightweight container and wound in such a manner that the coil may be unwound from the center without rotation or use of other auxiliary equipment. By this method wire may be laid at high speed from a plane or at low speed from a packboard or a soldier's back with equal facility. This method of packing wire has been successfully applied to wire W-130 of all types which in this form is packaged in Wire Dispenser LX-301/G. Prior to V-J Day, there was limited production of this dispenser for field use. It is believed that the method can be generally applied to field wires and cables and it is now being investigated for application to field Wires WD-1( )/TT and WD-14( )/TT, which will be packaged in Wire Dispenser LX-306/G.

B. Wires WD-1( )/TT and WD-14( )/TT. Development of these wires was initiated to provide a replacement for Wires W-110-B and W-130-( ) in the Infantry Division. They employ a new, more efficient, lightweight insulation with a thin, extruded plastic or braided cover. Talking range is equal to or slightly better than field wire W-110-B with 1/3 the weight and 2/3 of the strength. In range, strength, and durability, it far exceeds wires of the W-130 type with relatively small increase in weight. These wires have been standardized and some production of Wire WD-1( )/TT was obtained prior to V-J Day.

C. Switchboard SB-22/PT. As mentioned above, the present standard field Switchboards BD-71 and BD-72 were designed about switchboard units of World War I vintage. They were extremely heavy for man-pack and as a result development of Switchboard SB-22/PT, an eight line, patch cord type board was authorized. Present indications are that the board will be about 1/2 the weight of the present switchboards on equivalent functional basis. Latest advances in component design and moistureproofing techniques are being incorporated.

D. Teletypewriter TT-4/TG. As mentioned above, present teletypewriters in use in the Army networks are standard commercial machines adopted for military use. Their bulk and weight prevents man-pack and restricts use to the higher echelons. Development of Teletypewriter TT-4/TG was authorized to produce a machine which was especially designed for Army use. By complete mechanical redesign, simplification, adoption of new techniques and elimination of certain extraneous features not needed in Army circuits, a considerable reduction in weight has been found possible. Development is well underway and from present indications, the completed machine will weigh only about 25% of the weight of the present standard Teletypewriter TG-7-( ).

V. NE. REQUIREMENTS APPARENT AT CLOSE OF WAR. The potentialities of weapons under development at end of World War II are such that the future of military tactics cannot be foretold with any degree of assurance. It is obvious that the processes of war will be immensely speeded up, and that the scope of actual combat will not be localized. Military developments in the U. S. Army during World War II were all in the direction of higher specialization in all fields toward the end of enormously increasing the amount and the mobility of destructive fire power per combat unit of both land and air forces. There was a correspondingly great increase in the requirements for communication for planning and effecting the coordination and control of the highly specialized elements involved in supplying and delivering this fire power. Every present indication clearly points to a future course of greatly increased technical specialization, greatly increased destructive capacities and highly complex technical defensive and offensive systems. The concomitant need for greatly increased capabilities for communication and data transmission are inevitable. Accordingly, the trend of military communications must be toward a flexible, high grade communications system which affords the greatest number of channels for the transmission of intelligence in the shortest time over any distance and between any given points. Further, the equipment involved must be lighter, smaller, more durable, and so designed that it is possible to rapidly interchange and multiple units for the most efficient operation as the situation changes.

**A. The Communications System.** A discussion of the requirements for the future communications system and the various classes of wire communication equipments as they now appear follows. With the growth and size of the Army and greater interdependence of one unit on another, the vast amount of material required, and the increased movement it has become more and more imperative that all communications be integrated into a complete system. The following are suggested requirements for such a system:

1. Complete integration of wire and radio communications in a single network.
2. Four-wire or equivalent four-wire operation of all trunk (long distance) circuits either wire or radio.
3. Four-wire switching of trunk circuits at all switching centers so that high grade 6 db loss circuits may be established over long distance where required and so that all circuits may be interconnected at will on a voice-frequency basis.
4. Design of equipment to be such that a standard terminal impedance will be used, such as 600 ohms, the noise generated in the equipment will be less than 15 dbm, the distortion of the system less than one percent, the frequency response substantially flat over the operating range, radio receivers capable of delivering an output of plus 10 dbm and radio transmitters capable of accepting signals from minus 30 to 0 dbm with full modulation.
5. A tone source and transmission measuring equipment to be provided with all radio and wire trunk terminal equipment and at other points in the system where transmission levels are important.
6. Eliminate direct current whenever possible and particularly on all circuits that require switching.
7. Local loops, both wire and radio, be operated on a two-wire basis. In connection with the operation of local radio loops, the following requirements are suggested:
  - a. Operation to be full duplex on a continuous or intermittent basis. Intermittent full duplex service is defined as that type of operation in which the transmitter is under control of the switchboard operator.
  - b. A single remote control unit be developed to accomplish this type of service with no change in the usual telephone operating procedures and without substantial change in the switchboard.
  - c. Wherever practicable equipment should be designed to serve both in the fixed and tactical plant, thus simplifying maintenance, supply, training and operating problems.

**B. Wire and Cable.** The equipment which provides the transmission medium between switchboards of a wire communication system constitutes the major weight



and volume of such a system and consumes, in its installation and maintenance, a high percentage of the man-hours necessary for the overall operation of such a system. It is imperative, therefore, that this equipment be radically improved. The following objectives should be kept in mind:

1. Reduce the size and weight of these facilities by employing more efficient conductor, insulating and protective materials and by employment of new design methods.

2. Reduce the volume of these facilities required by improving message carrying ability in conjunction with new items of transmission equipment. This resolves itself fundamentally into increasing the usable frequency pass band. It is desirable that the facility be capable of passing video or other television signals as well as conventional communication frequencies.

3. Improve the durability of these facilities insofar as possible without substantial sacrifice of electrical properties.

C. Line Equipment. The construction and placement of wire lines is a development field where new methods would be of great benefit in the overall wire communication system. With improved methods, the amount of wire and cable required would be reduced and the reliability of the system increased. Some of the apparent requirements for developments in this category follow.

1. Devise methods for placement and construction of wire lines well off travelled roads. The method devised shall not endanger construction personnel by requiring them to work at sides of roads where mine fields are often present. Also, it shall not open new trails or roads through the use of a large vehicle in the construction work.

2. Improve security of wire lines from the effects of engineer's construction equipment, bombings, shell fire and vehicles.

3. Increase the speed of placement and construction of lines consistent with security and reliability.

4. Reduce the size and weight of the equipment required, particularly reels, reel units, plows, etc.

5. Eliminate open-wire lines as a transmission medium, thus reducing the amount and bulk of line construction equipment.

6. Provide fault location equipment which gives speedy precise locations of trouble on the line, both when located in the field or at a central office.

D. Transmission Equipment. This type of equipment was first extensively used in military communications during the war just ended. It is apparent that its use will be greatly extended in the future because it reduces the amount of outside plant equipment required, improves the performance of the communication system and facilitates integration of wire and radio systems. Some requirements for equipment in this category now apparent follow.

1. Reduction in size and weight of equipment to permit man-pack through employment of new materials and techniques. This will make possible the extension of the use of this equipment to lower echelons.
2. Employment of the unit principle to increase the flexibility of the equipment for use in both radio and wire applications.
3. Increase the message carrying ability of wire facilities by the development of carrier telephone equipment capable of placing any number up to 200 voice channels on a single four-wire facility.
4. Improve the quality of the voice channel by widening the frequency band, thus permitting the operation of a greater number of links in tandem as well as providing high quality circuits for special applications.
5. Provide voice-frequency carrier telegraph equipment usable on any carrier telephone channel and capable of at least 100 words per minute speed on each telegraph channel.
6. Provide equipment for placing video or other television signals on the communication system.
7. Investigate the possibility of utilizing simplified carrier equipment on local or command post telephone systems.

E. Telephone Equipment. Requirements apparent at the close of the war for this type of equipment follow.

1. A reduction in the number of types of switchboards by developing one universal magneto-common battery multiple switchboard capable of extension to a capacity of at least 1000 lines with as many positions as required by traffic considerations.
2. An all magneto multiple board of approximately 40 line capacity is required at Division. This board should be capable of being multiplied for approximately 120 line capacity.
3. The development of the lightweight field Switchboard SB-22/PT should be continued to meet the requirements for a light field switchboard.
4. Components employed in the switchboards should be standardized in design so as to simplify maintenance and supply procedures.
5. In every case, minimum size and weight should be achieved in both the overall equipment and the components employed.

F. Telegraph Equipment. One of the important advances in military communications in this war was the greatly increased use of the teletypewriter. As a consequence, the use of manual telegraphy in the wire system practically disappeared. With the development and employment of voice-frequency carrier

telegraph equipment, the use of d-c telegraph transmission was confined in greater part to short loops. From these trends, the following requirements for equipment in this category were apparent at the close of the war:

1. Development of teletypewriter for military use with greatly reduced size and weight and improvement in ruggedness. Development of such a teletypewriter will extend the use of this equipment to the lower echelons.
2. Development of equipment for extending voice-frequency telegraph operation throughout the telegraph system including the local loops. Development of such equipment provides advantages in simplified switching methods and transmission techniques.
3. Development of an ultra-lightweight teletypewriter possibly of the tape type for use in the extreme forward areas with optional manual or electrical power drive.

## VI. REQUIRED RESEARCH AND DEVELOPMENT.

A. Proposed Communication System. In order to more fully illustrate the necessity for and use of the various types of equipment which are suggested for development, a system for their employment is illustrated in Figure 1 attached, and described below. The center of the system is the System Control Board which is essentially a four-wire and four-wire - two-wire patching board. All trunk circuits, wire and radio, would terminate in this board on a voice-frequency four-wire basis. At the board they may be extended to the local telephone or telegraph switchboard on a two-wire basis by means of a four-wire terminating set or be patched through to another trunk on a four-wire basis. The various voice-frequency trunks emanating from the control board pass to carrier equipment for transmission over wire lines or radio. The wire facility would be spiral-four cable where only a few channels are required and twin coaxial cable for a greater number of channels. Where coaxial cable is used it is also possible to transmit television or other video signals over the same facility with proper equipment. The optional use of video filter equipment for this purpose is provided. It is anticipated that there will be a great need for rapid transmission of this type of information in air warning systems of the future. By proper operation of this system, it is possible to obtain a good 6 db loss circuit from the Pentagon to a foxhole command post in a far off theater if necessary. In other words, it seems to provide the necessary flexibility and quality which the best military communications of the future will require. The individual components, development of which is required are discussed in the following paragraphs.

B. System Control Board. As indicated above this will be essentially a voice-frequency patching board providing four-wire or four-wire - two-wire switching with auxiliary equipment consisting of four-wire terminating sets, voice-frequency ringing equipment and necessary test equipment. Two types of boards are envisioned as follows:

1. The system control board for the larger installations, probably echelons above Division including the fixed plant, would be a flexible patching board providing the necessary switching facilities and auxiliary equipment. The latter would consist of four-wire terminating sets with a hybrid coil and other necessary equipment, voice-frequency ringing equipment for insertion in those two-wire lines requiring it and a panel of test equipment, including an oscillator and transmission measuring equipment. It is essential that the method of establishing connections be completely flexible and rapid and that the wire chief in charge be familiar with circuit condition and requirements at all times. This required flexibility must be taken into consideration in the design.

2. For the lower echelons, a smaller version of this board is required consisting essentially of a jack panel and patching facilities with the necessary four-wire terminating sets, voice-frequency ringing equipment, transmission measuring set and fault location equipment preferably in separate packages to facilitate transportation.

### C. Transmission Equipment.

1. Carrier Telephone Equipment. Essentially it is required that carrier telephone equipment be developed which is capable of obtaining any number of channels from 4 to 40 or more for transmission over a single four-wire facility or suitable radio circuit. Two methods of achieving this objective, both of which should be investigated follow.

a. Step-by-Step Group Modulation Equipment Method. In this method, (Figure 2), there would be a basic four-channel unit with group modulation equipment for integrating three of these units to derive 11 or 12 channels and further group modulation equipment to integrate three or four of the latter to derive from 33 to 46 channels as design limitations may dictate. The group modulation technique may be carried out further to derive a greater number of channels provided the transmission medium is capable of accommodating them. At present, a minimum of 40 channels is the goal. With this method, the three different units of equipment are expected to be about the same size. A description of the equipment development required follows.

- (1) Four-Channel Carrier Telephone Equipment. This would serve as the basic unit in the system. It would serve to modulate the voice-frequency signals to cover a band from 200 to 16000 cps with 200 to 3500 cps band width per channel. Miniature design techniques would be employed as far as possible and package weight would be kept to 40 pounds or less. Military characteristics for Telephone Terminal AN/TCC-3 recently submitted appear satisfactory for this item.
- (2) Group Modulator - 11 or 12 Channel. This equipment would serve to step-up the signals from three basic four-channel units to occupy successive bands in the frequency spectrum making it possible to apply 11 or

12 channels to a single four-wire or radio facility. Minimum weight and size would, of course, be the goal in design including consideration of crystal filters.

- (3) Group Modulator - 44 Channels. This equipment would step-up the signals from three of the modulator equipments previously described to occupy successive channels in the frequency spectrum for application to a four-wire or radio facility. Minimum weight and size would, of course, be the goal in design.

b. Four-Channel Group Modulation Equipment Method. In this method, (Figure 3), the basic unit would be the four-channel unit described in subparagraph C-1a(1) above. For stepping-up the signals from the basic unit to the proper place in the frequency spectrum a single type of modulator would be developed with variable carrier oscillator and necessary plug-in filter units. This system has the advantage of permitting dropping of four-channel groups along the line with a minimum of equipment. However, the system requires close control to prevent interference and will require considerable administration.

c. Video Filter Equipment. There is every indication that the transmission of television and other video signals to widely scattered places will be an essential requirement of the Army tactical plan. For this reason, it is believed that equipment should be developed which will permit transmission of these signals and communication signals over suitable communication transmission mediums. The equipment would consist essentially of line terminating equipment, modulating equipment, filters and broadband amplifiers, if necessary. At first glance it appears that the most feasible method would place the video transmission in the lower region of the frequency spectrum and the communications signals above it.

d. Repeater Equipment. From present considerations, there are three types of this equipment required. All will be of the broadband, four-wire type. One will be required for each of the four-channel, 12-channel, and 44-channel systems. Means for dropping channels by bridging a carrier terminal unit at repeater points should be provided. Military characteristics for the four-channel repeater have been recently submitted. To decrease attendance required on the 40-channel system, it is expected that power for operating repeaters will be transmitted on the line so that a power source will only be required at every third repeater.

e. Voice-Frequency Carrier Telegraph Equipment. Six-channel voice-frequency carrier telegraph equipment capable of being applied to any channel of the four-channel basic carrier telephone equipment described above, or to other voice-frequency facilities is required. Design should be suitable for 100 words per minute telegraph transmission. Military characteristics recently submitted for Telegraph Terminal AN/TCC-4 are satisfactory for this development. In addition, it is believed that there is a requirement for equipment similar to present Telegraph Terminal TH-1( )/TCC-1 (speech plus duplex). With the anticipated development of voice-frequency telegraph operation, there is a

possibility that very simple equipment could be made to achieve this method of operation using the components of one channel of Telegraph Terminal AN/TCC-4 when developed. With the wide frequency band in the carrier telephone channel, consideration should be given to operating this equipment at the upper end of the voice band.

2. Voice-Frequency Repeater Equipment. For this type of equipment, investigation of methods of obtaining bidirectional transmission of intelligence without use of the balance principle is required. Voice relay switching and pulse switching of amplifiers are possible paths to follow.

3. Voice-Frequency Ringing Equipment. A requirement exists for the development of voice-frequency ringing equipment for general use. One universal unit capable of converting low frequency ringing signals to a suitable voice-frequency signal for use in the two-wire portion of any telephone channel is required. This unit will be used with the System Control Board carrier telephone equipment when used separately, or any other voice circuit. Some investigation and coordination is required to determine the most desirable frequency for ringing signals in the voice band.

4. Transmission Measuring Equipment. This type of equipment is very necessary for proper operation of the system. The Signal Corps has neglected operational test equipment in the past considering that testing was primarily an equipment repair problem. This is far from true since proper setting for operational controls is dependent on transmission loss of the circuit which is best determined by measurement on a transmission measuring set. Fortunately present carrier telephone sets incorporate such equipment. A single tone source and transmission measuring set is needed in the test panel of the proposed System Control Board. A compact, portable version is required for general use. For circuit maintenance, the development of a continuously variable voice-frequency oscillator and recording transmission measuring set would be a desirable addition.

5. Research. The following general research is desirable if advances are to be made in this type of equipment:

- a. Expanded use of electron tubes as basic circuit elements.
- b. New filter methods.
- c. Investigation of new methods of modulation to determine if they are better adapted to message security.

D. Wire and Cable. Based on the requirements of the system outlined above, three types of facilities appear to be required. Coaxial cable for wide band multi-channel and video transmission systems, spiral-four cable for four and 12 channel carrier telephone transmission, and field wire for voice-frequency transmission over local extensions. The discussion of the equipment required for development follows.

1. Coaxial Cable. To transmit the wide band of frequencies contemplated in the system, a twin coaxial cable or two single coaxial cables will be required. It is anticipated that it will be of the solid dielectric type construction with suitable conductor, insulation, shield and covering. Attenuations of about one and one-half db per 1000 feet at one megacycle with a cable of approximately .3 inch is now possible. This would give a repeater spacing of between five and six miles and with power transmitted through the cable to adjacent repeaters, attended repeater spacing would be approximately 15 to 20 miles. Constant impedance connectors are a necessity for joining two lengths of such cable. Considerable development is required on this item. It is anticipated that cables of this type with their superior message handling ability and inherent stability will replace open wire construction in the Army of the future. It will be suitable for both the tactical and fixed plant and capable of aerial, surface or subterranean placement. Military characteristics recently submitted for coaxial cable appear to be satisfactory.

2. Spiral-four Cable. Where transmission is confined to frequencies in the lower part of the spectrum, field cables of the spiral-four type are more efficient per unit of weight than coaxial types. From present considerations, it appears that two types of this facility may be required.

a. The first type, an ultra lightweight cable would be intended primarily for use within the division and would have a frequency pass band suitable for transmitting four-channels of the carrier telephone system. In this connection, it would replace field wire for use on the trunk circuits in the division. It would probably be advantageous to employ loading coils with this facility considering the relatively low cut-off frequency required. This would be provided in the connector associated with the cable.

b. The second type, a lightweight spiral-four cable, would be employed for transmission of 12 channel carrier telephone systems between Corps and Division. Inasmuch as the cut-off frequency is considerably higher than in the previous case, it is doubtful that efficient loading can be provided. However, connectors for joining two lengths of cable together will be required.

3. Field Wire. At the present stage of the art, it appears that a wire of the FD-1( )/TT or WD-14( )/TT type when fully developed has all the necessary characteristics for use in local loops and extended forward area operations on a voice-frequency basis. Continuation of the development of these two types of wire, it is believed, will fulfill the requirements for Army field wire.

4. Research. In view of the large volume of this material consumed during war time, it is essential that a continuing study on insulating, conducting and protective materials be made in order that advantage can be taken of such improvements in the art as are made and in order that the Army may be familiar with all similar materials which may be proposed as possible substitutes.

## E. Telephone Equipment.

1. Universal Switchboard. Military characteristics have recently been approved for a universal, common battery, local battery switchboard, part of AN/TTC-4. This board will have a capability of approximately 1000 lines and will be capable of extension to as many positions as the traffic requires. It is anticipated that it will be built with bookcase type construction with a minimum of 15 cord circuits at each operator's position. Each of the line circuits will be capable of being employed as either a common battery or local battery circuit with simple wiring change. As a universal switchboard, it will be capable of accommodating all radio circuits which are required to be employed in the integrated communications system. At present, plans are being made for accommodating so-called full duplex radio circuits operated on a continuous or intermittent basis as discussed previously. Decision is required as to whether other forms of radio circuit operation will be permitted in the integrated system so that the design will include the proper provisions. The jack appearances at each position will be similar. The type of construction and circuits employed will provide a very flexible switchboard which is capable of expansion from 60 to 1000 lines with a minimum of equipment and installation effort.

2. Magneto Switchboard. Inasmuch as common battery operation is never used at division headquarters, Army Ground Forces has proposed the development of a magneto switchboard with a capacity of 40 lines per position and capable of expansion to a three position multiple board with 120 line capacity. While it would be desirable to employ the universal switchboard described above, even at Division headquarters, it is felt that the line relays and other extra equipment used in that switchboard unnecessarily complicated the division headquarters problem. Discussion of provisions for accommodating radio circuit in the paragraph just above, apply to this switchboard also. Nomenclature Telephone Central Office Set AN/TTC-5 has been assigned to this item and military characteristics submitted by the Army Ground Forces.

3. Field Switchboard. Switchboard SB-22/PT now under development is an eight-line patch cord type of board which is capable of stacking in such a manner that four of these boards may be operated together without undue effort giving a total capacity of 32 lines. It is believed that completion of this development will solve the lightweight field switchboard problem at the present time.

4. Dial Telephone System. There has been considerable discussion of the possibilities of applying the dial telephone principle to Army communication systems. The use of dial switching equipment at Corps and higher echelons can materially reduce the operator load with a corresponding reduction in operating personnel required on these switchboards. It is generally conceded that dial switching equipment as at present designed, is not suitable for tactical use, due principally to its weight and structural design. However, it is the opinion of these Laboratories that a careful study could result in the design of dial switching equipment of such weight and unit construction as to be adaptable to tactical use.



a. In order to simplify dial equipment for field use, it is proposed that all local calls in a Corps, Army or Army Group Central be completed by station dialing. An "overriding busy feature" will be available to the switchboard operator so that priority I service will remain available to authorized personnel. Calls to outside switchboards will be completed by manual operation, using Telephone Central Office Set AN/TTC-4. A dial on the keyshelf of this board will provide a trunk dialing feature.

b. In order to determine the extent to which a dial system may be efficiently employed in the Army communication system, a dial system especially designed for mobile field use over tactical communication circuits should be provided for field trials. Nomenclature Telephone Central Office Set AN/TTC-6 has been assigned for a trial switchboard and suggested military characteristics prepared.

5. Remote Control Equipment. There is a requirement for universal remote control equipment for operation of single channel radio transceivers from a two-wire line where the radio circuit is operated on a full duplex or equivalent four-wire basis and the operation of the radio transmitter is under the control of the switchboard operator. Two proposals for equipment to achieve this method of operation have been given preliminary test and appear feasible. Both proposals permit normal switchboard operation and require little or no additional apparatus at the switchboard.

6. Telephone Station Set. Military characteristics have been approved for Telephone TA-43/PT which is a universal telephone set for attachment to either local or common battery lines to replace Telephone FR-8-( ). While extreme light weight appears to be the important consideration in development of this telephone, a number of conflicting additional requirements have been added to complicate the design. It is felt that some of these requirements are of use in only a very small percentage of the cases and might be eliminated without detracting from the usefulness of the telephone set. Inasmuch as the handset is the most important feature of the telephone, the report of the appropriate committee considering the item will be of value in anticipating the ultimate design.

F. Telegraph Equipment. The development of equipment for the improved telegraph system of the future follows two general trends, improvement of the teletypewriter for Army use and extension of transmission on a voice-frequency basis throughout the system, including the local loops. A description of the required equipment development to achieve this objective follows.

1. Page Type Teletypewriter. Development of a page type teletypewriter specially designed for Army use is now being conducted. Nomenclature Teletypewriter TR-4/TG, part of Teletypewriter Set AN/PGC-1, has been assigned. As mentioned previously, it is expected that the weight of this unit will be only 25% of the present standard Teletypewriter TG-7-( ). Improvement in mechanical reliability and weatherproofing techniques will also be features

of this machine. The equipment will be able to operate directly on field lines without the use of a line relay or separate line unit. Inasmuch as development of this machine was initiated on an expedited basis before the end of the Pacific war, all the desirable features and characteristics will not be incorporated in the first models and further improvement should be permitted on a long term basis.

2. Tape Type Teletypewriter. A tape teletypewriter is inherently lighter in weight than the page type machine with the same general construction since the bulky carriage, paper holder and paper feed mechanism are not necessary. Development of an ultra-lightweight machine of this type for use in extreme forward areas to supplement or replace the telephone and Morse code telegraphy is required. As visualized, this unit would be arranged for operation either by manually applied power or by a low current drain electric motor at the option of the user. It would also be capable of operation on a point-to-point basis and would inter-operate with page type teletypewriters now in use and under development.

3. Universal Voice-Frequency Telegraph Transmission Unit. In order to extend the advantages of voice-frequency transmission of telegraph signals throughout the system, it is proposed to develop a unit which is capable of operating on a half duplex basis on telephone lines having losses varying from 0 to 30 db without adjustment. Development of such equipment will eliminate the necessity for separate telegraph switchboards, repeaters, and other switching and transmission apparatus. Two general applications are visualized as follows:

a. Combination Telephone-Teletypewriter Station Set. The station set connected to the telephone switchboard would be capable of operation either as a telephone or teletypewriter at the option of the user. Placement and reception of calls would be by use of the telephone. The teletypewriter could be placed on the line when desired by operation of a simple switch and would transmit and receive through the voice-frequency unit described above. Automatic restoration to the telephone position when the station set is in the stand-by condition would be a feature. This equipment is expected to have considerable application for use by staff officers where security and accuracy of communication from station to station is important.

b. Teletypewriter Station Unit. Where the voice-frequency unit is part of a teletypewriter station set connected to a teletypewriter central office some means of signalling the operator must be provided. Since it is expected that the teletypewriter switchboard will be operated similar to an all magnet telephone switchboard, it is expected that 20 cycle ringing generators will be used at the station set for signalling purposes. Considerable experiment will be required to determine the best method of communicating with the operator and placing calls.

4. Teletypewriter Switchboard. With the wide spread use of voice-frequency telegraph transmission, it is expected that separate development of telegraph switchboards will not be required since telephone switchboards will be adequate for the purpose. The magneto switchboard of Telephone Central Office set AN/TTC-5 should provide all necessary facilities. The operator's teletypewriter set would be similar to the station teletypewriter set discussed in subparagraph 3 just above, and would be connected in place of the operator's telephone set. Signalling over local loops would be by means of a 20 cycle ringing generator but the method of signalling over trunks will require some experimentation to determine. It is expected that development of equipment of this type will greatly improve the ease, flexibility, and accuracy of teletype operation and considerably reduce the number of equipments required in wire communications.

5. Investigation and Research. For continuing improvement of the telegraph system, it is considered necessary that the following investigations be pursued on a long term basis:

a. Investigation of the telautograph principle to determine its application, if any, in the Army communications system. Present telautograph apparatus is operated on a d-c basis and is heavy, cumbersome, and not too accurate. There is some expectation that extension of this principle to operation on a voice-frequency basis would provide lighter weight, more reliable equipment for transmission of written messages.

b. Determination of optimum keyboard arrangement for the teletypewriter. There has been considerable contention that the present arrangement of the letters on the teletypewriter keyboard are not the most ideal for fast operation. It is suggested that the Army participate with industry and other Government departments in determining a suitable keyboard arrangement.

c. Investigation of lubricants and inks employed in teletypewriters with the aim of providing improved service over extended climatic conditions.

d. Investigation for improvement of teletypewriter paper and paper handling devices.

e. Determination of an optimum transmission speed. While the normal transmission speed at present is 60 words per minute, it is entirely feasible to materially increase this rate. There has been considerable operation on commercial facilities at 75 words per minute and 100 words per minute, although the latter is still mostly in an experimental stage. Although increased speed is probably desirable, it would appear impractical to increase it beyond a certain limit. Factors pertaining to this limit are:

- (1) Increased signalling speed reduces the range and margin of line and station equipment.
- (2) Increased signalling frequency requires broader band widths and consequently reduces the number of channels available in any given band width.

- (3) At speeds above the normal operator typing rate, a proportionate increase in personnel and equipment is required to prepare traffic for automatic transmission in order to effect most efficient circuit utilization.
- (4) Reliability and maintenance requirements for mechanical equipment are affected adversely at increased speeds.

G. Line Equipment. In this category, radically new equipment and techniques are required. With the great improvement in cable message handling ability through the use of new transmission equipment, it is expected that there will be little or no place in the Army communication system for open-wire line construction as we know it today. Less than 1/2 the weight of equipment and considerably less effort will be required to install cable of equivalent message handling ability. Discussion of line construction equipment is divided into two phases, equipment required for the tactical area and that required for the zone of communications or other stable areas.

1. Tactical Line Construction Equipment. It is expected that the speed and security demanded in the construction of wire lines in tactical areas will be such that no possible construction technique should be allowed to remain unexplored. Equipment development and investigations required follow.

a. High Speed Coils. Development of this method of packaging wire and cable should be extended to cover all types used in the tactical plant. Improvement of the methods and machinery used should be made so that wire and cable may be payed out at speeds up to 200 miles per hour.

b. Poles. Development should be conducted to produce small lightweight poles to conserve shipping space and reduce total weight of line construction equipment. Metal poles are indicated. The following general types are suggested:

- (1) Round sectional poles similar to pipe sections.
- (2) Tapered sectional poles.
- (3) Triped supported structures which are suitable for placement from a helicopter or other airplane without the necessity for digging pole holes.

c. Pole Erection. Truck K-44 pole hole digging equipment is unsatisfactory in all respects. A completely new and much more rugged vehicular pole hole digging equipment, designed around a standard Ordnance or Corps of Engineer's chassis is required. Portable pole digging equipment is required. Further investigation of explosive methods of producing suitable pole holes is suggested. With the use of smaller diameter poles, it is quite possible that simpler methods such as the use of a handuger or mallet and spike may be sufficient in most instances.

d. Air Flotation of Wire Lines. If the weight of the wire and cable can be made sufficiently light while retaining its longitudinal strength, considerably longer spans can be tolerated. This would be particularly advantageous for traversing difficult and inaccessible areas where poles can not be readily erected. Investigation of employment of small kite balloons from which the cable or wire is suspended as a means for obtaining increased air flotation is suggested.

e. Vehicles and Planes. Inasmuch as the erection of communication lines is a civil engineering construction problem similar to those encountered by the Corps of Engineers, it is considered that special purpose vehicles are justified for this work. Some of the vehicles and planes which should be considered follow.

- (1) A line construction truck equipped with an extensible side platform and derrick so that poles may be erected and equipment moved off the side of the road without the necessity for the personnel coming in contact with the ground and encountering mine fields should be developed.
- (2) The helicopter has considerable potentiality for line construction use. It can be used as auxiliary to the line construction and supply truck for placing a line well off the road, removing it from danger of damage by friendly vehicles. It is visualized that poles can be set and cables placed by the use of this machine. If a helicopter of sufficient capacity is available, it is possible that it could be used to carry the equipment and carry on the construction work without the necessity for frequent trips to the supply truck.
- (3) It is believed that in many cases sub-surface construction may be feasible and desirable even as far forward as division command posts. This is particularly true when the situation is such that following higher echelons will in turn take over and supplement the existing communication axis. For this purpose, it is required that a small plow capable of plowing-in two lightweight spiral-four cables be developed for use in conjunction with the "Weasel" or similar tracked vehicle.

b. Laying of wire on the surface of the ground from planes has already been successfully accomplished. Further experimentation along this line should be carried out. Some consideration might be given to the use of the rocket principle for accomplishing this mission.

2. Construction for Stable Areas. It is believed that line construction in this region will be mostly subterranean, since it is assumed to be the most secure of the various construction methods. In general, coaxial cable will be employed and a suitable vehicle for placing this cable is required. Since this type of construction is a major civil engineering problem,

it is again considered that special purpose vehicles similar to those used by the Corps of Engineers will be required. The plow and prime mover should be one unit equipped with treads for traversing all types of terrain. The vehicle should be capable of burying two cables simultaneously to depths of at least 30 inches when operating at speeds up to 15 miles per hour. In places it will be required that aerial construction be resorted to. Extension of the aerial construction techniques discussed just above to cover this field should meet requirements.

3. Fault Location Equipment. With the greatly increased use of cables, especially coaxial cables, and the higher frequencies employed in transmission, it is particularly important that improved fault location equipment be provided for use at a test board in the central office and by the linemen in the field. Development of the following types of equipment is required:

a. Pulse Reflection Equipment. Equipment employing this method transmits high frequency pulses which are reflected back along the line when impedance irregularities are encountered. Readings are obtained on a cathode ray tube. This is essentially a Radar technique applied to wire lines. It is capable of detecting faults and potential faults which are not found by any other method. While some development of this type of equipment was made during World War II, further development is required since the need will be more acute in future communication systems. It is visualized that this equipment will be the main component of a wire chief's test board used at every System Control Center. Development of a similar type equipment of considerably smaller size for use by the linemen in localizing trouble is also required.

b. Tone Test Sets. The use of sub-audio tone test sets and electrostatic and magnetic pick-up devices for location of faults on cables is now used to some extent in the commercial plant. It will be necessary to adapt and improve this equipment for Army field use.

*Harry W. Permer*

HARRY W. PERMER  
Lt. Col., Signal Corps  
Chairman

*Bryan S. Anderson*

BRYAN S. ANDERSON  
Alternate Chairman

*James J. Whely*

J. J. WHELY  
Lt. Col., Signal Corps  
Member

*M. L. Rife*

M. L. RIFE  
1st Lt., Signal Corps  
Member

*C. A. O'Malley*

C. A. O'MALLEY  
Member

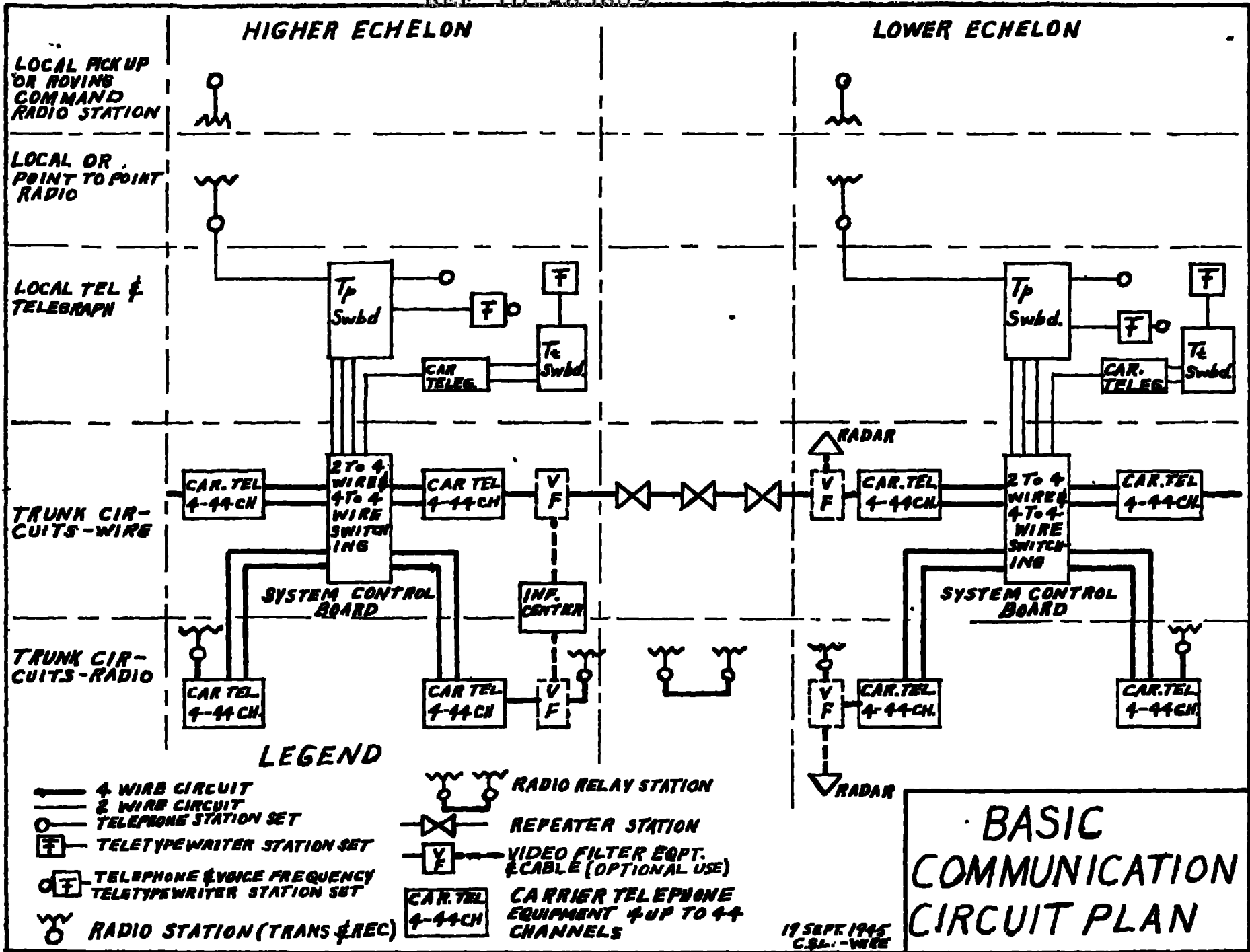


Fig. 1.

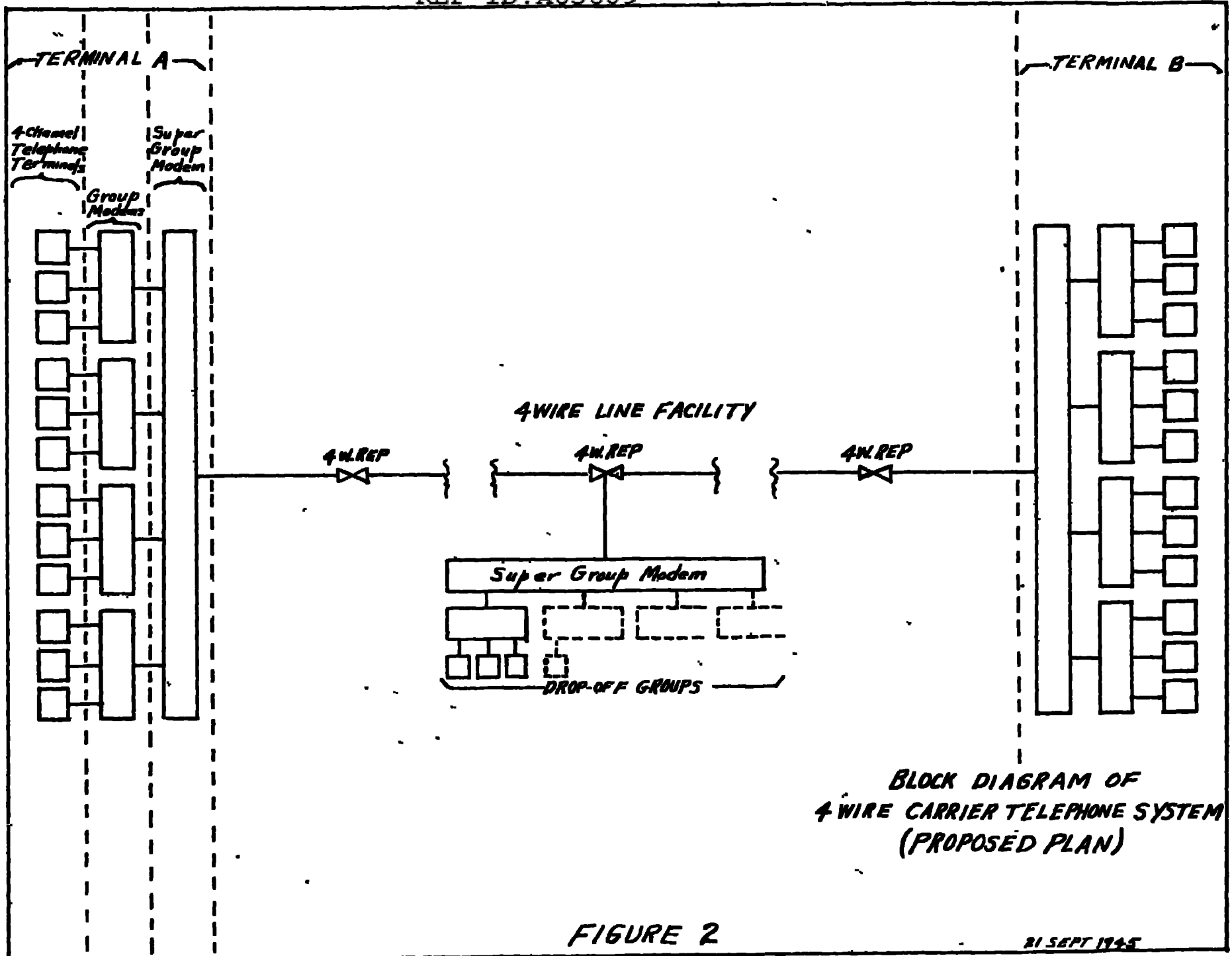


FIGURE 2

21 SEPT 1945



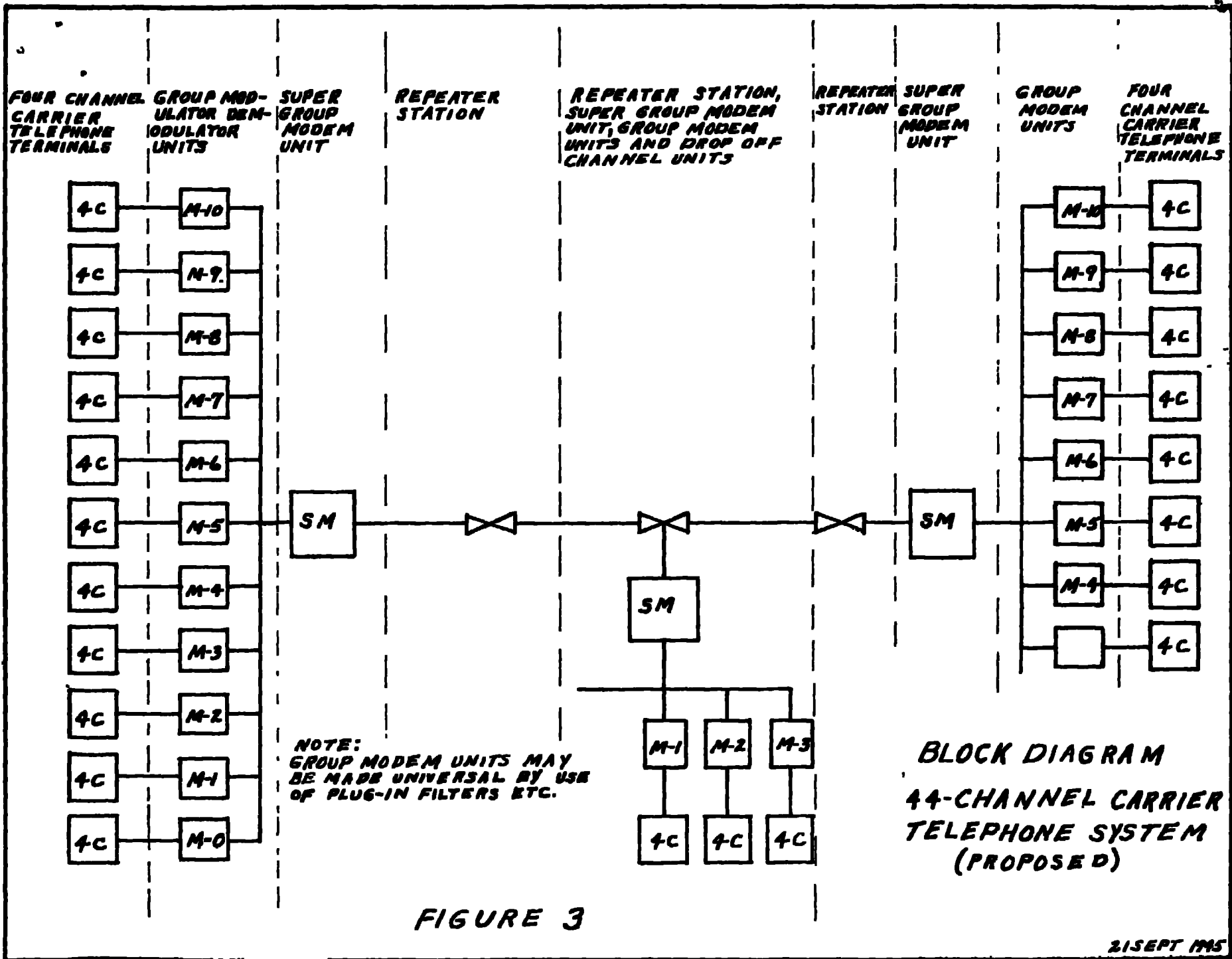


FIGURE 3