A Carrier Telegraph System for Short-Haul Applications

By J. L. HYSKO, W. T. REA and L. C. ROBERTS

(Manuscript received May 14, 1952)

A compact frequency-shift carrier telegraph system is described which provides channels in the voice range and above the voice. The channel terminal unit incorporates arrangements for handling TWX supervisory signals and employs no electro-magnetic relays.

INTRODUCTION

Most short Bell System telegraph circuits, particularly those in the less-densely populated areas of the country, have customarily been operated over direct-current facilities obtained by compositing or simplexing physical telephone circuits. Many of these extend from a telegraph repeater in a central office to another arranged as a subscriber set and mounted in the knee-well of the customer's teletypewriter table. Thus, for example, circuits are extended to Teletypewriter Exchange Service (TWX) subscribers located far from the switchboard. The TWX facilities are arranged to handle supervision as well as transmission. The form of supervision is identical to that obtained when local facilities are employed and hence uniform operating procedures are obtained at TWX switchboards for all subscriber stations without regard to their geographical location.

During and immediately following World War II, the growth of the Bell System's telegraph business resulted in some shortage of dc facilities. It was foreseen that this shortage would be rapidly intensified by the use of new short-haul carrier telephone systems, such as type N1,[1] in providing telephone circuits without adding physical conductors. Moreover, many of the existing direct-current facilities would be absorbed to meet signaling needs for the rapid expansion of telephone toll dialing. It therefore became evident that carrier telegraph methods must be adopted for relatively short hauls in fringe areas.

The existing 40C1 voice-frequency carrier telegraph system[2, 3] was designed for application in large groups at telegraph central offices and for trunk-service operation over toll telephone circuits employing standard levels. It has proved very economical in this field. However, the very features which make for economy in large installations (such as amplitude modulation, common carrier supply and testing equipment, and standardized operating conditions) cause this equipment to be costly when it is applied a few channels at a time in outlying offices; these may not be equipped with either telegraph battery supplies or telegraph boards. Moreover, the 40Cl equipment, being a carrier-on-for-mark and carrier-off-for-space system, does not lend itself to the provision of TWX toll subscriber line supervision identical to that of local stations without the addition of rather complex and expensive supervisory applique circuits. Where TWX supervision is involved these supervisory circuits are required to generate and recognize supervisory signal patterns capable of being distinguished from transmission space signals and communication breaks, which are long space signals.

Consequently, it was decided to develop a new carrier telegraph system especially aimed at the needs of fringe areas. One of the problems to which much thought was given concerned the choice between amplitude-modulation and frequency-shift operation. A frequency-shift system provides some reduction in the effect of noise and other interference on transmission and it is also less affected by rapid level changes. Although these advantages were attractive, it was not clear that they were sufficient to justify the added complexity and cost entailed by the adoption of this type of transmission, in view of the quiet and stable circuits encountered in the Bell System plant. What finally swung the balance to a frequency-shift system was its advantage in handling TWX supervisory signals. With transmission accomplished by shifting the carrier frequency, supervisory signals could be sent by turning the carrier on and off. A cheap and simple circuit might then be used to distinguish between transmission and supervision.

From the foregoing discussion it will be evident that during the twelve years since the 40Cl system was developed the needs of the Bell System have changed. Fortunately, the designer's art has concurrently made great strides in making available new miniature apparatus and electronic techniques such as have been exploited so successfully in the 143A type electronic telegraph regenerative repeater,[4] the V3 telephone repeater[5] and the N-1 carrier telephone system. As a result, the channel terminal of the new 43A1 carrier telegraph system, being small, inexpensive, self-contained and all-electronic with no electro-mechanical relays, is almost ideally suited to the needs of the smaller central offices and TWX stations.

FREQUENCY ALLOCATIONS

The 43A1 system provides two groups of channel-frequency allocations, as follows:

a—A three-channel high-frequency allocation, using frequencies between the upper edge of the voice-frequency band and the lower edge of the type-C carrier telephone band. This allocation is primarily for operation on open-wire lines but can also be operated on cable circuits where the loading provides a suitably high cut-off.

b—A voice-frequency allocation capable of providing six channels on two-wire circuits or twelve channels on four-wire circuits. The channels of this allocation are for operation over telephone speech channels on any of the standard facilities, including broad-band carrier and cable or open-wire physical circuits.

The present frequency allocations are shown in Fig. 1. The voice-frequency system is based on twelve nominal midband frequencies spaced 170 cycles apart from 595 cycles to 2635 cycles, omitting 1615 cycles. The carrier frequency is shifted ±35 cycles about midband, and either the higher or the lower frequency may be used for marking sig-

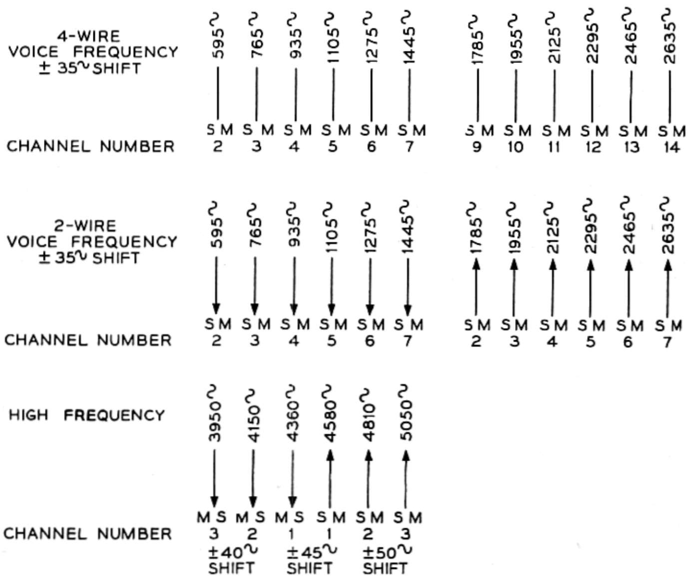

Fig. 1—Frequency allocations.

nals. The high-frequency system is based on six midband frequencies spaced from 200 to 240 cycles apart. The frequency shift ranges from ±40 cycles in the lowest channel to ±50 cycles in the highest. These wider spacings and shifts were adopted to ease the problem of designing inexpensive filters and oscillators for the higher frequencies.

Channel 1 of the high-frequency system employs adjacent frequency assignments for the two directions of transmission. The lower frequency path employs a downward shift for marking signals and the higher-frequency path an upward shift for marking signals. In half-duplex operation this minimizes interference from the strong signals at the transmitter output to the weak signals at the receiver input. The steady marking frequency, which is being sent against the flow of traffic, is shifted away from the band over which the message is passing.

CHANNEL TERMINAL CIRCUIT

Sending Circuit

The sending portion of the channel terminal circuit is shown in the upper part of Fig. 2. When the teletypewriter sending contacts open the loop to send a spacing signal, the sending triode is cut off. When the contacts close the loop to send a marking signal, the grid is made positive with respect to the cathode, the tube conducts and the potential at the plate is decreased. A varistor bridge modulator is connected between this plate and a source of potential having a value lying midway between the marking and spacing plate potentials. Thus, the potential applied across the modulator during marking signals is opposite in polarity to that applied during spacing signals. When the voltage across the varistor bridge is in the conducting direction, the varistors provide a low impedance path to alternating currents. Thus additional capacitance is coupled to the oscillator tank circuit and the oscillator operates at the lower of its two signal frequencies. When the voltage across the bridge is in the non-conducting direction, the varistors are biased to a high-impedance portion of their characteristic, the capacitor is effectively disconnected from the tank circuit and the oscillator operates at its higher signal frequency.

The reversing switch in the driving circuit of the modulator permits either the higher or the lower frequency to be used for marking signals.

The oscillator output power is adjusted by the SEND LEVEL potentiometer and passed through a buffer amplifier and a band pass filter to the send bus and line.

The filter is an impedance transforming structure which contains a

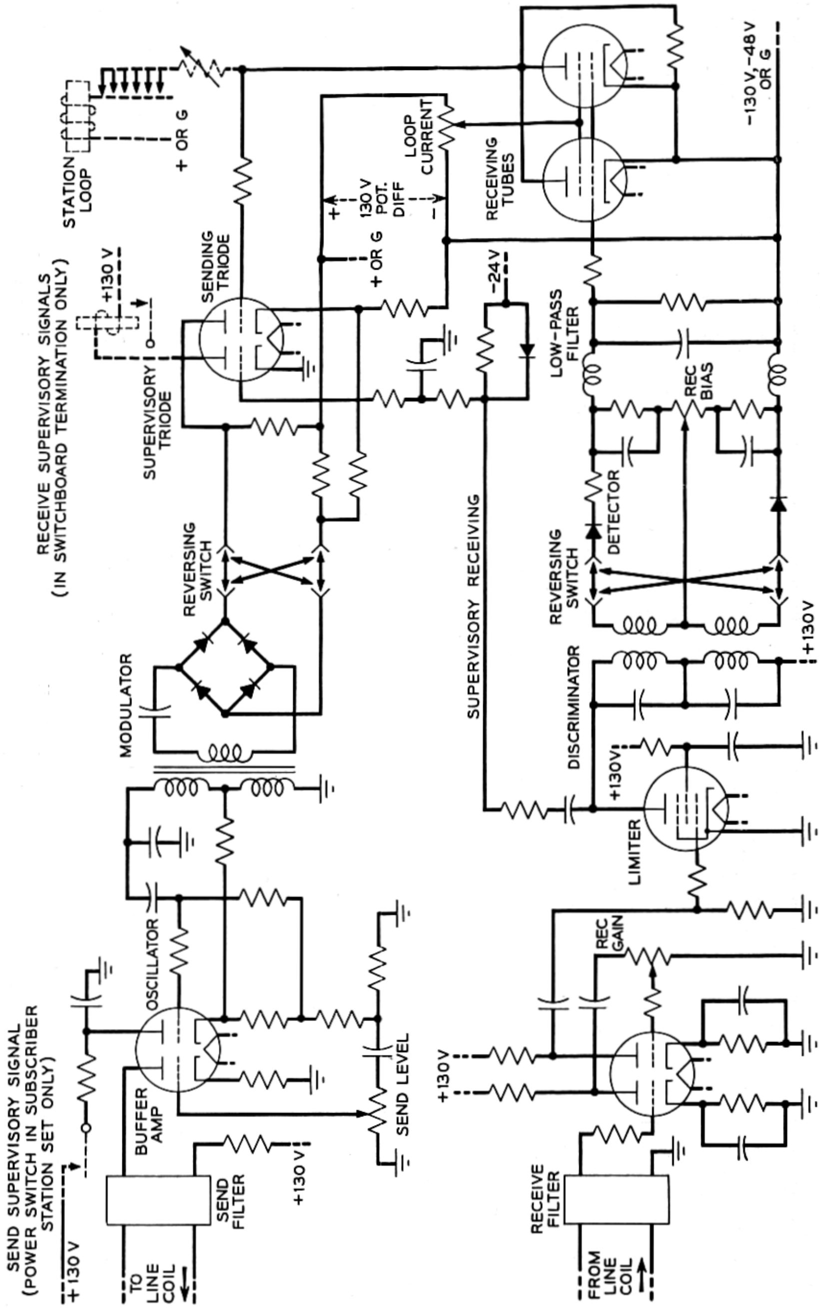

Fig. 2—Simplified diagram of channel terminal circuit, half-duplex.

downward transformation (7500:600) from the impedance of the buffer amplifier to that of the line so that no amplifier output transformer is required.

Either unity-ratio line coils or a hybrid coil may be used to connect the unbalanced sending and receiving filters to a balanced line. The hybrid coil is used with a two-wire line when the send and receive frequencies occupy adjacent bands.

Receiving Circuit

The receiving circuit, shown in the lower part of Fig. 2, is equipped with a filter which selects a narrow band of frequencies centered about the mark and space frequencies of the channel to be received. The receiving band filter has characteristics similar to those of the sending filter, except that it has a greater discrimination against unwanted frequencies and provides an upward transformation (600:140,000) from the line impedance to a value suitable for driving the grid of the first amplifier stage.

The frequency-loss characteristics of a typical receiving filter used in the voice band and of the corresponding sending filter are given in Fig. 3.

The carrier signals selected by the receiving filter are passed through a three stage amplifier limiter. Most of the limiting action is provided by the third stage; the first and second stages act as amplifiers only for weak signals but limit strong signals. An adjustment for receiving gain

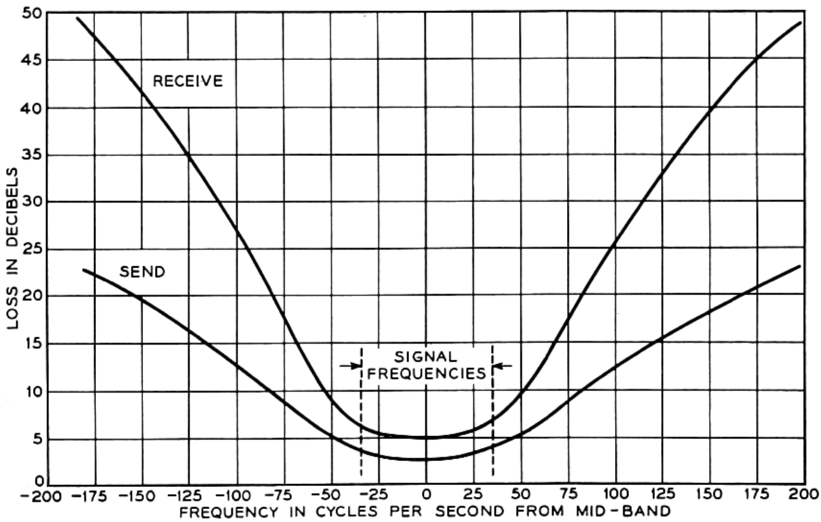

Fig. 3—Send and receive filter characteristics, VF allocation.

is provided between the first and second stages. With the REC GAIN control at maximum the third stage is driven to full output when the input to the receiving filter is greater than about −50 dbm*. Where it is not necessary to detect the presence or absence of carrier for supervision as described below, the control is generally set for maximum gain.

The limiter output is passed through a frequency discriminator consisting of two anti-resonant circuits in series, tuned so that one has a parallel resonance at the low frequency edge and the other at the high frequency edge of the channel band. The voltages appearing across the anti-resonant circuits are rectified separately by germanium varistor diodes and the resultant d-c output voltages are added algebraically, filtered and applied to the control grids of the output tubes.

Since at normal receiving levels the limiter removes all magnitude variations, the output from the discriminator detector circuit is dependent in magnitude and sign only on the signaling frequency. A negative voltage from the detector causes cut-off of the amplifier tubes and a positive voltage causes plate current to flow. A switch between the discriminator and the detector provides means for reversing the output connections of the discriminator so that a positive voltage from the detector can be obtained with either the higher or the lower signaling frequency. Fig. 4 shows the dc voltage output versus frequency characteristic obtained with a typical discriminator.

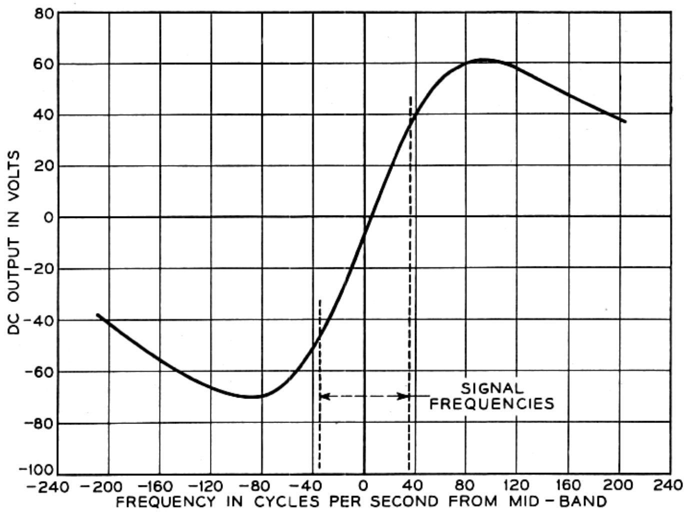

Fig. 4—Frequency characteristic of typical discriminator.

* "dbm" is an abbreviation for "decibels with respect to one milliwatt."

The low pass filter between the detector and last stage serves to remove carrier ripple and to decrease the effects of noise and other interference having demodulated frequency components greater than about 40 cps, which is slightly higher than the "dotting" frequency of 100-word per minute signals. In order to prevent a change in the tuning of the discriminator when the reversing switch is operated, a balanced low-pass filter structure without mutual inductance is employed. This presents high and nearly equal impedances to ground from the positive and negative sides of the detector circuit.

Nearly all the voltage gain of the receiver appears ahead of the detector. Since the detector output voltage applied to the grids of the beam power tetrodes is high enough to give an approximately square signal wave shape in the loop, no intermediate stage of dc amplification is needed following the detector. For unbiased signal reception, the demodulated signals should be centered on the grid characteristic of the receiving tubes; that is, the marking and spacing voltages applied to the grid circuit should be symmetrical about a potential a few volts negative with respect to the receiving tube cathodes. To obviate the need for a voltage source negative with respect to the cathodes, the signals are prebiased by unbalancing the detector so that the mean of the mark and space output voltages from the low pass filter is about −5 volts. Further adjustment of the mean signal value may be made by means of the REC BIAS potentiometer to compensate for bias of signals received from the line due to deviations in the mark and space frequencies from their theoretical values or to other causes originating at the sending terminal of the telegraph circuit as well as for bias due to discrepancies in the discriminator network or to differences between mark and space levels.

These arrangements permit great freedom in the assignment of loop battery voltages. The cathodes of the final stage may be fixed at −130-volt, −48-volt or ground potential and the plates operated from ground, +48-volt or +130-volt potential. The remainder of the circuit may be powered by +130-volt battery for the plates and −24-volt battery for the heaters of the tubes, regardless of the loop conditions.

By means of the reversing switch mentioned above, current may be caused to flow in the loop during the reception of the higher or the lower frequency. Thus not only can various frequency allocations be accommodated, but the local circuit may be operated neutral (current for mark) or inverse neutral (no current for mark).

One tube is used in the final stage for 20 ma or 30 ma loop current, and two for 60 ma loop current.

Supervisory Circuit

When the channel is used in TWX service as a toll subscriber line, the subscriber calls the operator to initiate a call by closing the power switch on his teletypewriter. This connects power to the teletypewriter motor, closes the transmission circuit to the teletypewriter and applies plate battery voltage to the transmitting oscillator in the channel terminal, resulting in the transmission of carrier current over the line. At the distant (switchboard) terminal the receipt of carrier current energizes a supervisory signal receiving circuit which is responsive to carrier-on and carrier-off conditions in the receive band. In this circuit, carrier voltage appearing at the plate of the limiter tube is rectified and applied to the grid of the supervisory triode. The operation of a relay in the plate circuit of this tube causes a line lamp at the switchboard to light.

A disconnect signal is sent by the subscriber at the end of a call by opening the teletypewriter power switch. This removes the oscillator plate voltage. At the central office, the receipt of the resulting no-carrier signal de-energizes the supervisory receiving circuit and causes the supervisory lamp in the operator's cord circuit to light steadily. To recall the operator during a call the subscriber opens and recloses his power switch. This causes the cord lamp at the switchboard to flash.

An RC circuit slows the rise of current in the supervisory receiving tube to guard against false operation of the switchboard line lamp due to noise impulses during the carrier-off, that is, the idle condition.

DC Circuits

On the dc side of the channel terminal, provision is made for optional wiring arrangements to connect to the circuits of the various telegraph test boards, service boards and TWX switchboards, as well as to local teletypewriter loops, using telegraph voltages of either 130 or 48 volts. In offices where a negative 130-volt battery is not provided, operation with a single positive 130-volt battery is possible.

The loop connections are made to an electronic circuit in the channel terminal which is similar to that employed in a recently-developed electronic loop repeater used in telegraph offices and which possesses several interesting features. Fig. 5 compares the action of this circuit, in transmitting toward the subscriber station, with that of more conventional arrangements:

(a) shows a conventional open-and-close circuit and the wave shapes which it produces at the central office end and at the far end of a capacitative loop. As is well known, the asymmetrical wave shape causes positive signal bias.

(b) shows an "effective polar" circuit along with the wave shapes it delivers. This is the circuit conventionally used to drive subscriber loops. It presents a constant low impedance to the loop and might therefore be considered a "close-and-close" circuit.

(c) shows the electronic loop circuit. The driving tetrodes are operated in their high-impedance region, above the knee of the plate-current plate-voltage curve. They deliver a highly symmetrical rectangular wave to the loop and little or no bias results. This circuit presents a nearly constant high impedance to the loop and might be considered an "open-and-open" circuit.

Although the rectangular wave is inferior to a peaked wave in that less average power is delivered for the same values of steady-state current and voltage, it provides entirely acceptable transmission for 19-gauge cable loops up to about 20 to 25 miles in length. Inasmuch as 80 volts potential is absorbed in the electron tube plate circuits, this is almost the maximum length over which 62.5 ma can be supplied when loop battery of 260 volts is used.

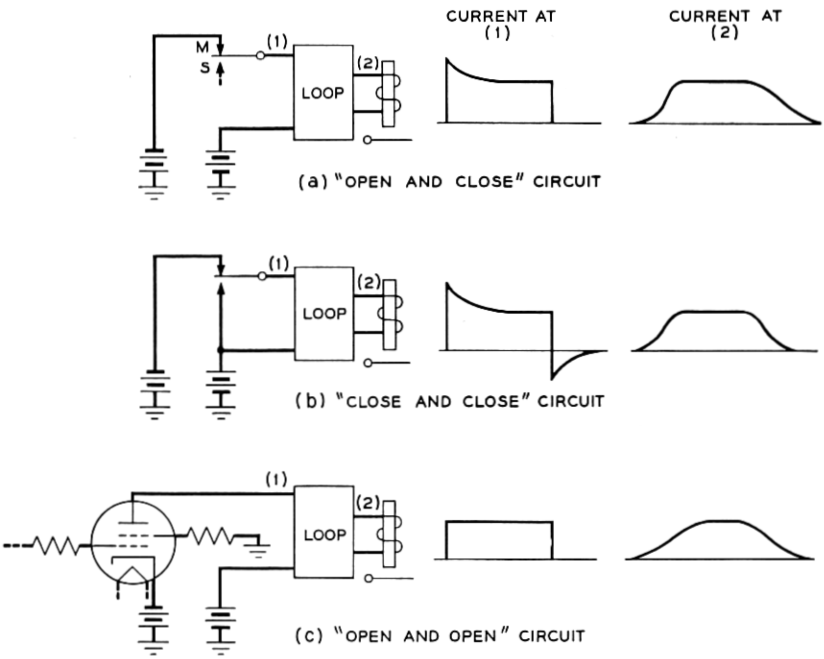

Fig. 5—Explanation of electronic loop circuit.

During open-and-close transmission by the subscriber, the high impedance termination of the loop at the tetrode plate circuits causes the current at the central office end of the loop to change very slowly—too slowly for good transmission at teletypewriter speeds. However, the voltage wave is very well shaped, and this is what is used to drive the grid of the transmitting tube. One noteworthy fact is that the bias of the signals repeated from loop to line is nearly independent of loop length; consequently no inductive wave shaping is required at the subscriber station, even in the longest operable loops.

Because of the high impedance termination, loop current is insensitive to circuit resistance. The loop padding rheostat is, therefore, adjusted to build out the loop resistance to a standard value and the amount of loop current required for proper operation of the station teletypewriter is obtained by varying the screen grid potential of the tetrode tubes.

Duplex Feature

In half-duplex operation, one dc loop at each channel terminal serves for both sending and receiving. The central office end of this loop is connected to the grid of the sending triode and to the plates of the receiving tetrodes. If a marking signal is being received from the carrier line while the teletypewriter contacts in the loop are closed, the receiving tubes conduct, current flows in the loop and the teletypewriter in the loop receives a marking signal. Under this condition the office end of the loop is positive with respect to the cathode of the sending triode; hence this tube passes a marking signal toward the carrier line. When a spacing signal is received from the carrier line the tetrodes are cut off, the loop current is reduced practically to zero, the teletypewriter receives a spacing signal and the voltage at the office end of the loop becomes more positive. Hence a marking signal continues to be transmitted to the line during the receipt of either mark or space signals from the line.

When the subscriber opens the loop to send a spacing signal to the distant terminal, the potential of the sending triode grid becomes negative with respect to its cathode, the tube cuts off and hence, as described previously, a spacing frequency is passed to the ac line.

In full-duplex operation, two loops are provided at each channel terminal to permit sending and receiving simultaneously. The grid of the sending tube is disconnected from the plates of the tetrodes and transferred to a resistive connection which terminates the full-duplex sending loop. The loop circuits operate in the same way as described for half-duplex operation except that no break action is provided.

Break Feature

When the subscriber opens the loop at the teletypewriter to break transmission coming from the distant terminal, a clean-cut space should be transmitted to the line regardless of any incoming signals. The resistor shunted between the plates and cathodes of the receiving tubes causes the central office end of the open loop to assume the same potential as the tetrode cathodes. This insures that a steady spacing potential will be applied to the send tube even though the tetrodes are cut off by an incoming space. This provides a rapid, clean break. However, if a large leakage exists across the loop conductors, the resistor will not be able to keep the sending tube in a cut-off condition and a break by the subscriber will result in the incoming transmission being reflected in an inverted condition to the distant carrier terminal. In such a case the distant sending subscriber would be broken by a "bust-up" of local copy or by operation of the keyboard break lock. This would normally be caused only by a trouble condition in cable loops.

If a break signal is received over the line from the distant end while the near end subscriber is sending, his loop current is reduced to practically zero. This operates the keyboard break lock thus breaking the subscriber. This circuit differs from the conventional loop circuit in that the receipt of a break signal does not stop the outgoing signals except via the break lock.

TELEGRAPH DISTORTION

On quiet circuits, total distortion per section averages 1 to 2 per cent at 60 words per minute and about 5 per cent at 100 words per minute. Plots of received signal distortion versus level of received carrier are shown on Fig. 6 for both signaling speeds.

EQUIPMENT FEATURES

The channel terminal employs a formed sheet-metal framework and occupies a space $10\frac{1}{2}$ inches high, $5\frac{1}{4}$ inches wide and $7\frac{3}{4}$ inches deep overall. Fig. 7 shows a 43A1 channel terminal. It is plug-terminated, and hence removable for maintenance or repair at a bench.

The basic portion of the channel terminal is common to all frequency allocations. The oscillator network and send filter, which constitute the elements determining the transmitted frequency, form a plug-terminated sub-assembly $7\frac{3}{4}$ inches high, $5\frac{3}{8}$ inches wide, and $1\frac{1}{2}$ inches deep. The receive filter and discriminator, which select the received frequency, form a plug-terminated sub-assembly of the same size.

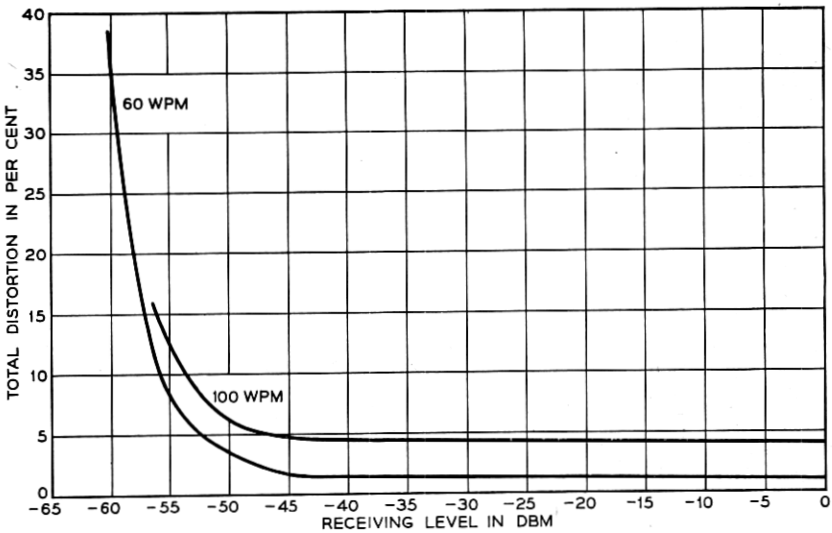

Fig. 6—Telegraph distortion vs receiving level.

A rear view of the channel terminal with the send frequency unit removed is shown in Fig. 8. With both frequency units in place, the rear of the channel terminal is almost completely enclosed. When they are removed, the wiring and apparatus terminals of the basic channel terminal are readily accessible for test and repair.

Tube sockets, potentiometers, test points, switches and the inductor of the low-pass filter are mounted on the front panel. Small resistors, capacitors, and germanium diodes are assembled on a plastic "ladder" which is mounted vertically in the space between the frequency units.

As shown in Fig. 9, three channel terminals may be mounted abreast on a welded metal frame which is fastened to any of the standard bay frameworks designed to accommodate 19-inch mounting plates. The unit mounting frame carries the multicontact receptacles into which the channel terminals are plugged. Twenty-four channel terminals may be mounted on an $11\frac{1}{2}$-foot relay rack, with line coils and certain auxiliary equipment.

Where arrangements for switching between half and full-duplex operation are required, duplex switches for a number of channel terminals are mounted on a narrow plate between the channel terminal mounting frameworks.

Loop rheostats, when required, may be mounted adjacent to the channel terminals or in a loop pad bay along with other loop rheostats that may be associated with electronic loop repeaters. The latter arrangement concentrates the heat dissipated by these rheostats at a place where it will not be harmful.

Subscriber Set

A channel terminal may also be mounted in a station set box appearing in the knee-well of a subscriber's teletypewriter table. This, called a 130B1 teletypewriter subscriber set, is illustrated in Fig. 10. It contains a line or hybrid coil and balancing network, as well as local circuit resistors and other miscellaneous apparatus. When so mounted, the

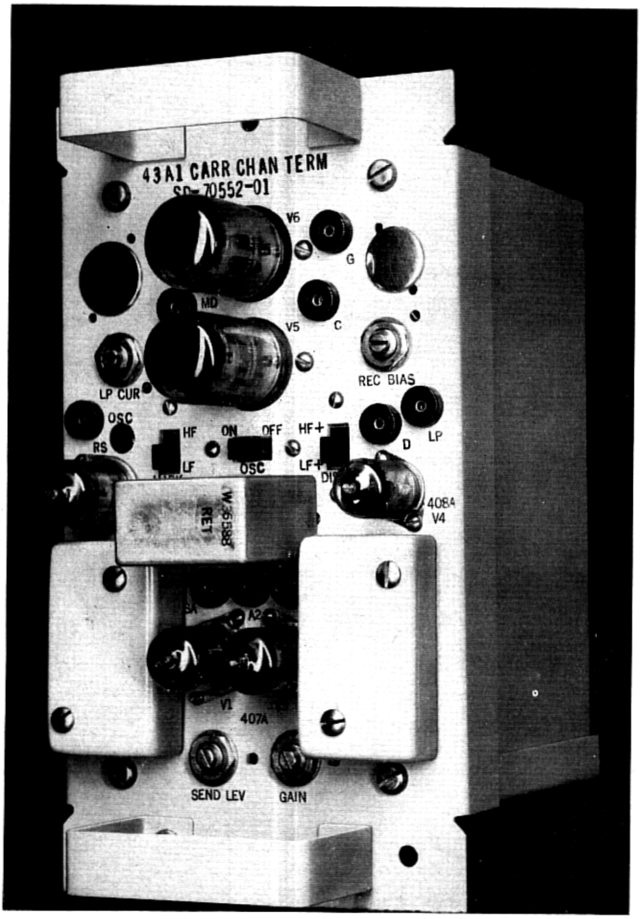

Fig. 7—Channel terminal, front view.

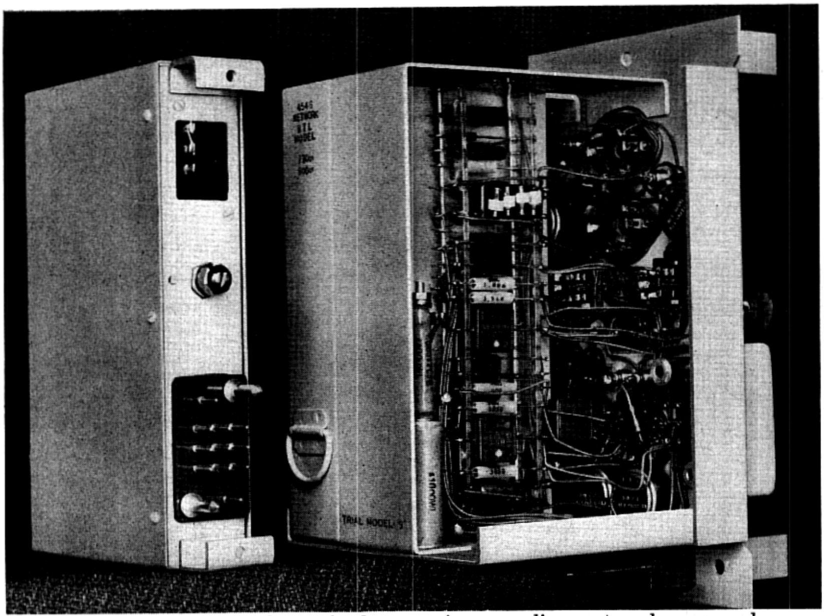

Fig. 8—Channel terminal, rear view, sending network removed.

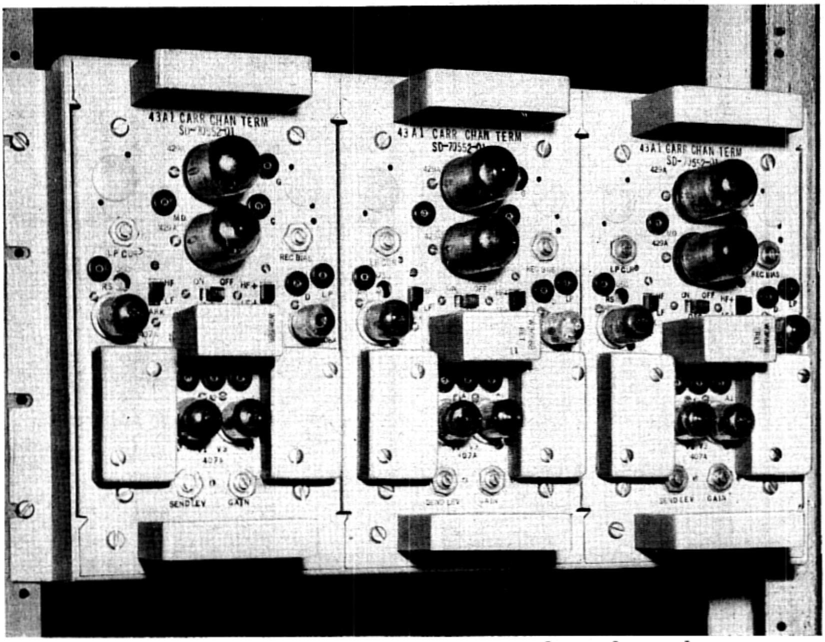

Fig. 9—Three channel terminals mounted on relay rack.

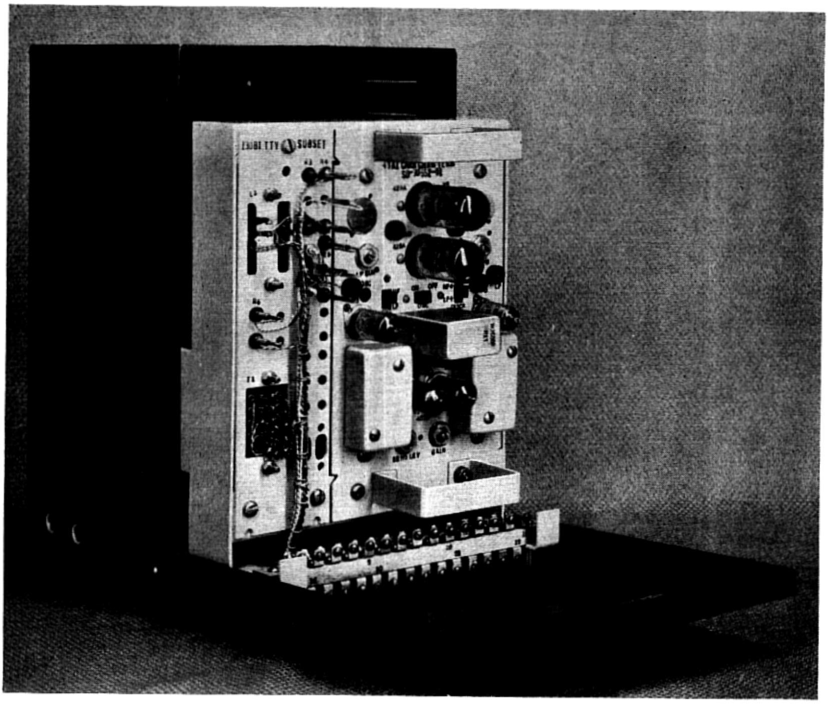

Fig. 10—130B1 teletypewriter subscriber set including channel terminal.

channel terminal is powered by the teletypewriter rectifier, which furnishes 130-volt dc and 20-volt ac power.

The 130B1 set may be employed in private-line or TWX service. In the latter, the application and removal of oscillator plate battery is controlled as described above by the teletypewriter power switch, so that the equivalent of telephone "switch-hook" supervision is attained.

Supervision and transmission are largely independent. The telegraph receiving circuit at the central office terminal remains marking during recall and disconnect signals; hence these supervisory signals do not pass through the cord-circuit repeater to the TWX toll line. Since there is no frequency discrimination in the supervisory receiving circuit, either marking or spacing carrier from the station energizes the supervisory circuit. Hence a communication break (spacing) signal from the subscriber station is transmitted through the operator's cord without any effect on the supervision.

On a TWX call to the subscriber station, a series of alternate marks and spaces, generated by applying 20-cycle ringing voltage to the grid of the sending tube at the central office terminal, actuates the station ringer, which is connected to the local loop whenever the teletypewriter power switch is in the OFF position.

The circuit which terminates the TWX toll subscriber line at the switchboard office is operable with all existing types of TWX cord circuit repeater. All the features of TWX service, including unattended service, are therefore available.

POWER DRAINS

A channel terminal dissipates about 25 watts. Tube heaters consume about half an ampere at 24 volts and the remainder of the channel terminal, exclusive of its loop-terminating portion, consumes 50 ma at 130 volts. The loop terminating portion dissipates 20, 30 or 62.5 ma at 80 volts, depending upon the type of local circuit employed.

LINE LEVELS

The 43A1 system is capable of working with a great variety of line levels. The send level may be adjusted for any value from +6 dbm downward. The receiving equipment operates satisfactorily with −45 dbm or even −50 dbm. But the levels actually used are controlled by crosstalk and noise conditions in the line.

Receiving levels are normally limited by lightning interference on open wire and by noise on cable circuits. The minimum tolerable levels are about −40 dbm on open wire, −45 dbm on four-wire cable circuits and −35 dbm on two-wire cable.

In Fig. 11, a comparison is made of the effects of static on the 43A1 system and on the 40C amplitude-modulation system. It gives the results of simultaneous tests on the 2465-cycle bands of the two systems, using the static from a record made at Madison, Florida. The 43A1 channel could tolerate about 4 db stronger static than the 40C.

SYSTEM LAYOUTS

A typical circuit layout of the 43A1 system working in the frequency band between the voice and type-C carrier on an open-wire line is shown in Fig. 12. The telegraph circuits extend from 43A1 channel terminals located in a central office, at the left, to 130B1 sets in subscriber stations, at the right. In the central office, the send and receive paths of the channel terminal are combined in a hybrid coil. With the moderate degree of balance provided by the network of this hybrid coil, the allowable difference between send and receive levels of the middle channel may be

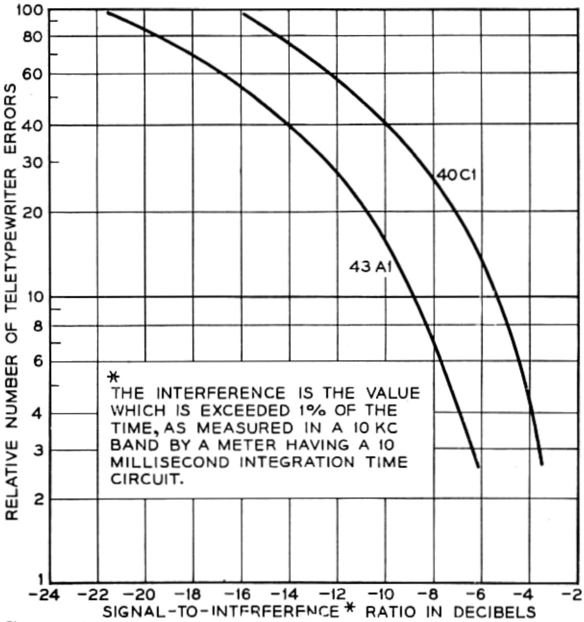

Fig. 11—Comparison of amplitude and frequency shift modulation with static interference.

35 db or more. The telegraph channels are next combined with the voice frequency circuit by means of a 150A filter, and are connected to the composite set and line through the low-pass section of the 121A (type -C) carrier line filter. As a result of the cut-offs of the 150A high-pass and 121A low-pass filter components, the pass band of the telegraph is about 3.7 to 5.4kc. At the outlying terminal of the open-wire line, the telegraph is separated from the voice and type-C carrier circuits by similar filters and connected to the individual subscriber stations by a branching network and branch lines.

The typical arrangement on a two-wire circuit in the voice frequency range is shown in Fig. 13. Six channels are available, using six of the twelve frequency bands for transmission east to west and the other six bands west to east. As in the high frequency case, a branching network and branch lines at the outlying end connect the circuits to the subscribers. Fig. 14 shows a layout in which branch lines are connected at intermediate points in the telephone circuit. At these intermediate points the impedance of the branching network is made high, in order to keep the balance at the telephone repeater from being harmed excessively. Though the network attenuates greatly the signals through it, the telegraph level is usually sufficiently high so that this loss can be tolerated.

The branching network at the outlying terminal has low impedance. Taps on the transformers in the network permit the impedance ratios to be adjusted to suit the line impedances between which the network operates. Since several circuits may pass through this network, a short-circuit on one branch should not be capable of degrading transmission in the other branches. To prevent this, resistances are inserted in series with each branch of such a value that a short circuit will not cause more than 3 db excess loss in other channels. It has been shown by tests that,

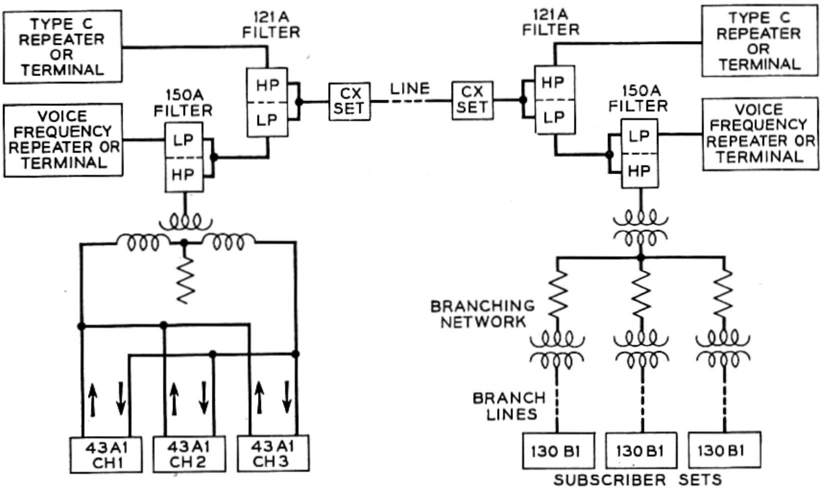

Fig. 12—System layout, above the voice.

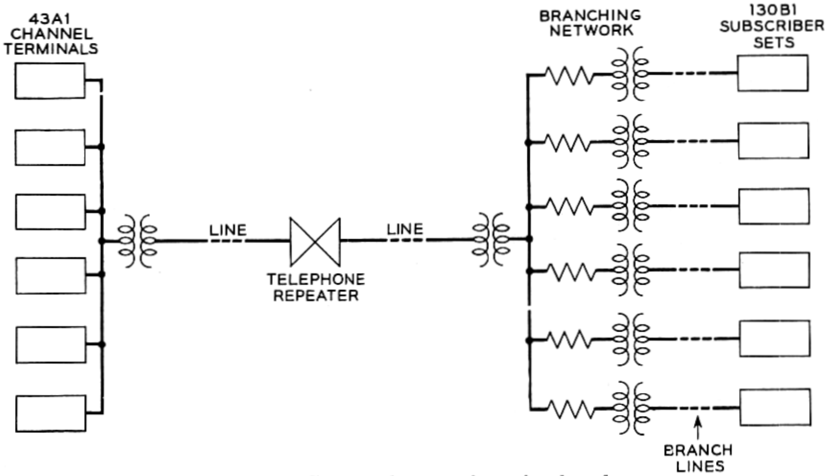

Fig. 13—System layout, in voice band.

in this frequency-modulation system, a sudden loss of 3 db causes little distortion. The series resistances may serve another purpose besides protecting against short circuits. If one branch has a much greater attenuation than the others, the resistance values in series with the shorter branches may be increased so that more energy is directed into the longer branch.

Emergency Circuits

If a circuit containing no intermediate branches fails, a regular message circuit can be patched in to replace it until the trouble is cleared. Fig. 15 shows trunks to be used for making this patch in the case of two-wire circuits. They contain 3 db pads which reduce the signal level to compensate for the change from 0 db transmission level on the regular line to +3 db level on the message circuit.

The 43A1 system may operate also over a four-wire circuit, which accommodates twelve telegraph channels. A patch to an emergency message circuit would then be made at the four-wire patch bay. Since the circuit used for telegraph would usually be similar to those used for telephone message service, no pads to adjust levels would be required for this

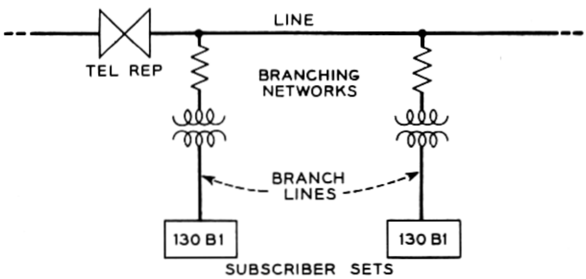

Fig. 14—Intermediate branch lines.

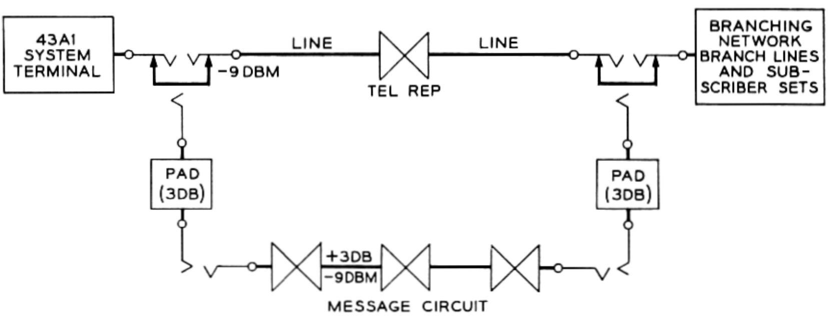

Fig. 15—Emergency circuit.

patch. Obviously echo suppressors must be disabled when a message circuit is used for telegraph.

When the telegraph circuit contains one or more branches at intermediate points, it would be difficult and often impractical to use an ordinary message circuit to replace the telegraph stem in emergencies. The branching location frequently will not be manned and so no one will be available to patch the branch line to the message circuit. In such cases each intermediate branch circuit may be made good over a separate message circuit which is individual to it. Fig. 16 shows this arrangement. A patch trunk is provided between the 43A1 channel terminal at the central office and the telephone switchboard. At the switchboard which is nearest to the intermediate branch subscriber, the branch line is

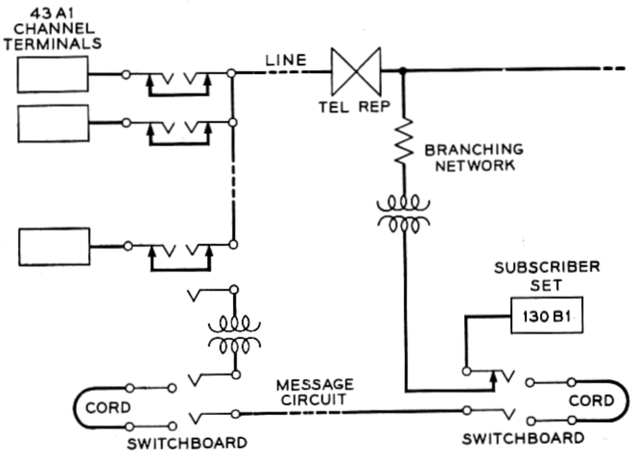

Fig. 16—Emergency circuit for intermediate branch.

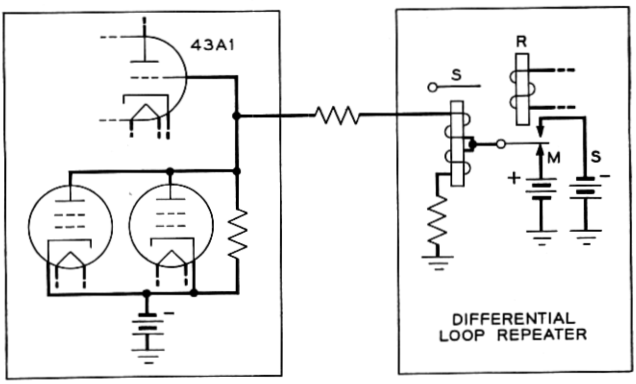

Fig. 17–Connection to other telegraph repeaters.

carried through a cut-off jack. The toll operators then can patch the circuit to the subscriber, thus by-passing the main line when it is in trouble. Since the telegraph energy from only one channel is impressed on the emergency circuit, no adjustment of levels is required.

The channel terminals which are at the central office, shown at the left of Figs. 12 to 16, may be connected to subscribers over dc loops or they may be connected to other types of telegraph repeaters. Fig. 17 indicates the latter connection schematically. Since the loop circuit must supply positive potential to the 43A1 channel terminal, the connecting repeater must be arranged to supply positive battery for marking signals.

FUTURE EXTENSIONS

It is expected that the field of application of the 43A1 system will be broadened by further development over the next few years. More frequencies will be provided, both in and above the voice band. Means will be designed for passing TWX supervisory signals over a direct-current loop from a subscriber station to a channel terminal installed in a nearby central office. The built-in supervisory arrangements of the 43A1 equipment will be exploited to obtain inexpensive straightforward trunks for use both between TWX switchboards and from switchboards to Line Concentrating Units. The supervisory feature will also be employed in private line service to provide an open circuit alarm.

REFERENCES

1. R S. Caruthers, H, R. Huntley, W. E. Kahl, L. Pedersen, "A New Telephone Carrier System for Medium-Haul Circuits," *Elec. Eng.*, **70,** pp. 692–697, Aug. 1951.
2. B. P. Hamilton, "Carrier Telegraphy in the Bell System," *Bell Labs. Record*, **26,** pp. 58–62, Feb. 1948.
3. J. A. Duncan, R. D. Parker and R. E. Pierce, "Telegraphy in the Bell System," A.I.E.E. Transactions, **63,** pp. 1032–1044, 1944.
4. B. Ostendorf, Jr., "New Electronic Telegraph Regenerative Repeater," *Elec. Eng.*, **69,** pp. 237–240, March, 1950.
5. R. L. Case, "Transmission Features of V3 Repeaters," *Bell Labs. Record*, **27,** pp. 94–95, March, 1949.