TYPE 47

VOICE-FREQUENCY

REPEATER

(with electronic amplification)

Bulletin 509

AUTOMATIC ELECTRIC

Originators and Developers of the Strowger Step-by-Step "Director" for Register-Translator-Sender Operation . . . Machine Switching Automatic Dial Systems

Makers of Telephone, Signaling and Communication Apparatus . . . Electrical Engineers, Designers and Consultants

Factory and General Offices: 1033 West Van Buren Street, Chicago 7, U.S.A.

Factory and General Offices of Automatic Electric Company, Chicago, U. S. A.

AUTOMATIC ELECTRIC COMPANY is an organization of designing, engineering, and manufacturing specialists in the fields of communication, electrical control and allied arts. For more than sixty years the company has been known throughout the world as the originator and parent manufacturer of the Strowger Automatic Telephone System. Today Strowger-type equipment serves over 75% of the world's automatic telephones. The same experience and technique that have grown out of the work of Automatic Electric engineers in the field of telephone communication are also being successfully applied on an ever-increasing scale to the solution of electrical control problems in business and industry.

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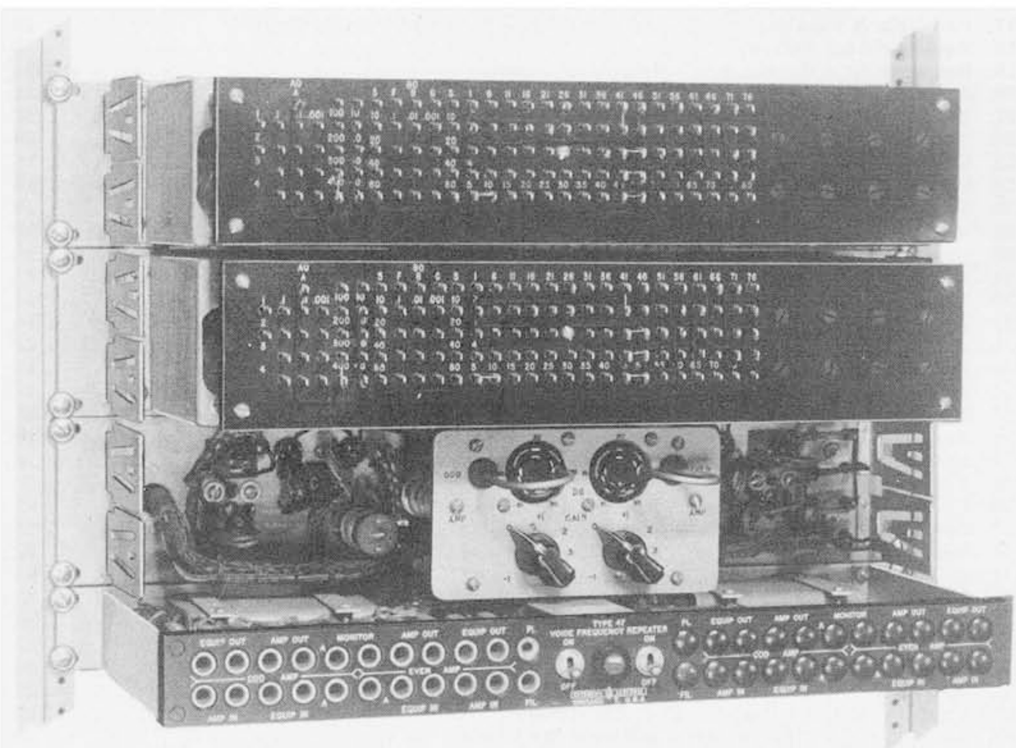


Fig. 1: Type 47 Two-Wire Intermediate Repeater

PART I

TYPE 47 VOICE FREQUENCY REPEATERS

1. INTRODUCTION

Automatic Electric Company's Type 47 voice frequency repeaters, which are assembled from standard, integral units, are designed to improve toll telephone service under widely varying field conditions - at terminals or intermediate points; on two-wire or four-wire circuits. This equipment also finds application on dispatch or trunk lines operated by railroads and pipe line companies, and provides facilities for accomplishing the by-passing, repeating and compositing of the various ringing and d-c signals employed by these industries. Type 47 voice frequency repeaters may be operated on circuits also carrying telegraph and carrier frequency channels.

In addition to amplifying voice frequency currents, Type 47 repeaters improve transmission by equalizing for frequency distortion and by eliminating excess noise. The repeater achieves the latter by confining the utilized voice frequency spectrum to values necessary only for effective voice communication.

The basic units from which different types of Type 47 repeaters are assembled are designated; amplifier unit, line and line balancing unit, four-wire line unit, two-wire terminating unit and jack panel unit. These mount on a standard 19'' rack. Connections to lines and external apparatus are made to rear terminal blocks. Connections between components mounted on each unit and adjustments within units (balancing, equalizing etc.) are made on jumper panels conveniently located on the fronts of the respective units. Directly calibrated gain controls appear at the front of the amplifier unit. Monitoring and testing of the repeaters are facilitated by the jack unit which carries the jack fields for two repeaters.

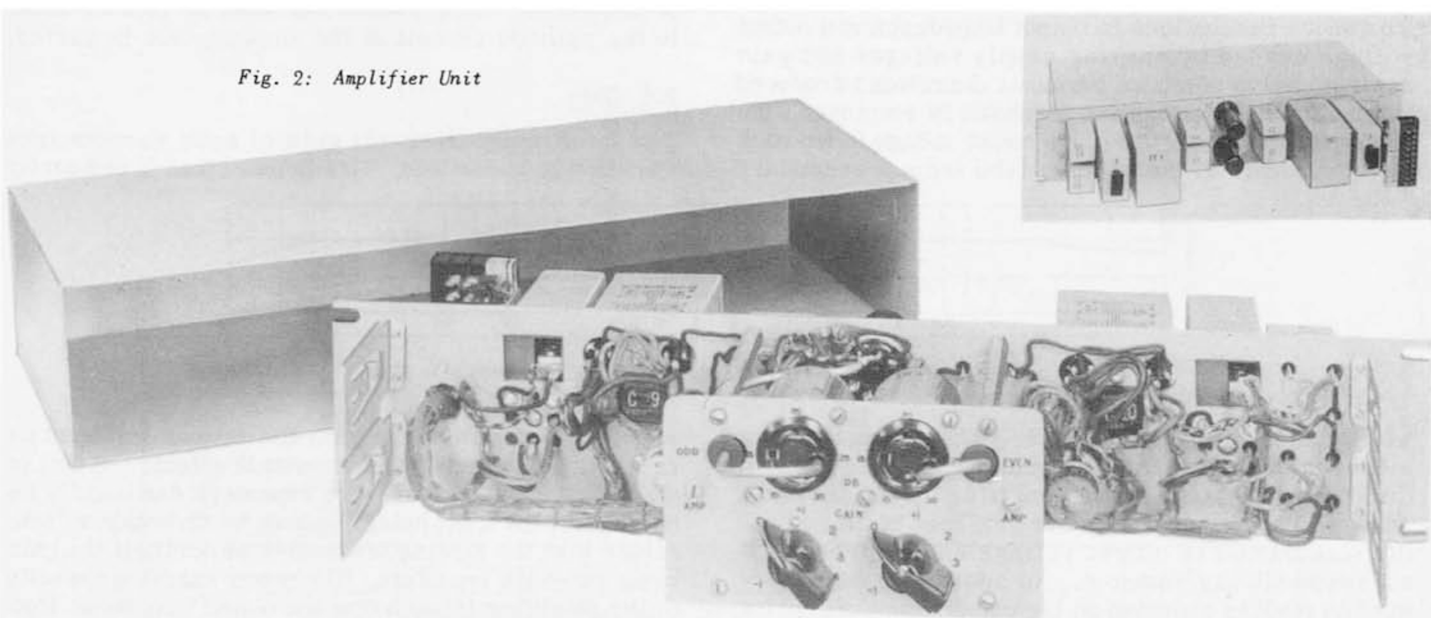
Power for the repeater may be obtained from the power supply unit operating from a 105-125 volt, 50-60 cycle source, or from exchange batteries. When provided, the power supply is contained in the jack panel unit and provides power, sufficient to operate two repeaters. For battery operation, the repeater requires 24 or 48 volts for the vacuum tube heaters and 130 volts for the plates.

The first part of this bulletin provides general information on Type 47 repeaters. Arrangements for signaling through and around repeaters are outlined in the second part. A testing and maintenance section suggests procedures for balancing, adjusting and testing.

2. THE AMPLIFIER UNIT

The basic unit, common to all Type 47 repeaters, is the amplifier unit. It occupies 3-1/2'' vertical rack space and consists of two identical vacuum tube amplifiers - each amplifies voice frequencies for one direction of transmission.

Fig. 2: Amplifier Unit



Gain adjustments for both amplifier sections are made from the front of the unit (Fig. 2). The terminal block at the rear of the unit facilitates interconnection between the amplifier unit and other associated apparatus of the repeater (power supply, line units, etc.). In the discussion following, the term "vacuum tube amplifier" or "amplifier" will indicate one amplifier of the amplifier unit.

2.1 Circuit

Each amplifier consists primarily of an input transformer, vacuum tube, alarm relay, potentiometer and output transformer (Fig. 3). Voice frequency voltages appearing in the primary of the input transformer are fed to the control grid of the vacuum tube from the tapped secondary. The amplified voltages developed across the impedance of the relay A windings in the plate circuit of the tube, pass through a condenser to the primary winding (1-2) of the output transformer, to ground. The amplified voice frequency currents then appear in the secondary (3-4) of the output transformer.

To reduce fluctuations in output impedance and output voltage caused by varying supply voltages and gain settings, and to minimize harmonic distortion introduced by the amplifier, negative feedback is employed. To accomplish this, a portion of the output voltage is fed back to the cathode of the vacuum tube from a secondary winding on the output transformer. Thus, when the input voltage is in the positive half-cycle, for example (Fig. 3), the cathode is also driven positive by the feedback voltage. The change in negative grid bias is limited and the fluctuation in output voltage and impedance is correspondingly reduced. An additional secondary winding (5-6) is provided on the output transformer for monitoring purposes.

2.2 Frequency Response

The frequency response of the amplifier is essentially flat, the characteristic dropping very slightly at the low and high ends as shown in figure 4.

2.3 Impedance - Input and Output

The impedance of the amplifier input and output is 600 ohms. To maintain this impedance throughout the range of voice frequencies, the input is made essentially non-reactive by placing resistors R1 and R2 across the primary winding of the input transformer as shown in Fig. 3.

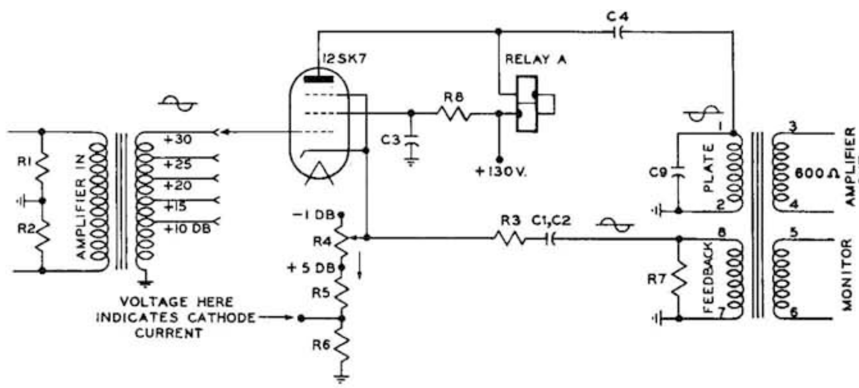


Fig. 3: Vacuum Tube Amplifier - Schematic

To reduce the reactance in the output impedance of the amplifier, a condenser (C9) is placed across the primary of the output transformer. Another resistor (R7) placed across the feedback winding helps to maintain the nominal output impedance at 600 ohms and tends to keep the impedance from varying with changes in frequency. This resistor, together with resistors R3, R5 and R6 also tends to keep constant the impedance reflected into the primary of the output transformer when the potentiometer in the cathode circuit of the vacuum tube is varied.

2.4 Gain

The maximum over-all gain of each vacuum tube amplifier is 35 decibels. This is more than is ordinarily required because of the gain limitations imposed on repeaters by singing and crosstalk effects. Gains of amplifiers used in four-wire repeaters can usually be set higher, the limit being imposed by crosstalk effects rather than the singing tendencies which limit the gain in the two-wire repeaters. The power carrying capacity of the amplifier is such that the output may be as high as +10 dbm.

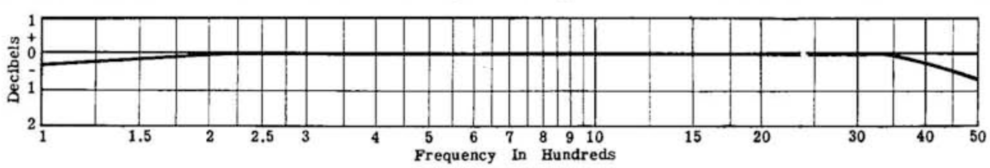


Fig. 4: Amplifier Frequency Response (Referred to 1000-Cycle Gain)

2.5 Gain Controls

Coarse gain control in five decibel steps is provided by five directly calibrated gain taps on the secondary of the input transformer. A gain variation from 10 to 30 decibels is obtained here. This coarse control is effected by placing a pin ended cord (from the vacuum tube grid) into one of five pinholes in a socket assembly (See Fig. 2). A potentiometer in the vacuum tube cathode circuit (Fig. 3) affords fine gain control over a 6-decibel range and may be used for making settings between the coarse gain steps. When the coarse control is at maximum (30 db) and the potentiometer is at full gain position (+5 db), the over-all amplifier gain is 35 decibels. When the potentiometer is adjusted so that more resistance is introduced between cathode and ground, the bias increases with a consequent reduction in gain. An increase in the feedback voltage also contributes to this decrease in gain. The feedback voltage is affected by the potentiometer setting because the used portion of the potentiometer is part of a divider (across the feedback winding) which includes resistors R3, R5 and R6. Harmonic distortion introduced by the amplifier, may be reduced by maintaining the potentiometer at a lower gain position. Potentiometer control knobs for both amplifiers appear on the same panel as the coarse controls. Gain adjustment procedures are described in Part III of this bulletin.

2.6 Alarm Relay

Normally operated relay A, in the vacuum tube plate circuit (Fig. 3) is the plate inductor and, in addition, serves as an alarm relay in case of tube or power supply failure. Should the vacuum tube plate current cease for any reason, the relay is de-energized, and through associated external equipment, sets off an alarm. Where the amplifier section is part of a two-wire repeater, the relay in addition to providing an alarm, de-energizes other relays (in other units of the repeater) which in turn, cut out and by-pass the defective amplifier unit so that communication can be maintained.

3. REPEATERS

Through the proper combination of the amplifier unit with line units or line and terminating units, repeaters for service at terminal or intermediate points are obtained.

Terminal repeaters are located in or close to exchanges, and are connected between the toll switchboard and the associated two or four-wire toll circuits (physical or phantom).

Intermediate repeaters are placed in two or four-wire toll lines at a distance from either of the associated terminals. Usually, they are located in repeater offices in exchanges which are conveniently located between the terminals of a given toll circuit. If such housing accommodations are not available, however, the repeaters may be housed in separate buildings specially intended for this purpose. The number of repeaters required on a circuit depends on the transmission losses of the circuit, commercial transmission requirements, etc.

4. TWO-WIRE INTERMEDIATE REPEATER

The following standard units comprise a two-wire intermediate repeater:

Quantity	Unit Designation
1	Amplifier unit
2	Line and line balancing unit
1	Jack panel unit (1/2 unit required per repeater) - with (optional) power supply

4.1 General Description

The relationship of standard units in a two-wire intermediate repeater is shown in figure 5. Equipment of an auxiliary nature such as the jack panel unit and power

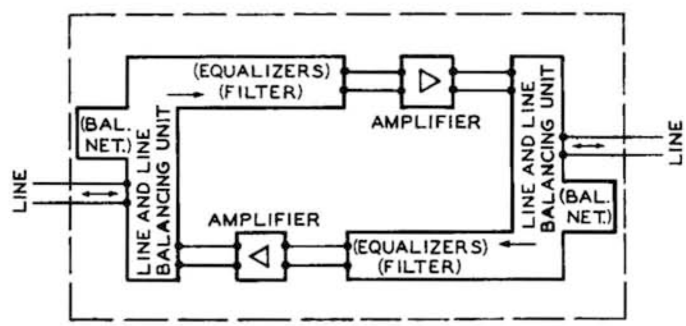


Fig. 5: Unit Relationship - Two-Wire Intermediate Repeater

supply, is not shown. Voice frequency signals originating from either end of the two-wire line enter the repeater through line and line balancing units and are directed to the amplifiers. The amplified voice currents pass out of the repeater to the line through the line and line balancing unit on the opposite side of the repeater. Figure A (Appendix) presents the schematic of a two-wire intermediate repeater.

Since each amplifier in the repeater is characteristically unidirectional and the same toll wires carry conversation in both directions, it is necessary to provide means for channeling the voice currents (according to direction) into separate paths so that they may be separately amplified. This separation of voice currents consists, in essence, of preventing the output of one amplifier from feeding back into the input of the other amplifier, thereby eliminating the formation of an oscillatory path subject to "singing". Establishment of separate voice paths, among other functions, is accomplished in the line and line balancing unit.

4.2 Line and Line Balancing Unit

The line and line balancing unit performs several functions related to associating the amplifiers with the toll line. These include: Matching the toll circuit impedance to the amplifier input impedance, separating the conversation paths, eliminating unwanted higher voice frequencies, compensating (equalizing) for unequal attenuation of the different voice frequency currents by the line, and providing signaling facilities.

The basic components of each line and line balancing unit (Figure 13) are:

(a) Repeating coil hybrid

(b) Balancing networks

(c) Low pass filter

(d) Equalizing networks

(e) Cut-out relay

The line and line balancing unit is also designed to carry apparatus (repeating coils, composite coils, retard coils, etc.) required for ringing and d-c signaling or for the balancing of certain signaling equipments (See Signaling, Part II).

A nominal loss is introduced by the line and line balancing unit which must be taken into consideration when amplifier working gains are set. The input insertion loss (without equalization) is 5-1/2 db; the output loss is 4 db. Input losses with equalization are listed in the equalization charts in the Appendix. The unit requires 3-1/2'' vertical rack space.

4.21 Repeating Coil Hybrid

The repeating coil hybrid along with its associated balancing networks, is that component of the line and line balancing unit whose function it is to match the toll line impedance to the amplifier input or output impedance and act as the "voice current separator" by preventing the output of one amplifier from reaching the input of the other. Figure A (Appendix) snows how the repeating coil hybrid appears in the circuit of a two-wire intermediate repeater. Note: The heavy, vertical broken lines on this schematic, set off the various units that comprise the repeater.

A repeating coil hybrid is arranged by connecting together two identical repeating coils of the type symbolically shown in figure 6. Note that the repeating coils have 6 windings. Functionally, however, the repeating coils may be considered as having 3 windings as the windings are employed in pairs. Impedance ratios are presented on this basis. As indicated in figure 6, there are four available types of repeating coils providing various impedance ratios. Amplifier windings 1-2 and 11-12 are designated as unity impedance as they are associated, in the repeater, with the fixed impedance (600 ohms) of the amplifier input and output (Figure A). In each repeating coil the windings designated "line" are identical to those designated "network." The impedance ratios given for these windings are the ratios of these windings to the amplifier windings. The repeating coils are stamped with the letters A, B, C, or D corresponding to the ratios shown.

Combining two identical repeating coils to form the hybrid arrangement (Figure 7) doubles the impedance ratio of the line windings (3-4, 5-6) and network windings (7-8, 9-10) to the amplifier windings. With four types of repeating coils available, a selection of four, line-to-amplifier impedance matching ratios is therefore provided (.6 to 1.0, 1.0 to 1.0, 1.69 to 1.0, 2.69 to 1). These line-to-amplifier impedance ratios provide a coverage which enables the repeater to match any toll line with a characteristic impedance lying between

IMPEDANCE RATIOS — COIL D-283686-A	D-283686-B	D-283686-C	D-283686-D	Windings	D-C RESISTANCES (OHMS) — COIL D-283686-A	D-283686-B	D-283686-C	D-283686-D
1	1	1	1	AMPLIFIER WINDINGS 1–2	15	15	14	13
				AMPLIFIER WINDINGS 12–11	15	15	14	13
0.3	0.5	0.845	1.345	NETWORK WINDINGS 10–9	5.8	9	18	27
				NETWORK WINDINGS 7–8	5.8	9	18	27
0.3	0.5	0.845	1.345	LINE WINDINGS 6–5	5.8	9	18	27
				LINE WINDINGS 3–4	5.8	9	18	27

Fig. 6: Standard Repeating Coils

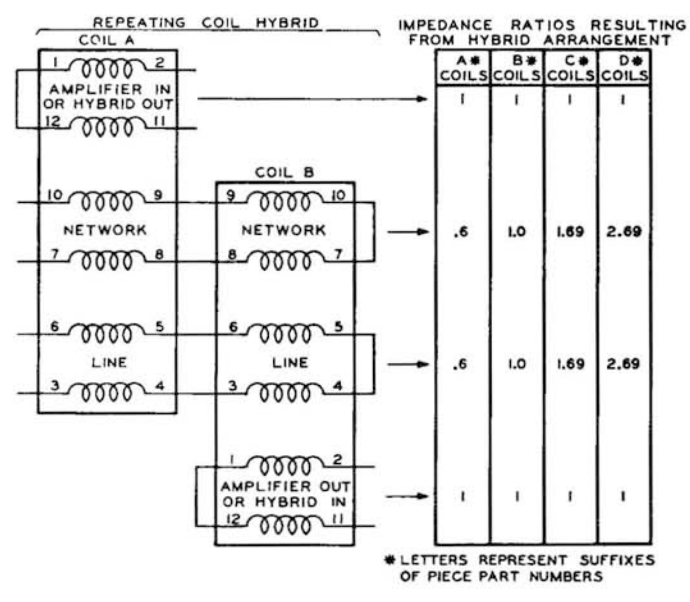


Fig. 7: Repeating Coils in Hybrid Arrangement

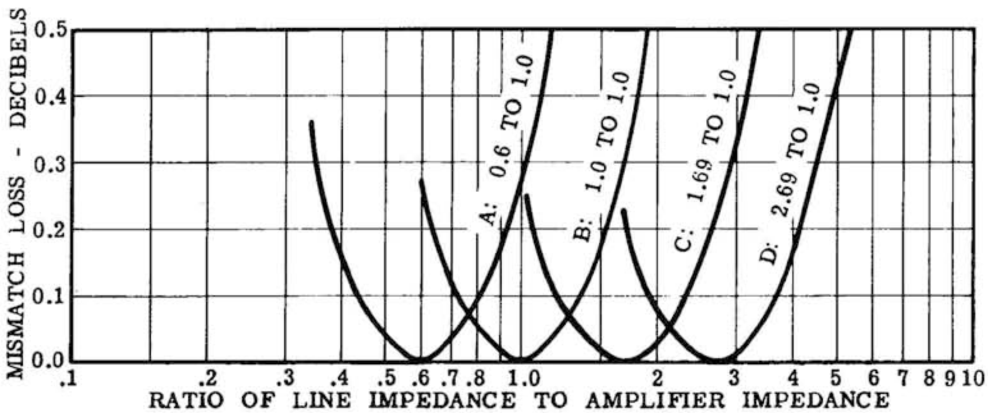


Fig. 8: Mismatch Loss of Standard Repeating Coil Hybrids

260 to 2160 ohms with not more than a .1 decibel mismatch loss (Figure 8). Tables I, II and III in the Appendix, list the proper repeating coils to be used for matching the repeater to various kinds of toil lines.

When two repeating coils are connected in a hybrid arrangement, the line-windings of both coils are connected in series aiding. The network-windings, however, are connected so that the windings of one repeating coil oppose the windings of the other coil (the odd numbered terminals are of the same polarity). The toll line is connected to terminals 6 and 3 of the line-windings on repeating coil A of the hybrid. Terminals 2 and 11 of coil A (henceforth called "hybrid-out" windings) are connected to the input of one amplifier while terminals 2 and 11 of coil B (henceforth called "hybrid-in" windings) are connected to the output of the other amplifier. This arrangement is duplicated on both sides of a two-wire intermediate repeater (Figure A). The designations, "Coil A" and "Coil B" shown above the hybrid in figure 7, serve to distinguish one coil of the hybrid from the other and are not to be confused with the piece part suffixes (A, B, C, D) of the individual coils which actually comprise the hybrid.

The action of the hybrid in establishing separate conversation paths for each direction of transmission is demonstrated in figures 9 and 10.

Figure 9 demonstrates the action of the hybrid when voice currents are emanating from the toll line. This action is shown at an instant when the alternating voice current (in one-half of a cycle) is traveling in the direction indicated. The line-windings (6-5, 4-3) in both coils are in series aiding and act as primary windings since they are carrying the incoming voice currents. Currents flowing in the opposite direction (Lenz's Law) are induced into both pairs of network-windings (7-8, 9-10) and into the hybrid-in and hybrid-out windings. The current induced into the hybrid-in windings of coil B, is dissipated in the output circuit of the "even" amplifier. Current induced into the hybrid-out windings of coil A is fed to the input of the "odd" amplifier and thereafter repeated. Because the network-windings (7-8, 9-10) of both coils are connected to oppose, currents induced in them by the line (primary) windings, tend to flow in opposite directions with the result that no current flows in the network circuit.

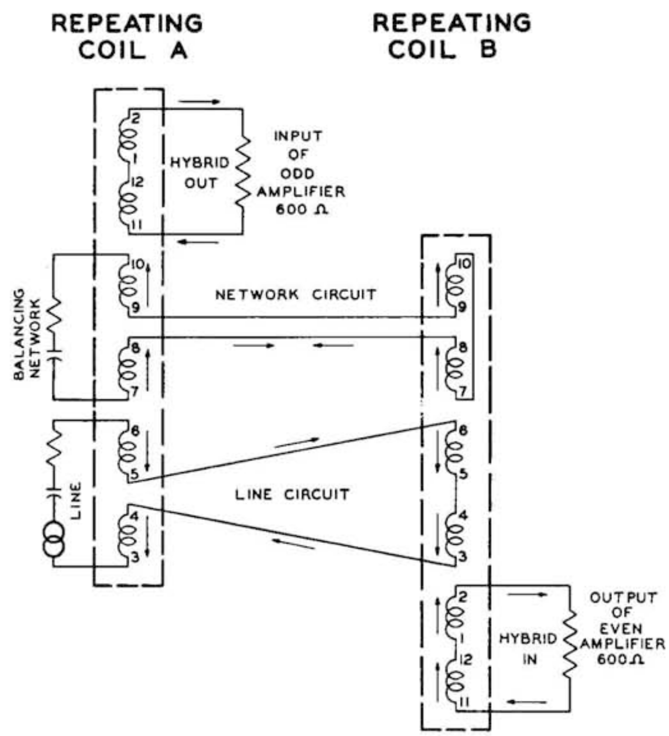


Fig. 9: Current Relationships in the Hybrid (Current Entering from Line)

Figure 10 explains the "separating" action of the hybrid when voice currents from the output of the even amplifier appear in the hybrid-in windings of coil B. The hybrid-in windings in this case appear electrically as the primary windings and induce currents into the line-windings (3-4, 5-6) and network-windings (7-8, 9-10) of coil B.

These induced currents flow in an opposite direction to that of the current in the hybrid-in windings. Current induced into the line-windings of coil B flows through the line-windings of coil A. Current induced into the network-windings of coil B flows through the network-windings of coil A. As the network-windings of the coils are connected in opposition, current in the network-windings of coil A, flows in an opposite direction to the current in the line-windings of coil A. If the currents are equal, the magnetizing forces created by each of these currents, cancel out and no voice currents appear in the hybrid-out windings of coil A or consequently in the odd amplifier input. The output of one amplifier is thus prevented from feeding back into the input of the other amplifier while a portion of the amplified voice currents are permitted to enter the toll line.

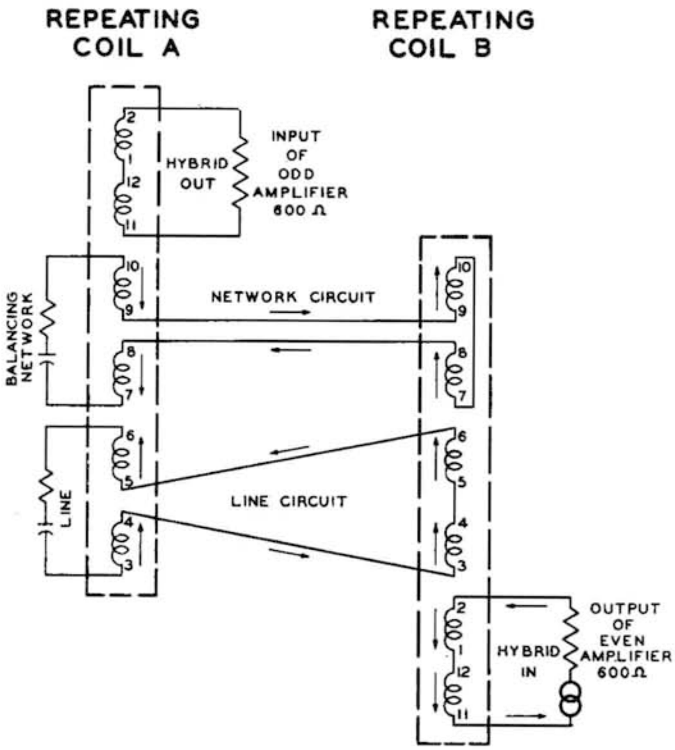


Fig. 10: Current Relationships in the Hybrid (Current Entering from Amplifier)

The extent to which feedback is prevented, is consequently determined by the degree of equality between the currents in the network-windings and the line-windings of the hybrid. This arrangement requires that the network-windings and line-windings of the same repeating coil, be balanced to a high degree, but does not require the matching of the two coils comprising the hybrid. Thus, while the repeating coils are wound with a high degree of precision, it is necessary that the characteristic impedance of the toll circuit associated with the line-windings, be duplicated with an electrically similar "artificial line" associated with the network-windings so that the currents through the network-windings can be made to equal the currents through the line windings. The degree of balance between this artificial line and the actual line, is the most important single factor relating to the amount of gain that may be introduced into the toll circuit without causing singing.

<u>4.211 Balancing Equipment</u> - To properly balance the network circuit against the toll circuit, every electrical component found in the toll circuit (the toll line, entrance cable, composite sets, carrier filters etc.) must be simulated electrically in the balancing network. These balancing components are arranged in the network circuit in the same order as they appear on the line (Fig. 11).

The electrical equivalent of a toll line (cable or open wire) and entrance cable, can be represented by networks of resistors and condensers. Adjustable networks for this purpose are standard equipment in the line and line balancing unit and provide a highly satisfactory balance. Adjustments are made by selecting desired values of resistance and capacitance from the adjustable networks

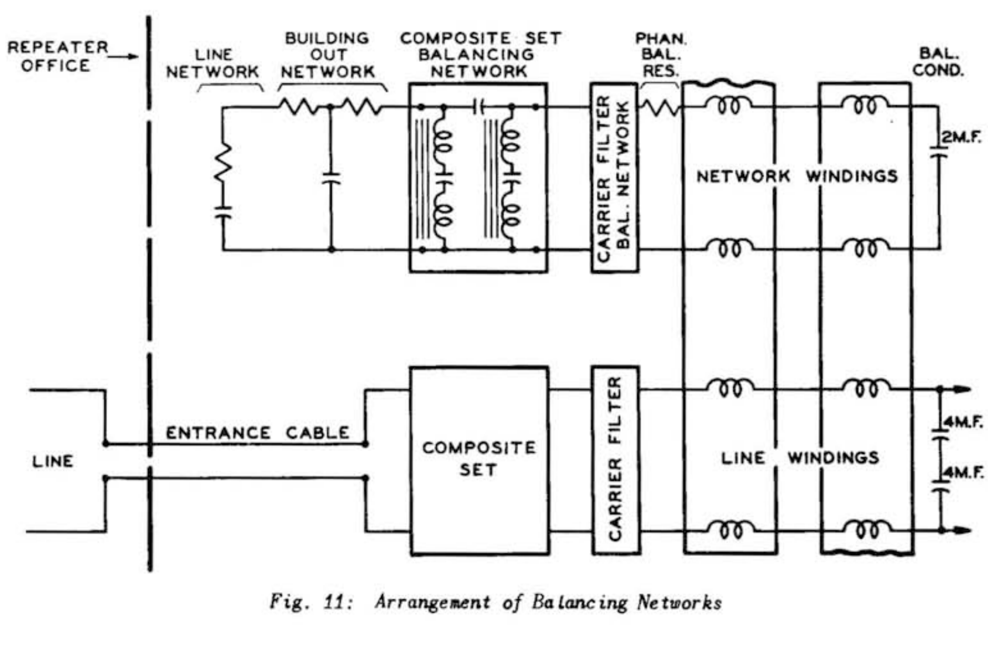


Fig. 11: Arrangement of Balancing Networks

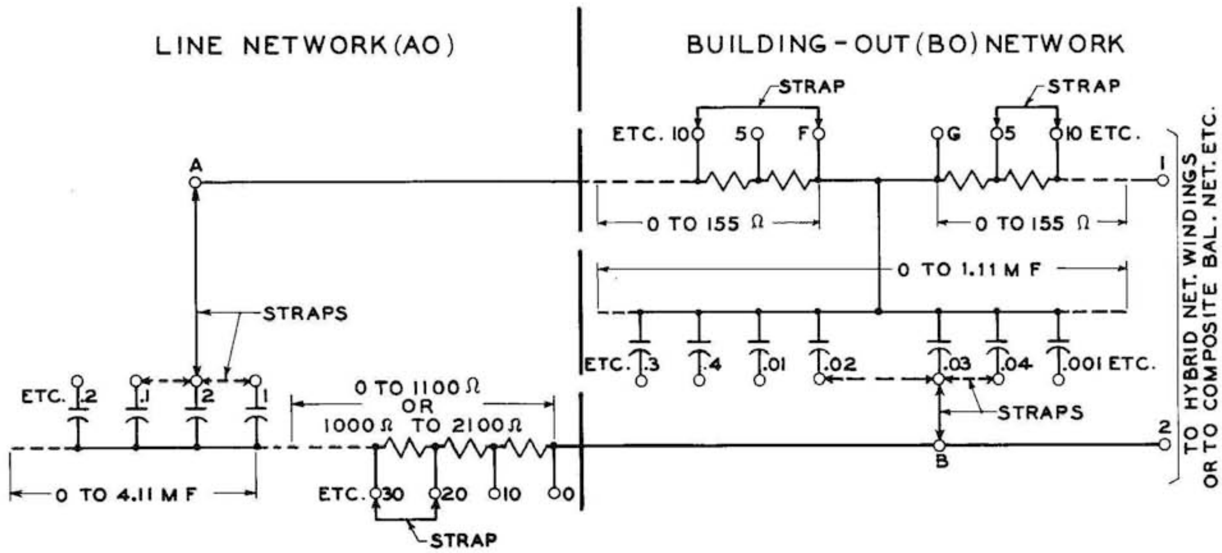


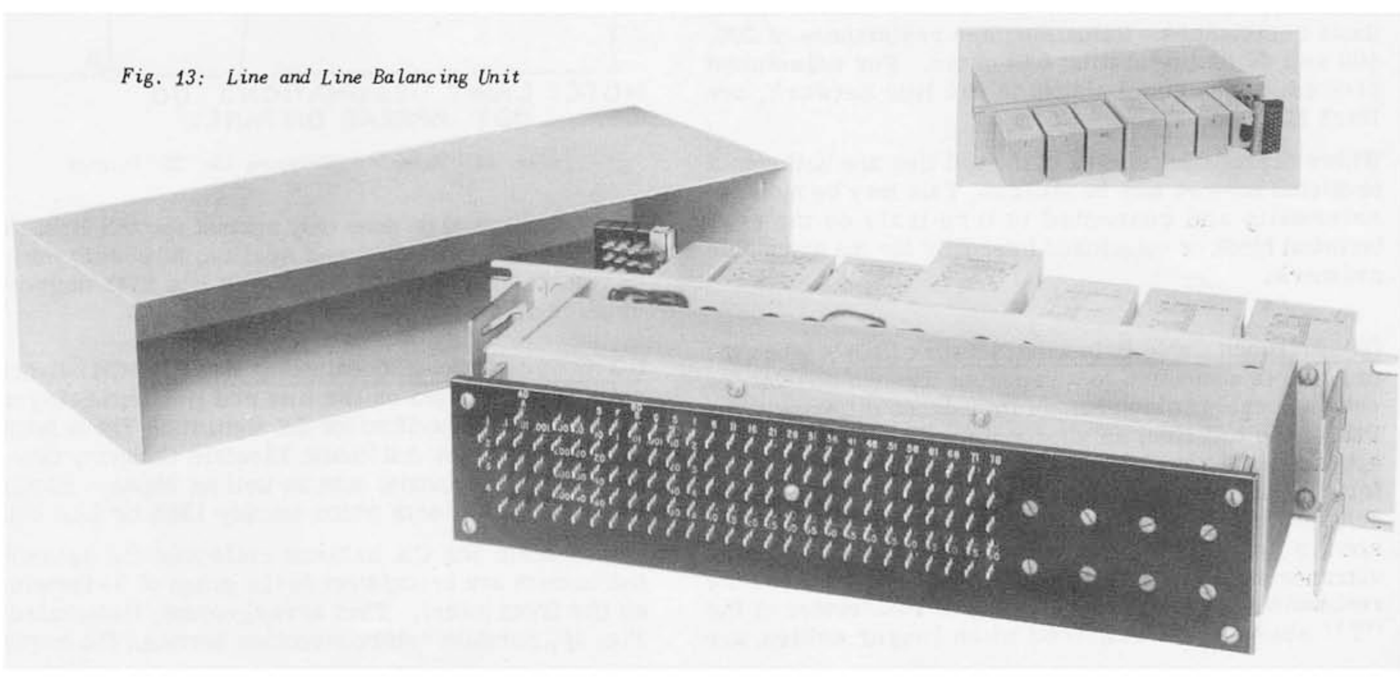
Fig. 12: Line (AO) and Entrance Cable (BO) Balancing Networks

and inserting these in the network circuit of the hybrid. This is done by strapping together, terminals on the front panel of the line and line balancing unit (See Fig. 13). Composite balancing coils mounted on the line unit are also placed in the network circuit by means of terminals on this panel. External networks, when required, are connected to the rear terminal block and are connected into the balancing network through terminals on the front panel.

The strapping panel of the line and line balancing unit may be considered as consisting of three groups of terminals. The line balancing group (designated "AO") on the left side of the panel (Fig. 13) consists of six vertical rows of terminals which are identified to correspond with the values of capacitance and resistance in the associated network. The entrance cable balancing group (BO) consisting of five vertical rows of terminals, is also marked with the values of the balancing elements. The terminals of the third group are consecutively numbered from 1 to 80. Equalizing, composite balancing, side-circuit balancing (in phantom repeaters) and condenser balancing adjustments are made in this group. Also, access to various components mounted on the line unit (repeating coils, retard coils etc.) is obtained in this group thereby permitting interconnection for signaling purposes etc. Details of the various networks follow. For line balancing procedure see Part III.

(A) Line Balance Network (AO) - The characteristic impedance of the toll line is balanced by means of the line network shown schematically in figure 12. This network permits adjustments in capacity from 0 to 4.11 mf in steps of .001 mf. Capacitance is increased by

Fig. 13: Line and Line Balancing Unit



connecting additional capacitor terminals representing the desired values, to terminal A. Resistance may be increased from 0 to 1100 ohms in steps of 10 ohms. The value of resistance is decreased by shorting out the undesirable values.

Figure 14 illustrates the method of strapping the line balancing network. Note that condenser values (where marked) appear above the associated terminals. Resistor

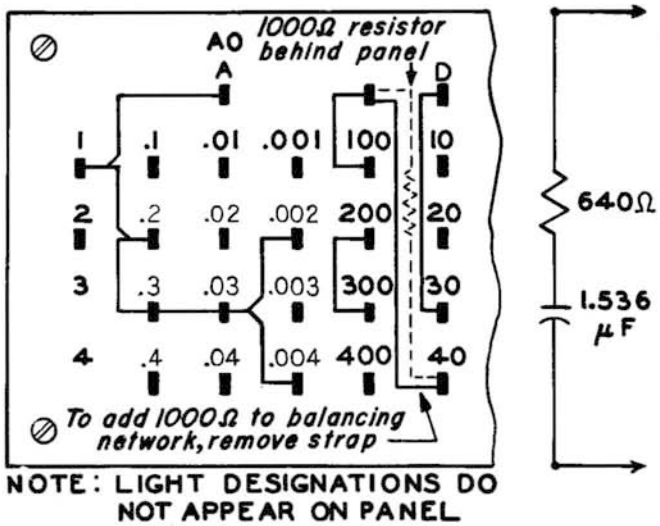


Fig. 14: Example - Strapping the 'AO' Network

values appear between the terminals to which the resistors are connected. To obtain the capacity of 1.536 mf as illustrated, condenser terminals 1, .2, .3, .03, .002 and .004 (adding to 1.536) are strapped to terminal A. The resistance of 640 ohms is obtained by shorting out resistances so that the value of the remaining resistances total 640. Thus, the strap connected around designations 10, 20 and 30 shorts out these resistances. The strapping around the designations 100 and 300 shorts these resistances. Remaining are resistances of 200, 400 and 40 ohms totaling 640 ohms. For adjustment procedures when balancing the line network, see Part III, Sec. 2.1.

Where the characteristics of the toll line are uniform, a precision network may be utilized. This may be mounted externally and connected to terminals on the rear terminal block or substituted internally for the adjustable network.

<u>(B) Entrance Cable Balancing Network (BO)</u> - When the toll line is connected to a repeater through non-loaded entrance cable (which has an impedance differing from that of the toll line) an appropriate network must also appear in the network circuit. The adjustable network for this purpose, Building-Out Network (BO), shown schematically in figure 12, provides the "T" section seen in figure 11. For comparatively short lengths of entrance cable only the BO capacity is required and the resistances may be shorted out. The resistances of the "T" section are required when longer cables are encountered. While the grade of balance required is a determinant, these resistances are ordinarily inserted when the resistance of the cable exceeds 20 ohms.

Figure 15 illustrates the method of strapping the building-out network. For example, if two miles of 19 gauge non-loaded cable comprise the entrance facilities, then 170 ohms (85 ohms loop resistance per mile) and .124 mf (.062 mf per mile) will be required in this network. Resistance groups F and G are each made to equal 1/2 the resistance of the cable (1/2 x 170) while the condenser is adjusted to equal the total capacity of the cable. Resistances 10, 20 and 40 are shorted out in both the F and G resistor groups as shown. Remaining in each group are 80 ohms and 5 ohms totaling 85 ohms. (The 5-ohm resistors are located between the terminals "F" and "5" and "G" and "5" as shown in figure 12.) Condenser terminals .1, .02 and .004 totaling .124 mf are connected to terminal B.

A building-out network is not ordinarily required when a loaded entrance cable connects the toll line to the repeater. The impedance of the loaded cable is usually made to approximate that of the line and it appears electrically as an integral part of the line. Balancing

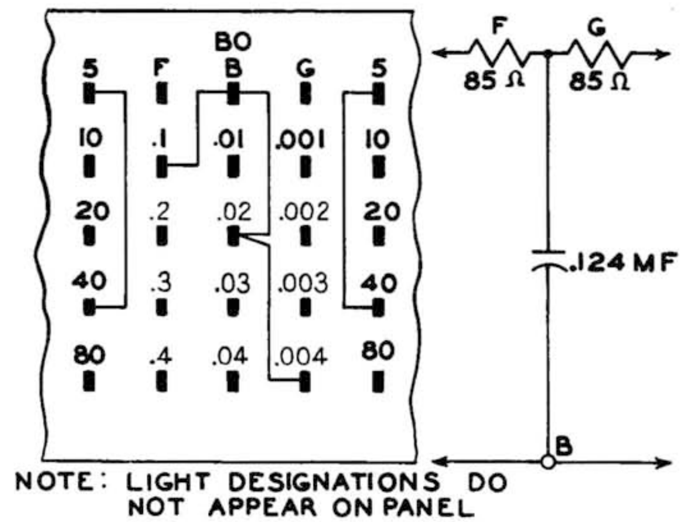


Fig. 15: Example - Strapping the 'BO' Network

in this case need be done only against the toll line. The capacity of the loading end section, however, may be balanced with the BO capacitors if a high degree of balance is required.

<u>(C) Composite Set (CX) Balancing Network</u> - CX balancing coils are provided on the line and line balancing unit assembly when specified for CX signaling. The balancing coils will balance Automatic Electric Company type 51 (heavy duty) composite sets as well as Western Electric Company type C sets which employ 158A or 5AA coils.

Leads from the CX balance coils and CX balancing condensers are brought out to the group of 80 terminals on the front panel. This arrangement, illustrated in Fig. 16, permits interconnection between the various

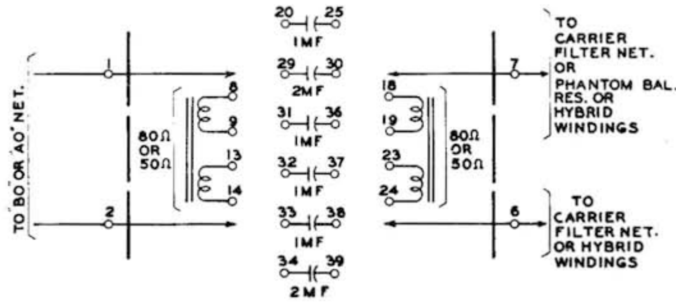


Fig. 16: Composite Set Balancing Network

components of the network to be made as dictated by the composite signaling arrangement on the line (See Part II Signaling). Eighty-ohm (80Ω) balancing coils are used in side-circuit balancing networks for balancing composite sets in the side-circuits. They are also employed in the phantom-circuit balancing network for balancing composite sets in the phantom circuits. Fifty-ohm (50Ω) balancing coils are used in the phantom balancing network when the side-circuits are composited.

No balancing is required for Automatic Electric type 52 composite sets except in the phantom network when the side-circuits are composited (See Part II Signaling, Sec. 5.1). Where type 52 sets are employed in the side-circuits, the proper balancing coils (retard coils employed in both the type 52 composite set and low frequency by-pass circuit) are connected into the phantom network. These coils, whether for balancing or compositing, are used in conjunction with the condenser bank shown in figure 16. When required, the coils mount on the line and line balancing unit.

(D) Carrier Equipment Balancing - When a two-wire line is used simultaneously for carrier as well as voice frequency transmission, carrier filters appearing at either side of the repeater must be balanced in the balancing networks. When required, the filter balancing network is connected externally to the rear terminal block.

(E) Balancing Condensers - If condensers are placed across the line-windings of the repeater for signaling purposes (See Part II) an equivalent capacity must appear in the network circuit of that repeater (Fig. 11). Thus, a 2-mf condenser is required in the network circuit of the repeater to balance the equivalent series capacity of the two, 4-mf condensers across the line windings.

(F) Phantom Balancing Resistance and Condenser - See Section 4.27 (A).

(G) Balancing Auto-Transformers, Etc. - When impedance matching transformers (usually auto-transformers) are associated with non-loaded entrance cable for the purpose of improving carrier frequency transmission, they must also be inserted at appropriate positions in the balancing network provided that voice frequencies as well as carrier frequencies are required to pass through them.

4.22 Low Pass Filter

Filters are provided in the line and line balancing unit for limiting the range of frequencies passed by the repeater. This is desirable because line balancing becomes more difficult at the higher voice frequencies and in addition, intelligible, commercially satisfying conversation is obtainable below 3000 c.p.s. The inherent tendency of the repeating coil hybrid to attenuate frequencies below 100 c.p.s. sets the low limit of the repeater. Thus, the repeater will amplify 135-cycle ringing signals but will greatly attenuate 20-cycle signals. (Arrangements are provided, however, for by-passing very low frequency signals: See Signaling, Part II.)

The low pass filters appear in the circuit between the hybrid-out windings of the repeating coil hybrid and the amplifier input (Fig. A) and are available in three cut-off frequencies: Type A, 3500 c.p.s.; Type B, 2850 c.p.s.; Type C, 2450 c.p.s. Tables I, II, and III in the Appendix, list the low pass filters to be used with various toll lines.

4.23 (Equalization and Equalizers)

Because telephone lines attenuate the higher frequency voice currents more than the lower frequencies, it is sometimes necessary to provide compensation or equalization at the repeater before amplifying the voice. The effect of this equalization is to attenuate the lower frequencies, thereby modifying the repeater's overall response. That is, for the frequencies where the line loss is high, the repeater gain is also high. This compensates for the inequalities of the line attenuation and results in a substantially uniform frequency-attenuation characteristic on the repeatered toll section involved.

Figure 17 illustrates the equalizing principle. Curve 1 is the frequency characteristic (relative level referred to 1000 cycles) of a 45-mile section of 19-H44 cable. From an examination of this curve it is evident that the higher frequencies are attenuated more than the lower frequencies. Curve 2 indicates what can be considered as a desirable characteristic for the entire 45-mile section. It can be seen that the desired characteristic for the section is flat from 300 to approximately 2600 cycles with frequencies over 3500 cycles and under 300 cycles being sharply attenuated. Curve 3 indicates the response required from the repeater in order to compensate for curve 1 and establish curve 2 as the resulting characteristic for the entire section. Frequencies over 3500 cycles (the desired cut-off in this example) are sharply attenuated by the repeater's low pass filter. The repeater also has an inherent tendency to amplify to a lesser degree, the frequencies below 300 cycles. (Generally, the range from 300 to 3000 cycles is equalized. It may be advantageous, however, to extend equalization down to 135 cycles, for example, in order to increase the repeater's response at these frequencies for the repeating of 135-cycle signals.)

Where highly accurate equalization is required, however, the frequency characteristic of the circuit, must first be precisely determined. To accomplish this, it is necessary to have a variable frequency oscillator which can produce frequencies of 250 to 3500 cycles, plus a suitable transmission measuring set for measuring the line attenuation throughout this range.

Condensers, resistors, inductors or combinations thereof, used for equalizing, are designated "equalizers" and appear in that part of the repeater circuit which precedes the amplifier. These are part of the line units and are placed in the circuit as needed by means of the strapping terminals on the front panels of these units.

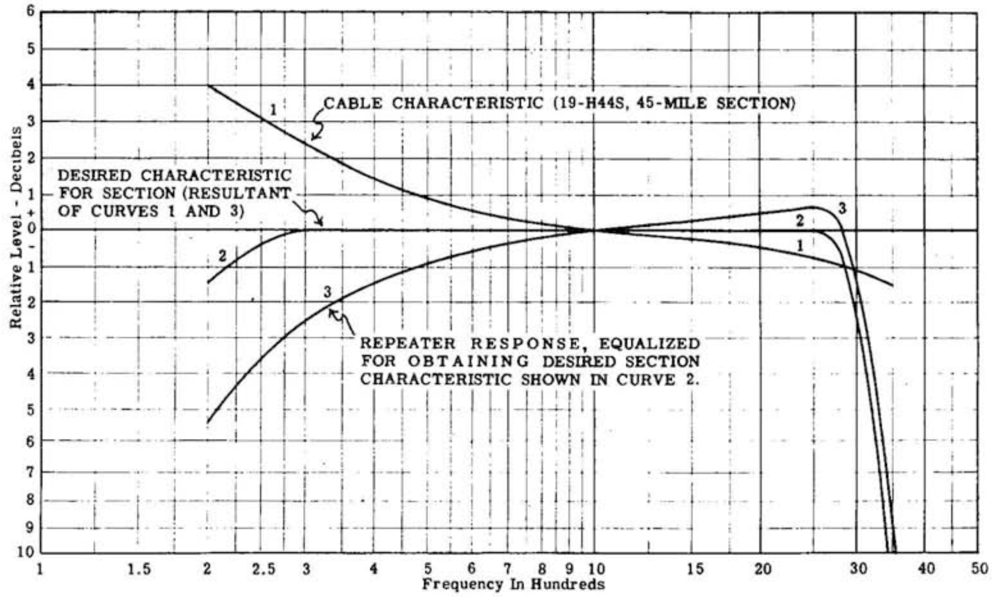


Fig. 17: Principle of Equalization (Relative Level Referred to 1000-Cycle Gain)

The sets of curves shown in section 4.24 below (and in section 6.23 - Four-Wire Equalization) provide illustrations of how the repeater's response is modified with various degrees of equalization. The frequency characteristic of the toll circuit under consideration can be roughly estimated from a study of the physical toll facilities. Equalizer values can then be selected to modify the repeater's response and thereby compensate for the characteristic of the toll section involved.

Tables listing equalizer values for various two and four-wire circuits will be found in the Appendix of this bulletin. Strapping information for inserting desired equalizer values into the repeater circuit is available on A.E.Co. blueprints.

4.24 Two-Wire Equalization

Figure 18 illustrates possible equalization arrangements for two-wire repeaters. For changing the frequency characteristic of the repeater below 1000 cycles (low-frequency equalization), a condenser (Ca) is placed in

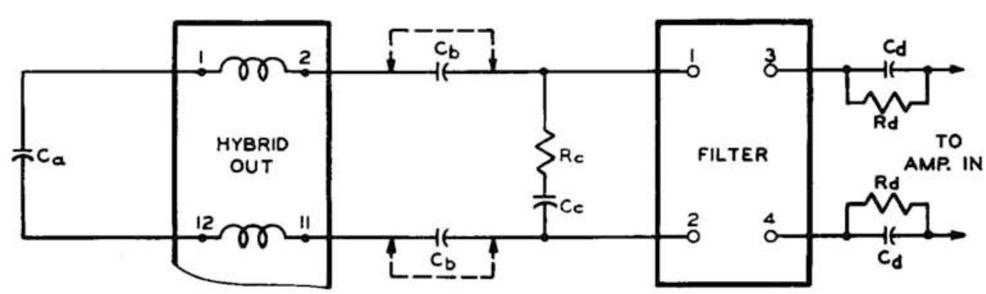


Fig. 18: Equalizers for Two-Wire Repeater

series with the hybrid-out windings. By increasing or decreasing the value of this capacitor, the low-frequency portion of the repeater's frequency response curve may be respectively raised or lowered as shown by the graphs in figure 19. (With reduced low-frequency response, less interference - clicks and thumps - is likely to occur from d-c signaling apparatus associated with the repeatered line.) Some high-frequency equalization results, however, when Ca is reduced to certain values. This effect may be observed at the high ends of curves 3 and 4 where an increase in response occurs as the capacity of Ca is diminished.

Where 135-cycle signaling is employed condenser Ca is replaced by two condensers (Cb - Fig. 18) having a combined series capacity equivalent to Ca. These condensers act as a low frequency blocking circuit for the 135-cycle half-ringer which is bridged across them as explained in Part II, 135-Cycle Signaling.

The series combination of resistance Rc and condenser Cc, placed across the input to the low pass filter, increases the repeater's response below 1000 cycles as illustrated by curve 5 in figure 19. The low-frequency portion of the response curve will rise still further as the value of Rc is decreased. The combination of Rc and Cc, or Rc alone, across the input to the low pass filter produces a slight rise in response at frequencies closely preceding the filter cut-off frequency as observed on the high end of curve 5. Thus, some degree of high frequency equalization may be realized through the use of Rc, or Rc and Cc in combination.

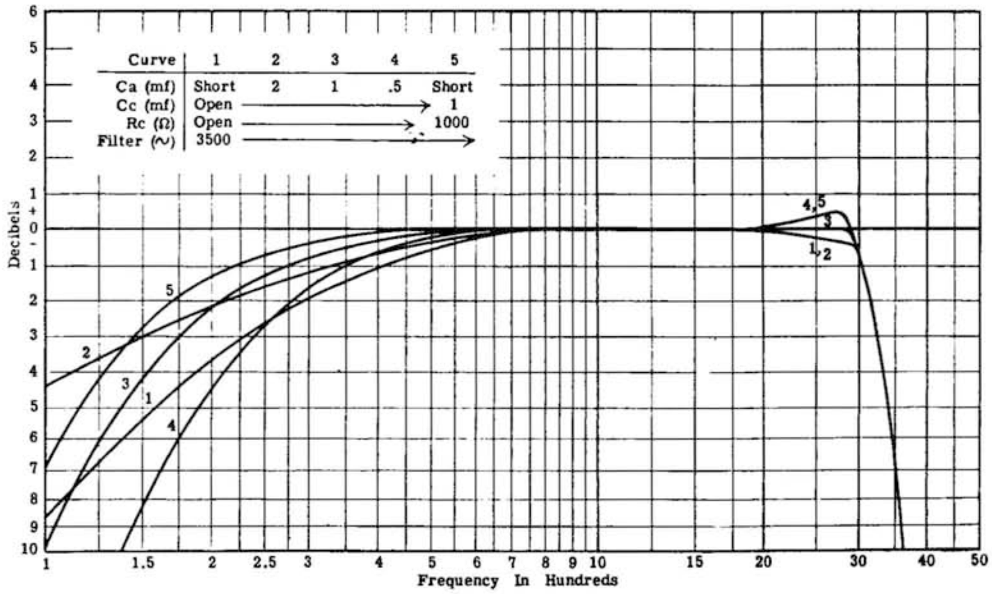


Fig. 19: Response With Equalization - Two-Wire Repeater

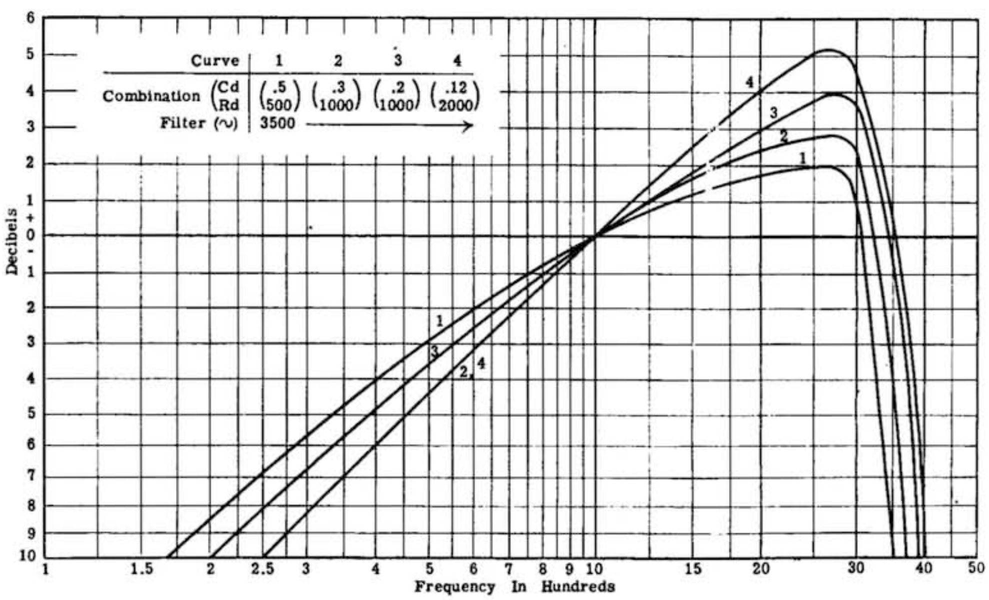


Fig. 20: Response With Equalization - Two-Wire Repeater

Condensers Cd in combination with resistors Rd provide both high and low-frequency equalization and are placed between the filter and the amplifier input. The values of capacitance and resistance comprising these combinations are permanently fixed so that resistance Rd, for example, cannot be adjusted independently of the condenser with which it is associated. As indicated by the graphs in figure 20, inserting these capacitance-resistance combinations causes the low portion of the characteristic to fall while the high end rises. Inserting combinations which employ smaller capacitances causes the frequency characteristic to rise more sharply at the high end, while the low end tends to fall. However, because the impedance-frequency characteristic of the condenser is affected by the resistance across it, the degree of fall with changes of capacitance is not uniform. Thus, the low end of curve 3 (Fig. 20) has not fallen as far as that of curve 2 even though the capacity employed for curve 3 is smaller.

Combinations of equalizers may also be employed to achieve varied equalization effects as shown in figure 21. The high-frequency cut-off point is always determined by the type of filter placed in the amplifier input circuit. Recommended equalizer constants for equalization on standard types of toll circuits are presented in the Appendix, tables IV, V, and VI.

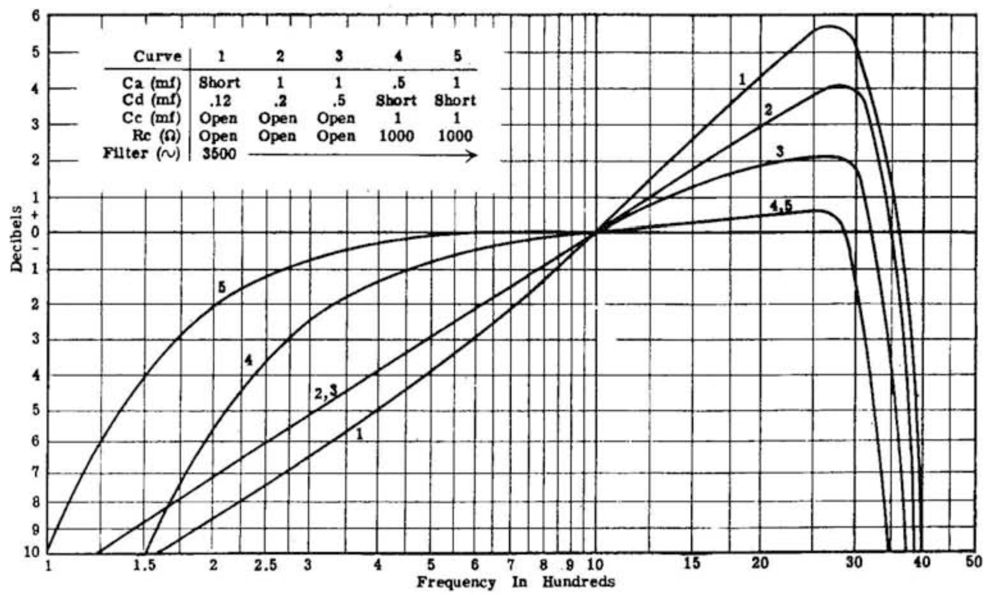


Fig. 21: Response With Equalization - Two-Wire Repeater

4.25 Regulating Networks (External)

The extent to which a toll line attenuates voice frequency signals and thereby affects transmission may vary periodically with temperature and other climatic conditions. Sometimes, to compensate for these changes without disturbing the gain settings of the amplifiers, regulating networks are switched in or out of the transmission circuit as conditions warrant. Terminals are provided on the terminal block of the line and line balancing unit between which the external regulating networks are connected. If utilized, the networks appear in the repeater circuit between the equalizers (Rc-Cc, Fig. 18) and the low-pass filter. Switching of the networks may be performed manually or automatically.

4.26 Cut-Out Relay

A cut-out relay is provided in each line and line balancing unit (Fig. A). While the repeater is in operation, the cut-out relays of the line units (in series with an external alarm relay) are energized so that voice frequency currents pass from the repeating coil hybrids to the amplifiers and vice versa.

Should one of the vacuum tube amplifiers fail or plate current cease for any other reason, the alarm relay in the plate circuit of the vacuum tube will release and remove ground from the cut-out circuit. This causes the cut-out relays in the line units to release, thereby removing both amplifiers from the repeater circuit, thus permitting voice currents to pass directly from hybrid to hybrid. The conversation is therefore maintained but at a lower level. When cut-out occurs, the external alarm relay, in series with the cut-out relays, releases and sets off an alarm. The external alarm relay is not part of the repeater equipment but may be furnished separately.

4.27 Phantom Arrangements

Arrangements for repeating a phantom circuit at an intermediate point are shown in figure 22. The phantom circuit is derived from the electrical mid-points of the line-windings of each hybrid in the side-circuit repeaters. These connections are made at the rear terminal blocks of the line and line balancing units of each repeater. The condensers across the line-windings in the side-circuits are not required when low-frequency signaling facilities are not employed.

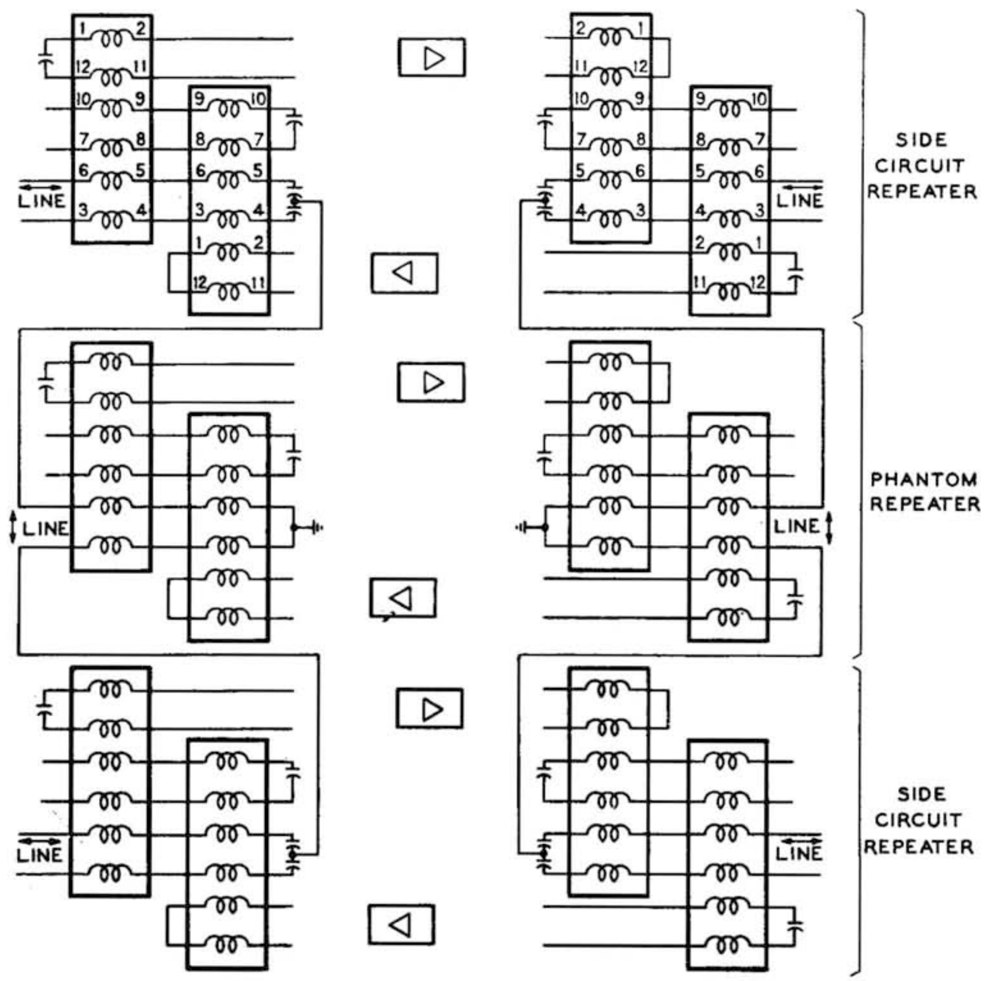


Fig. 22: Two-Wire Phantom Arrangements at Intermediate Points

The repeating coils for the phantom hybrid should be selected so that the hybrid matches the impedance of the phantom line as closely as possible (See Sec. 4.21 and Figs. 7 and 8). The phantom repeater will ordinarily require hybrids with lower impedance ratios than those used in the associated side-circuit repeaters. Tables I and II in the Appendix list the proper repeating coils to be used for matching the repeater to various phantom circuits.

(A) Balancing The Phantom Network - The network of the phantom repeater, in addition to balancing the phantom line, must also balance the effective d-c resistance of the side-circuit line-windings since these line-windings appear on the phantom line as non-inductive resistances. The balancing resistance for this purpose is seen in figure 11 (Phantom Balancing Resistance). The values required are as follows:

Hybrid Rept. Coils In Sides	Res. In Phantom
B	18
C	36
D	54

If condensers are placed across the line-windings of the side-circuit repeaters (for signaling purposes) the equivalent effective capacitance (4 mf) must appear in the network circuit of the phantom repeater. Another capacity (2 mf) is also required in the phantom network if low-frequency signaling is employed in the phantom circuit (Sec. 4.211E). Phantom balancing resistors and condensers are strapped in as required at the group of 80 terminals on the front panel of the line and line balancing unit.

(B) Split Phantom Group - At an intermediate point, an arrangement is possible where the phantom circuit and one side-circuit may be repeated but where one side-circuit is dropped off or frogged. In order to maintain the proper balance between both side-circuits in this instance, the non-repeatered side utilizes repeating coils identical to those used in a hybrid set, but which are interconnected to serve primarily as single repeating coils (Fig. 23). The line-to-drop impedance ratios (shown below) resulting from this arrangement, are somewhat higher than the corresponding line-to-amplifier ratios obtained in the hybrid. These line-to-drop impedance ratios are as follows:

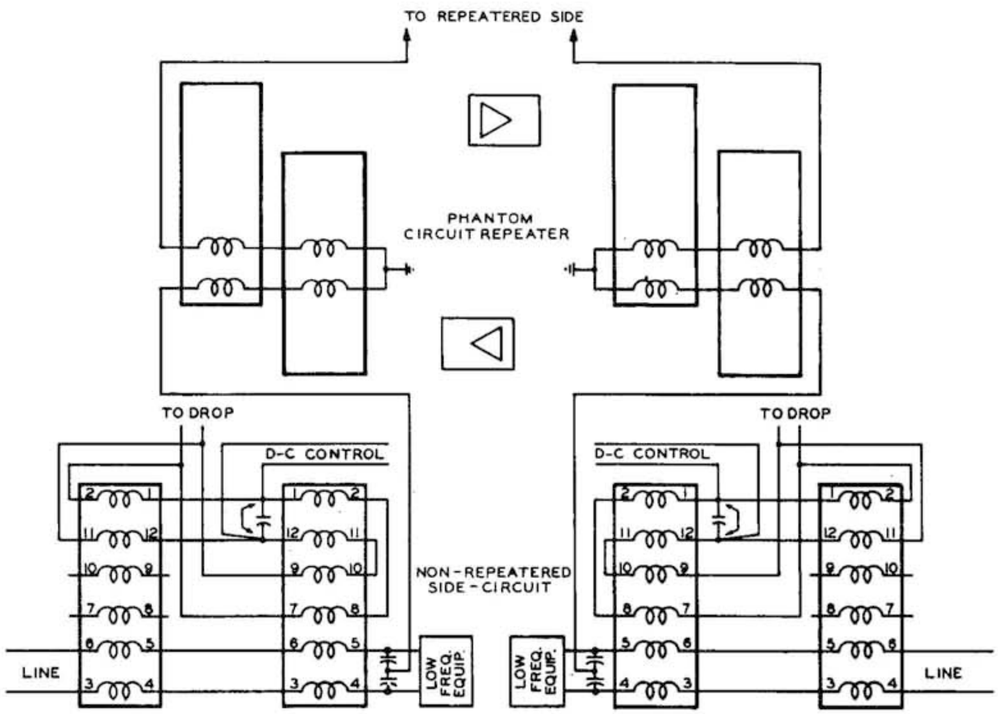


Fig. 23: Two-Wire Split Phantom Group

Coil	Line	Drop
A	.81	1
B	1.26	1
C	1.95	1
D	2.88	1

The non-repeatered side also provides facilities for by-passing or repeating low frequency signals as shown.

4.3 Jack Panel Unit and Power Supply - See Section 8.

4.4 Signaling Through Two-Wire Intermediate Repeaters - See Part II

5. TWO-WIRE TERMINAL REPEATER

Located at an exchange, one side of a two-wire terminal repeater is associated with the toll switchboard. The other side is connected to the toll line. The use of terminal repeaters is dependent upon the transmission problem encountered, along with considerations of available housing for intermediate repeaters. Lower net gains are obtained from terminal repeaters as a result of their location at the ends of toll circuits.

The following standard units are required for a two-wire terminal repeater:

Quantity	Unit Designation
1	Amplifier Unit
1	Line and line balancing unit
1	Two-wire terminating unit
1	Jack panel unit (1/2 unit required per repeater) - with (optional) power supply

5.1 General Description

Figure 24 represents the relationship of units in a two-wire terminal repeater. A line and line balancing unit identical to that used in the intermediate repeater is employed on the line side of the repeater. Requirements for balancing on the line side of the repeater are the same as outlined for two-wire intermediate repeaters. The drop side of the terminal repeater incorporates a

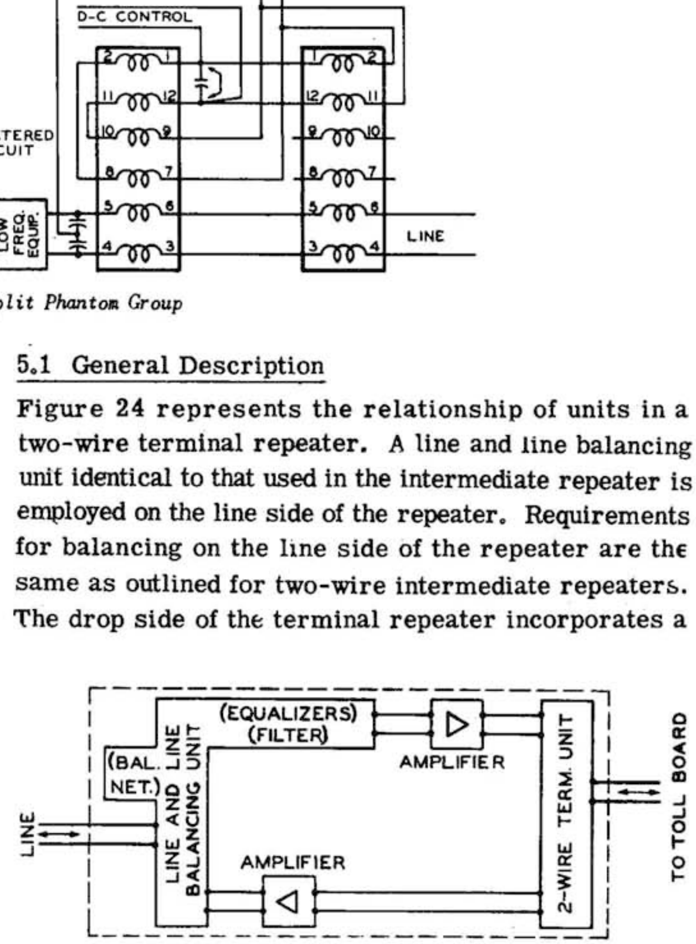


Fig. 24: Unit Relationship - Two-Wire Terminal Repeater

two-wire terminating unit which performs essentially the same functions as the repeating coil hybrid, establishing separate transmission paths in the repeater. Figure B in the Appendix gives the schematic of a two-wire terminal repeater.

5.2 Two-Wire Terminating Unit (Fig. 25)

The terminating unit incorporates a resistance hybrid arrangement with a fixed balancing network and carries, in addition, one cut-out relay and two condensers for d-c blocking purposes. It occupies 1-3/4'' vertical rack space.

5.21 The Resistance Hybrid

The eight resistances of the hybrid, R1 to R8 (Fig. 26) form a bridge that presents 600 ohms impedance in four directions; to the exchange trunk, the input circuit of the even amplifier, the output circuit of the odd amplifier and to the balancing network. The resistance hybrid prevents the output current of the odd amplifier from reaching the input circuit of the even amplifier by an arrangement which utilizes the null points of the bridge. The output circuit of the odd amplifier is connected across the bridge at the junctions of resistors R1-R5 and R4-R8. The input circuit of the even amplifier is connected to the opposite corners of the bridge at the junctions of resistors R2-R6 and R3-R7. The even amplifier input is thus at a zero potential point with respect to output voltages of the odd amplifier. Consequently, no voltages appear in the even amplifier input circuit. The switchboard drop and the balancing network are connected midway between the corners of the bridge as shown, and receive equal portions of the odd amplifier output. The energy level appearing in the switchboard drop, however, will be approximately 10.7 decibels lower than the odd amplifier output level due to inherent losses in the resistance hybrid.

When voice currents emanate from the drop circuit and appear across the bridge, the input circuit of the even amplifier and the output circuit of the odd amplifier (as a result of bridge connections) receive equal amounts of energy from the drop. The portion reaching the odd amplifier output circuit is dissipated while that appearing in the even amplifier input is repeated. In this instance, also, due to the losses introduced by the resistance hybrid, the signal level in the even amplifier input

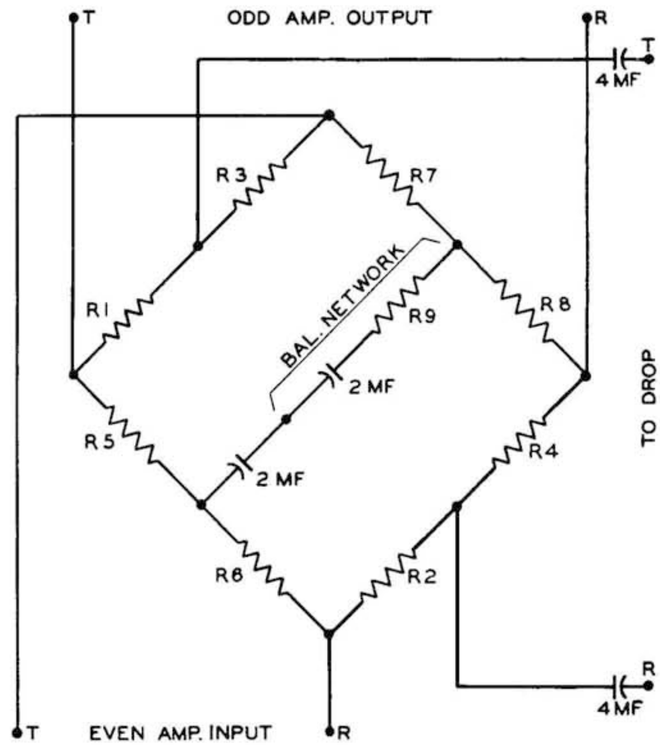
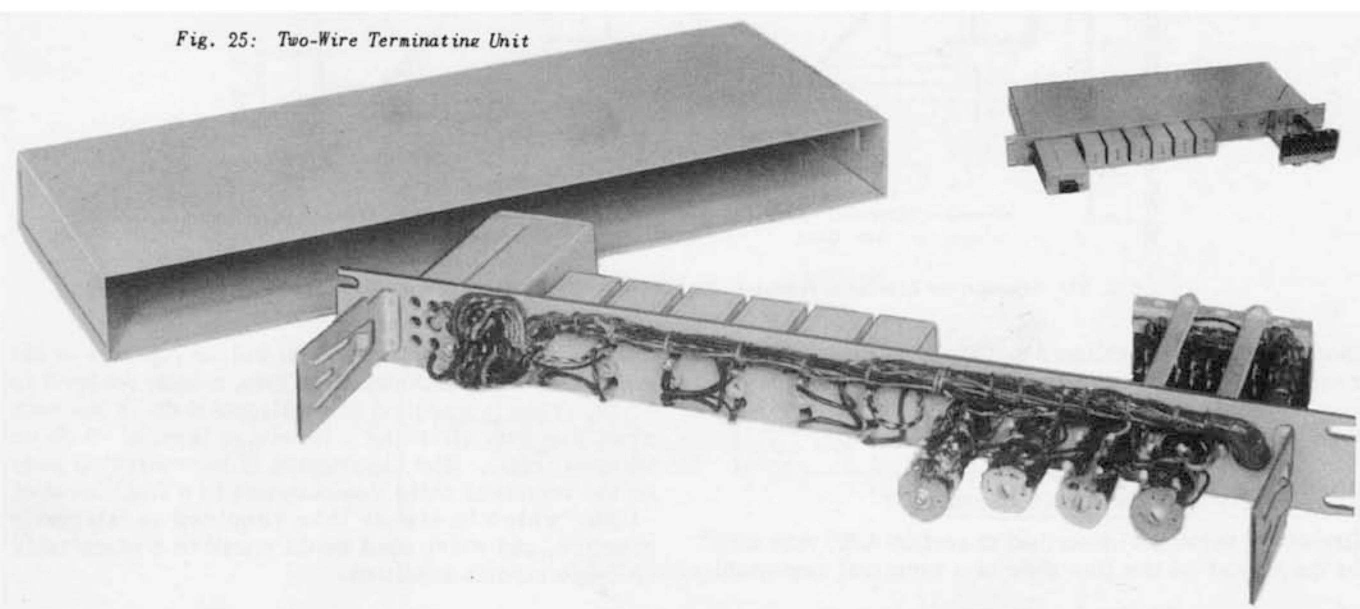


Fig. 26: Resistance Hybrid

circuit will be 10.7 decibels lower than the level in the drop circuit. This initial insertion loss of the resistance hybrid must be taken into consideration when amplifier working gains are set.

5.211 Balancing - The appearance of the drop circuit impedance, (600Ω) across the resistance hybrid, requires that an equivalent network representing the drop circuit

Fig. 25: Two-Wire Terminating Unit



impedance be used to keep the bridge balanced Because of constantly varying impedance of drop circuits and of subscriber's loops under call and no-call conditions, however, sustained accurate balancing is virtually impossible.

Therefore, a compromise network consisting of a 600Ω resistor in series with a 2-mf condenser is placed across the bridge to balance the drop circuit. (Other drop circuit balancing networks may be substituted for the compromise network across the resistance hybrid by connecting such networks to terminals on the rear terminal block of the two-wire terminating unit.) Another 2-mf condenser is used in series with the balancing network for balancing the two, 4-mf d-c blocking condensers on the drop side of the terminating unit.

A 600-ohm terminating impedance should be bridged across the drop circuit at the toll switchboard to provide proper termination under "idle line" conditions. This idle line termination is removed when a call is established, either by manual control, or automatically under control of relay circuits.

5.3 Equalizers and Low Pass Filter

Equalizing and filter arrangements for the line side of two-wire terminal repeaters are generally identical with those outlined for two-wire intermediate repeaters (Sec. 4.22, 4.24). Equalizers and low pass filters are not required on the drop side of terminal repeaters and consequently no provision is made in the two-wire terminating unit for these components.

5.4 Regulating Networks (External)

Regulating networks (described in section 4.25) may also be employed on the line side of a terminal repeater.

5.5 Switching Pads

To maintain a satisfactory transmission level on a call where two or more repeatered circuits are connected in tandem for the purpose of extending the call (via call), it is generally necessary that the amplifier gain settings in all participating terminal repeaters, be higher than required for a terminal call. Because the increased amplifier gains will result in too high a transmission level for terminal calls, attenuators or switching pads are placed between the repeaters and the toll switchboards. On a terminal call, the switching pads introduce losses of 3 to 5 decibels each, depending on the type used, to provide a satisfactory transmission level. On a via call, the switching pads at the junction of the repeatered toll circuits are switched out so that the available additional gain of the terminal repeaters, affords a transmission level on the via calls, comparable to that obtained on terminal calls.

Figure 27 presents two repeatered circuits (A to B, and B to C) which are also utilized in the circuit A to C. The repeater gains indicated are intended to provide adequate transmission power for a satisfactory level on a via call (A to C). On terminal calls (indicated by solid black lines) with the output at the A or B switchboard as the reference (0 dbm) level, the switching pads first introduce a 4 decibel loss. The terminal repeater with a gain of 13 db raises the level to +9 db. The loss in the toll line drops the level to -15 db and the repeater at the end of the circuit provides 10 db gain, raising the level to -5 db. This is reduced an additional 4 db by the next switching pad, affording a receiving level of -9 db on terminal calls. The elimination of the switching pads on the terminal calls would result in a final level of -1 db, which is higher than required in telephone practice, and which also would result in a completely unstable circuit condition.

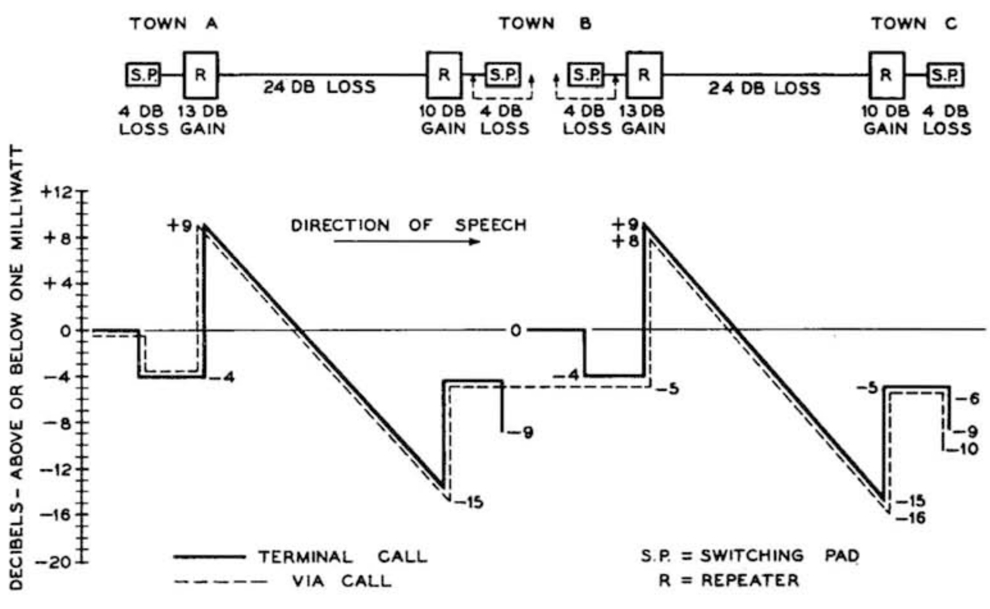


Fig. 27: Comparative Levels on Terminal and Via Calls (Relating to Use of Switching Pads)

On a via call (broken line) from A to C, the switching pads at the junction of the two repeatered circuits (B) are removed from the toll circuit, eliminating an 8 db loss and resulting in an overall loss of 10 db, a value which is entirely suitable for commercial transmission. Retention of the two switching pads at B would have resulted in a total loss of 18 db at C. The inclusion of another similar repeatered circuit for the purpose of further extending the call would therefore result in a prohibitive total loss providing all switching pads were retained. No balancing difficulties are experienced at B when both terminal repeaters are working directly into each other on via calls, because the drop impedances of the two repeaters are essentially constant and equal.

5.6 Phantom Arrangements at Terminals

Connections for deriving a phantom at a repeatered terminal are provided by making accessible, the midpoints of the line windings of the repeating coil hybrids in the line units of each side-circuit repeater. A phantom repeater may be used at this point if transmission conditions require it (Fig. 28). The requirements for adjusting the phantom line-balancing networks at a repeatered terminal, are the same as previously outlined for phantom repeaters at intermediate points (Sec. 4.27).

5.7 Jack Panel Unit and Power Supply - Section 8

5.8 Signaling Through Two-Wire Terminal Repeaters - See Part II.

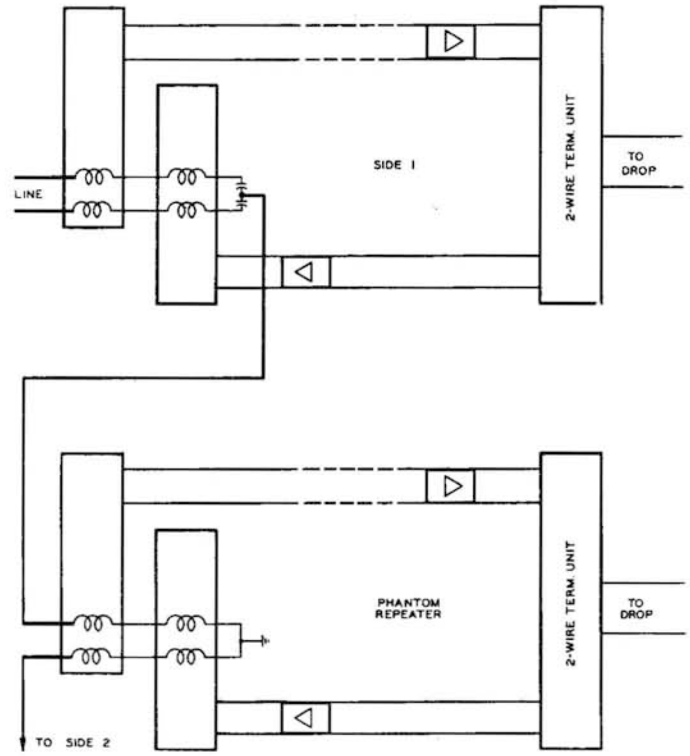


Fig. 28: Two-Wire Phantom Arrangements at Terminals

6. FOUR-WIRE INTERMEDIATE REPEATER

On four-wire circuits, the use of separate paths for each direction of transmission (2 wires to each direction) obviates the use of line and line balancing units and the accompanying line balancing problems. Amplifier gains in four-wire repeaters may therefore be higher than in two-wire repeaters thus permitting a greater spacing of four-wire repeaters on toll lines. The gain limiting factor here is generally the permissible crosstalk between pairs in the toll circuit.

The four-wire intermediate repeater consists of the following units:

Quantity	Unit Designation
1	Amplifier unit
1	Four-wire line unit
1	Jack panel unit (1/2 unit required per repeater) - with (optional) power supply

6.1 General Description

The block diagram of a four-wire intermediate repeater is seen in figure 29. Voice currents from each pair, enter the repeater through a repeating coil and are repeated by their respective amplifiers. Repeating coils on the output sides of the amplifiers, couple the amplified signal to the line. Each transmission path in the repeater

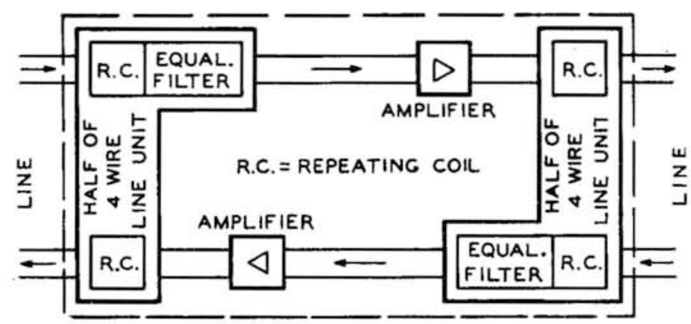


Fig. 29: Unit Relationship - Four-Wire Intermediate Repeater

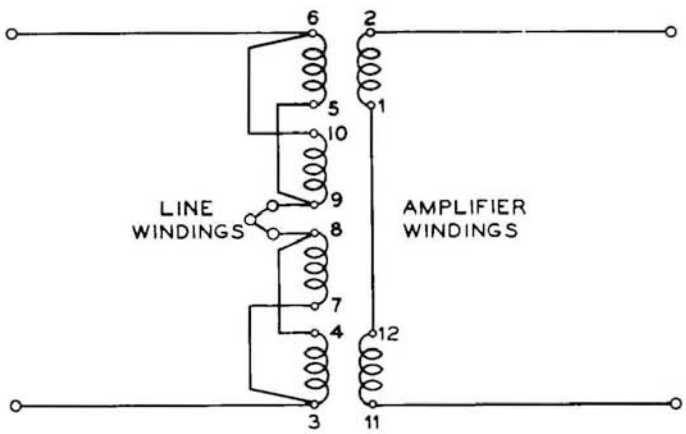
is independent of the other. Figure C in the Appendix provides the schematic of a four-wire intermediate repeater.

6.2 Four-Wire Line Unit - (Fig. 32)

This unit carries the four repeating coils required to match the repeater to the line as well as the necessary equalizing networks and low pass filters. The input insertion loss for each input of the four-wire line unit (without equalization) is 2 db; output loss (for each output) is 1 db. These losses must be taken into consideration when the working gains of the amplifiers are set. For equipment losses with equalization, refer to equalization charts in Appendix. The four-wire line unit requires 3-1/2" vertical rack space.

6.21 Repeating Coils

The repeating coils employed in the four-wire repeater, are identical to those used for the repeating coil hybrid of two-wire repeaters (See Fig. 6). Windings 1-2 and 11-12 are associated with the 600-ohm input or output circuit of the amplifier. Utilizing the four remaining windings (6-5, 10-9, 8-7, 4-3) in a parallel arrangement as the line windings (Fig. 30) affords line-



COIL SUFFIX	IMP. RATIOS	
	LINE	AMP.
A	.3	1
B	.5	1
C	0.845	1

Fig. 30: Repeating Coil Impedance Ratios for Four-Wire Repeater (Line Windings in Parallel)

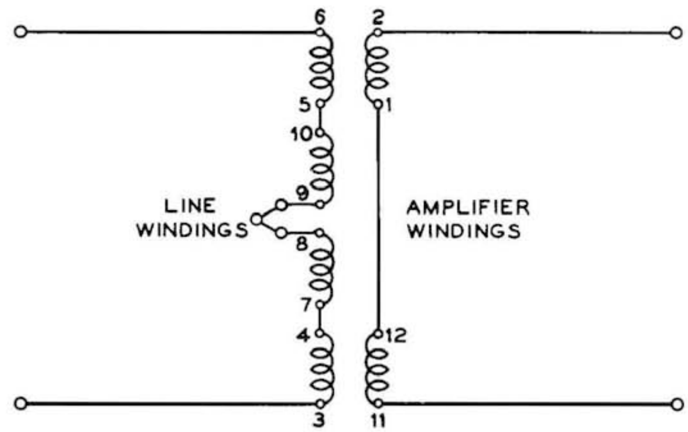
to-amplifier matching ratios of .3 to 1, .5 to 1 and .845 to 1 depending upon the type of repeating coil used.

The same four windings of the repeating coil used in series (Fig. 31) as the line windings, affords impedance ratios four times greater than that of the arrangement shown in figure 30.

With the six available matching ratios listed in figures 30 and 31, the repeater can be matched to any line having an impedance between 134 ohms and 2760 ohms with not more than a .1 decibel mismatch loss (Fig. 33). Tables II and III (Appendix) list repeating coils for matching a four-wire repeater to various toll lines.

6.22 Low Pass Filter

The low-pass filters described in section 4.22 (two-wire intermediate repeater) are also used in four-wire



COIL SUFFIX	IMP. RATIOS	
	LINE	AMP.
A	1.2	1
B	2.0	1
C	3.38	1

Fig. 31: Repeating Coil Impedance Ratios for Four-Wire Repeater (Line Windings in Series)

repeaters at the inputs to the amplifiers (Fig. C). They are furnished as an integral part of the four-wire line unit. Tables II and III (Appendix) show which filters are required for various four-wire toll lines.

6.23 Four-Wire Equalization

The line units of Type 47 repeaters (See Sec. 4.23) carry equalizing networks which may be placed in the repeater circuit by means of strapping terminals at the fronts

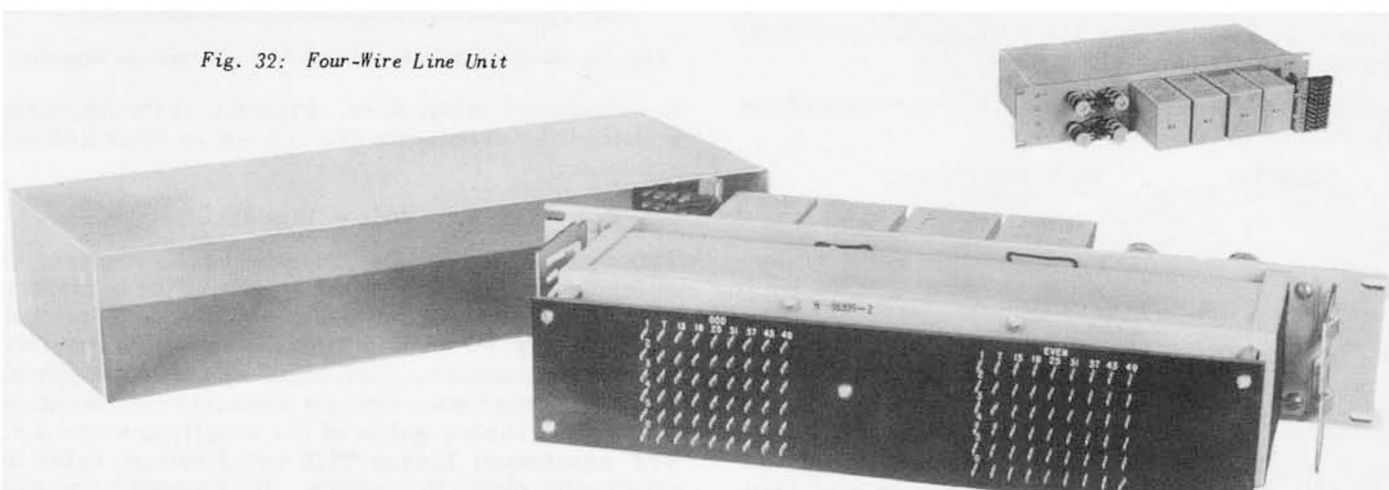


Fig. 32: Four-Wire Line Unit

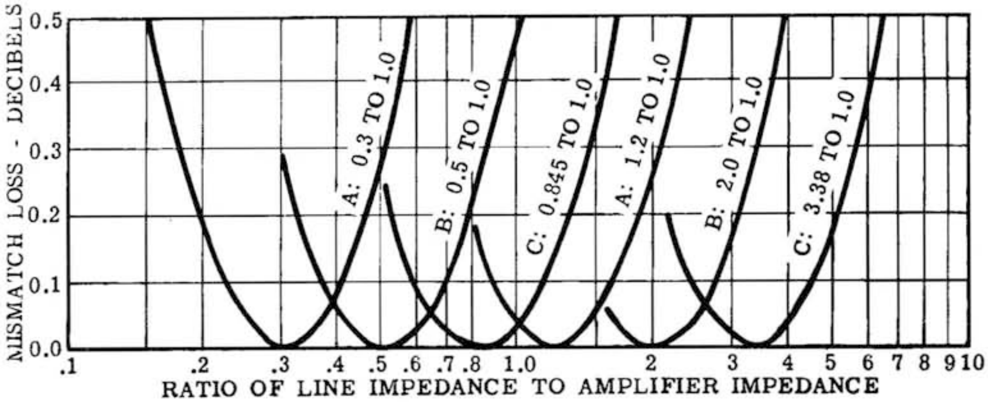


Fig. 33: Mismatch Loss of Standard Repeating Coils - Four-Wire Repeater

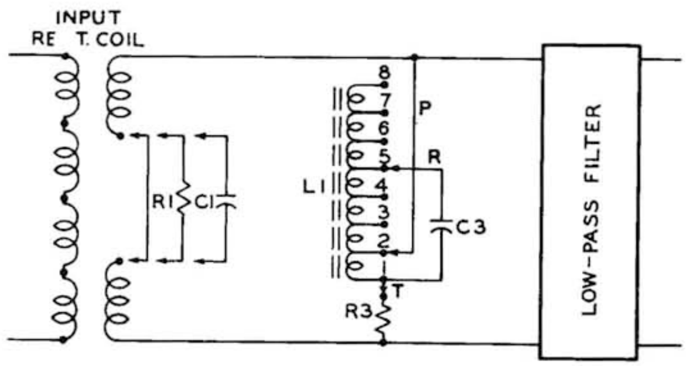


Fig. 34: Equalizers for Four-Wire Repeater

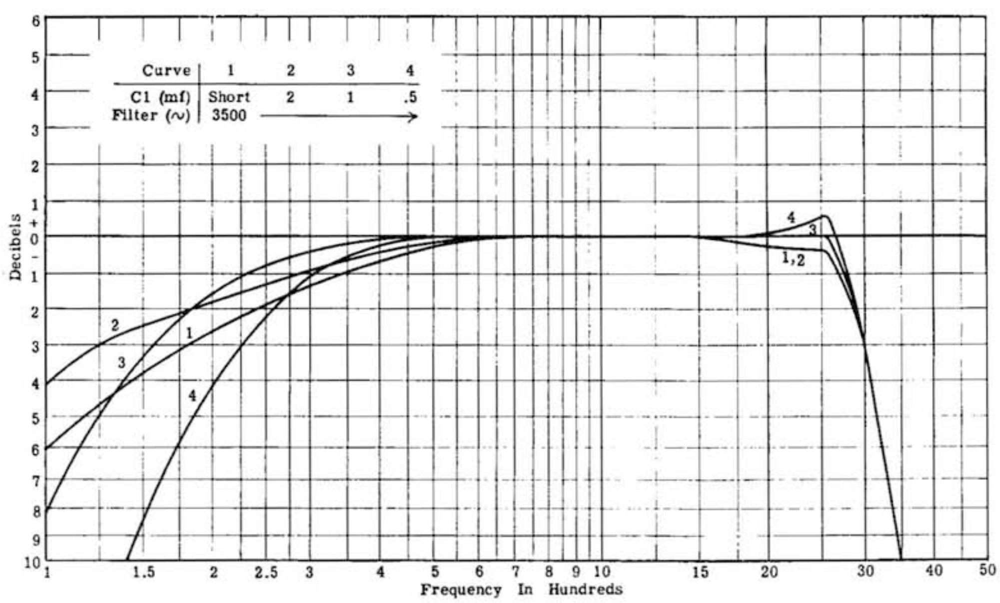


Fig. 35: Response With Equalization - Four-Wire Repeater

of these units. Equalizing components in the four-wire line unit (Fig. 34) consist of an adjustable resistance-capacitance network placed in series with the winding on the amplifier side of the input repeating coil, and a resistance-capacitance-inductance network which is placed across the input to the filter.

The first network (R1 and C1) provides equalization below 1000 cycles (low frequency equalization). Reducing the value of capacitor C1 causes the low frequency portion of the repeater's response curve to fall as shown in figure 35. Note that the response drops more sharply, especially at the lower extremity, when smaller capacitances are employed. Shunting condenser C1 with resistance R1 makes the fall in low frequency response begin at a higher frequency (Fig. 36). As the resistance of R1 is reduced, the low frequency portion of the response curve is displaced progressively downward (Curves 2, 3 and 4).

Equalizers R1 and C1 thus permit some control over the shape of the response curve below 1000 cycles. For example, if it is desirable to raise the response of the repeater at 200 cycles but reduce it at 500 cycles, C1 should be increased and R1 decreased in value. Where a large amount of low frequency equalization is obtained (as in figure 35) some high frequency equalization also results.

Modification of the response curve from 1000 cycles upward (high frequency equalization) as well as low frequency equalization. is afforded by the inductance-

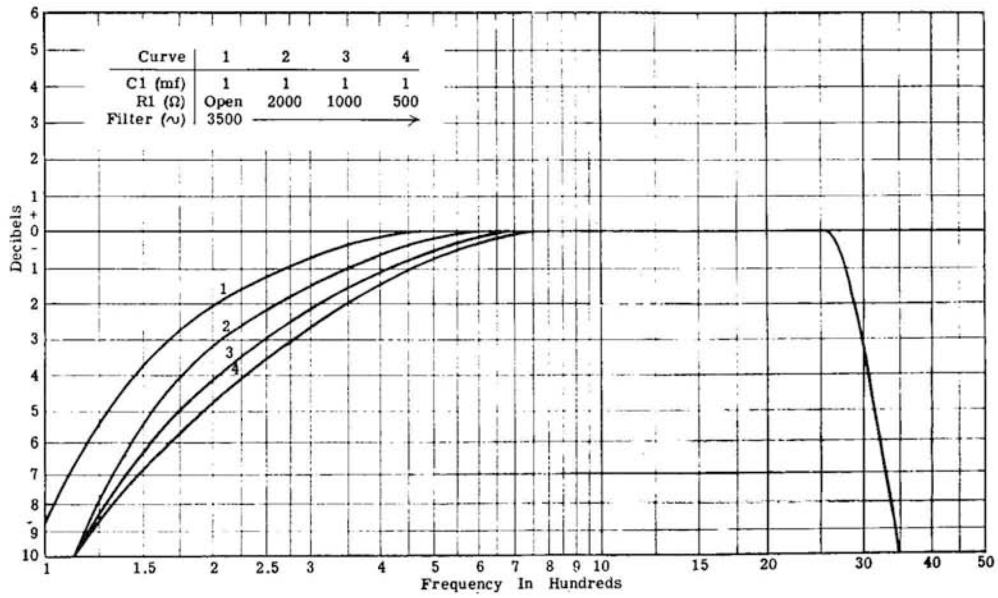


Fig. 36: Response With Equalization - Four-Wire Repeater

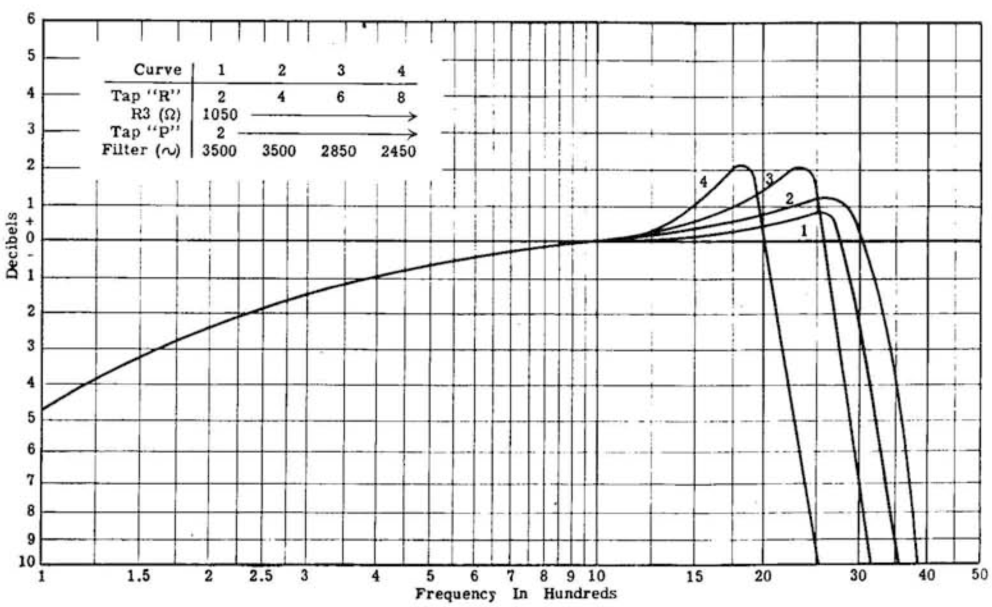


Fig. 37: Response With Equalization - Four-Wire Repeater

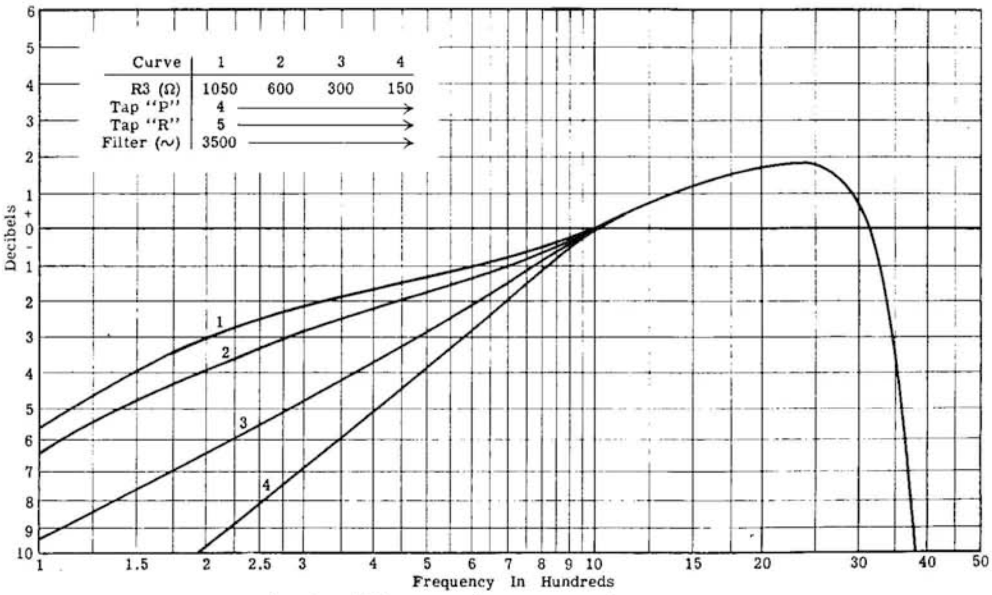


Fig. 38: Response With Equalization - Four-Wire Repeater

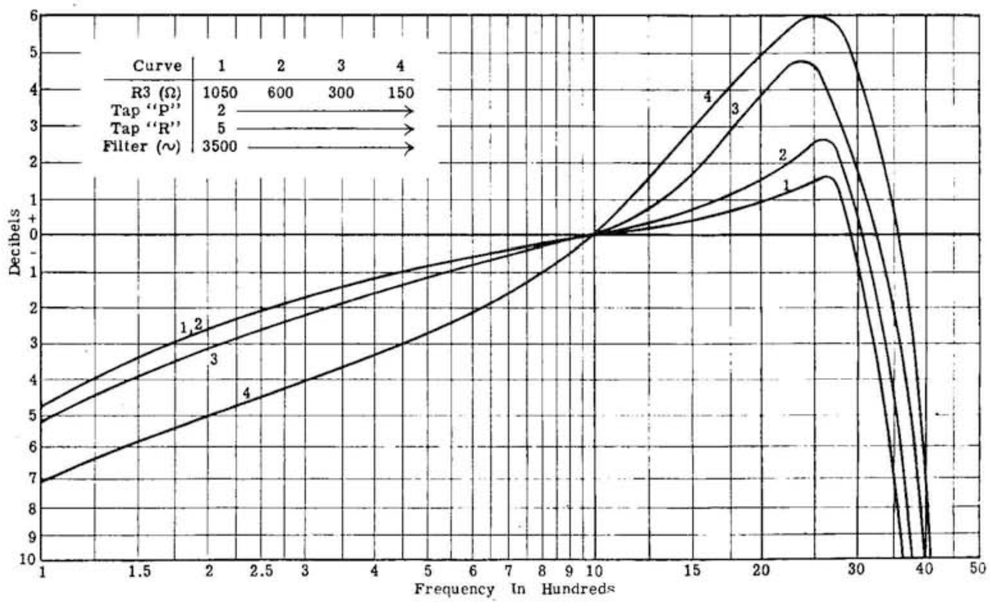


Fig. 39: Response With Equalization - Four-Wire Repeater

resistance-capacitance (R3-C3-L1) network shown in figure 34. Several methods of adjusting this network are provided by taps P, R, and T.

The inductance L1 is resonated by the condenser C3 and peaks the high end of the repeater's response curve. These resonant peaks occur at points between 1800 and 5000 c.p.s. depending on whether C3 is connected across a smaller or a larger portion of the inductance (Fig. 37). Note that varying the position of the condenser tap R affects only the high end of the response curve while the low end remains unchanged. Where tap R is adjusted so that resonance occurs at frequencies above the cut-off frequency of the filter, peaks of reduced amplitude will appear at the high ends of the response curves (Fig. 37, Curves 1 and 2).

Other variations in the frequency response of the repeater are effected by adjustment of line tap P and the resistance R3. As tap P is moved to a higher position on inductance L1, the resonant peaks produced by condenser C3 become less sharp and a tendency towards "rounding off" is noted. This effect is demonstrated by the differences between the sets of curves in figure 37 (tap P on position 2 of L1) and figure 38 (tap P on position 4 of L1). The effect on the response curve of moving condenser tap R, is greatly minimized when tap P is set above position 4 on L1.

The degree of high frequency equalization, in general, varies directly with the bridging loss presented by the network at 1000 cycles. The bridging loss is determined by the value of R3 and the size of the inductance between taps T and P. Thus, changing tap P or adjusting the value of R3, or both, provides the varying degrees of high frequency equalization illustrated in figures 38 and 39. Since the reactance of the inductance always rises with increments in frequency, the response of the repeater tends, likewise, to increase with frequency.

The rate at which the response drops as frequency is reduced, depends upon the size of the inductance between taps T and P. With less inductance between the aforementioned taps, the response drops more quickly. When the impedance of the C3-L1 combination becomes equal to the resistance of R3, as the frequency is reduced, the characteristic tends to level off. Thus, the relation between the value of R3 and the size of the inductance between taps T and P is a determining factor in controlling the shape of the response curve.

Resistor R3 exercises varying degrees of high and low frequency equalization depending on the position of line tap P. Where tap P is on position 2 or 3 of L1, a decrease in the value of R3 drops the response below 1000 cycles and raises the response above 1000 cycles (Fig. 39). As tap P is moved to position 4 or higher, however, variations in the value of R3 have little effect on the high frequencies and only changes in low frequency equalization result (Fig. 38).

As indicated in figure 40, the frequency characteristic of the repeater can be additionally modified by employing both equalization networks (R1-C1, R3-C3-L1) in combination. Because the effects of the variables in these networks are interdependent, especially where large amounts of equalization are involved, it may be necessary to make various combinations and several adjustments before optimum results are obtained. Recommended equalizer constants for various four-wire toll circuits will be found in the Appendix, tables VII VIII, IX.

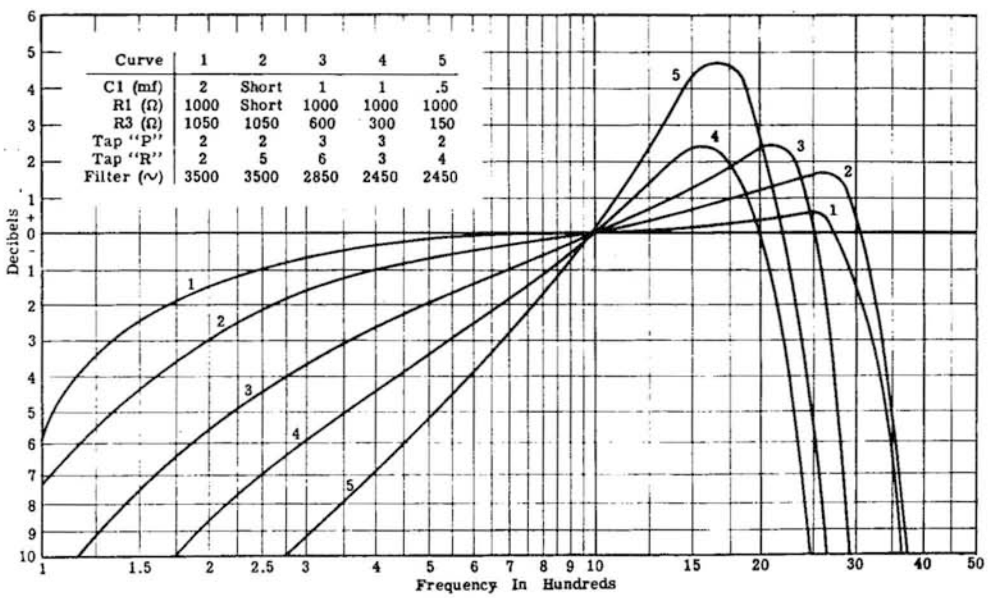


Fig. 40: Response With Equalization - Four-Wire Repeater

6.24 Regulating Networks (External)

In four-wire repeaters, regulating networks (See Sec. 4.25) when required, are inserted between the equalizing equipment and low pass filters ahead of the amplifier inputs. Terminals are provided on the four-wire line unit for placing these external networks into the repeater circuit.

6.25 Phantom Arrangements

A four-wire repeater may be used to repeat a phantom at an intermediate point. The phantom is derived from the midpoints of the repeating coil line-windings in each side-circuit repeater. The repeating coils for the phantom repeater should be selected to match the impedance of the phantom line as closely as possible (See Sec. 6.21, Figs. 30, 31 and 33). Coils with lower impedance ratios than those in the associated side-circuits, will generally be required. Tables II and III in the Appendix list repeating coils for matching the repeater to various four-wire circuits. Interconnections for establishing the phantom arrangement are made between the rear terminal blocks of the four-wire line units.

6.3 Quad Connections For Minimizing Crosstalk

Four-wire repeaters should be connected to quadded toll cable so that their low level ends (inputs) are in one quad, while their high level ends (outputs) are in another quad. Crosstalk will thus be minimized since the quadded pairs will be at similar transmission levels. Figure 42 illustrates the correct manner of connecting four-wire terminal repeaters to quads. Where four-wire intermediate repeaters are involved, both sides of these repeaters should be connected in the same manner as the line side of figure 42.

6.4 Jack Panel Unit and Power Supply - Section 8

6.5 Signaling Through Four-Wire Intermediate Repeater - Part II

7. FOUR-WIRE TERMINAL REPEATER

The following units are required for a four-wire terminal repeater.

Quantity	Unit Designation
1	Amplifier unit
1	Four-wire line unit (1/2 unit required per repeater)
1	Two-wire terminating unit
1	Jack panel unit (1/2 unit required per repeater) - with (optional) power supply

7.1 General Description

The four-wire terminal repeater incorporates a four-wire line unit (described in section 6.2) on its line side (Fig. 41) but utilizes only half of the unit (the other half may be utilized in another four-wire, terminal repeater). Since toll board facilities are generally two-wire arrangements, a two-wire terminating unit (described in section 5.2 under two-wire terminal repeaters) is utilized on the drop side of the repeater to resolve the four-wire toll circuit into a two-wire toll board termination. However, the cut-out relay and associated cut-out circuit in the two-wire terminating unit (as shown in Fig. B, Appendix) is not required for a four-wire terminal repeater. It is necessary, therefore, to mechanically block the cut-out relay in operated position so as to permanently complete the transmission paths through the repeater to the drop. Refer to figure D in Appendix for basic circuit of four-wire terminal repeater.

The requirements for connecting the four-wire terminal repeater to the drop circuit, use of switching pads, etc.

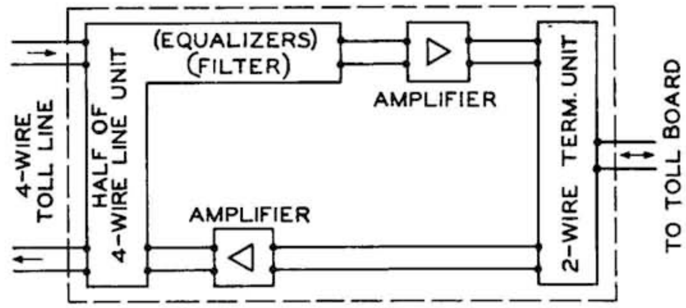


Fig. 41: Unit Relationship - Four-Wire Terminal Repeater

are the same as previously outlined for two-wire terminal repeaters (Sec. 5).

7.2 Low Pass Filter and Equalizers

The low pass filter and equalizers for the four-wire terminal repeater appear in the four-wire line unit (Fig. 41). Equalizing procedures for the four-wire terminal repeater are generally identical with those outlined for four-wire intermediate repeaters (See section 6.23).

7.3 Regulating Networks

Regulating networks may also be employed on the line side of four-wire terminal repeaters (See Sec. 6.24).

7.4 Phantom Arrangements

At a terminal, the phantom is derived from the midpoints of the repeating coil line-windings on the line side of the side-circuit repeaters (See Sec. 6.25).

7.5 Quad Connections for Minimizing Crosstalk

Figure 42 illustrates the proper method of connecting the quads to four-wire terminal repeaters (See Sec. 6.3).

7.6 Jack Panel Unit and Power Supply - See Section 8

7.7 Signaling Through Four-Wire Terminal Repeaters - See Signaling Part II

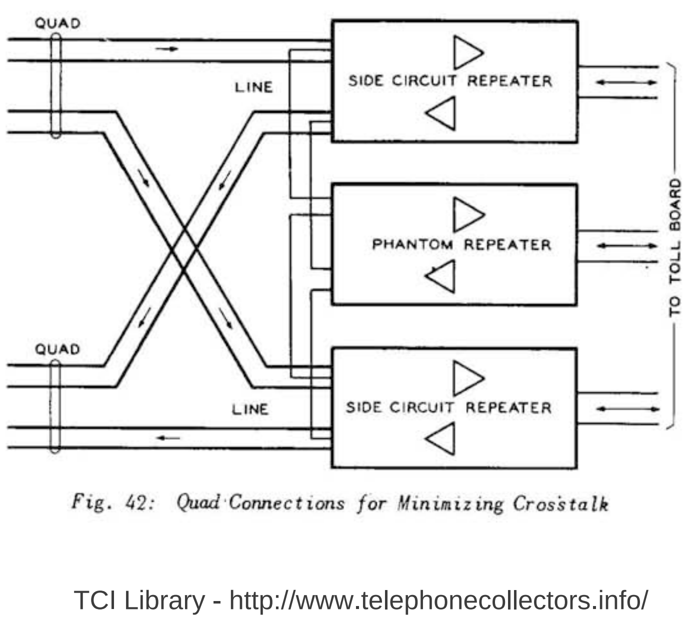


Fig. 42: Quad Connections for Minimizing Crosstalk

8. JACK PANEL UNIT AND POWER SUPPLY

Jacks for monitoring and testing repeater performance as well as a power-supply (if required) are incorporated into the jack panel unit (Fig. 43). The unit is designed to serve two repeaters, with jack space provided for both. The power supply furnishes power, adequate for the operation of two repeaters. The jack panel unit requires 1-3/4'' vertical rack space.

8.1 Jack Panel

Each half of the jack panel (Fig. 43) carries the jack field for one repeater. Where only one repeater is employed, the right half of the panel may be unequipped but is cabled to permit the future addition of jacks.

The jack field for each repeater consists of a group of jacks associated with the odd amplifier and a like group associated with the even amplifier. In addition, a plate jack and filament jack for testing the two amplifier tubes, are provided. The functions of the jacks follow. Refer to drawings A, B, C, D in Appendix.

Equipment-Out Jacks (EQUIP OUT) - Provide access to the output of the line equipment or terminating equipment. The left and right jacks connect to the tip and ring sides, respectively. This also applies to the EQUIP IN, AMP IN and AMP OUT jacks.

Amplifier-In Jacks (AMP IN) - Provide access to the amplifier input. Normally, the amplifier input circuit is connected through break contacts of the "AMP IN" and "EQUIP OUT" jacks to the equipment-out circuit.

Amplifier-Out Jacks (AMP OUT) - Provide access to the amplifier output.

Equipment-In Jacks (EQUIP IN) - Provide access to the input of the line equipment or terminating equipment. Normally, the amplifier output circuit is connected through break contacts of the "AMP OUT" and "EQUIP IN" jacks to the equipment-in circuit.

Monitor Jacks (MONITOR) - Four monitor jacks are associated with the monitor windings of the output transformers of both amplifiers. They are arranged so that a twin plug (of an operator's set) or a single (tip-sleeve) plug can be used to connect to either the odd or even monitor-windings, or to both windings simultaneously.

Placing a twin plug in the top monitor jacks permits monitoring of both amplifiers simultaneously. Connections are made to the sleeves to permit use of the standard operator's set. Inserting the twin plug vertically into the left monitoring jacks connects the receiver to the monitor winding of the odd amplifier output transformer. Placing the twin plug vertically into the right monitor jacks, connects the receiver to the even amplifier monitoring circuit.

To monitor the odd amplifier without interference from the "east" line, and to monitor the even amplifier without interference from the "west" line it is necessary to insert 600-ohm plugs in the "EQUIP IN" jacks on both sides.

The monitor jacks designated "A" afford the same monitoring facilities when a receiver equipped with a single tip-sleeve plug is used. Both amplifiers can be monitored simultaneously by plugging into the upper left "A" jack. Monitoring of the odd or even amplifiers is obtained by plugging into the lower left or lower right "A" jacks, respectively. The level in the monitor windings will be approximately 11db below the level in the associated amplifier-out winding.

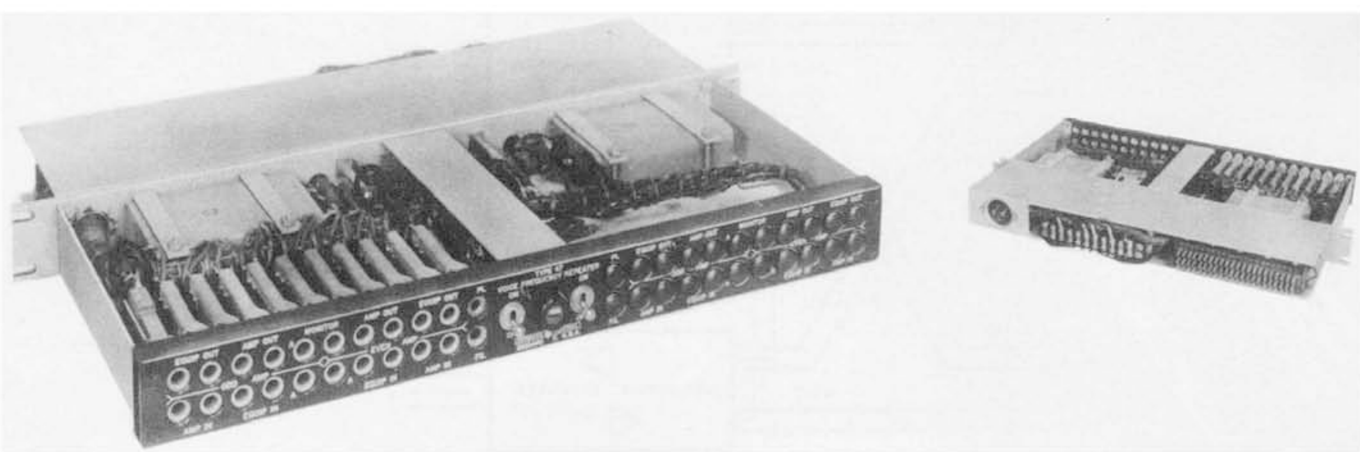


Fig. 43: Jack Panel Unit With Power Supply

Plate Jack (PL) - A tip-ring-sleeve jack which permits voltage measurements across a 100Ω resistor in the cathode circuit of each amplifier for an indication of plate current (see Testing, Part III). The voltage for the odd amplifier is measured between the tip and sleeve, and that for the even amplifier, across the ring and sleeve.

Filament Jack (FIL) - A tip-ring-sleeve jack which permits a current-limiting resistor to be placed in series with the heaters of both vacuum tubes to make tube emission checks (see Testing, Part III). Also, the heater current (150 ma.) can be measured.

8.11 Test Cords and Plugs

A.E.Co. cord assemblies used with the jack panel unit:

Piece No.	Length	For patching to:
H-87767-1	2 feet	EQUIP or AMP jacks
H-87767-2	4 feet	EQUIP or AMP jacks
H-87767-3	6 feet	EQUIP or AMP jacks
H-87767-4	5 feet	FIL jack
H-87767-5	5 feet	PL jack

In place of assemblies H-87767-1, -2, or -3, any equivalent patching cords may be used. These should have at both ends twin plugs such as A.E.Co. D-57094-A or W.E.Co. 241-A, with 3-conductor cords connecting the two tips and the sleeves. Ground must be extended over the sleeve conductor of the cord to the "EQUIP OUT" jacks associated with the odd amplifier, to maintain the cut-out relays (when used) operated. When a spare amplifier is patched in (Part III §4), this ground is automatically furnished through the odd "AMP IN" jack from the alarm circuit of the spare amplifier.

In lieu of assembly H-87767-4, one can use a 3-conductor cord with a 0.250"-diameter plug (W.E.Co. 310 plug or similar).

In lieu of assembly H-87767-5, one can use a 3-conductor cord with a 0.205"-diameter plug (such as W.E.Co. 109).

For disabling purposes (see Part III, §2.1) an A.E.Co. 600Ω plug is also available -- piece no. D-57095-B. This is equivalent to the W.E.Co. 217-D plug.

8.2 Power Supply

The circuit of the power supply is shown in figure 44. Utilizing selenium rectifiers and the essential chokes and capacitors for filtering action, the supply provides 130 volts, 70 milliamperes d.c. for the vacuum-tube plates and 24 volts, 300 milliamperes a.c. for the filaments - sufficient power to operate two repeaters. Power is also supplied for operating the cut-out relays in both repeaters. The supply draws 12.5 watts from a 115-volt line when supplying power for one repeater - 25 watts when powering two repeaters.

Each of the two switches on the jack panel (Fig. 43) will turn the power supply on and light the tube filaments in one repeater. The power supply may be operated from commercial power voltages ranging from 105 to 125 volts, 50-60 cycles, through adjustment of taps on the power transformer primary. Three taps (Hi, Med, Low) on the high-voltage secondary, provide an adjustment of d-c plate voltage. Both adjustments are made at the rear of the jack panel unit on the transformer terminal strip.

If 48-volt central-office battery heats the filaments, connect 2 repeaters' filaments in series (blueprint H-85143 figures 1, 2, and 3 wiring R)....or, for a lone repeater, connect 170Ω in series with the filaments (blueprint H-85143 figure 1, figure 3 wiring S, and figure 5).

The 1/2-ampere fuse on the jack panel is in series with the 115-volt power line input (Fig. 44). However, when power is obtained from exchange batteries (see Introduction §1) the fuse is wired in series with the 130-volt plate battery supply.

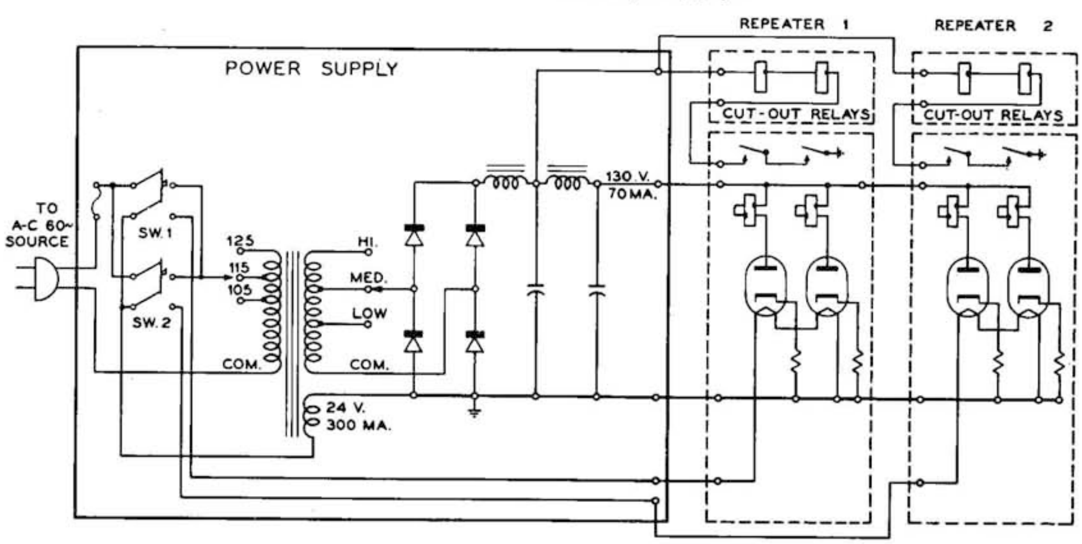


Fig. 44: Power Supply - Schematic

PART II

SIGNALING ARRANGEMENTS

1. INTRODUCTION

Facilities for handling standard a-c telephone signals (20, 135, 1000-cycle) are provided in the Type 47 repeater. Accommodations are also provided for arranging the by-passing or repeating of d-c signals including 3-1/2 cycle signals (used in railway dispatching) telegraph, and dial pulses.

Thousand-cycle signals are repeated in two-wire or four-wire repeaters in the identical way that voice currents are repeated. (On four-wire circuits, 1000-cycle telephone signaling is generally employed.) Because 20-cycle signals are greatly attenuated by the voice transmission paths in a two-wire repeater, it is necessary to by-pass the 20-cycle currents. While the repeater will amplify 135-cycle signals, generally, these signals are by-passed around the amplifier and repeated with half-ringers.

The switchboard signal equipment at terminals ordinarily requires 20-cycle or d-c for operation. It becomes necessary, therefor to convert signals of other frequencies received at terminals, to the type of signal required. Half-ringers are also used for this purpose.

At intermediate points, conversion from one signaling frequency to another may be accomplished between any of the three signaling frequencies - 20, 135 or 1000-cycles - by means of half ringers.

2. THE HALF-RINGER

The half-ringer converts a-c ringing signals to d-c signals and conversely, d-c signals applied to the half-ringer causes it to send a-c ringing signals. The half-ringer thus may actuate another half-ringer of a different frequency to provide a new signaling frequency (Fig. 45) or two half-ringers of the same frequency

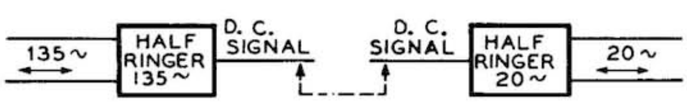


Fig. 45: Relaying Signals With Half-Ringers

may be used "back to back" to repeat the signaling frequency. Half-ringers are available in the three telephone signaling frequencies mentioned above. These mount on 19" panels. Rear terminals are provided for cabling to standard Type 47 repeater assemblies.

3. TWO-WIRE A-C SIGNALING

More diversified methods of signaling are utilized on two-wire circuits, while four-wire circuits generally employ 1000-cycle signaling. The signaling arrangements outlined below will therefore be concerned essentially with two-wire facilities. Strapping data for obtaining desired signaling arrangements will be found on A.E.Co. blueprints.

3.1 20-Cycle Signaling at Intermediate Points

3.11 By-Passing

(A) Retard Coil By-Pass - Twenty-cycle signals may by by-passed around the amplifiers of a repeater by connecting the line windings of the hybrids together through retard coils (part of line and line balancing unit) as shown in figure 46. The condensers across the line windings of each hybrid offer low impedance to voice currents but high impedance to the 20-cycle currents. The retard coils offer high impedance to voice currents but low impedance to 20-cycles so that the voice currents circulate in the line-windings while the 20-cycle signal by-passes the amplifier and travels directly from the incoming line to the outgoing line. Use of the retard coil by-pass, however, requires that an equalizing condenser (Ca, Fig. 46) be employed between terminals 1 and 12 of the hybrid coil to prevent low-frequency singing (See Equalization, Part I).

Where by-pass circuits are used in the side-circuits of phantom groups, the effective inductance of the retard coils must be balanced in the phantom balancing network as shown. When all circuits of a phantom group are not carried through and one side-circuit is dropped off or frogged (Part I, Sec. 4.27B) the 20-cycle signaling facilities in that side-circuit require repeating coils. It is then necessary to employ repeating coils in the other side-circuit by-pass, in order to maintain the phantom balance.

The retard coil by-pass arrangement will also pass composited d-c signals including short-haul telegraph (See Sec. 5.2).

(B) Repeating Coil By-Pass - Repeating coils may be used in the by-pass circuit when it is desirable to isolate the lines on each side of the repeater (Fig. 47). The signaling range is, however, materially reduced when this method is employed. In this arrangement, retard coils are placed between the hybrids and the 20-cycle repeating coils to prevent voice frequencies

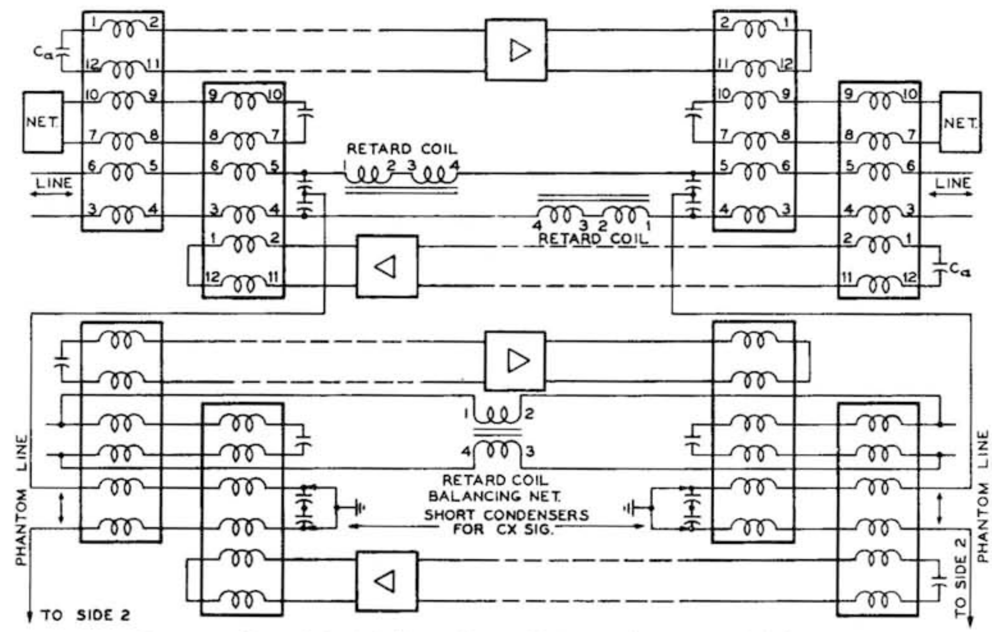


Fig. 46: Retard Coil By-Pass for 20-Cycle or Composited D-C Signals

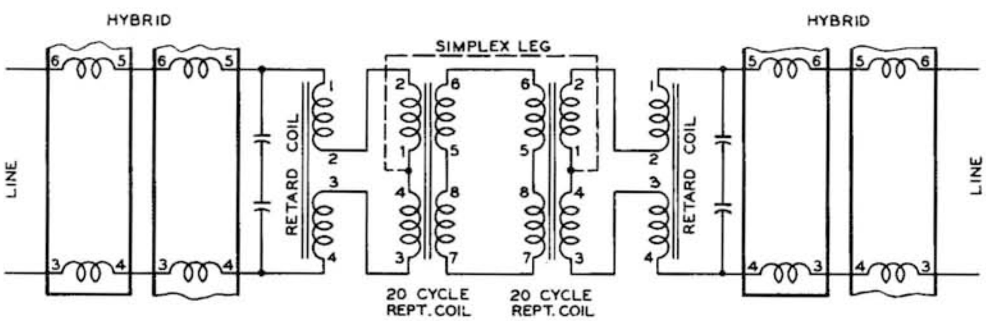


Fig. 47: Repeating Coil By-Pass for 20-Cycle Signals

from by-passing the amplifiers. The lead designated "simplex leg" is required only when the by-passing of simplex signals as well as 20-cycle signals, is desired (See Sec. 5.31). Space is provided on each line and line balancing unit for the retard and repeating coils.

3.12 Repeating 20-Cycle Signals

Twenty-cycle signals may be repeated at an intermediate point through the use of half-ringers (Fig. 48). This arrangement is similar to that shown in figure 47 except that a 20-cycle half-ringer is connected to each 20-cycle repeating coil and the signals are relayed from one half-ringer to the other, over the d-c signal lead.

A 20-cycle signal coming into the repeater from the line, therefore passes through the hybrid line-windings, the retard coils and through the repeating coil into a half-ringer. This half-ringer controls the other half-ringer over the d-c signal lead. The second half-ringer sends a new 20-cvcle ringing current over the line.

The outgoing 20-cycle signal currents contain harmonics, which, in passing through the line-windings of the repeating coil hybrid to the line, also appear at the input of one amplifier on that side and are transmitted back towards the calling telephone. This produces an objectionable signal at the calling end after the ringing signal has been terminated and in some instances, where mixed signaling is employed (Sec. 4), this fed-back signaling current appearing on the line and subsequently at the repeater input on the calling side, may be sufficient to prevent the half-ringers from releasing after the impressed signal has been removed. The half-ringer provides facilities for short-circuiting the voice transmission path during the signaling operation so as to eliminate this effect.

3.2 20-Cycle Signaling at Terminals

At terminals, 20-cycle signals may be by-passed, repeated, or changed to d-c signals if switchboard facilities so require.

3.21 By-Passing

Figure 49 shows a by-passing arrangement for transmitting the 20-cycle signal to the drop. A condenser

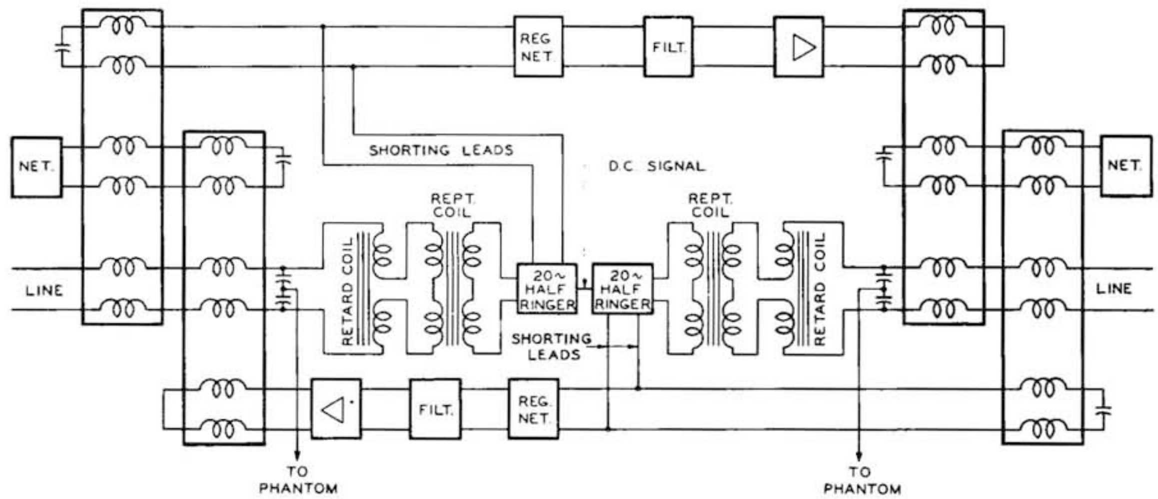


Fig. 48: Repeating 20-Cycle Signals At Intermediate Points

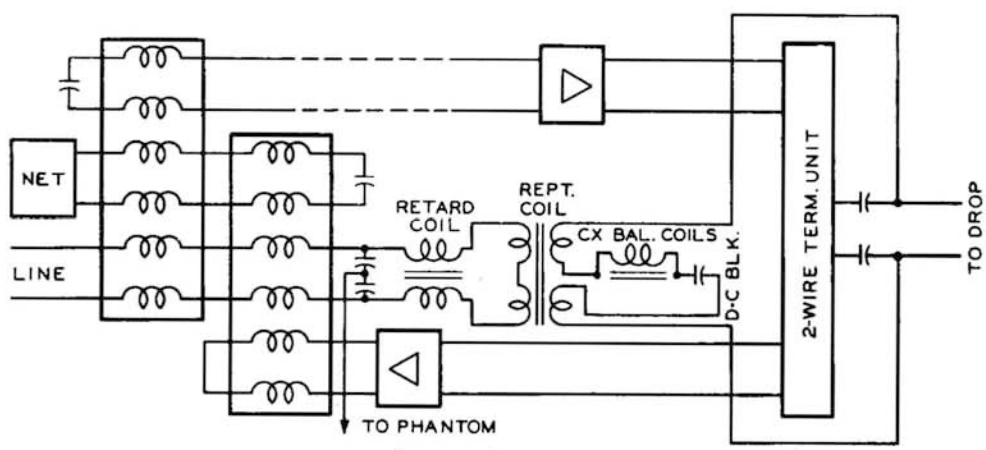


Fig. 49: 20-Cycle By-Pass - Terminal Arrangement

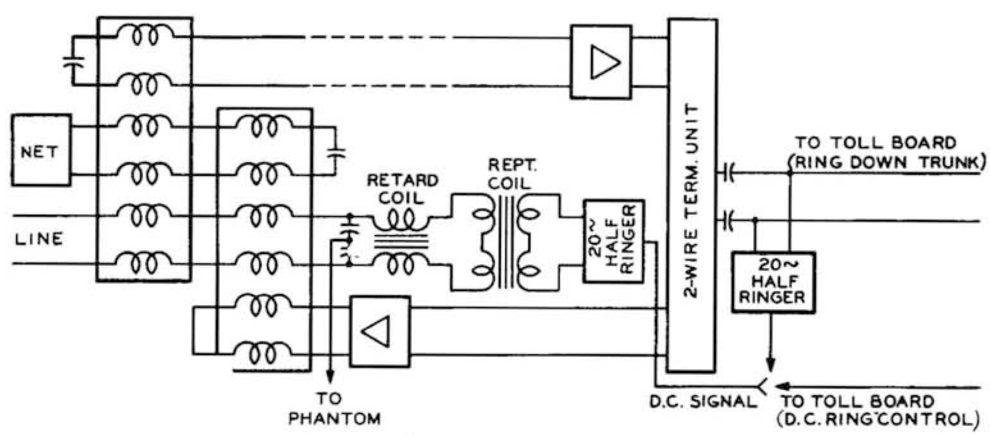


Fig. 50: 20-Cycle Relaying Arrangements at Terminals

and retard coils placed in series with the windings on the drop side of the by-pass repeating coil, provide a resonant circuit which blocks d-c while permitting 20-cycle signals to pass through to the switchboard. As 20-cycle signaling and composited d-c signaling are not employed simultaneously, the set of CX balancing coils (80 or 50 ohms) on the line and line balancing unit, is used in this resonant circuit.

3.22 Repeating Or Converting To D-C Signals

Figure 50 illustrates the method of changing the incoming 20-cycle signal to d-c and placing it on a d-c ring control lead to the switchboard. A 20-cycle half-ringer is employed for this purpose. The d-c signal lead of this half-ringer can be connected instead, to another half-ringer on the drop side of the repeater.

3.3 135-Cycle Signaling at Intermediate Points

The two-wire repeater will amplify 135-cycle signaling currents. However, where it is advisable to by-pass the amplifier and relay the signal, the 135-cycle signal is handled on a half-ringer basis, connection being made to the circuits which precede the amplifier inputs (Fig. 51). The condenser normally placed in series with the hybrid-out windings for equalizing purposes, is replaced by two condensers having an equivalent series capacity. These are placed in the T and R leads at the hybrid-out windings, ahead of the regulating network, filter, etc. The 135-cycle half-ringer is bridged across these condensers as shown.

As illustrated by figure 51, the d-c signal leads of both 135-cycle half-ringers are tied together and 135-cycle signals entering from one side of the repeater through the hybrid-out windings, are repeated by the half-ringers. New signaling current is therefore supplied to the line through the hybrid-out windings on the opposite side of the repeater.

A 135-cycle half-ringer may be used in conjunction with another half-ringer of a different frequency if signaling facilities on one side of the repeater so require. (See Mixed Signaling, Sec. 4)

3.4 135-Cycle Signaling at Terminals

Terminal arrangements for 135-cycle signaling are shown in figure 52. The d-c signal lead from the 135-cycle half-ringer may be connected to another half-ringer associated with a ringdown trunk to the switchboard, or, this lead can be placed directly on a d-c ring control lead.

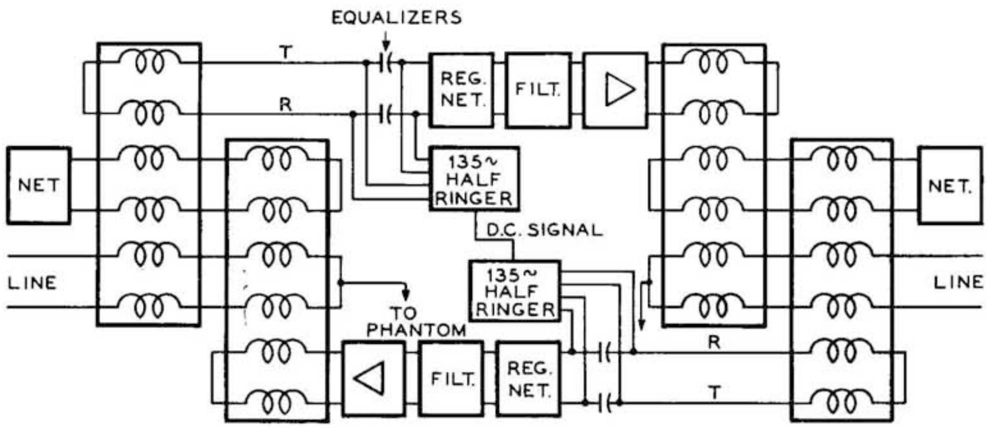


Fig. 51: 135-Cycle Signaling Arrangements at Intermediate Points

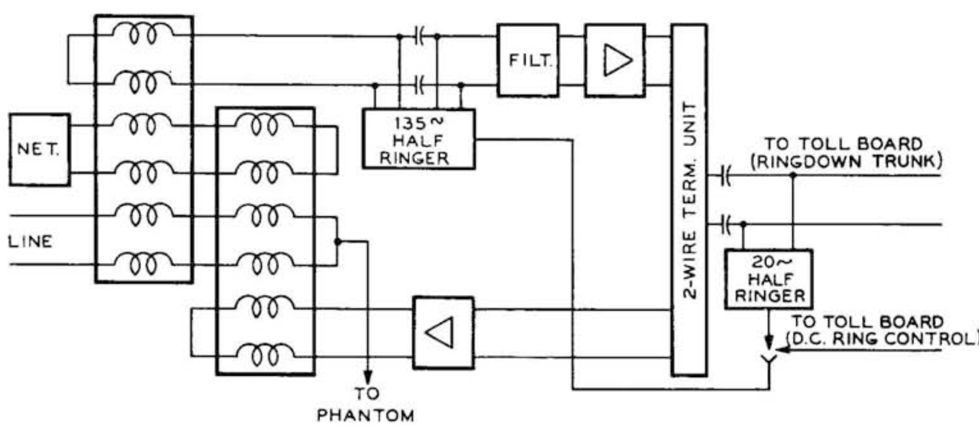
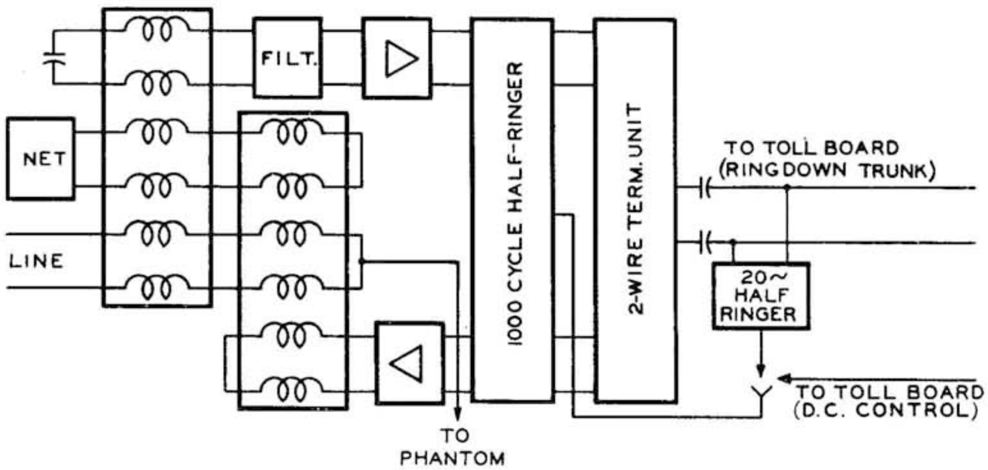


Fig. 52: 135-Cycle Signaling - Terminal Arrangements

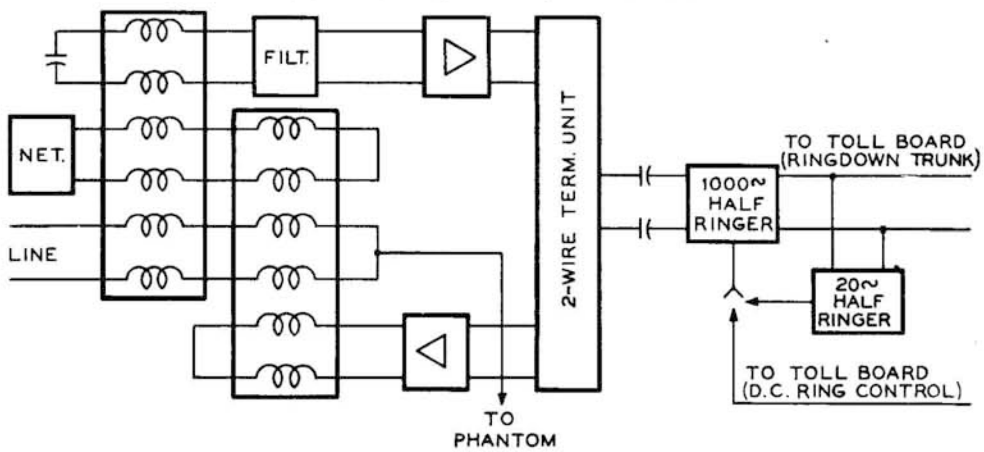
3.5 1000-Cycle Signaling at Intermediate Points

The voice frequency repeater will amplify 1000-cycle signals and does not require any signaling equipment unless a change of signaling frequency is required on the opposite side of the repeater (See Mixed Signaling).

Converting an incoming signal to the frequency required by the toll facilities on the repeater's opposite side, involves the use of half-ringers. Thus, 135-cycle signals may be converted to 1000-cycle or 20-cycle signals and vice versa, 20-cycle signals may be converted to 1000 or 135-cycle signals and vice versa.



(a) Half-Ringer in Repeater Circuit



(b) Half-Ringer on Drop Side

Fig. 53: 1000-Cycle Signaling - Terminal Arrangements

3.6 1000-Cycle Signaling at Terminals

As toll terminal facilities are generally arranged for d-c or 20-cycle signals, conversion of 1000-cycle signals is required. Thousand-cycle half-ringers are employed for this purpose. The half-ringer may be inserted ahead of the two-wire terminating unit in the 4-wire branch of the repeater as shown in figure 53a or it may be placed on the drop side of the repeater as indicated by figure 53b. In either arrangement, the d-c signal lead of the 1000-cycle half-ringer may be connected to another half-ringer on the drop side of the repeater, or, it may be connected directly to a d-c ring control lead to the switchboard.

4. MIXED A-C SIGNALING

The signaling frequency employed on one side of a repeater may differ from that used on the opposite side. It is also possible to employ a different type of signaling or different combinations of signaling in each circuit of a phantom group. Considerations pertaining to phantom balance must be observed, however, when this is done. Use of the retard-coil by-pass in one side-circuit, for instance, requires the use of a similar by-pass in the other side-circuit. If the 20-cycle repeating coil by-pass shown in figure 47 is employed in one side-circuit, the other side-circuit must retain the series condensers across the hybrid line-windings.

Figure 54 gives an example of mixed signaling in an intermediate phantom group. Not all of the possible combinations are shown and it is emphasized that this illustration does not necessarily constitute an example of typical telephone practice. It will be seen that the signaling frequency on one side of each side-circuit repeater is different from the frequency employed on the other side. Different signaling frequencies could be employed on each side of the phantom repeater, if desired.

At terminals, however, conversion of all incoming signals to toll board facilities is necessary. Thus, if the toll board incorporates 20-cycle ring down facilities, those circuits carrying other ringing frequencies will require half-ringers at the terminal.

5. D-C SIGNALING ON TWO-WIRE CIRCUITS

Repeatered toll circuits may be utilized for the transmission of d-c signals (telegraph, dial pulses, 3-1/2 cycle dispatch signals, etc.) through the use of composite sets, d-c by-pass arrangements or simplex arrangements.

5.1 Compositing at Terminals

At terminals, d-c signals are placed on the line by compositing. Automatic Electric Company's type 51 (heavy duty) or type 52 composite sets may be used for this purpose. Figure 55 shows compositing arrangements at terminals when type 52 composite sets are employed in each side-circuit. These require no balancing in the side-circuit networks but both must be balanced in the phantom network as shown. Provision is made for mounting type 52 composite sets on the line and line balancing units. Type 52 composite sets employ the same kind of retard coils (44-ohm) that are used in the retard-coil or repeating-coil by-pass. Condensers for the set are obtained from the bank shown in figure 16. The same kind of retard coils are also used in the phantom balancing network for balancing these composite sets in the side-circuits. These mount on the line and line balancing unit.

On lines utilized for carrier as well as voice transmission, only type 51 composite sets may be used. This composite set (external) is placed on the line (Fig. 56) ahead of the carrier filter and provides a d-c blocking arrangement which prevents current from flowing through the carrier filter. When the side-circuits are composited with type 51 sets balancing is required in the networks of the side-circuits as well as in the phantom network. CX balancing coils (see Part I, Sec. 4.211C) for balancing type 51 composite sets are mounted on the line and line balancing unit.

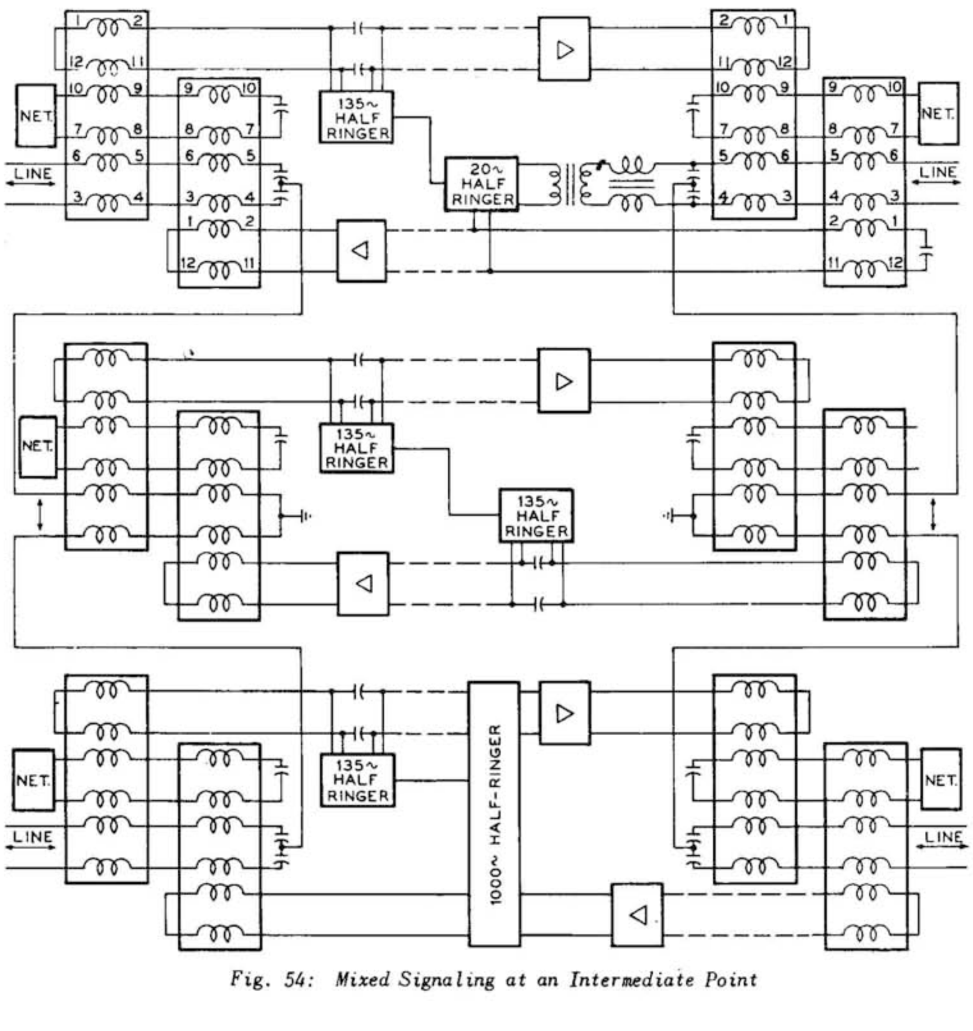


Fig. 54: Mixed Signaling at an Intermediate Point

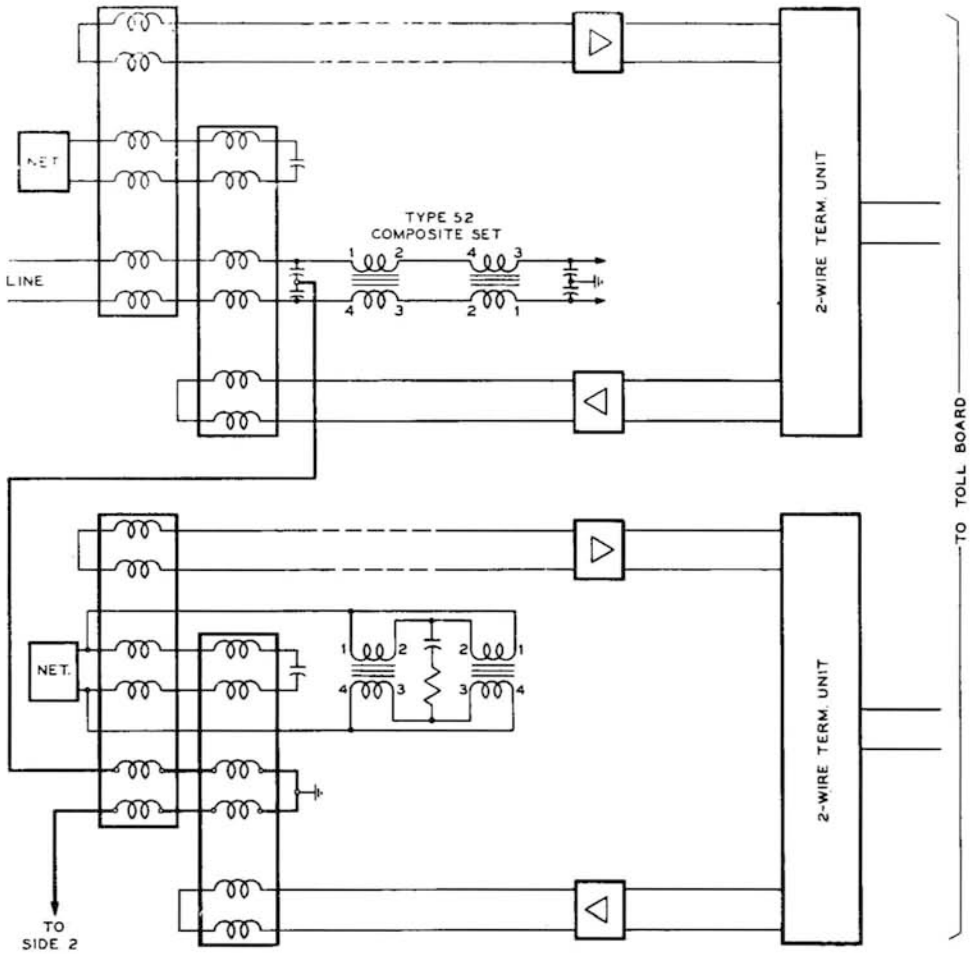


Fig. 55: Type 52 Composite Set Employed at Terminal

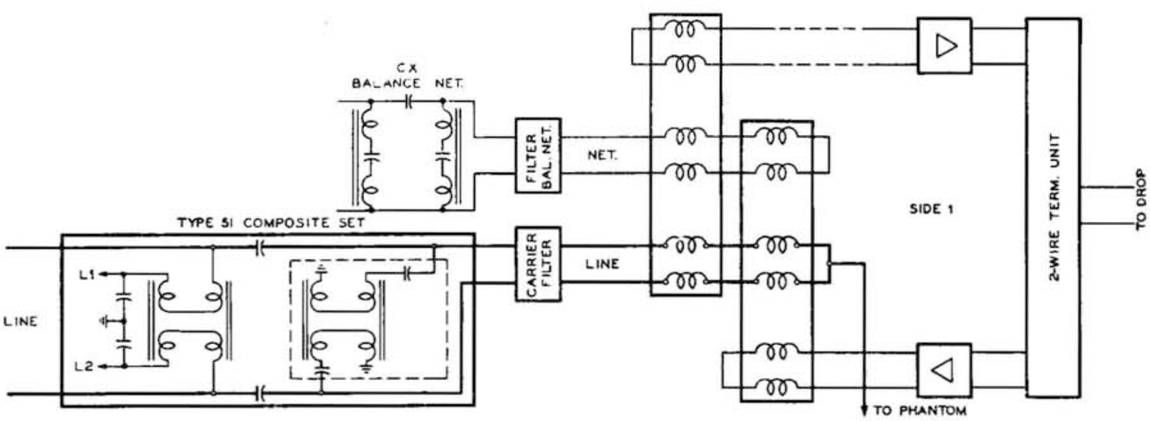


Fig. 56: Type 51 Composite Set Employed at Terminal

Type 51 or 52 composite sets are required in both side-circuits of a phantom group even though only one side may be used for d-c signaling. This is essential for maintenance of the phantom balance. However, when only one circuit is to be composited, the phantom circuit is usually chosen for this purpose. In this instance, the side circuits cannot be composited and balancing of the composite set is required (if type 51 sets are employed) only in the phantom network (See Part I, Sec. 4.211C).

5.2 By-Passing Composited Signals at Intermediate Points

5.21 Retard Coil By-Pass

The retard coil by-pass arrangement shown in figure 46 will pass composited d-c signals (telegraph, dial pulses, 3-1/2 cycle railway dispatch signals) or 20-cycle signals. When CX signaling is used in the side-circuits of a phantom group, the line condensers of the phantom repeater must be shorted to prevent cross-fire between the signaling circuits.

5.22 Composite Set By-Pass

D-C signals may be by-passed around an intermediate repeater through the use of type 51 composite sets (Fig. 57). This is required when the toll lines are also employed for carrier so that d-c is kept out of the carrier filters and inter-channel interference thereby prevented. As stated for terminal arrangements, the use of type 51 composite sets in the side-circuits at an intermediate point, requires that these be balanced in the network circuit of each side-circuit repeater as well as in the phantom network (See Sec. 5.1 above).

When it is desirable to repeat d-c signals, an impulse repeater may be inserted in the composited by-pass circuit as shown in figure 57.

5.3 Simplex Arrangements

5.31 By-Passing at Intermediate Points

When d-c signals are carried on repeatered toll lines under a simplexing arrangement, the metallic portion of the simplex is by-passed around the repeater in several fashions. If 20-cycle telephone signaling is not employed, a d-c path or simplex leg may be provided by connecting together the mid-points (2-3) of retard coils associated with the line windings of each hybrid (Fig. 58).

Connections for deriving a phantom simplex leg at a point where 20-cycle signaling facilities do not exist, are shown in figure 59. Two simplex coils are employed here, for deriving the midpoints of the side-circuits.

In the case of the repeating coil, 20-cycle by-pass described in Sec. 3.11B, the midpoints of the line - windings (2, 1, 4, 3) of the repeating coils, are connected to provide a simplex leg (Fig. 47). With this arrangement it is possible to employ 20-cycle ringing on the toll circuit even while d-c signals are being transmitted.

Where 20-cycle, repeating coil by-pass arrangements exist in both side-circuits of a phantom group, both side-circuits may be used to carry the metallic portion of a phantom simplex circuit as illustrated in figure 60.

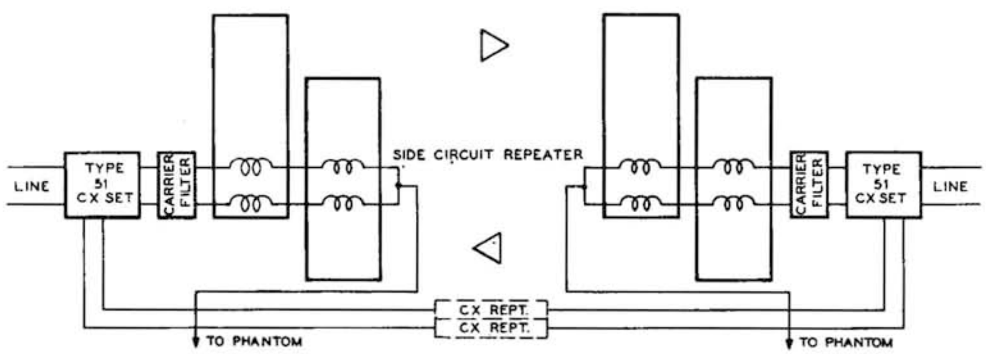


Fig. 57: Composite Set By-Pass

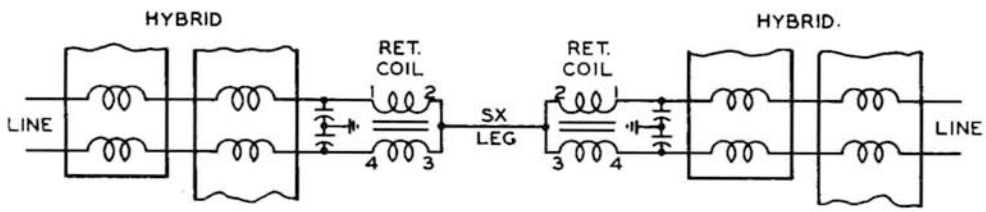


Fig. 58: Simplex By-Pass

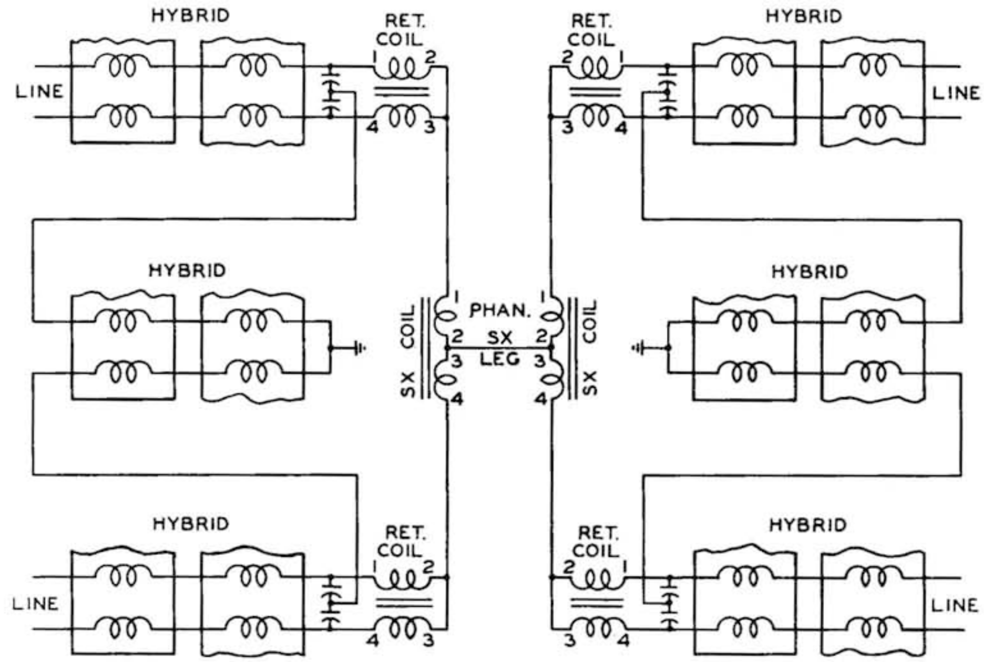


Fig. 59: Phantom Simplex By-Pass

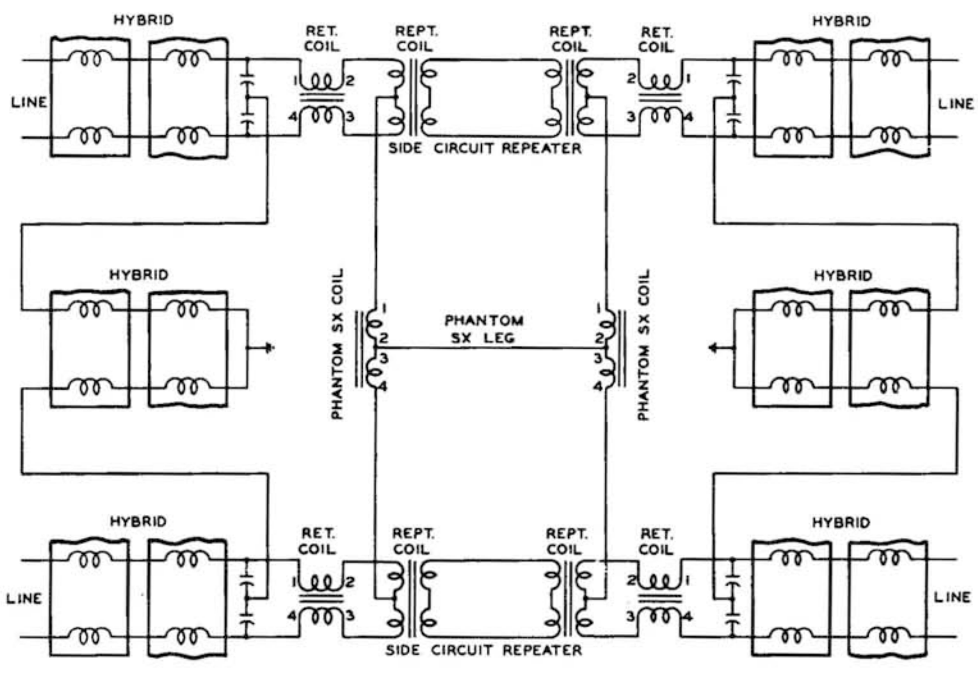


Fig. 60: Phantom Simplex By-Pass with 20-Cycle Signaling Facilities

5.32 Simplex Terminal Arrangements

At terminals where 20-cycle signaling is not employed, the simplex signaling or telegraph equipment is connected between the mid-point of the hybrid line-windings and ground (or battery) - see fig. 61. This arrangement cannot be used on side-circuits of a phantom group.

Phantom simplexing arrangements at a terminal where 20-cycle telephone signaling is not employed, are shown in figure 62. In this instance, the simplex signaling equipment is connected between the mid-point of the phantom hybrid line-windings and ground (or battery).

Where 20-cycle signaling arrangements exist at a terminal, the simplex signaling equipment is connected

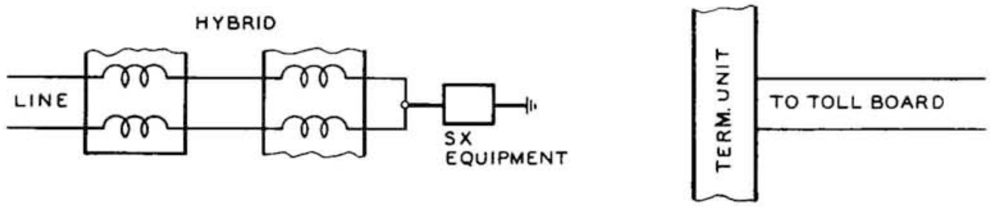


Fig. 61: Simplex Terminal Arrangements

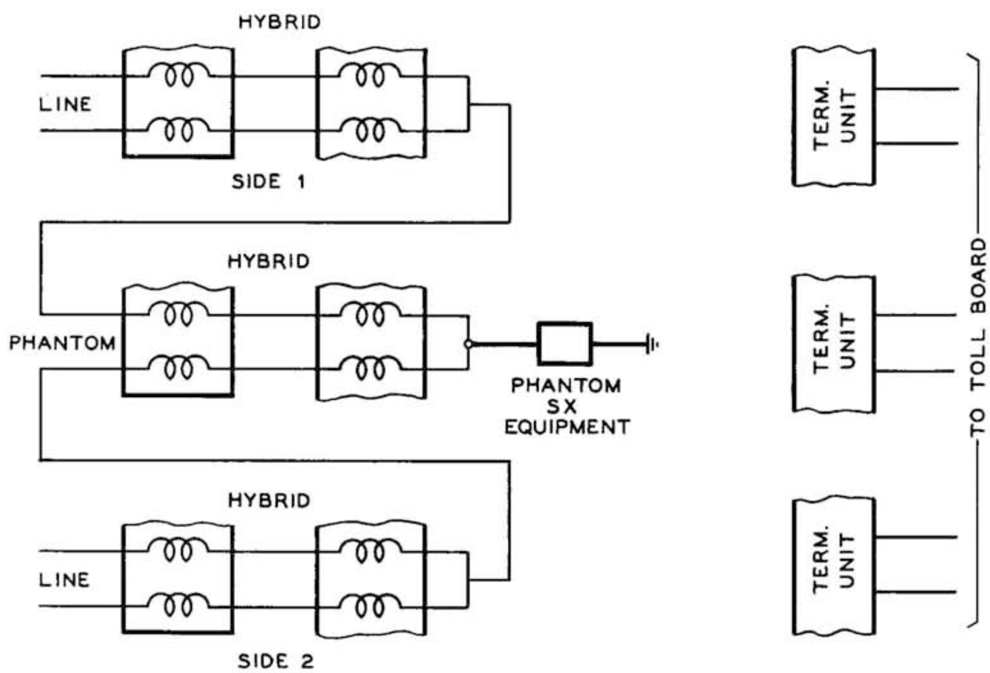


Fig. 62: Phantom Simplex Terminal Arrangements

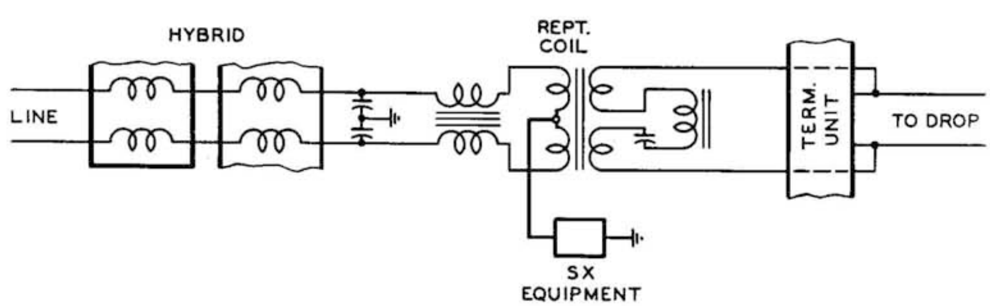


Fig. 63: Simplex at Terminals With 20-Cycle Signaling Facilities

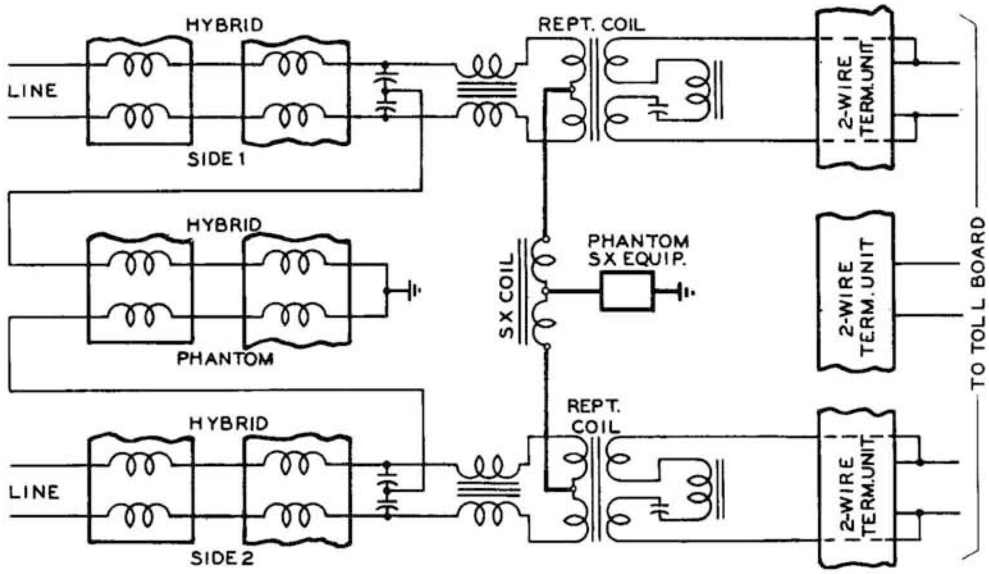


Fig. 64: Phantom Simplex at Terminals With 20-Cycle Signaling Facilities

between the mid-point of the repeating coil line-windings and ground (or battery) as shown in figure 63. This arrangement cannot be used on side-circuits of a phantom group. A phantom simplex arrangement at terminals where the side-circuits employ 20-cycle telephone signaling, is shown in figure 64. D-C signals and 20-cycle signals may be received or transmitted simultaneously in both of the above arrangements.

6. D-C SIGNALING ON FOUR-WIRE CIRCUITS

When telegraph and other d-c types of signaling (usually metallic) are employed on four-wire toll lines, by-passing

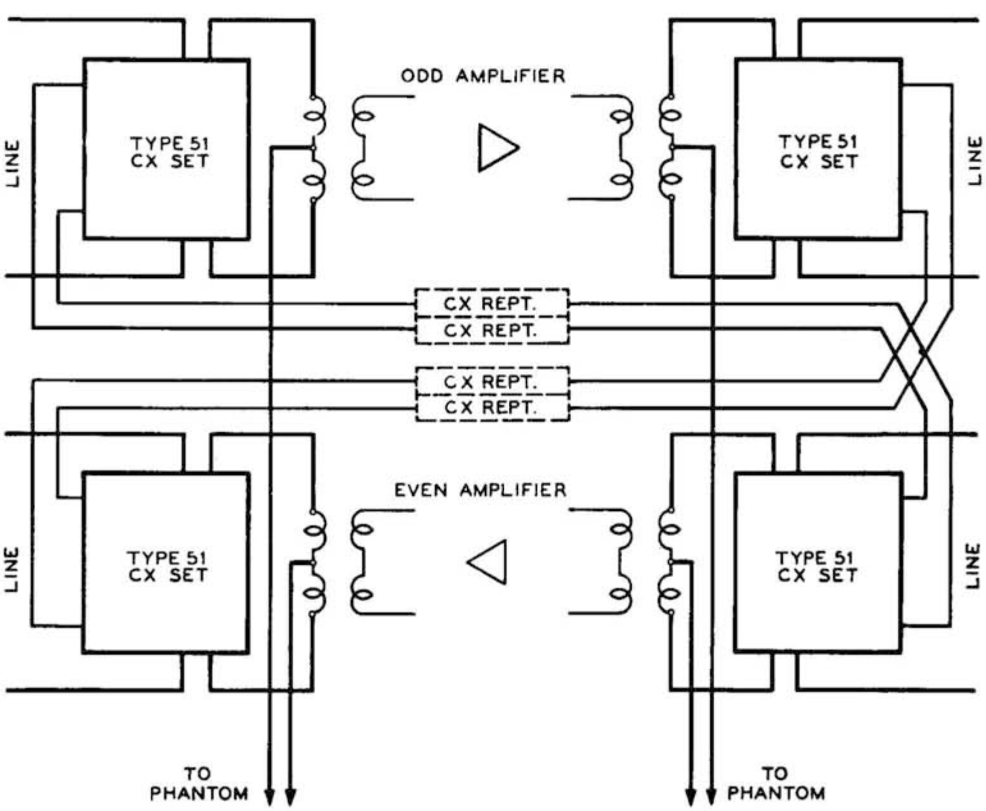


Fig. 65: Composite Set By-Pass on Four-Wire Circuits

around an intermediate repeatered point is accomplished through the use of type 51 (heavy duty) composite sets. The composite sets are cross-connected (Fig. 65) so that the d-c signal path is established between the pairs associated with both repeater inputs or both outputs. By cross-connecting in this manner, the composited signal paths occur between pairs whose voice frequency levels are similar. The attenuation offered by the composite sets to voice frequencies will then be adequate for the prevention of excessive coupling between the circuits.

7. CONNECTIONS FOR SIGNALING ARRANGEMENTS

Connection of external signaling equipment to the line units is made to the rear terminal blocks of these assemblies. Interconnections between equipment associated with, or mounted on the line units, are made on the front strapping panels. Type 52 composite sets, retard coils, 20-cycle repeating coils and CX balance coils, when required, are mounted on the line and line balancing units. Connections between repeaters are made from the rear terminal blocks of the sub-assemblies involved.

PART III

TESTING AND MAINTENANCE

1. VACUUM TUBE CHECK

1.1 Emission

A check of the cathode emission of the amplifier's 12SK7 tube provides a relatively good indication of the tube's condition. Comparison of the results of these checks from month to month will aid in determining whether or not an abrupt depreciation in the tube's condition has occurred. The life expectancy of most brands of 12SK7 tubes is approximately 7500 hours, so it is generally advisable to replace the tubes every 6 months.

Cathode current, for an indication of tube emission, is not measured directly but is determined from the voltage drop across a 100-ohm resistor (R-6) in the tube's cathode circuit (See Fig. 3). Voltage readings are taken with the filament voltage at normal and with filament voltage reduced.

Access to the current measuring resistor in the cathode circuit of each amplifier tube is made through the plate (PL) jack on the jack unit. The tip connects to the odd amplifier and the ring to the even amplifier. The sleeve is grounded. A voltmeter with a minimum sensitivity of not less than 1000 ohms-per-volt should be used for measuring the voltage across each resistor. To place the meter in the cathode circuit, a three-conductor plug and cord assembly (See Part I, Sec. 8.11) is employed. The sleeve is fastened to the meter's negative terminal and the tip and ring are alternately connected to the meter's positive terminal depending upon which tube in the amplifier unit is to be checked.

Note the gain control setting of the amplifier whose tube is under test so that it may be returned to that position after the test. Then set it to the highest gain point (+5 decibels) for the emission check. The voltage obtained at the plate jack should be as follows:

Plate Supply Voltage	Voltage at Plate Jack
125-145	1.2-1.7

The emission of a tube which is in excellent condition, should not change substantially with a nominal reduction in the heater voltage supply. To check for this, first reduce the heater voltage by placing a 30-ohm resistor in series with the heaters. This is accomplished through the "FIL" jack. A three-conductor plug and cord assembly (See Part I, Sec. 8.11) is employed and the voltage dropping resistor is connected between the tip and ring leads. (The resistor drops the voltages to both heaters as they are normally in series - See Fig. 44.) With the resistor in the heater circuit, the voltage indication at the plate jack should not differ more than .1 volt below that measured previously without the resistor.

1.2 Other Tube Checking Methods

More complete indications of tube conditions may be obtained through the use of good commercial tube checking instruments, which provide evidence of tube shorts and measure transconductance or power output.

2. SINGING POINT TESTS AND BALANCING ADJUSTMENTS

The degree of balance between the toll circuit and the balancing network (or "artificial line") of a two-wire repeater is determined by making "singing point" tests. These tests depend on the phenomenom that continued oscillation or singing occurs in the repeater when the sum of the amplifier gains just equals or exceeds the sum of the losses in the transmission paths of the repeater, providing that favorable phase relations are obtained. If a high degree of balance exists between the toll circuit and the balancing network, the "trans-hybrid" loss is high, that is, the hybrid-coil circuit presents a high impedance to those amplified currents which tend to travel from the output of one amplifier to the input of the other (See Part I, Sec. 4.21). In this case, the amplifier gains can be set high before the trans-hybrid loss (plus the insertion loss of the filters, equalizers, etc.) is exceeded, with consequent singing. But if a poor balance exists, the trans-hybrid loss is low and singing will begin at lower amplifier gains. Thus, the point at which the repeater begins to sing, indicates the effectiveness of balance between the actual line and the "artificial line" (balancing network circuit).

In practice, the singing point (or balance) of each side of the repeater is determined separately. These singing point tests can be performed concurrently with balancing adjustments of the networks as described in section 2.1 below. Singing point tests can be made for the drop side of terminal repeaters (Sec. 2.11) but as a compromise network is employed across the resistance-hybrid (Part I, Sec. 5.211) no balancing adjustments are ordinarily required.

2.1 Procedure for Singing Point Tests and Balancing Adjustable Networks

Before making adjustments in the AO network to balance the toll line, the other components existing in the toll circuit must be balanced. It will therefore be necessary to strap in the building-out (BO) network, composite balancing network, phantom balancing resistance (for phantom repeaters) and carrier filter network etc., to conform to the characteristics of the toll facilities (See Part I, Sec. 4.211). When not required, these networks must be strapped out of the balancing network circuit.

For the singing test, the line on the side undergoing adjustment (for example, the "west" side) must be terminated at its distant end in a 600-ohm resistance or in a subset with the receiver off-hook (Fig. 66). Where another repeater is adjacent (with intervening line facilities) to the side of the repeater being balanced, the adjacent repeater is disabled (made "passive") and the line terminated in it. This is accomplished by inserting 600-ohm plug assemblies in the "EQUIP IN" and "EQUIP OUT" jacks of the adjacent repeater on the side which is facing the repeater undergoing test. (The 600-ohm plugs are available from A.E.Co. See Part I, Sec. 8.11.)

In addition, a feedback circuit is formed within the repeater by connecting the output of one amplifier to the input of the other amplifier. To accomplish this, a cord terminated at each end in twin, two-conductor plugs (See Part I Sec. 8.11) is patched between the "AMP OUT" and "AMP IN" jacks on the east side of the amplifiers. The feedback circuit thus includes the gains of both amplifiers and the west line-equipment losses. (The east line-equipment is disconnected from the repeater by patching of the amplifiers as described above.)

The procedure for making balancing adjustments is as follows:

(a) Plug a receiver into the monitor jacks.

(b) Turn the amplifier gains up until singing just occurs. (It is necessary to operate the repeaters on the singing threshold when balancing.)

(c) The AO network on all line units shipped by A.E.Co., is normally strapped for 600-ohms and 1 mf. Increase or decrease resistance (20-80 ohms) until a drop in level or cessation of singing is obtained.

(d) Increase or decrease capacitance in sizable steps (.1 mf) until the audible level in the receiver diminishes or ceases.

(e) When singing ceases, carefully increase the amplifier gains until singing just begins again.

(f) Adjust the network again in smaller steps until singing ceases. (As a condition of balance is approached, subsequent changes of capacitance and resistance must be made in increasingly small steps.) The capacity and resistance of the AO network is alternately adjusted and the amplifier gains increased until additional network adjustments achieve no cessation of singing.

(g) Reverse one plug of the patch cord connecting the amplifiers. If singing does not cease, restore the plug to its original position. If singing ceases when the plug is reversed, however, increase the amplifier gains until singing again begins. Adjust the network and increase gains etc., until the highest singing point is established.

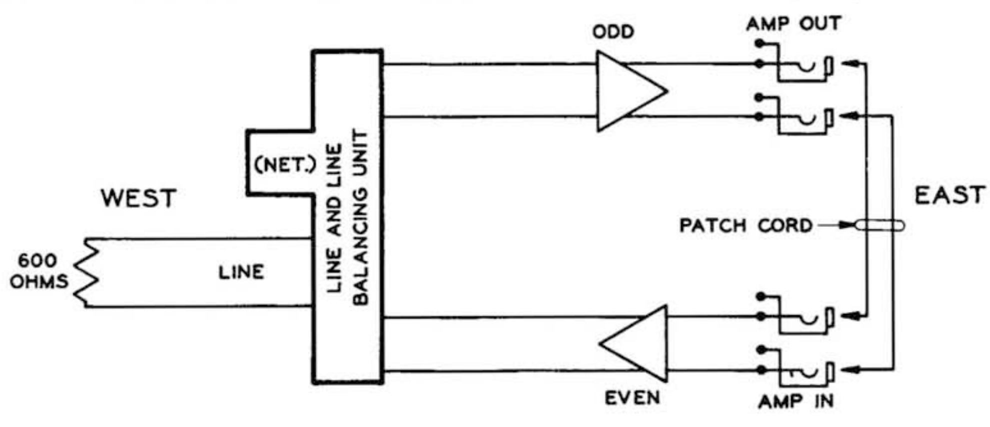


Fig. 66: Arrangements for Singing Point Tests

(h) Set the amplifier gains just below the singing point. When the building-out "T" section (BO) is employed, the capacity has been set as explained in Part I, Sec. 4.211B. In this case change the value of capacity in .01 mf steps on each side of the original value. If this causes the repeater to sing, return to the original value as this is the best value. If, however, the singing point is raised, increase the capacity in small steps until no further improvement is obtained. The gains of the amplifiers should be recorded.

(i) To balance the east side of a two-wire intermediate repeater, remove the patch cord from the "AMP IN - AMP OUT" jacks presently on the east side and patch the corresponding jacks on the west side of the repeater. Terminate the line on the east side at its distant end with 600-ohms or in a passive repeater.

(j) Proceed with adjustments on the east line-balancing panel as outlined in steps a to h. If the line on the east side is the same as the line on the west side, the initial values of capacitance and resistance for the east side, should be the same as the final values obtained for the west side.

(k) Set the amplifiers to give the working gain of the repeater for each direction (See Sec. 3 following).

2.11 Singing Point Test for Terminal Repeaters

The line sides of two-wire terminal repeaters are balance-tested as described in section 2.1 above. Singing point tests can also be made to determine the balance on the drop sides, but network adjustments are precluded since a compromise network is used across the resistance hybrid (See Part I, Sec. 5.211). Drop side singing test arrangements consist merely of patching the "AMP IN - AMP OUT" jacks on the line side and terminating the drop circuit with 600-ohms or with a single subset with the receiver off-hook. The amplifier gains are then advanced until the singing point is reached. The amplifier gains should be recorded.

2.12 Determination Of Singing Point Value

When the optimum balance for one side of the repeater has been obtained according to the procedure in Section 2.1 or 2.11, the singing point value for that side will then be:

Singing point value = Sum of amplifier gains minus the sum of the input and output equipment losses of that side.

Equipment losses are as follows:

Equipment	Input Loss (Without Equal.)	Output Loss
L & L Bal. Unit	5.5 db	4 db
Terminating Unit	10.7 db	10.7 db

Line equipment input losses which include the insertion losses of the hybrid, equalizers and filter, are given in the two-wire equalization charts in the Appendix.

EXAMPLE: Assume that the optimum balance for the west side of the repeater, has been obtained (as indicated in Sec. 2.1) with the following results:

Odd Amp Gain = 16 db
Even Amp Gain = 17 db

Further assume that the line equipment losses on the west side are as follows: Input loss (including equalizers, filter, etc.) = 8 db; output loss = 4 db. From the formula above, the singing point value for the west side will be:

Singing Point Value = 16 db + 17 db - (8 db + 4 db)
= 33 db - 12 db
= 21 db

The singing point value for the line side may be as low as 10 db, and still afford a satisfactory margin for operation of the repeater on certain lines. A singing point test toward the drop side of a terminal repeater (as outlined in section 2.11) should give a minimum singing point value of 6 db.

2.2 Balancing Adjustments for Dispatch Circuits

The adjustment of the AO network for dispatch circuits is made in a manner similar to that for trunk circuits. Before making adjustments, however, about every third subset should be connected to the line in the listening condition for a distance of approximately 85 miles. The line should be terminated at the distant end in a subset with the receiver off-hook or in a repeater in passive condition.

After a satisfactory adjustment is obtained, connect a subset in the talking condition to the line, at, or near the repeater. If the repeater sings or if poor quality results, reduce the gain for both directions until good quality is obtained. The final setting of the amplifier gain controls should be such, that both can be advanced 3 or 4 db without causing singing.

Large impedance irregularities are caused by subsets connected across the line, particularly when these are in the talking position. Because of this, the balance obtained will be inferior to that ordinarily obtained on trunk circuits. This naturally reduces the effective gain that may be introduced into most dispatch circuits. Somewhat larger gains are permitted when "impedance correctors" are inserted between the line and each subset to increase the bridged impedance. The impedance corrector may be a resistance or an inequality ratio coil with its high side in series with a d-c blocking condenser, toward the line.

3. AMPLIFIER WORKING GAIN ADJUSTMENT

When the optimum balance for both sides of the repeater has been obtained, the patch cords between the amplifiers are removed, so that the repeater is in the normal operating condition. The amplifiers may now be adjusted to give the desired gain for each direction. No further adjustments of the balancing networks should be made. The "working" amplifier gain settings should be made in accordance with the toll circuit gain requirements and good engineering practices, or specific instructions.

In normal operation, the gain of each amplifier should be adjusted so that the sum of the net gains in both directions is at least 8 db below the sum of the singing point values. By operating in this manner, greater stability and more satisfactory repeater operation is experienced. Once established, this singing "safety margin" should not be exceeded.

To determine the maximum usable gain of the repeater, simply add the two singing point values (as obtained for each side according to instructions in Sec. 2.12 above) and subtract the 8 db singing "safety margin". For example:

West singing point value	21 db
East singing point value	19 db
Sum of singing point values	40 db
Subtract singing "safety margin"	-8 db
Net (effective) gain.	32 db

This net gain may be divided equally between the east and west directions or it may be distributed unequally as the requirements indicate. To provide the required net gain (insertion gain) for each direction, however, it is necessary to set the amplifier for each direction to a value, higher than the desired net gain so as to allow for the insertion losses of the input and output equipment in that direction. For example:

Assume that the total net gain of 32 db shown above, is to be divided equally in both directions - 16 db for each direction. Further assume that for a signal in the east-to-west direction, the input equipment loss is 7 db and the output equipment loss is 4 db. Accordingly, the amplifier gain setting required to obtain a net gain of 16 db in the west direction, will be:

$$16 \text{ db} + 7 \text{ db} + 4 \text{ db} = 27 \text{ db}$$

To determine the amplifier gain setting for the east direction, the input and output equipment losses in the west-to-east direction are used.

3.1 Amplifier Gain Measurement

Although the gain controls on the Type 47 repeater are directly calibrated in decibels for ease of adjustment, other means of setting the gains or of checking existing calibrations are available. Amplifier gains may be measured by means of any suitable transmission measuring set and test tone source, access to the amplifier being provided by the "AMP IN" and "AMP OUT" jacks. The test tone source should be a 1000-cycle oscillator having 0 dbm output into 600 ohms; the oscillator itself must have an impedance of 600 ohms. When measuring in this fashion, the output of the amplifier should not exceed .010 watt (+10 dbm).

Another method of measuring gain or checking calibration, is established by insertion of a calibrated, variable-loss, 600-ohm attenuator pad between the input and output of the same amplifier. The attenuator acts as a feedback control and is adjusted until singing begins. The setting of the pad at this singing point provides an indication of amplifier gain. The singing point (using the attenuator pad) should also be determined with the connections between the amplifier input and output, reversed. This is accomplished by reversing one plug of the cord assemblies which patch the attenuator pad to the amplifier. The higher of the two pad indications should be taken as the amplifier gain. This indication should agree within 1 db with the setting of the amplifier gain controls. If this check is made periodically and the gain settings of the amplifier have not been disturbed, any sharp variation in the attenuator pad indication may be due to a faulty tube or other cause such as low voltage or a defective component.

Should the attenuator pad be connected between the amplifiers so that the feedback voltage is out of phase, audible singing may not occur regardless of the pad setting. This situation is remedied by reversing the connections to the amplifier as described above. The pad may then be readjusted until singing begins.

4. PATCHING IN SPARE AMPLIFIER UNIT

In case of amplifier failure requiring extensive trouble shooting, an amplifier unit from another repeater may be temporarily patched in to maintain toll service. Patching connections are easily made at the jack panel unit of the spare repeater to the jack panel unit of the working repeater by means of four standard patching cords terminated at each end with twin, tip-sleeve plugs (See Part I, Sec. 8.11).

In making the amplifier transfer, the ends of the cords are patched to the "AMP IN, AMP OUT" jacks of the spare repeater. The other ends are patched to the "EQUIP IN, EQUIP OUT" jacks of the working repeater as indicated below:

Cord	Spare Repeater		Working Repeater
	Odd Amp Jacks		Odd Amp Jacks
1	Amp In	To. . . .	Equip Out
2	Amp Out . . .	To. . . .	Equip In
	Even Amp Jacks		Even Amp Jacks
3	Amp In	To. . . .	Equip Out
4	Amp Out . . .	To. . . .	Equip In

In two-wire repeaters, it is imperative that both amplifiers of the working amplifier unit be replaced even though only one amplifier in the working unit may be defective. This is necessary for correct operation of the cut-out relays (See Sec. 4.26 Part I) in the line or terminating units. Four-wire repeaters do not incorporate a cut-out circuit so that one amplifier of the working unit may be replaced by one amplifier of the spare unit.

Appendix

TABLE I

APPROXIMATE CHARACTERISTICS OF OPEN WIRE CIRCUITS AT 1000 C.P.S.*
(COPPER, COPPERWELD, STEEL)

Gauge of Wire (Mils)	Spacing (Inches)	Constants Per Loop Mile R Ohms	L Henrys	C Mf	Line Impedance (Ohms) R	X	Z	Angle (Degrees)	Loss DB Per Mile	Rept. Coils For Hybrid D-283686	Low Pass Filter D-283688
Copper - Side Circuits											
104	8.0	10.15	.00340	.00905	629	141	644	12.63	.070	B	A
104	12.0	10.15	.00366	.00837	677	141	692	11.75	.066	B	A
104	18.0	10.15	.00393	.00797	717	139	730	10.97	.062	B	A
128	8.0	6.74	.00327	.00944	596	94	603	8.97	.049	B	A
128	12.0	6.74	.00353	.00871	643	94	650	8.32	.046	B	A
128	18.0	6.74	.00380	.00825	686	93	693	7.72	.044	B	A
165	8.0	4.11	.00311	.00996	562	58	565	5.88	.032	B	A
165	12.0	4.11	.00337	.00915	610	57	612	5.35	.030	B	A
165	18.0	4.11	.00364	.00863	651	57	653	5.00	.028	B	A
Copper - Phantom Circuits											
104	12.0	5.08	.00223	.01409	415	71	421	9.70	.056	A	A
104	18.0	5.08	.00222	.01454	397	69	403	9.83	.056	A	A
128	12.0	3.37	.00216	.01454	398	47	401	6.73	.039	A	A
128	18.0	3.37	.00215	.01501	382	46	384	6.83	.039	A	A
165	12.0	2.06	.00208	.01514	372	28	373	4.3	.025	A	A
165	18.0	2.06	.00207	.01563	365	28	366	4.33	.025	A	A
Copperweld 40% - Side Circuits											
104	8.0	24.8			691	324	763	25.1	.162	B	A
104	12.0	24.8			736	328	806	24.0	.152	C	A
128	8.0	16.6			635	230	676	19.9	.120	B	A
128	12.0	16.6			674	232	712	19.0	.112	B	A
165	8.0	10.1			572	143	590	14.0	.0784	B	A
165	12.0	10.1			615	143	631	13.1	.0729	B	A
Copperweld 40% - Phantom Circuits											
104	8.0	12.4			467	172	498	20.2	.120	B	A
104	12.0	12.4			440	171	472	21.2	.127	B	A
128	8.0	8.3			438	120	454	15.3	.086	A	A
128	12.0	8.3			410	119	427	16.2	.092	A	A
165	8.0	5.05			411	73	417	10.1	.055	A	A
165	12.0	5.05			383	73	390	10.8	.059	A	A
Steel - Side Circuits											
109	12.0				1279	629	1425	26.2	.289	D	A
134	12.0				1252	520	1356	22.6	.250	D	A
Steel - Phantom Circuits											
109	12.0				721	334	795	24.9	.259	C	A
134	12.0				711	281	765	21.6	.220	C	A

* Values based on dry weather, average temperature conditions.

TABLE II

APPROXIMATE CHARACTERISTICS OF PAPER INSULATED, QUADDED CABLE CIRCUITS AT 1000 C.P.S.

Loading	Constants Per Loop Mile R Ohms	L Henrys	C Mf	Line Impedance (Ohms) R	X	Z	Angle (Degrees)	Cut-Off Freq. C.P.S.	Loss DB Per Mile	Rept. Coils For Hybrid D-283686	Rept. Coils Four-Wire* D-283686	Low Pass Filter D-283688
19 Gauge Side Circuit												
NL	85.8	.001	.062	345	319	470	42.8		1.08	B	C (par)	C
B-88	98.7	.156	.062	1588	77	1590	2.8	5700	.28	D	C (ser)	A
H-31	88.2	.028	.062	691	162	710	13.2	6700	.56	B	A (ser)	A
H-44	89.4	.039	.062	806	141	818	9.9	5700	.49	C	A (ser)	A
H-88	92.2	.078	.062	1126	103	1131	5.2	4000	.36	C	B (ser)	A
H-172	97.3	.151	.062	1563	77	1565	2.8	2900	.28	D	B (ser)	C
H-174	100.0	.152	.062	1568	79	1570	3.0	2900	.29	D	B (ser)	C
16 Gauge Side Circuit												
NL	42.1	.001	.062	251	215	331	40.7		.73	A	B (par)	C
B-88	54.9	.156	.062	1587	41	1587	1.5	5700	.16	D	C (ser)	A
H-31	44.5	.028	.062	677	83	683	7.0	6700	.29	B	A (ser)	A
H-44	45.7	.039	.062	805	73	808	5.2	5700	.26	C	A (ser)	A
H-88	48.5	.078	.062	1123	53	1124	2.7	4000	.19	C	B (ser)	A
H-172	53.6	.151	.062	1562	41	1562	1.5	2900	.16	D	B (ser)	C
H-174	56.3	.152	.062	1566	43	1567	1.9	2900	.17	D	B (ser)	C
19 Gauge Phantom Circuit												
NL	42.9	.0007	.100	195	175	262	42.0		.96	A	B (par)	C
B-50	49.4	.089	.100	944	40	945	2.4	5900	.24	C	B (ser)	A
H-18	44.1	.017	.100	421	83	429	11.1	7000	.46	A	C (par)	A
H-25	44.7	.023	.100	485	72	491	8.5	5900	.40	B	C (par)	A
H-50	46.2	.045	.100	673	53	675	4.5	4200	.30	B	A (ser)	A
H-63	48.3	.056	.100	750	50	752	3.8	3700	.29	B	A (ser)	B
H-106	50.1	.095	.100	975	39	976	2.5	2900	.23	C	B (ser)	C
16 Gauge Phantom Circuit												
NL	21.0	.0007	.100	144	116	185	39.0		.65	A	A (par)	C
B-50	27.5	.089	.100	944	21	944	1.3	5900	.14	C	B (ser)	A
H-18	22.2	.017	.100	415	42	417	5.8	7000	.24	A	C (par)	A
H-25	22.8	.023	.100	481	37	483	4.4	5900	.21	B	C (par)	A
H-50	24.3	.045	.100	672	28	672	2.4	4200	.16	B	A (ser)	A
H-63	26.4	.056	.100	749	27	749	2.0	3700	.16	B	A (ser)	B
H-106	28.2	.095	.100	975	21	975	2.3	2900	.14	C	B (ser)	C

* Data specifies mode of connecting windings employed on line side of repeating coil ("ser" = series, "par" = parallel). See Part I, Sec. 6.21.

TABLE III

APPROXIMATE CHARACTERISTICS OF NON-QUADDED EXCHANGE TYPE CABLE AT 1000 C.P.S.

Loading	Line Impedance R	X	Z	Phase Angle (Degrees)	Cut-off Freq. C.P.S.	Loss DB Per Mile	Rept. Coils For Hybrid D-283686	Rept. Coils Four Wire* D-283686	Low Pass Filters D-283688
					26 Gauge ST, AST				
NL	718	706	1007	44.5		2.67	C	B (ser)	C
B-88	1567	344	1604	12.4	——	1.30	D	C (ser)	A
H-88	1192	453	1275	20.8	3800	1.68	C	B (ser)	A
H-135	1440	383	1490	14.9	——	1.40	D	B (ser)	C
					26 Gauge BST				
NL	672	660	942	44.5		2.86	C	A (ser)	C
B-88	1464	322	1499	12.4	——	1.38	D	B (ser)	A
H-88	1114	423	1192	20.8	3600	1.80	C	B (ser)	A
H-135	1346	358	1393	14.9	——	1.50	D	B (ser)	C
M-88	988	490	1103	26.4	——	1.92	C	B (ser)	A
					24 Gauge M, SM, ASM, CSM				
NL	558	542	778	44.2		2.14	C	A (ser)	C
B-88	1515	216	1530	8.0	5300	.86	D	B (ser)	A
H-44	844	372	922	23.8	5300	1.46	C	A (ser)	A
H-88	1123	292	1160	14.6	3700	1.14	C	B (ser)	A
					24 Gauge DSM				
NL	517	503	721	44.2		2.31	B	A (ser)	C
B-88	1402	200	1416	8.1	4900	.936	D	B (ser)	A
H-44	781	345	854	23.8	4900	1.58	C	A (ser)	A
H-88	1039	271	1074	14.6	3500	1.23	C	B (ser)	A
					22 Gauge SA, ASA, BSA, CSA				
NL	416	399	576	43.8		1.79	B	C (par)	C
B-88	1414	130	1420	5.3	5000	.60	D	B (ser)	A
H-44	748	233	783	17.3	5000	1.04	C	A (ser)	A
H-88	1036	177	1051	9.7	3500	.79	C	B (ser)	A
					22 Gauge NA, ANA				
NL	442	424	612	43.8		1.69	B	A (ser)	C
					22 Gauge TA				
NL	479	460	664	43.8		1.55	B	A (ser)	C
					22 Gauge TS				
NL	457	438	633	43.8		1.63	B	A (ser)	C
					19 Gauge BNB, CNB				
NL	295	273	402	42.8		1.25	A	C (par)	C
B-88	1393	69	1395	2.8	4900	.335	D	B (ser)	A
B-135	1741	52	1742	1.7	3900	.264	D	C (ser)	A
H-44	713	122	723	9.7	5000	.56	B	A (ser)	A
H-88	1013	92	1017	5.2	3500	.423	C	B (ser)	A
H-135	1281	74	1283	3.3	2800	.337	C	B (ser)	C
					19 Gauge TB, ANB, DNB				
NL	333	308	453	42.8		1.11	A	C (par)	C
B-88	1563	76	1565	2.8	5500	.297	D	B (ser)	A
B-135	1951	61	1952	1.8	4400	.243	D	C (ser)	A
H-44	799	138	811	9.8	5600	.496	C	A (ser)	A
H-88	1132	103	1137	5.2	3900	.374	C	B (ser)	A
H-135	1423	82	1425	3.3	3100	.30	D	B (ser)	C

* Data specifies mode of connecting windings employed on line side of repeating coil ("ser" = series, "par" = parallel). See Part I, Sec. 6.21.

TABLE IV

TWO-WIRE EQUALIZATION
COPPER OPEN WIRE - 150 MILE SECTION

Ca = SHORT Cd = SHORT

FACILITY		SIGNAL		SIDE	EQUALIZATION			INPUT EQ. LOSS
Size (mils)	Ckt.	Phant. (c.p.s.)	Side (c.p.s.)	CX	Cb (mf)	Cc (mf)	Rc (ohms)	1000 c.p.s.
165 123 104	Side or Phant.	—	—	—	2	1	1000	8 db
80	Side		20		1	1		
			1000	none, E	1	1		
				C	2	1		
			135	none, E	1	1		
				C	2	1		
			Cx		2	1		
	Phant.	20	—		2	1		
		1000,135	20	—	1	1		
			1000,135	none, E	1	1		
				C	2	1		
		Cx	—		short	1		

TABLE V

TWO-WIRE EQUALIZATION
LOADED CABLE - 45 MILE SECTION

Facility	SIGNAL		SIDE	EQUALIZATION				INPUT EQ. LOSS
	Phant. (c.p.s.)	Side (c.p.s.)	CX	Ca (mf)	Cb (mf)	Cc (mf)	Rc (ohms)	1000 c.p.s.
19H-44 S 16H-44 S		20,1000, Cx	—	1	short	1	1000	8 db
		135	—	short	2			
19H-25P 16H-25P	20,1000	—	—	1	short			
	135	20	—	short	2			
		135,1000	—	short	2	1	500	10 db
	Cx	—		short	short			
19H-88 S 16H-88 S		20,1000, Cx	—	1	short			
		135	—	short	2			
19H-50P 16H-50P	20,1000, Cx	—	—	short	short			
	135	—	—	short	2			

TABLE VI

TWO-WIRE EQUALIZATION
NON-LOADED CABLE

Length (miles)	Facility	SIGNAL Phant. (c.p.s.)	SIGNAL Side (c.p.s.)	SIDE CX	EQUALIZATION Ca (mf)	EQUALIZATION Cb (mf)	EQUALIZATION Cc (mf)	EQUALIZATION Rc (ohms)	EQUALIZATION Cd (mf)	INPUT EQ. LOSS 1000 c.p.s.
15	19S		20,1000, Cx	—	1	short	open	open	0.12	13.5 db
			135	—	short	2				
	19P	20,1000	—	—	1	short				
		135	—	—	short	2				
		Cx	—		short	short				
7.5	19S		20,1000, Cx	—	1	short	open	open	0.2	11 db
			135	—	short	2				
	19P	20,1000	—	—	1	short				
		135	—	—	short	2				
		Cx	—		short	short				
15	16S		20	—	short	short	open	open	0.2	11 db
			1000	E	short	short				
				none, C	1	short				
			135	—	short	2				
			Cx		short	short				
	16P	20	—		short	short				
		1000	20	—	short	short				
			135,1000	none	1	short				
				E,C	short	short				
		135	—	—	short	2				
		Cx	—		short	short				
7.5	16S		20	—	short	short	short	500	short	10 db
			1000	none	1	short				
				E,C	short	short				
			135	—	short	2				
			Cx	E	1	short				
				C	short	short				
	16P	20	—		short	short				
		1000	20	—	short	short				
			135,1000	none	1	short				
				E,C	short	short				
		135	—	—	short	2				
		Cx	—		short	short				

TABLE VII

FOUR-WIRE EQUALIZATION
COPPER OPEN WIRE - 150 MILE SECTION

FACILITY Size (mils)	FACILITY Ckt.	CX	EQUALIZATION C1 (mf)	EQUALIZATION R1 (ohms)	EQUALIZATION R3 (ohms)	Taps On L1 P	Taps On L1 R	INPUT EQ. LOSS 1000 c.p.s.
165 128 104	Side or Phant.	Cx or No Cx	1	open	1100	2	2	5.2 db
80	Side	sides	1	1000	1100	3	5	4.8 db
		none	2	1000				
	Phant.	sides	1	2000				
		none	2	2000				

TABLE VIII

FOUR-WIRE EQUALIZATION
LOADED CABLE - 45 MILE SECTION

FACILITY	EQUALIZATION					INPUT EQ. LOSS
	C1 (mf)	R1 (ohms)	R3 (ohms)	Taps On L1		1000 c.p.s.
				P	R	
19H-88-50	1	open	1100	2	3	4.2 db
19H-44-25	2				3	
16H-88-50	1				5	
16H-44-25	1				5	

TABLE IX

FOUR-WIRE EQUALIZATION
NON-LOADED CABLE

LENGTH (miles)	FACILITY	CX	EQUALIZATION					INPUT EQ. LOSS
			C1 (mf)	R1 (ohms)	R3 (ohms)	Taps On L1		1000 c.p.s.
						P	R	
15	19S or P	sides	0.5	2000	300	2	6	7.7 db
		none		2000	200	2	3	8.7 db
	16S or P	sides		1000	900	3	8	5.2 db
		none		500	600	2	7	6.2 db
7.5	19S or P	sides	1	500	900	3	7	5.2 db
		none		1000	600	3	4	5.2 db
	16S or P	sides		1000	1100	3	5	4.2 db
		none		1000	900	2	7	5.2 db

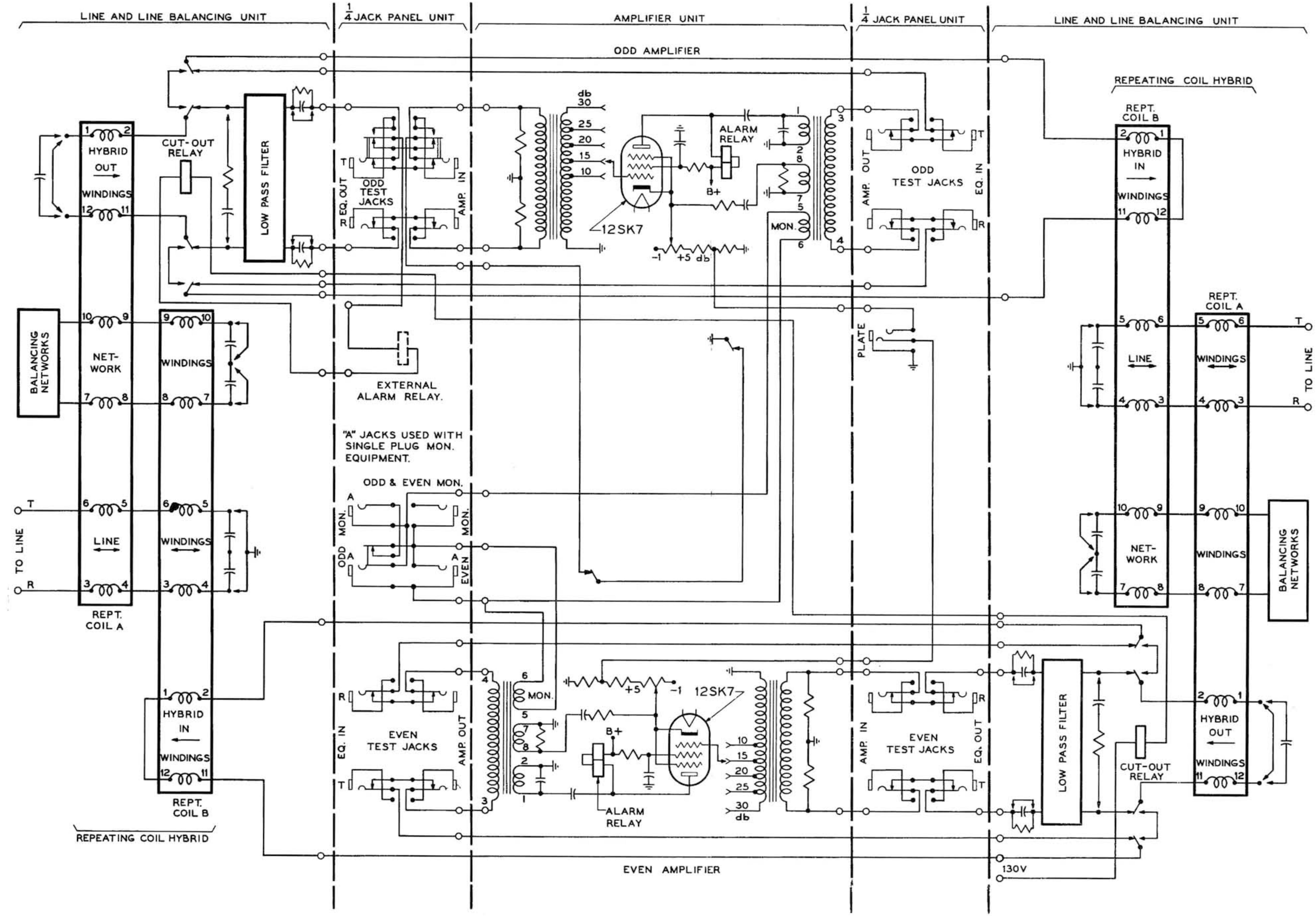


Fig. A: Two-Wire Intermediate Repeater - Simplified Schematic

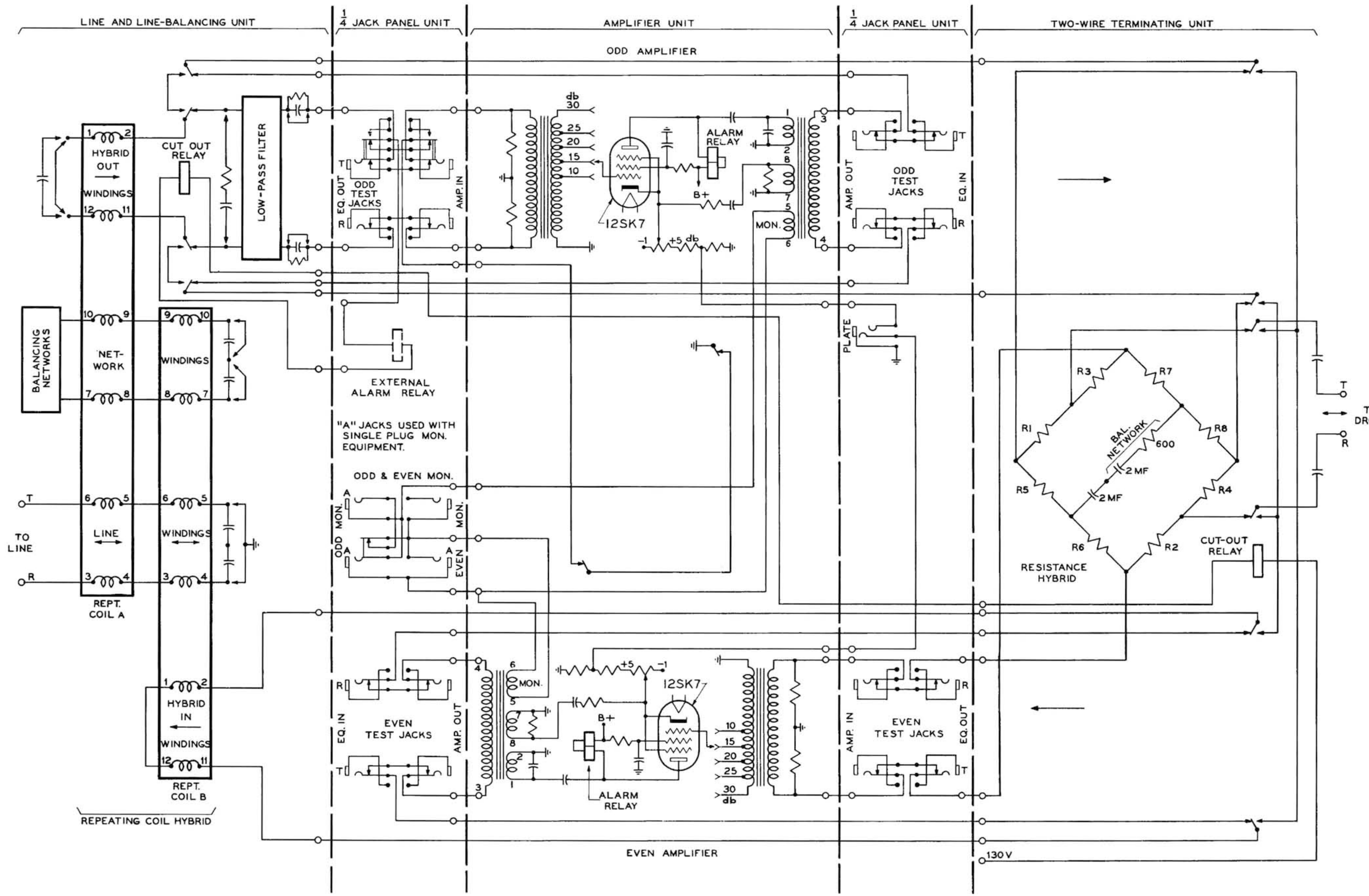


Fig. B: Two-Wire Terminal Repeater - Simplified Schematic

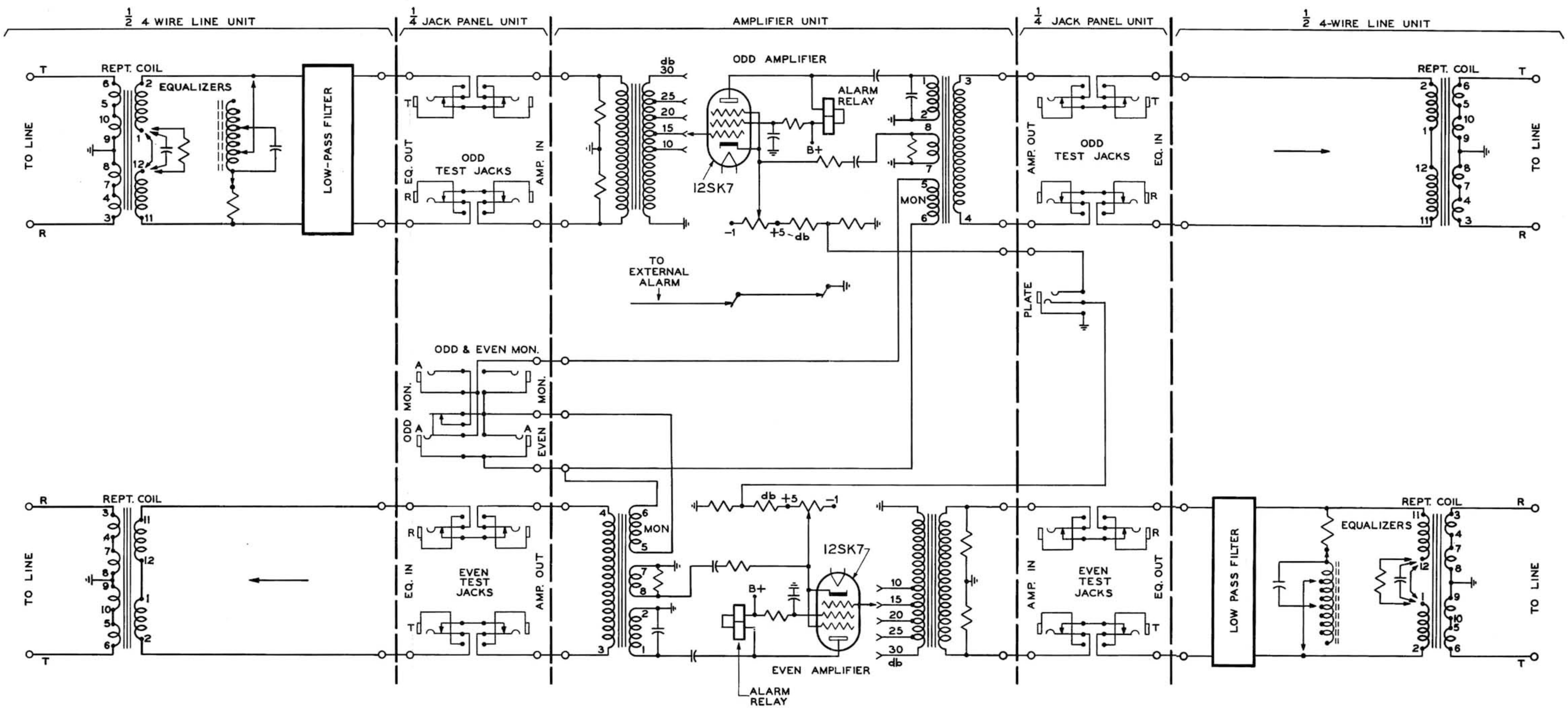


Fig. C: Four-Wire Intermediate Repeater - Simplified Schematic

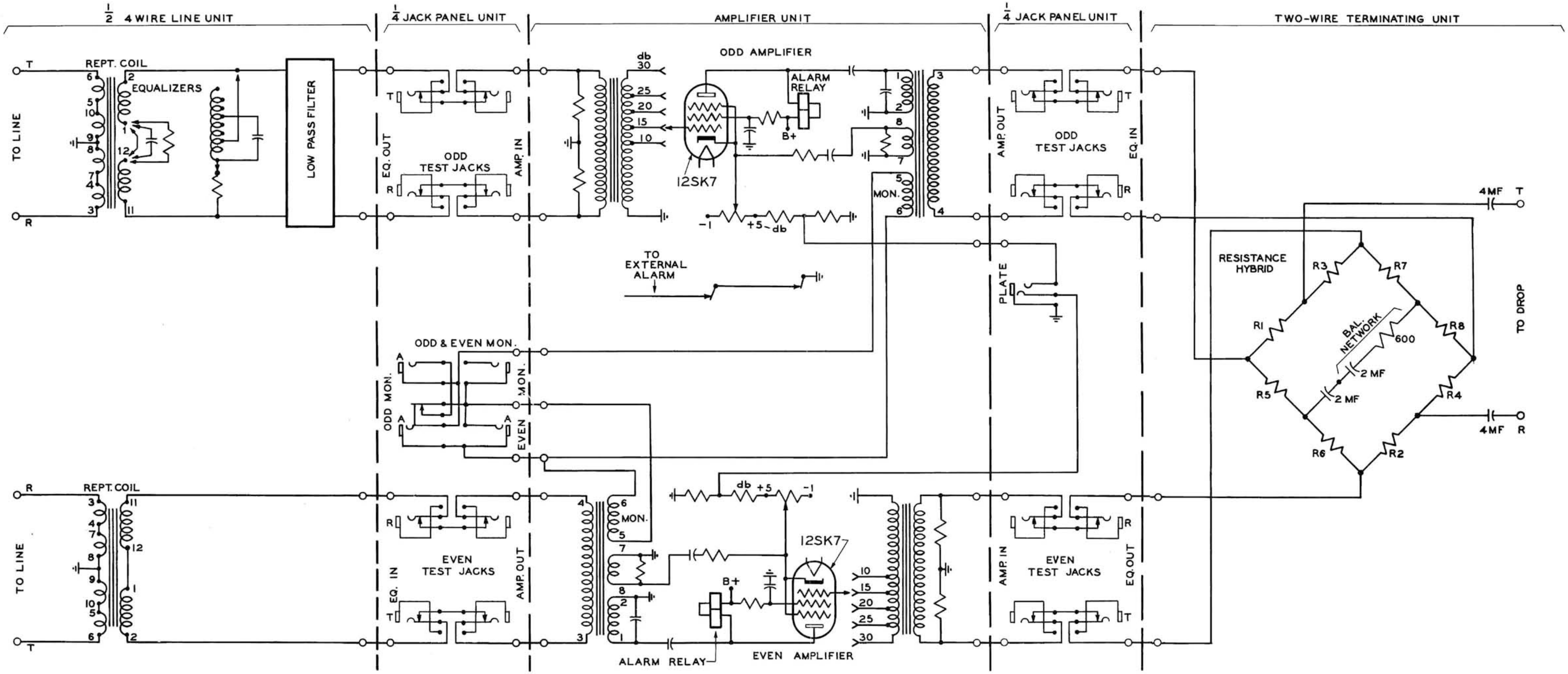


Fig. D: Four-Wire Terminal Repeater - Simplified Schematic

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