Feb. 26, 1946. P. G. EDWARDS 2,395,540

ORDER WIRE CIRCUIT FOR CARRIER TRANSMISSION SYSTEMS

Filed June 27, 1942 4 Sheets-Sheet 1

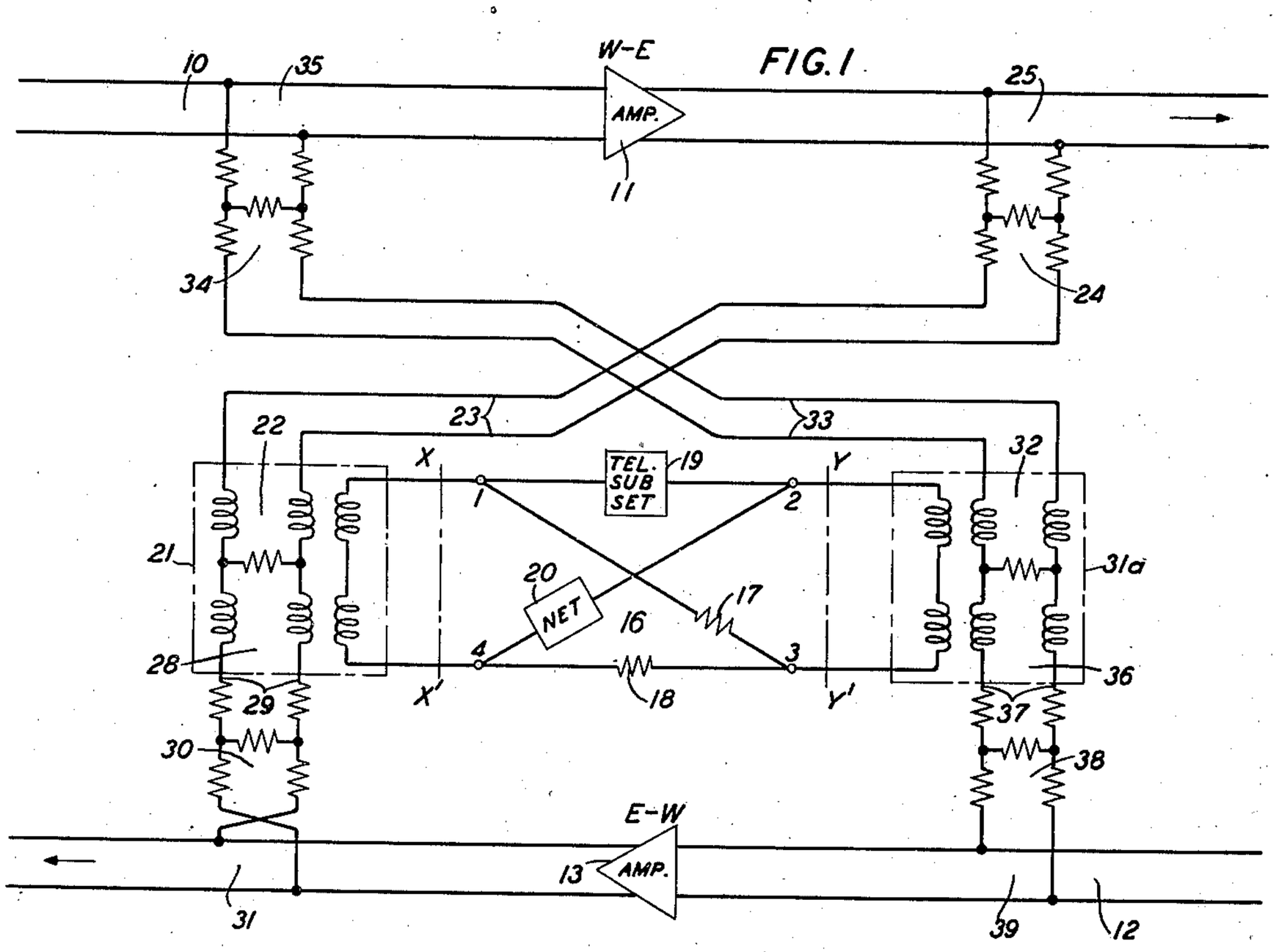


FIG. 2

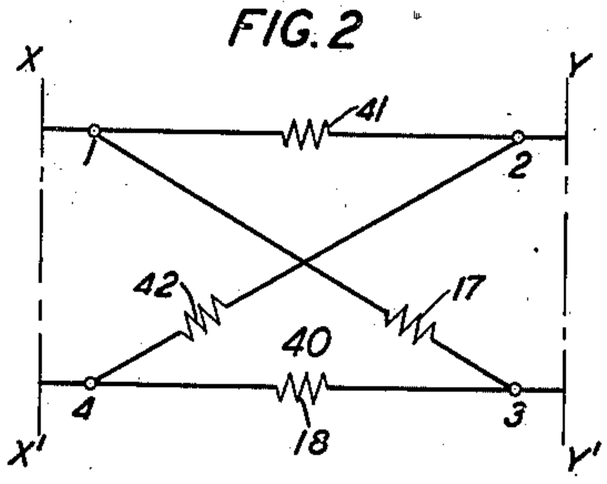
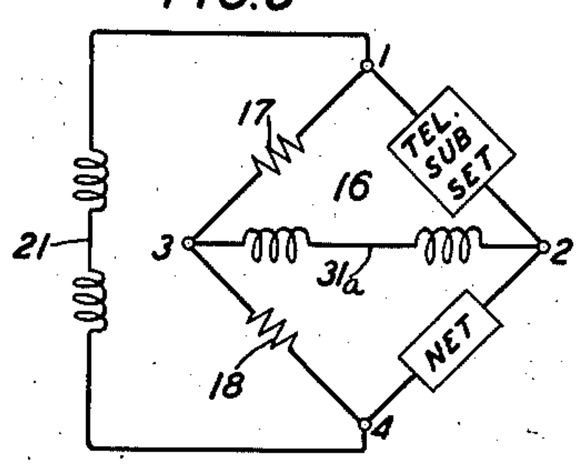


FIG. 3



INVENTOR
P.G. EDWARDS
BY H.O. Burgess
ATTORNEY

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Filed June 27, 1942 4 Sheets-Sheet 2

FIG. 4

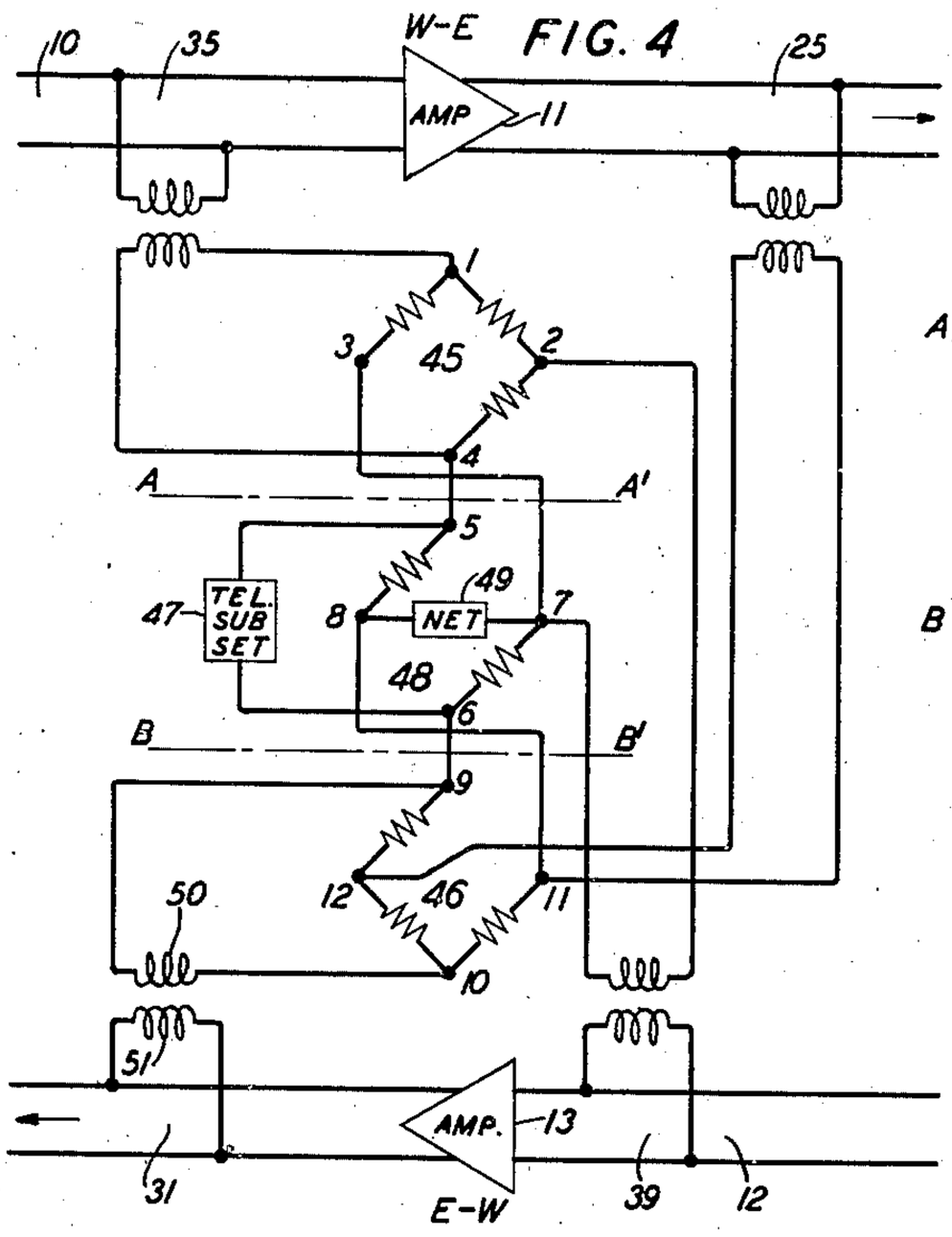


FIG. 5

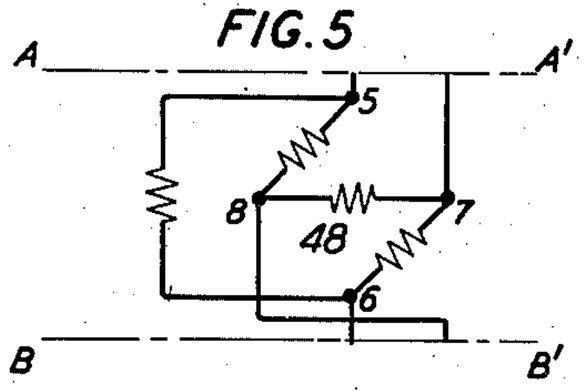


FIG. 6

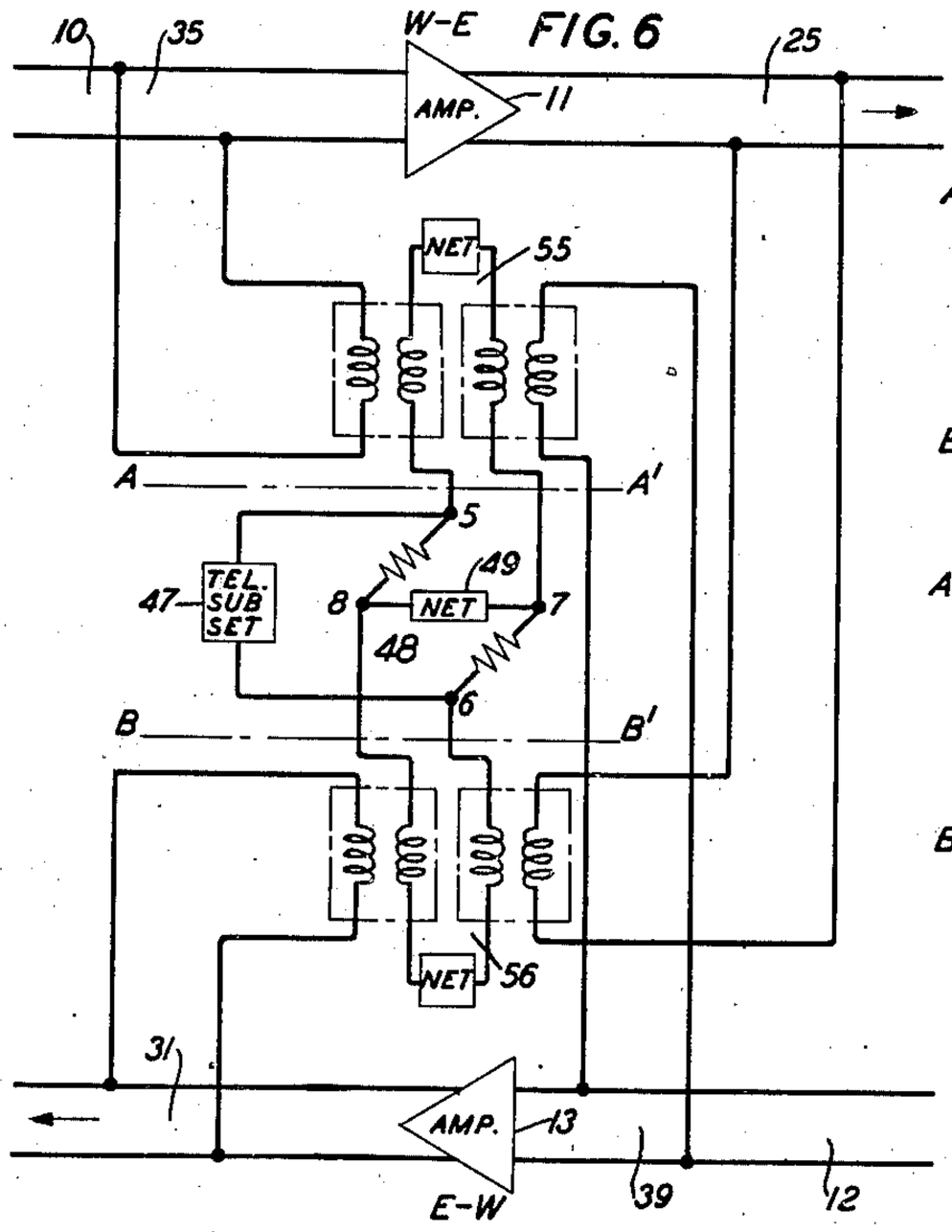


FIG. 7

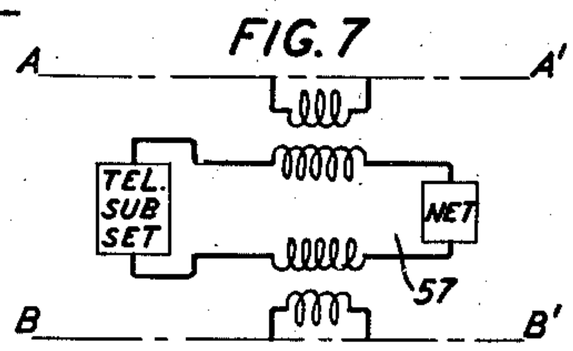
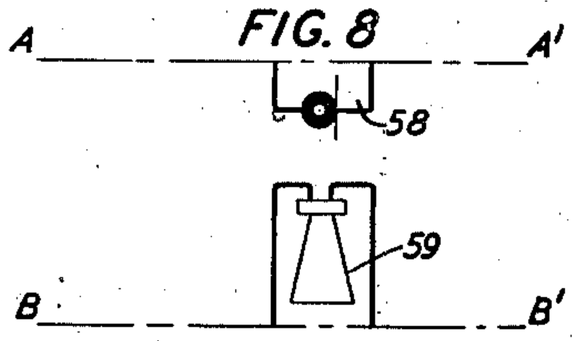


FIG. 8



INVENTOR
P. G. EDWARDS
BY H. A. Burgess
ATTORNEY

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Filed June 27, 1942 4 Sheets-Sheet 3

FIG. 9

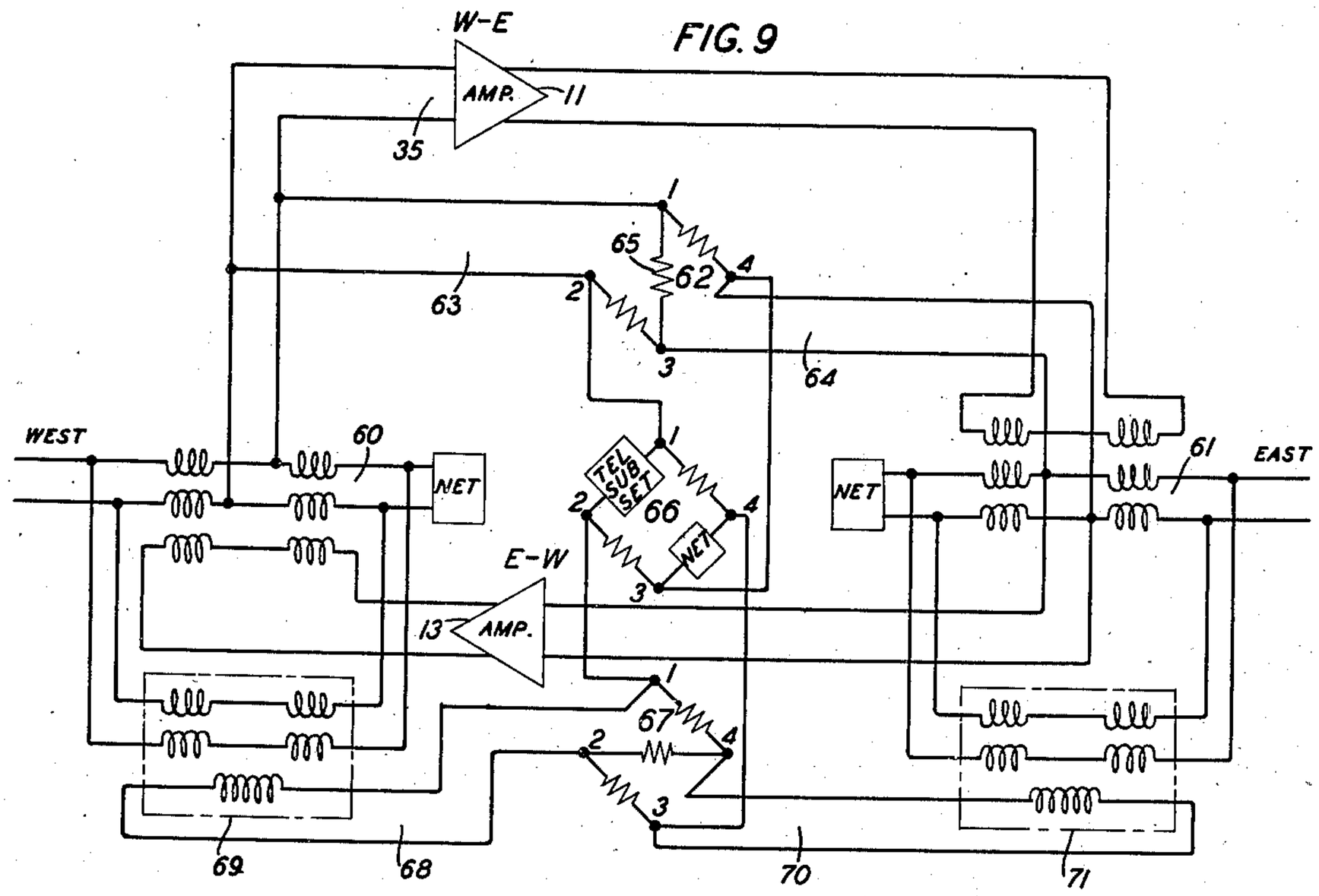
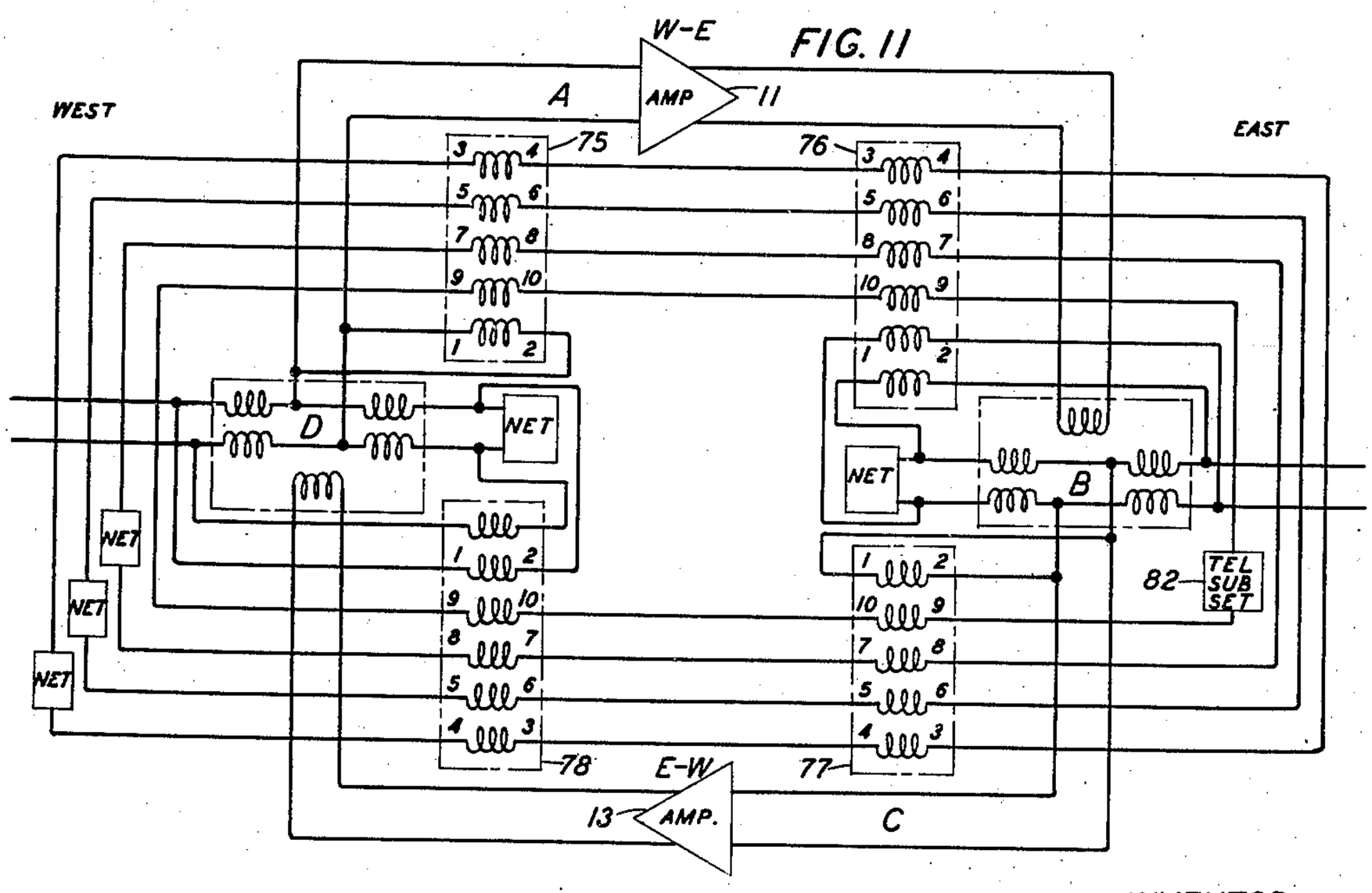


FIG. 11



INVENTOR
P.G.EDWARDS
BY
T. A. Burgess
ATTORNEY

Feb. 26, 1946. P. G. EDWARDS 2,395,540

ORDER WIRE CIRCUIT FOR CARRIER TRANSMISSION SYSTEMS

Filed June 27, 1942 4 Sheets-Sheet 4

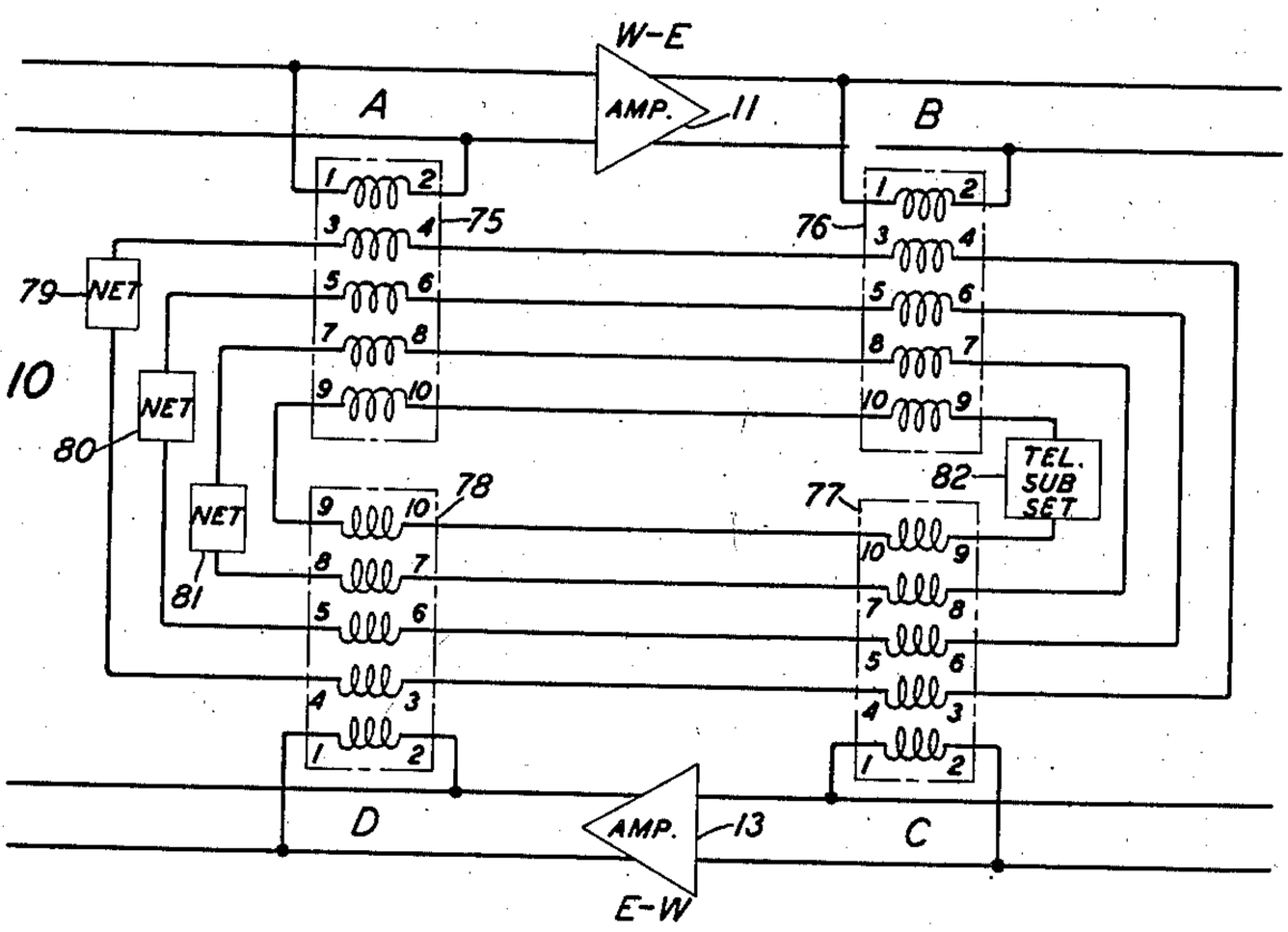


FIG. 10

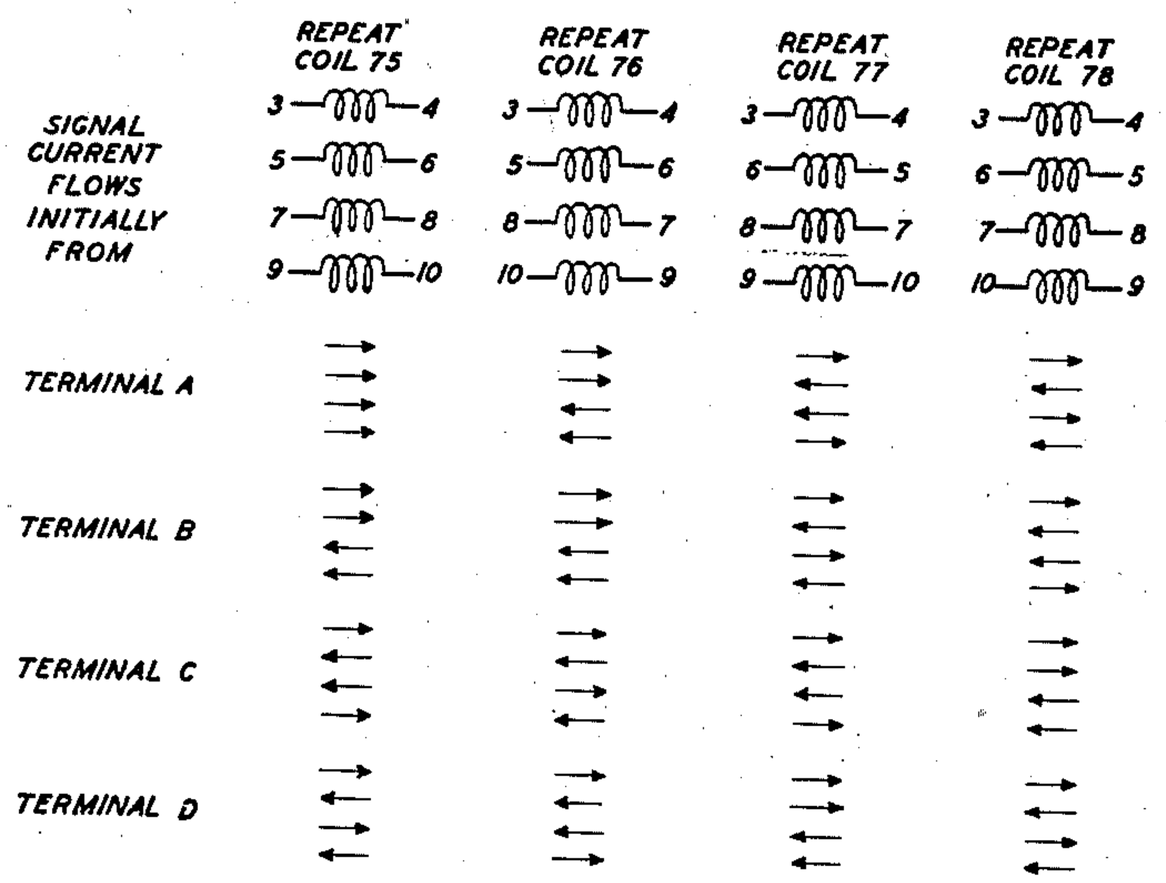


FIG. 12

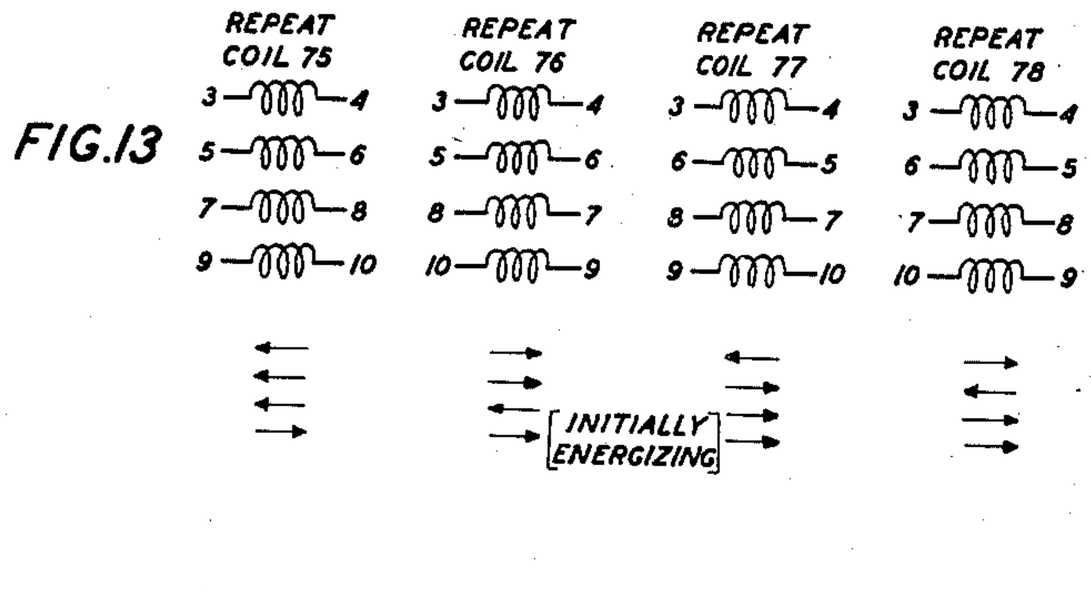


FIG. 13

INVENTOR
P. G. EDWARDS
BY H. A. Burgess
ATTORNEY

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UNITED STATES PATENT OFFICE

2,395,540

ORDER WIRE CIRCUIT FOR CARRIER TRANSMISSION SYSTEMS

Paul G. Edwards, Verona, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application June 27, 1942, Serial No. 448,740

8 Claims. (Cl. 179—170)

This invention relates to a signal transmission system, and more particularly to an order wire circuit connected across the input and output terminals of certain amplifiers of each one-way pair of a four-wire circuit embodied in such system.

In the operation of a long telephone circuit extending through a plurality of repeater stations, circuits for communicating between certain repeater stations are required to facilitate maintenance of the telephone circuits. Such maintenance circuits are known as order wires. Originally, long voice circuits and carrier systems employed telegraph channels for the order wire service. When long voice frequency cable circuits were introduced into commercial use, voice order wire circuits were obtained by utilizing monitoring windings of line repeaters, together with idle lines. In multiconductor cable systems, individual conductor pairs were reserved for order wire service.

With the introduction of a cable carrier system in which a plurality of channels were provided on individual conductor pairs of a multiconductor cable, the telephone circuits were extended to longer distances and more repeater stations were required for a given length of these circuits. This meant that an increased number of telephone subsets would probably be bridged on the order wire line at a given time. As each bridged telephone subset was a source of transmission loss and echoes, it was found that an order wire circuit, suitable for a telephone circuit extending over a distance of the order of a few hundred miles with repeater stations located fifty miles apart, was unsatisfactory on a telephone circuit extending over a distance of the order of a thousand miles with repeater stations disposed approximately at seventeen mile intervals for auxiliary stations and at fifty miles for main stations. In addition, the disposition of auxiliary repeater stations between main repeater terminals tended further to render the prior order wire circuits unsatisfactory on the longer telephone circuits. In the longer telephone circuits, a four-wire order wire circuit was selected to minimize echoes, and was provided by utilizing an individual conductor pair in each of two oppositely transmitting cables.

In the earlier type of four-wire order wire circuit, a telephone subset was bridged across the output terminals of corresponding one-way amplifiers embodied in a four-wire circuit through a transformer applied to each one-way conductor pair. This constituted a single bridge telephone order wire. With such telephone subset prepared for talking, a relatively low transmission loss and echo path extended through the two transformers and the telephone subset, being of the order of 18 decibels in one example. Due to the multiplicity of telephone subsets bridging the four-wire order circuit on a long telephone circuit, echoes would be relatively large. Another transmission loss would be encountered in the bridging telephone subsets per se. A further disadvantage of the single bridge order wire circuits resided in the low level of outgoing speech current on the transmission line. As the single bridge telephone subset is applied across the output terminals of corresponding one-way amplifiers, the outgoing speech current from the telephone subset was found to be approximately 18 decibels below the normal level of signals at such output terminals. As the order wire circuits were embodied in the same cable with the through circuits carrying other voice currents, cross-talk from the latter circuits to the order wire circuits was found to be excessive.

The present invention therefore contemplates an order wire circuit tending to minimize echo and singing effects and other transmission losses in cable carrier systems extending over a length of the order of one thousand miles with main repeater stations located approximately at fifty-mile intervals.

The main object of the invention is to promote the efficiency of order wire operation in long cable carrier telephone systems.

Another object is to minimize the interfering effect of the operation of order wire circuits on associated repeaters.

A further object is to minimize deleterious transmission effects during both talking and non-talking intervals on a four-wire order circuit.

In a specific embodiment in connection with a pair of one-way transmission paths each embodying at least one one-way amplifier, the present invention comprises a bridge network embodying a telephone subset in one arm, a balancing network in an adjacent arm, and individual resistors in each of the two other arms, a hybrid coil applied to each of the two opposite diagonals of the bridge network, and circuit means to connect one hybrid coil to the output terminals of corresponding one-way amplifiers and the other hybrid coil to the input terminals of the corresponding one-way amplifiers. During intervals when the telephone subset and balancing network are not being used, suitable individual resistors are substituted therefor in the bridge network.

Other embodiments comprise a plurality of

bridge networks applied simultaneously to both the input and output terminals of certain one-way amplifiers of the four-wire circuit; or a combination of two hybrid coils and a bridge network; or a plurality of bridge networks effectively connected across the spaced two-wire circuits; or a plurality of multiwinding repeat coils connected across either the four-wire circuit or the spaced two-wire circuits.

The invention will be readily understood from the following description taken together with the accompanying description in which:

Fig. 1 is a schematic circuit diagram showing a specific embodiment of the invention including hybrid coils and a bridge network;

Fig. 2 is a fragmentary circuit diagram showing an alternate bridge network for substitution in Fig. 1;

Fig. 3 is a schematic circuit diagram illustrating a rearranged configuration of the bridge network in Fig. 1;

Fig. 4 is a schematic circuit diagram delineating another embodiment of the invention including bridge networks only;

Figs. 5 and 8 are fragmentary circuit diagrams which may be embodied in both Figs. 4 and 6;

Fig. 6 is a schematic circuit diagram showing another embodiment of the invention including hybrid coils and a bridge network;

Fig. 7 is a fragmentary circuit diagram which may be substituted in Fig. 6;

Fig. 9 is a schematic circuit diagram showing another embodiment of the invention including bridge networks applied effectively to the spaced two-wire portions of a signal transmission line;

Fig. 10 is a schematic circuit diagram illustrating another embodiment of the invention including repeat coils only and applied across the four-wire circuit;

Fig. 11 is a schematic circuit diagram showing an alternate embodiment of Fig. 10 such that the repeat coils, are effectively applied between the spaced two-way circuits; and

Figs. 12 and 13 are tables representing the current flow obtainable in Figs. 9 and 10 under certain conditions.

Referring to Fig. 1, west-east path 10 embodies one-way amplifier 11, and east-west path 12 embodies one-way amplifier 13. These paths constitute one portion of the four-wire circuit of a cable carrier signal transmission system in which the individual east and west terminals, not shown, comprise two-way, two-wire paths connected to the four-wire path through terminal hybrid coils in the usual manner. Such four-wire portion may be duplicated at main repeater terminals, and at each auxiliary repeater terminals located between associated main repeater terminals.

A bridge network 16 embodying individual resistance arms 17, 18, telephone subset 19 and balancing network 20 has diagonal 1—4 applied to hybrid coil 21 whose terminal 22 is connected by leads 23, 23 and resistance pad 24 across output terminal 25 of the W.-E. amplifier 11, and whose terminal 28 is extended over leads 29, 29 and resistance pad 30 across output terminal 31 of the E.-W. amplifier 13. The other diagonal 2—3 of the bridge network 16 is applied to hybrid coil 31*a* whose terminal 32 is connected over leads 33, 33 and resistance pad 34 to the input terminal 35 of the W.-E. amplifier 11, and whose terminal 36 is extended over leads 37, 37 and resistance pad 38 to the input terminal 39 of the E.-W. amplifier 13. The bridge network 16 of Fig. 1 illustrated in the more usual form in Fig. 3 shows that the diagonals 1—4 and 2—3 constitute the vertical and horizontal diagonals, respectively.

In the operation of Fig. 1, voice currents on the W.-E. and E.-W. paths 10 and 12 are taken from the output terminals 25 and 31 of the respective amplifiers 11 and 13 and applied through hybrid coil 21 to the telephone subset 19 in the bridge network 16; and voice current originating in the telephone subset 19 in the bridge network 16 is applied through hybrid coil 31*a* to the input terminals 35 and 39 of the respective amplifiers 11 and 13 embodied in the W.-E. and E.-W. paths 10 and 12. As the gain of the amplifiers 11 and 13 is the same, the voice currents in the respective output terminals 25 and 31 of the individual W.-E. and E.-W. paths 10 and 12 are always substantially at normal level.

Voice current at the input terminal 35 of the W.-E. amplifier 11 may reach the output terminal 31 of the E.-W. amplifier 13 over path I which further includes resistance pad 34, leads 33, 33, hybrid coil 31*a*, leads 37, 37, resistance pad 38, input terminal 39 and the E.-W. amplifier 13; or alternately over path II which further embodies W.-E. amplifier 11, output terminal 25, resistance pad 24, leads 23, 23, hybrid coil 21, leads 29, 29 and resistance pad 30. The net transmission loss in each of the paths I and II is, for the purpose of this illustration, approximately 55 decibels.

If the voice currents in the output terminal 31 of the E.-W. amplifier 13, due to the paths I and II were in phase, the total of such voice currents would be twice the voice current in either path I or II or for the purpose of this illustration, of the order of 6 decibels greater than the output of the E.-W. amplifier 13. The net transmission loss of such voice currents in the output terminal 31 of the E.-W. amplifier 13 would be of the order of 49 decibels. As the leads of the output terminal 31 of the E.-W. amplifier 13 are reversed with respect to the leads of output terminal 25 of the W.-E. amplifier 11, the voice currents due to the paths I and II combine at the terminal 31 in an out-of-phase relation. Hence, such voice currents substantially cancel each other. Due to some phase differences of the paths I and II such voice currents may not cancel completely; but it was found that the interference effect of such currents in the output terminal 31 was down approximately 65 decibels, in one example for the purpose of this illustration.

Voice current at the output terminal 25 of the W.-E. amplifier 11 may reach the input terminal 39 of the E.-W. amplifier 13 over a path III embodying resistance pad 24, leads 23, 23, hybrid coil 21, bridge network 16, hybrid coil 31*a*, leads 37, 37, and resistance pad 38. Path III has a transmission loss for such current that the normal operation of the E.-W. amplifier 13 is substantially unimpaired. As a shunting, or singing path may extend around individual W.-E. or E.-W. amplifiers 11 and 13, respectively, the transmission loss in such paths should be made sufficiently large so as to avoid interference with the normal functioning of these amplifiers. For the purpose of this illustration, such paths comprise path IV including the terminals of the telephone subset 19 embodied in the bridge network 16, hybrid coil 31*a*, leads 33, 33 and resistance pad 34; and path V including output terminal 25 of the W.-E. amplifier 11, resistance pad 24, leads 23, 23, hybrid coil 21 and terminals of the telephone subset 19 embodied in the bridge network 16. Thus, the complete transmission loss extending around the W.-E. amplifier 11 and

comprising the paths IV and V should be such magnitude as to permit substantially normal operation of the W.-E. and E.-W. amplifiers 11 and 13. Likewise, the transmission loss obtaining with respect to E.-W. amplifier 13 through similar shunting and singing paths should be such that normal operation of the latter is substantially provided for.

The arrangement of Fig. 1 further embodies anti-side tone characteristics because of the turnover of the output terminal 31 of the E.-W. amplifier 13. Voice current from the telephone subset 19 is impressed on the hybrid coil 31*a* wherein this current divides such that one half is transmitted over leads 33, 33 and resistance pad 34 to the input terminal 35 of the W.-E. amplifier 11, and the other half of such voice current is transmitted over leads 37, 37 and resistance pad 38 to the input terminal 39 of the E.-W. amplifier 13.

After these current portions pass through the respective amplifiers 11 and 13, the current portions are then applied through respective resistance pads 24 and 30, leads 23, 23 and 29, 29 to the hybrid coil 21 wherein their cancellation is effected because the two current portions are now of opposite phase, due to the reversal of the output terminal 31 of the E.-W. amplifier 13. The balance between the vertical terminal 1—4 and horizontal terminal 2—3 of the bridge network 16 in Figs. 1 and 2 is approximately 0.9 decibel for the purpose of this illustration, and patching the telephone subset 19 and network 20 thereinto does not materially affect such balance.

Fig. 2 shows a bridge network 40 which is similar to the bridge network 16 of Figs. 1 and 3 but the resistor 41 is substituted for the telephone subset 19 and the resistor 42 for the balancing network 20 as above described, and may be substituted in Fig. 1 between the lines X—X′ and Y—Y′ during non-talking intervals on the order wire. The loss transmission characteristics specified above in connection with the paths I, II, III, IV, and V of Fig. 1 also substantially obtain in Figs. 1 and 2. This means that the normal operation of the W.-E. and E.-W. amplifiers 11 and 13 encounters substantially tolerable interference from the order wire circuit during both talking and non-talking intervals thereon.

Fig. 4 is a four-wire order circuit along the lines of the one illustrated in Fig. 1, and accomplishes substantially the transmission losses and echo and singing margins pointed out hereinbefore in connection with the latter figure. Referring to Fig. 4, the W.-E. and E.-W. transmission paths 10 and 12, respectively, including one-way amplifiers 11 and 13 are identical with the corresponding circuit elements of Fig. 1; vertical diagonal 1—4 of resistor bridge network 45 is applied to the input terminal 35 of the W.-E. amplifier 11 while the horizontal diagonal 2—3 of the bridge network 45 is extended to the input terminal 39 of the E.-W. amplifier 13; vertical diagonal 9—10 of the bridge network 46 is connected to the output terminal 31 of the E.-W. amplifier 13 while the horizontal diagonal 11—12 of the bridge network 46 is impressed on the output terminal 25 of the W.-E. amplifier 11; telephone subset 47 is applied across the vertical diagonal 5—6 of bridge network 48 while balancing network 49 is disposed across the horizontal diagonal 7—8 of the bridge network 48; arm 3—4 of the bridge network 45 is extended to arm 5—7 of the bridge network 48 while arm 6—8 of the latter bridge network is extended to arm 9—11 of the bridge network 46; and the output terminal 31 of the E.-W. amplifier 13 is reversed relative to the output terminal of the W.-E. amplifier 11. Coupled coils 50 and 51 interposed in each path associated with the vertical and horizontal diagonals of the respective bridge networks 45 and 46 serve to minimize noise effects by keeping the original voice circuit balanced with respect to ground. Resistance pads may be interposed in Fig. 4 as in Fig. 1, if desired, to afford the desired transmitting and receiving gains. During non-talking intervals individual resistors may be substituted for the respective telephone subset 47 and balancing network 49 by embodying Fig. 5 in Fig. 4 between the lines A—A′ and B—B′. It may be shown substantially in the manner set forth previously with regard to Fig. 1 that the normal operation of the W.-E. and E.-W. amplifiers 11 and 13 encounter such transmission losses, and singing and echo effects that tolerable interference from the order-wire circuit of Figs. 4 and 5 with respect to the normal operation of Figs. 4 and 5 is substantially maintained during both talking and non-talking intervals on the order-wire circuit.

Fig. 6 is a four-wire order circuit similar to that shown in Fig. 4, and achieves substantially the transmission losses and singing and echo margins identified above regarding both Figs. 1 and 4. Referring to Fig. 6, the W.-E. and E.-W. transmission paths 10 and 12 including one-way amplifiers 11 and 13 are identical with similar circuit elements in Fig. 1; the input terminals 35 and 39 of the respective W.-E. and E.-W. amplifiers 11 and 13 are connected through hybrid coil 55 (replacing the bridge network 45 of Fig. 5); the output terminals 25 and 31 of the respective W.-E. and E.-W. amplifiers 11 and 13 are joined through a hybrid coil 56 (replacing the bridge network 46 of Fig. 4); arms 5—7 and 6—8 of the bridge network 48 are connected to the hybrid coils 55 and 56, respectively; and during non-talking intervals individual resistors may be substituted for the respective telephone subset 47 and 49 by embodying Fig. 5 in Fig. 6 between the lines A—A′ and B—B′. It may be demonstrated substantially in the manner specified hereinbefore concerning Figs. 1 and 4 that normal operation of the W.-E. and E.-W. amplifiers 11 and 13 meets with tolerable interference from the order-wire circuit of Figs. 5 and 6 during both talking and non-talking intervals on the latter circuit.

Fig. 7 is similar to Fig. 6 except a hybrid coil 57 is substituted for the bridge network 48 of the latter figure by embodying Fig. 7 in Fig. 6 between the corresponding lines A—A′ and B—B′. Fig. 8 is similar to Fig. 6 except a transmitter 58 is applied to the hybrid coil 55 and a suitable signal translator 59 is connected to the hybrid coil 56, both of which connections may be effected by substituting Fig. 8 in Fig. 6 for the circuit portion included between the corresponding lines A—A′ and B—B′ of the latter figure. The hybrid coils 55 and 56 may be so poled that electrical energy from one echo path tends to cancel the electrical energy from the other path.

Fig. 9 shows an order-wire circuit applied to two-way two-wire east and west terminals which are coupled to a four-wire circuit of the type shown in Fig. 1 by means of the usual hybrid coils 60 and 61. Signal transmission between the east and west terminals takes place in the well-known manner. Bridge network 62 has arm 1—2 connected over path 63 to the input terminal 35

of the W.-E. amplifier; arm 3—4 over path 64 to the two conductors constituting the two-wire two-way output of the east terminal hybrid coil 61; and a resistor 65 across the vertical diagonal 1—3. The horizontal diagonal 2—4 of the bridge network 62 is applied to the vertical diagonal 1—3 of bridge network 66 embodying in individual arms a telephone device, balancing network and resistors. The horizontal diagonal 2—4 of the bridge network 66 is applied to the vertical diagonal 1—3 of bridge network 67 whose horizontal diagonal 2—4 embodies a resistor, whose arm 1—2 is connected over path 68 to repeat coil 69 which is effectively connected in shunt of the two-wire two-way output of the west terminal hybrid coil 60, and whose arm 3—4 is connected over path 70 to repeat coil 71 which is effectively connected in shunt of the two conductors constituting the two-wire two-way output of the east terminal hybrid coil 61.

In the operation of Fig. 9, the windings of the repeat coils 69 and 71 are so poled as to be effectively connected to the output terminals of the one-way W.-E. and E.-W. amplifiers 11 and 13. Thus, voice current originating in the telephone subset embodied in the bridge network 66 is effectively applied through the bridge network 62 and over the paths 63 and 64 to the inputs of the one-way W.-E. and E.-W. amplifiers 11 and 13 and the output of the W.-E. amplifier 11 for transmission over the two-wire lines while incoming voice current on the two-wire lines at the east and west terminals is effectively applied through respective repeat coils 69 and 71, paths 68 and 70, and bridge network 67 to the telephone subset embodied in the bridge network 66. Transmission losses and echo and singing margins of the order-wire circuit of Fig. 9 are substantially of the order mentioned above in connection with Fig. 1, and may be individually identified similarly to the manner hereinbefore specified with respect to Fig. 1. Hence, the normal operation of the W.-E. and E.-W. amplifiers 11 and 13 in Fig. 9 may be accomplished substantially with tolerable interference from the order-wire circuit both during talking and non-talking intervals on the latter circuit. In the non-talking intervals, it is to be understood that individual resistors may be substituted for the telephone device and balancing network as pointed out above with respect to Figs. 1 and 2.

Fig. 10 illustrates an order-wire circuit embodying a plurality of multiwinding repeat coils and applied to a four-wire circuit such that the gain of the W.-E. and E.-W. amplifiers 11 and 13 is effective with respect to both transmitting and receiving on the telephone device 82. Referring to Fig. 10, repeat coil 75 has winding 1—2 applied to input terminal A of W.-E. amplifier 11, repeat coil 76 has winding 1—2 connected to output terminal B of the W.-E. amplifier 11, repeat coil 77 has winding 1—2 extended to the input terminal C of the E.-W. amplifier 13, and repeat coil 78 has winding 1—2 applied to the output terminal D of the E.-W. amplifier 13. Windings 3—4, 5—6, and 7—8 of individual repeat coils 75, 76, 77 and 78 are serially connected to respective networks 79, 80 and 81. Windings 9—10 of the individual repeat coils 75, 76, 77 and 78 are serially extended to the telephone apparatus 82.

The operation of Fig. 10 will be readily understood by referring to Fig. 12 in which the arrows indicate the direction of current flow in corresponding windings of individual repeat coils 75, 76, 77, and 78 when current is initially caused to flow from either terminal A, B, C, or D to the winding 1—2 of the repeat coil connected to the particular terminal. Assuming signal current to flow initially from terminal A to the winding 1—2 of repeat coil 75, other currents are thereby caused to be induced in the remaining windings of the repeat coil 75. Current flows in the same direction in the windings 3—4 of all repeat coils, and therefore flows in the network 79 connected thereto. Current also flows in windings 5—6, 7—8 and 9—10 of all repeat coils, and in the networks 80 and 81 and telephone apparatus 82 associated therewith, the amounts of current in each network and in the telephone apparatus being substantially the same.

Assuming signal current to flow from the terminal B to the winding 1—2 of repeat coil 76 in Fig. 10, other currents are thereby caused to be induced in the remaining windings of the repeat coil 76. Current tends to flow in the same direction in windings 3—4 of all repeat coils, and therefore flows in the network 79 connected thereto. Current also flows in windings 5—6, 7—8, and 9—10 of all repeat coils, and in the networks 80 and 81 and the telephone apparatus 82 associated therewith, the amount of current in each network and the telephone apparatus being substantially the same.

Assuming signal current to flow from terminal C to the winding 1—2 of repeat coil 77 in Fig. 10, other currents are thereby caused to be induced in the remaining windings of the repeat coil 77. Current flows in the same direction in windings 3—4 of all repeat coils, and therefore tends to flow in the network 79 connected thereto. Current also flows in windings 5—6, 7—8, and 9—10 of all repeat coils, and in the networks 80 and 81 and the telephone apparatus 82 associated therewith, the amount of current in each network and the telephone apparatus being substantially the same.

Assuming signal current to flow from terminal D to the winding 1—2 of repeat coil 78 in Fig. 10, other currents are thereby caused to be induced in the remaining windings of the repeat coil 78. Current flows in the same direction in windings 3—4 of all repeat coils, and therefore flows in the network 79 applied thereto. Current also flows in windings 5—6, 7—8 and 9—10 of all repeat coils, and in the networks 80 and 81 and the telephone apparatus 82, the amount of current flowing in each network and the telephone apparatus being substantially the same.

Referring to Fig. 12, it will be observed that when signal current is introduced from the terminal A into the winding 1—2 of the repeat coil 75, the relative poling of the windings 3—4, 5—6, 7—8, and 9—10 of individual repeat coils 76, 77 and 78 is such that current tends to flow in one direction in two windings but in an opposite direction in the other two windings. As the net magnetic effect of such current flow in the repeat coils 76, 77 and 78 is substantially zero, no current is supplied to the terminals B, C and D from the respective repeat coils connected thereto. Similarly, when a signal current is introduced from the terminal B into the winding 1—2 of repeat coil 76, the net magnetic effect in the repeat coils 75, 77 and 78 is such that no current is supplied thereby to the respective terminals A, C and D; or when a current is introduced from the terminal C into the winding 1—2 of repeat coil 77, the net magnetic effect in the repeat coils 75, 76 and 78 is such that no current is supplied

by these repeat coils to the respective terminals A, B and D; or when a current is introduced from the terminal D into the winding 1—2 of the repeat coil 78; the net magnetic effect in the repeat coils 75, 76 and 77 is such that no current is applied by these repeat coils to the respective terminals A, B and C. This means that the W.-E. amplifier 11 will not sing over the loop including repeat coils 75 and 76; that E.-W. amplifier 13 will not sing over the loop including repeat coils 77 and 78; and that echoes will not be effectively transmitted over loops embodying any combination of the repeat coils 75, 76, 77, and 78.

Fig. 11 is a modification of Fig. 10 to the extent that certain multiwinding repeat coils are effectively applied to the two-way two-wire west and east terminals. Thus, repeat coil 75 is connected to terminal A which is the input terminal of W.-E. amplifier 11; repeat coil 76 is effectively applied to terminal B which is two-wire two-way east terminal, or output terminal of the W.-E. amplifier 11; repeat coil 77 is applied to the terminal C which is the input terminal of E.-W. amplifier 13; and repeat coil 78 is effectively connected to terminal D which is the two-wire two-way west terminal, or output terminal of the E.-W. amplifier 13. Similarly, to Fig. 10, it can be shown in Fig. 11 that when current is introduced from individual amplifier terminals into windings 1—2 of individual repeat coils, current will flow in the other individual windings and the networks and telephone apparatus associated therewith; that the W.-E. and E.-W. amplifiers 11 and 13 will not sing through loops including certain repeat coils; and that no echo loops are effective through any combination of repeat coils.

Assuming speech current originates in the telephone apparatus 82 of Fig. 10 and flows in the windings 9—10 of the repeat coils 75, 76, 77, and 78 in a clockwise direction as indicated by the arrows in Fig. 13. This current sets up magnetizing flux in the individual repeat coils. Referring to Fig. 13, it is seen that the poling of the windings of the individual repeat coils is such that current tends to flow in the winding 3—4, 5—6, 7—8, and 9—10 of the respective repeat coils 75, 76, 77, and 78 in certain relative directions. Thus, it is seen that current tends to flow in three windings in the same direction but in a direction opposite thereto in a fourth winding. Hence, a voltage is produced across the individual windings of each repeat coil, and is supplied from the windings 1—2 of each repeat coil to the respective terminals A, B, C, and D to which the former are connected. Further, it is seen in Fig. 13 that the current in windings 3—4 of repeat coils 75 and 77 tends to flow in the same direction but in a direction opposite thereto in repeat coils 76 and 78. Hence, the voltages due to such oppositely directed currents in the windings 3—4 cancel each other and therefore no speech power is absorbed in the network 79, Fig. 10, connected to these windings. Likewise, current in windings 5—6 of repeat coils 75 and 78 tends to flow in the same direction but in a direction opposite thereto in repeat coils 76 and 77. Thus, the voltages occasioned by such oppositely directed current in the windings 5—6 cancel each other, and therefore no speech power is absorbed in the network 80, Fig. 10, applied to these windings. Similarly, current in the windings 7—8 of repeat coils 75 and 76 tends to flow in the same direction but in a direction opposite thereto in repeat coils 77 and 78. Consequently, the voltages caused by such oppositely directed current in the windings 7—8 cancel each other, and therefore no speech power is absorbed in the network 81, Fig. 10, connected to the windings 7—8. Similarly, it can be demonstrated with Figs. 11 and 13 that current originating in the telephone apparatus 82 is effectively transmitted through repeat coils 75, 76, 77 and 78 to the effective terminals A, B, C, and D associated with the respective W.-E. and E.-W. amplifiers 11 and 13; and further that no speech power is absorbed in the networks 79, 80, and 81.

It is to be understood that the embodiments of the invention illustrated in Figs. 4, 6, 9, 10 and 11 may also include resistance pads in the individual paths interconnecting the one-way paths or two-way two-wire circuits similarly to the resistance pads 24, 34, 30 and 38 shown in Fig. 1; and further that the bridging loss of the order-wire circuits is compensated for in the gain setting of the amplifiers, and is preferably kept constant by replacing the telephone devices with equivalent loss devices when the order-wire circuits are not in use at individual stations, as above pointed out.

What is claimed is:

1. In combination in a four-wire signal transmission circuit comprising two oppositely directed one-way signal transmitting paths, each embodying at least one one-way amplifier having input and output terminals, and means to interconnect said paths for telephoning and non-telephoning conditions such that interference with the normal operation of said amplifiers in both said one-way paths for signal transmission is limited substantially to a tolerable amount, comprising a bridge network adaptable for telephoning and non-telephoning conditions, a hybrid coil applied to each diagonal of said bridge network, and circuit means to connect each of said hybrid coils to both said one-way paths at opposite corresponding terminals of said amplifiers embodied therein.

2. The combination according to claim 1 in which said bridge network embodies a resistor in each arm, and is thereby adapted for the non-telephoning condition.

3. The combination according to claim 1 in which said bridge network embodies a telephone device in one arm, a balancing network in an adjacent arm, and individual resistors in the remaining two arms, and is thereby adapted for the telephoning condition such that the speech energy originating in said telephone device is applied initially to said input terminals of said amplifiers in both said one-way paths.

4. The combination according to claim 1 in which said circuit means connects one hybrid coil to said output terminals of each amplifiers embodied in both said one-way paths and the other hybrid coil to said input terminals of said amplifiers embodied in both said one-way paths.

5. The combination according to claim 1 in which said circuit means connects one hybrid coil to said output terminals of said amplifiers embodied in both said one-way paths and the other hybrid coil to said input terminals of said amplifiers embodied in both said one-way paths, said portion of the circuit means connecting said one hybrid coil to said output terminal of said amplifier in one of said two one-way paths being reversed with respect to the further portion of said circuit means connecting said one hybrid coil to said output terminal of said amplifier in the other of said two one-way paths.

6. In combination in a four-wire signal system,

two oppositely directed one-way paths for transmitting signal current, each path embodying at least one one-way amplifier having input and output terminals, and means to interconnect said two paths for telephoning and non-telephoning conditions such that interference with the normal operation of said amplifiers in said two paths for signal transmission is limited substantially to a tolerable amount, comprising a bridge network adaptable for telephoning and non-telephoning conditions, a hybrid coil applied to each diagonal of said bridge network, circuit means to connect one hybrid coil to said output terminals of said amplifiers in said two paths, and further circuit means to connect the other hybrid coil to said input terminals of said amplifiers in said two paths.

7. In combination in a four-wire signal system, two oppositely directed one-way signal transmission paths, each embodying at least one one-way amplifier having input and output terminals, and means for applying voice current to said input terminals of said amplifiers in said two paths and receiving voice current from said output terminals of said amplifiers in said two paths and at the same time for limiting interference with the normal operation of said amplifiers in said two paths for signal transmission substantially to a tolerable amount, said means comprising a bridge network embodying a telephone device in one arm, a balancing network in another arm, and individual resistors in each of the remaining two arms, a pair of multiwinding hybrid coils, each of which is applied to one diagonal of said bridge network, circuit means to connect one hybrid coil to said output terminals of said amplifiers in said two paths for receiving incoming speech energy therefrom, and further circuit means to connect the other hybrid coil to said input terminals of said amplifiers in said two paths for supplying outgoing speech energy thereto.

8. A two-way repeatered telephone transmission system comprising at a repeater station two transmission lines, an amplifier connected to each of said lines and having an input and an output circuit, and means for transmitting voice currents to and receiving voice currents from both said lines comprising telephone apparatus, at least one bridge network having a plurality of terminals, and circuit means for connecting two of said terminals to said apparatus, said circuit means also connecting said two terminals and the remainder of said terminals to said input and output circuits of both said lines whereby the voice currents originating in said apparatus are applied to said input circuits in both said lines for outgoing transmission thereon, and the voice currents incoming on both said lines are picked up from said output circuits of both said lines and applied to said apparatus.

PAUL G. EDWARDS.