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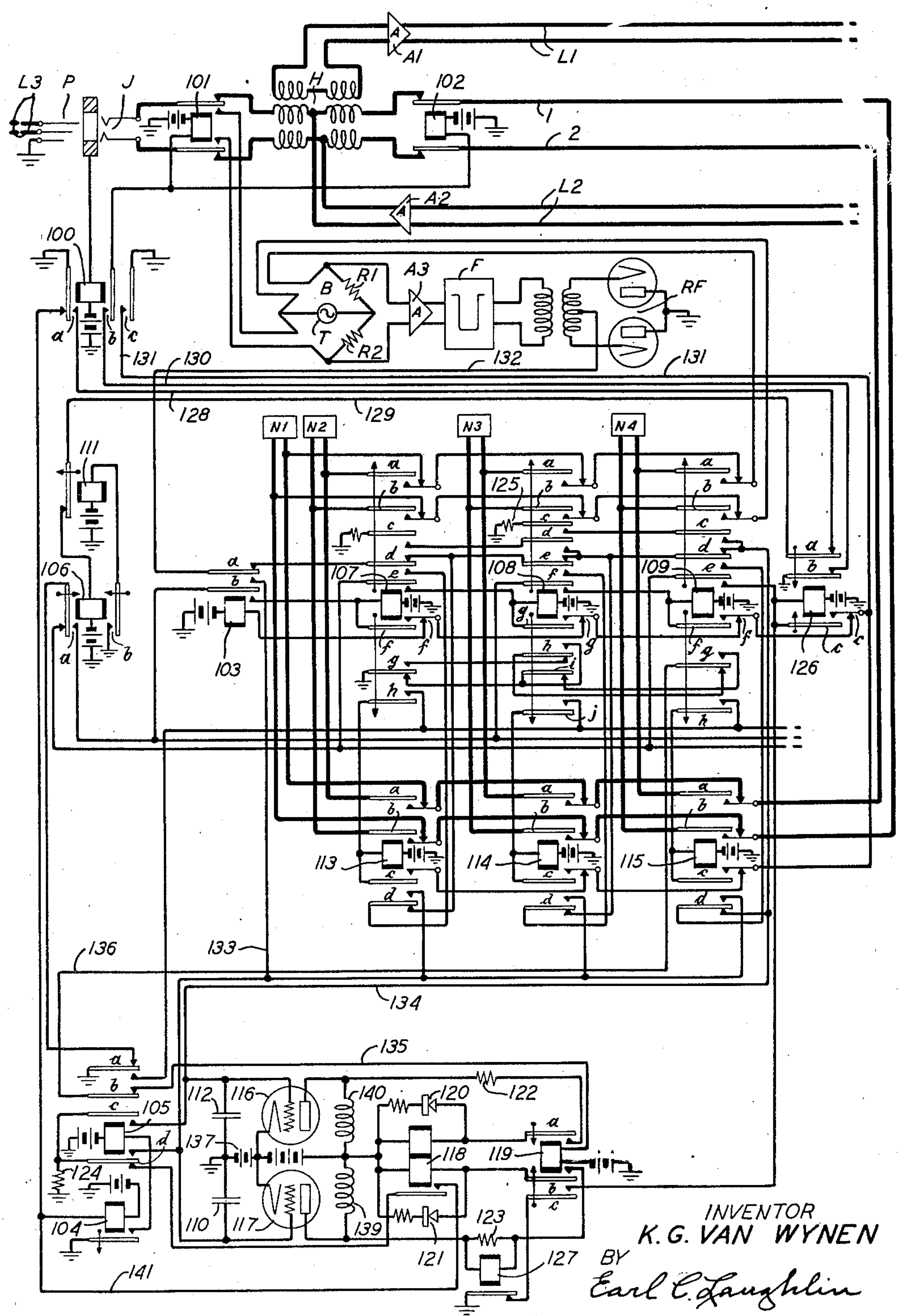

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TWO-WAY TELEPHONE TRANSMISSION SYSTEM

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The invention relates to a two-way telephone transmission system and particularly to a system of this sort in which a four-wire toll telephone circuit is associated at a terminal switchboard with a connection extending to a local subscriber's line. The four-wire toll circuit provides two two-wire circuits respectively used for transmission in opposite directions and the two-wire circuit to the subscriber circuit transmits in both directions.

It is usual to connect the four-wire circuit to the two-wire circuit by means of a special type of transformer known as a hybrid coil. In such arrangements for efficient and satisfactory signal transmission an artificial line or network is provided in association with the hybrid coil to balance the two-wire line. Where the four-wire circuit terminates in a toll board, it may be there connected with a variety of two-wire lines of different impedances in establishing a connection to a subscriber's line. Because the subscriber's loops may be of different impedances and the connection may include a variable number of interoffice trunks, an artificial balancing line which will provide an accurate balance for one connection may not be sufficiently accurate for other connections and may thus result during voice transmission over the system in the production of undesired unbalance echo currents in the four-wire circuit. This condition heretofore has been taken care of by providing a compromise artificial balancing line having an impedance equal to the average impedance of the two-wire lines with which connection is to be made and by the provision of other means such as echo suppressors to compensate for unbalance conditions.

In accordance with one embodiment of the present invention, a number of artificial balancing lines, so-called balancing networks, of various selected impedances, simulating those of different ones of the range of two-way lines to be connected to the four-wire circuit, are provided together with means to automatically compare the balancing networks with the line to be balanced and to bring about the association with the hybrid coil of the particular balancing network which gives the most advantageous balance in any given connection. Also, in accordance with the invention, the selection and connection of the optimum balancing network takes place in the early stages of setting up the connection and before the connection is placed in final condition for signal transmission.

In the drawing there is shown a portion of the usual four-wire toll circuit having an outgoing line L1 including one-way amplifier A1, and an incoming line L2 including one-way amplifier A2, adapted to be connected through the usual hybrid coil H to a subscriber's line L3. As the subscriber's line L3 may include in addition to the subscriber's loop intermediate connecting links such as interoffice trunks, it is necessary to associate with the hybrid coil an artificial balancing line or network which is a close approximation in impedance to that of the local line L3 which it is desired to balance. The subscriber's line L3 is shown as terminating in a plug P which, when inserted in the jack J, associates the particular line with the toll circuit and the balancing network selected in any particular instance. When the plug P is inserted in the jack J the line L3 is associated with the line windings of the hybrid coil H through the back contacts of the relay 101. It is, therefore, necessary to connect across conductors 1 and 2 a balancing network which gives the nearest approximation to an exact balance. Inasmuch as it is impracticable to provide an infinite number of such networks, a sufficiently good approximation may be obtained by providing a number of such networks which have impedances equal to the various line conditions most likely to be encountered in practice and to associate with any particular connection that one of such networks which provides the nearest approximation to a balance under any given condition.

At B there is shown a Wheatstone bridge provided with the usual resistance arms R1 and R2, a source of audio frequency tone T connected across one diagonal of the bridge and an amplifier-filter-rectifier combination A3, F and RF connected across the other diagonal of the bridge. Any usual form of this apparatus may be used, the arrangement being such that the voltage produced by the tone appears as a direct current potential on the conductor 132, the voltage of which depends upon the degree of unbalance of the bridge under any given set of conditions. As the line L3 is connected in one arm of the bridge and a particular balancing network under test is connected in another, this direct current potential is a measure of the degree of unbalance between the subscriber's line and the particular network under test.

For purposes of illustration in describing the operation of the system, four balancing networks are shown, N1, N2, N3 and N4, of various impedances which may comprise a number of resistance, inductance and capacitance elements in such circuit combinations and of such relative values as to simulate both in magnitude and phase different lines of those which may be connected to the four-wire circuit, although it is understood that a larger number may be used, depending upon the range of impedances which it is expected to encounter in the lines to be balanced.

The test for the optimum balancing network takes place before the connection is cut through to the subscriber and conversation takes place and, in order to reduce the time to the minimum for making the test and selecting the desired network, the selection is made by means of fast-operating relays, as will appear from the following description of the operation. While there is a large number of these relays involved in the system disclosed and a description of their operation will be somewhat involved, it will be understood that the operation takes place at a very rapid rate in order that there shall be the minimum amount of delay in setting up the actual connection between the subscribers.

In general, the test and selection are accomplished by associating in succession with the Wheatstone bridge a number of balancing networks, and storing a charge on reference condensers 110 and 112 which serve as a measure of the difference between the impedance of the line L3 and the successive balancing networks which may be associated with the bridge. These two potentials are then compared through a comparison circuit including the vacuum tubes 116 and 117 and the differential relay 118, this comparison being repeated with the association of various networks with the bridge until a network is found which gives the best balance and this network is finally connected to the hybrid coil.

Inasmuch as many of the relays are provided with a number of armatures and contacts operated thereby, for the purpose of convenience in describing the operation, each relay is designated by a reference number and the armatures are designated by letters. Thus, reference to the contact 109c is to a contact which is operated by the armature *c* of the relay 109. Also, contacts operated by the energization of the relay are referred to as front contacts and those operated by the relay in unenergized condition as back contacts.

Referring now to the detailed operation of the testing and selecting optimum networks, it will be noted that this operation is initiated when the operator inserts the plug P into the jack J. As a result of this operation the start relay 100 is operated through the sleeve of the jack with the following result. Relay 100, in operating, places ground through front contact 100*a* on the conductor leading to relay 106 through conductor 128, back contact 126*a*, conductor 129, back contact of relay 111, to relay 106, to battery, operating relay 106. It is here noted that relay 106 which as shown is slow to operate, causes the operation of slow-release relay 111 which, in operating, opens the energizing circuit for relay 106. Thus, these relays, which in effect form a timing or pulsing device, will continue to operate and release while the selecting and testing operation to be described takes place.

At front contact 100*b* a circuit is established for relays 101 and 102 in parallel through contact 100*b*, conductor 130, back contact 126*b* to ground, thus operating relays 101 and 102. Relay 101, when operated, connects line L3 to one arm of the bridge B and relay 102, when operated, disconnects conductors 1 and 2 from the hybrid coil H.

A locking circuit for relay 103 is closed at front contact 100*c* which may be traced from the contact through conductor 131, back contacts 126*c*, 109*f*, 108*g*, 107*f* through relay 103 to battery. It will be observed that network N1 is normally connected through the *a*—*b* contacts of relays 107, 108 and 109 to the other arm of the bridge and the comparison between the impedance of the network N1 and the line L3 takes place as soon as the relay 103 is operated. As soon as relay 103 is operated, there will be applied to the conductor 132 a rectified potential which represents the degree of unbalance of the bridge B, or, in other words, a potential which represents the difference in balance between the network N1 and the line L3. Through the make contact 103*a* the conductor 132 is extended to conductor 133 and causes the charging of the condenser 110 to the potential placed on conductor 132.

It will be recalled that relay 106 is shown as a slow-to-operate relay and hence does not operate until after the condenser 110 has been charged, as previously described. When relay 106 operates, a circuit is established for relay 107 which may be traced from battery through the relay, through front contact 103*b*, front contact 106*a* to back contact 105*a* to ground. Through front contacts 107*a* and 107*b* the network N2 is connected to the bridge B and the network N1 is disconnected therefrom.

The relay 107, when operated, closed a locking circuit for itself through its contact 107*f*, back contacts 108*g*, 109*f*, 126*c*, front contact 100*c* to ground. The previously traced locking circuit for relay 103 through contact 107*f* is opened when relay 107 operates, and relay 103 releases. Also as a result of the operation of relay 107, conductor 132 is extended through front contact 107*d*, back contact 113*d*, back contact 108*e*, back contact 109*d*, conductor 134 to condenser 112. Under these conditions condenser 112 will accumulate a charge which is a measure of the unbalance between the line L3 and the network N2 which is now connected to the bridge B through the operation of the relay 107. It will be noted that the relays 107, 108 and 109, when operated, successively connect the networks N2, N3 and N4 to the bridge through their *a*—*b* contacts and disconnect the previously connected network.

We now have a charge on the condenser 110 which represents the degree of unbalance between the line L3 and the network N1 and on condenser 112 a charge representing the degree of unbalance between the line L3 and the network N2. These charges are now compared to determine which of the two networks most nearly approximates a balance, or, in other words, which network is better for balancing purposes.

When relay 107 operated, a circuit was also established for relay 119 as follows: from battery through relay 119, conductor 135, back contact 105*b*, conductor 136, back contact 109*g*, back contact 108*h*, front contact 107*g*, to ground. With the relay 119 operated the differential relay 118 is associated with the plate circuits of the vacuum tubes 116 and 117. These tubes are of the three-electrode high vacuum type. By means of the biasing battery 137 the grids are negatively biased to an extent which insures that the potential impressed on the grid by the charges on condensers 110 and 112 is in any case insufficient to make the grids positive. In order to prevent the discharge of these condensers before the charges are compared, as will presently appear, the plate battery of the tubes is connected through retard coils of high impedance 139 and 140 to the plates of the tubes. It will also be noted that with relay 119 operated the windings of the differential relay 118 are in shunt with these retard coils and, as they are of low impedance relative to that of the retard coils, as soon as this connection is made current will flow through the windings of relay 118 which is proportional to the potentials on the grids of the tubes and, consequently, proportional to the potential on the condensers 110 and 112, respectively. The relay 118 is constructed and arranged so that if the current in the upper winding of the relay is less than that in the lower winding, the relay will attract its armature and close its contact, whereas if the reverse condition obtains the armature will not be attracted.

Varistors 120 and 121 are included in shunt with the windings of the differential relay to protect them in the event that a very large plate current should flow in one and not in the other due to a large difference in the charges on the condensers 110 and 112. Resistances are included in series with the varistors to limit the flow of current in the event that the varistors should break down.

Assuming that the charge on condenser 112 is less than the charge on condenser 110, indicating that balancing network N2 is better than N1, the circuit proceeds to compare the balance with balancing network N2 against that with balancing network N3 in the following manner. Under the assumed condition relay 118 is operated, establishing an operating circuit for relay 104 from battery through relay 104, conductor 141, contacts of relay 118, back contact 105d to ground. As soon as relay 104 is operated it operates relay 105 which opens the energizing circuit for relay 104. Relay 104 is slow to release in order that the relay 105 may be completely operated before the energizing circuit of relay 104 is opened at the back contact 105d. The closing of front contacts 105c and 105d, when the relay 105 is operated, discharges condensers 112 and 110 through the resistance 124. Relay 105 through operated contact 105a operates relay 113 over a circuit extending from battery through relay 113, make contact 107h, and the front contact 105a to ground.

With relay 107 operated and relay 113 operated, conductor 132 is extended through the contact 103a, 107d front, 113d front to condenser 110. Bearing in mind that with relay 107 operated artificial line N2 is now connected in the bridge B, the charge accumulated on condenser 110 represents the degree of unbalance between network N2 and the line L3. It may be well to point out here that each of the relays 113, 114 and 115 when operated close a locking circuit extending through its own front *c* contact and contact 109c. When relay 105 releases, as above described, upon the next operation of timing relay 106, ground is placed either on the front or back contact 106a. Under the conditions assumed, if the front contact is made nothing happens as relay 107 is locked up and relay 108 has not been operated, but when the back contact is made a circuit is established for relay 108 from battery through the winding of the relay, make contact 107e, back contact 106a, back contact 105a to ground. Relay 108 is operated and causes the release of relay 107 since it opens the previously traced locking circuit for relay 107 at back contact 108g.

With relay 108 operated and 107 released, balancing network N3 is connected to the bridge through the *a—b* contacts of relay 108 and the *a—b* contacts of relay 109. As soon as this connection has been made conductor 132 is extended through back contact 107d, front contact 108e, back contact 114d, back contact 109d, conductor 134 to condenser 112. Therefore condenser 112 is charged to a potential which represents the degree of unbalance between line L3 and balancing network N3. We now have the two condensers 110 and 112 charged to potentials representing the degree of unbalance between line L3 and the balancing networks N2 and N3 and the circuit will proceed to make the comparison as before.

Relay 119 operates over a circuit from battery through the relay, conductor 135, 105b, conductor 136, contact 109g back, contact 108h front, to ground through contact 107g back. As in the case previously described, the relay 119 connects the relay 118 in operative relation to the two vacuum tubes 116 and 117 and the comparison takes place as before described. It will be recalled that it was assumed that the second network, N2, afforded a better balance to the line L3 than network N1 and the action of the circuit in comparing network N2 with N3 has been described. In order to show the operation of the circuit when the last network appears to be less favorable than the network previously tested, it will now be assumed that network N2 is better than N3. In this case the differential relay 118 fails to operate. It is therefore necessary to retain the charge representing the balance of N2, or the better network, on condenser 110 and to discharge the condenser 112. If 118 fails to operate under the conditions assumed, the next closure of the timing relay contact 106a front will cause the operation of the relay 109 over a circuit which may be traced from battery through the relay 109, make contact 108f, make contact 106a, back contact 105a to ground. Under these conditions condenser 112 is discharged through a grounding resistance 125 through front contact 108c before that relay releases, due to the operation of relay 109. This discharge circuit may be traced from ground, resistance 125, contact 108c front, 109c front, conductor 134 to condenser 112.

As the locking circuit of relay 108 included a contact of relay 109, which is now open, relay 108 releases. Also the previously traced circuit for relay 119 is opened through back contact 109g preventing false operation of relays 118 and 119 at this time. With relay 109 operated the network N4 is connected to the bridge B through the *a—b* contacts of the relay and under this condition the conductor 132 is extended through contact 103a back, 107d back, 108e back, 109d front, 115d back to conductor 134 and thence to condenser 112. Also as a result of the operation of relay 109 a circuit for relay 119 is extended to conductors 135 and 136 through the front contact 109g, back contact 108h, back contact 107g to ground, and the circuit is set up to make the test as before and to compare the charges now on condensers 110 and 112.

If N4 is better than N2 as indicated by the test, relay 118 operates as before causing the operation of relay 104 and the consequent operation of relay 105 and discharges both condensers 110 and 112. With relay 105 released, which takes place immediately after its energization owing to the release of relay 104, on the next closure of the back contact of 106a back of the timing relay, relay 109 operates relay 126 which is the last relay in the chain and is operated over a circuit which may be traced from battery through the relay 126, contact 109e front, 106a back and 105a back to ground. Relay 126 operated removes the ground over which relays 101 and 102 were previously energized causing these relays to release. The release of relay 102 connects the network N4, which has been selected as the best for the purpose, to the right-hand winding of the hybrid coil H and the release of the relay 101 connects the line L3 to the left-hand winding of the hybrid coil, and conditions are now such that the talking connection may be cut through. Incidentally, the circuit for the timing relays 106 and 111 is opened at contact 126a and any operated relay of the series 109 which may be locked up through the contact c of 126 is released. However, relay 115 which was operated when relay 109 was operated locks up through its contact 115c through conductor 131 to contact 109c and maintains the network N4 connected to the conductors 1 and 2 after the relay 109 is released. The bridge B is disconnected through the release of the relay 101, and the entire testing system is restored to normal and made ready for use when the next connection is established.

Thus far no mention has been made of the relay 127 and its function since this function may be omitted without affecting the above-described operation of the testing system. Relay 127 may be connected, however, in bridge with resistance 123 when it may be desired to terminate the testing if a network is found that is sufficiently good for practical purposes. This condition will be indicated by a small current flow in the circuit including the resistance 123 indicating a slight degree of unbalance between the line L3 and the network under test. However, if this condition does not obtain and a substantial current passes through the relay 127 and the resistance 123, the relay 127 will remain energized and the testing will proceed as described. If, however, the relay 127 releases its armature when relay 119 is energized, relay 126 will be energized and will stop the testing operation and cut the selected network through to the hybrid coil H. Relay 127 is a fast-operating relay, although marginal, whereas relay 126 is slow to operate so that the relay 127 will ordinarily operate to open the energizing circuit of relay 126 through the armature and contact 119c and will not interfere with the testing procedure unless it fails to operate for a period of time necessary for the relay 126 to operate. It should be noted that resistance 122 in the circuit through the upper winding of relay 118 affects the current through said winding in the same manner that resistance 123 affects the current through the lower winding of said relay, thereby maintaining a balanced circuit relation.

Various modifications of the circuits illustrated and described which are within the spirit and scope of the invention will be apparent to persons skilled in the art. For example, the hybrid coil bridge at one terminal of the four-wire telephone circuit may be employed to provide, in addition to its usual function, that of the auxiliary Wheatstone bridge in the measuring and network selecting circuit, so as to allow elimination of the latter bridge. In that case, relays operatively responsive to the connection of the line L3 to the line side of the hybrid coil forming one arm of the hybrid coil bridge, would be employed to connect the input of amplifier A3 and the source of tone T respectively to one of the two diagonals of the hybrid coil bridge, and to connect the balancing networks N1, N2, etc., in sequence to the net side of the hybrid coil forming another arm of the hybrid coil bridge, and to disconnect the measuring circuit and the source of tone from the hybrid coil bridge when the balancing network of optimum value is selected and connected to the net side of the hybrid coil so that two-way voice transmission between the four-wire telephone circuit and the associated two-way line may take place in the usual manner.

What is claimed is:

1. In combination in a two-way signal transmission system, a four-wire signal transmission circuit comprising two oppositely directed signal paths, a hybrid coil bridge circuit at one terminal of said four-wire circuit, having line and balancing network terminals in two opposing bridge arms and the input and output of said paths at said terminal respectively connected in the other two opposing arms, a plurality of two-way signal lines adapted for selective connection to said line terminals, and means to reduce signal echoes for a signal connection between said four-wire circuit and any one of said lines, comprising automatic means responsive to the connection of a selected line to said line terminals to test the line to determine an electrical characteristic thereof and to provide a balancing network of a tolerable matching electrical characteristic connected to said network terminals.

2. The combination of claim 1 in which the determination of the electrical characteristics of the connected line and the provision of the balancing network of matching electrical characteristic in connection with said network terminals are made before the signal connection between said four-wire circuit and the selected line is established.

3. In combination in a two-way telephone system, a four-wire telephone circuit including two oppositely directed telephone transmission paths and at one terminal of the circuit a hybrid coil bridge circuit having line and balancing network terminals in two opposing bridge arms, the input and output respectively of said two transmission paths at said terminal respectively forming the other two opposing bridge arms, a plurality of two-way telephone lines adapted for selective connection to said line terminals, a plurality of balancing networks each simulating an electric characteristic of one or more of said lines, and automatic means responsive to the connection of one of said lines to said line terminals, to test the connected line to determine an electrical characteristic thereof, and to select and connect to said network terminals one of said balancing networks having a tolerable matching electrical characteristic.

4. The combination of claim 3 in which said automatic means comprises means for comparing the connected line in sequence with a number of said balancing networks, means for discarding the networks providing insufficient balance for the connected line and for selecting and connecting to said network terminals, one network which provides a tolerable balance.

5. The combination of claim 3, in which each of said balancing networks simulates the impedance characteristics both in phase and magnitude of a different one of said lines, and said

automatic means comprising an auxiliary bridge circuit, a source of current connected across one diagonal of said auxiliary bridge circuit, means responsive to the connection of a selected line to said line terminals to connect said selected line in one arm of said auxiliary bridge circuit, to connect said balancing networks in sequence in another arm of said auxiliary bridge circuit, to determine the unbalance of that bridge for each balancing network connected therein, to compare the determined unbalances for the several balancing networks, to discard those networks providing insufficient balance of said connected line, and to select and connect to said balancing network terminals of said hybrid coil bridge circuit one of said balancing networks having an optimum impedance matching characteristic.

6. The system of claim 3 in which said automatic means comprises an auxiliary Wheatstone bridge circuit having two equal arms of predetermined equal value and two other arms, a source of current connected across one diagonal of said auxiliary bridge circuit, relay means responsive to the connection of said selected line to said line terminals of said hybrid coil bridge circuit to connect said selected line in one and said balancing networks in sequence in the other of said other arms of said auxiliary bridge circuit, means for storing energy proportional to the unbalance current of said auxiliary bridge circuit for each balancing network connected therein, means to effectively compare the amount of stored energy for the several connected balanced networks to determine which one provides the least amount of stored energy indicating that it provides the best balance for the selected line, and means to select and connect said one balancing network to the network terminals of said hybrid coil bridge circuit and to reconnect said selected line in the line arm of the latter bridge circuit.

7. In combination in a telephone system, a four-wire telephone circuit including a hybrid coil set having line and balancing network terminals, at a terminal thereof, a plurality of different two-way telephone lines terminating at said terminal, means for selecting and connecting to said line terminals any one of said two-way lines, and means to reduce echoes in said circuit during telephone transmission between said circuit and any connected two-way line comprising a plurality of balancing networks each simulating the impedance characteristic both in phase and magnitude of different ones of said lines, a Wheatstone bridge circuit, a source of current connected across one diagonal of said bridge circuit, means responsive to the connection of the selected line to said line terminals for connecting said selected line in one arm and said balancing networks in sequence in another arm of said bridge circuit, means for storing energy proportional to the unbalance current of said bridge circuit for each balancing network connected thereto, means for comparing the stored energy for the several connected networks, means for selecting on the basis of this comparison one of said networks providing a tolerable balance of the selected line, and for connecting the selected network to the network terminals of said hybrid coil set and simultaneously disconnecting said selected line from said bridge circuit.

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