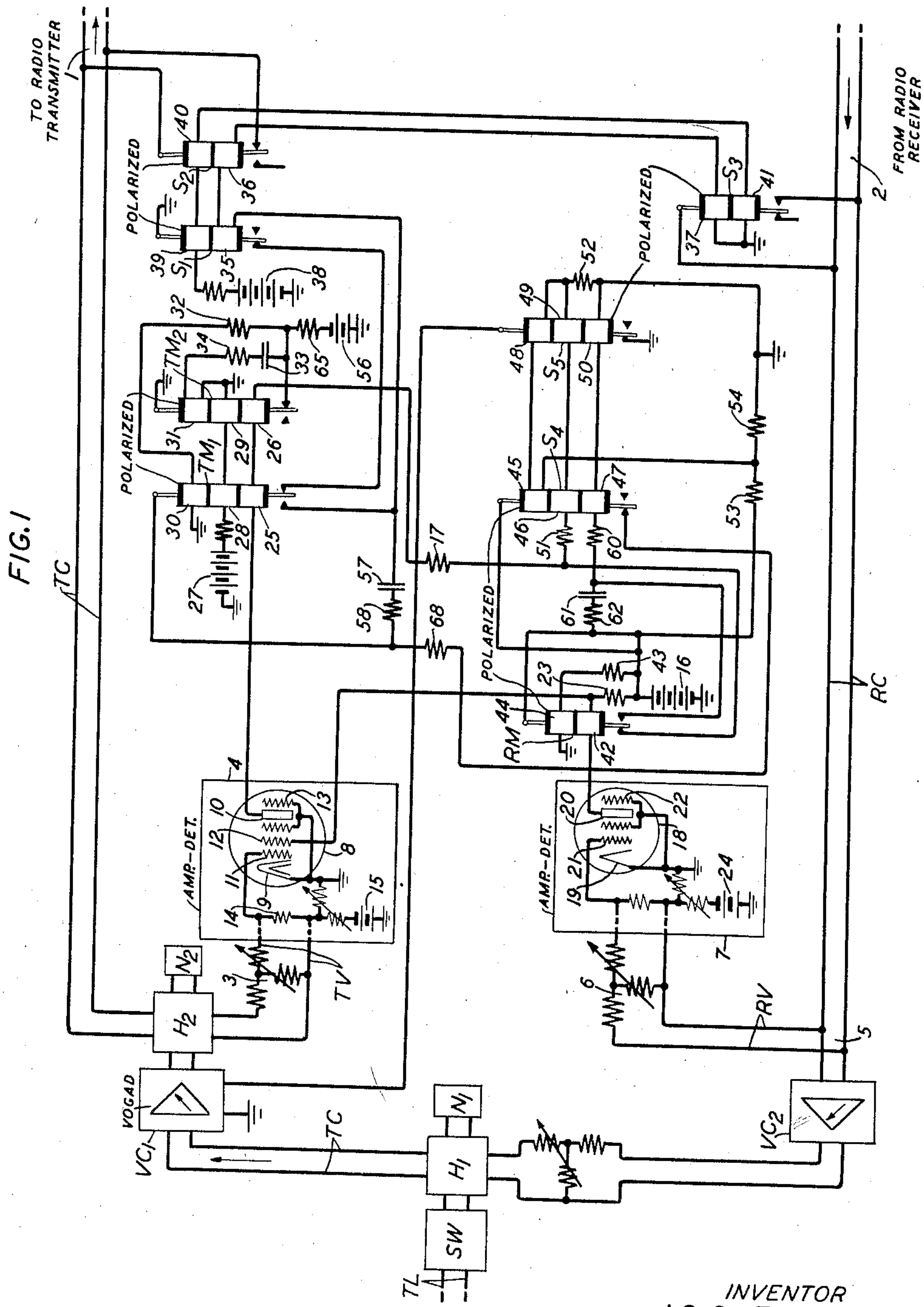
Dec. 31, 1940. J. O. SMETHURST 2,226,952

SWITCHING CIRCUIT

Filed Dec. 13, 1939 2 Sheets-Sheet 1



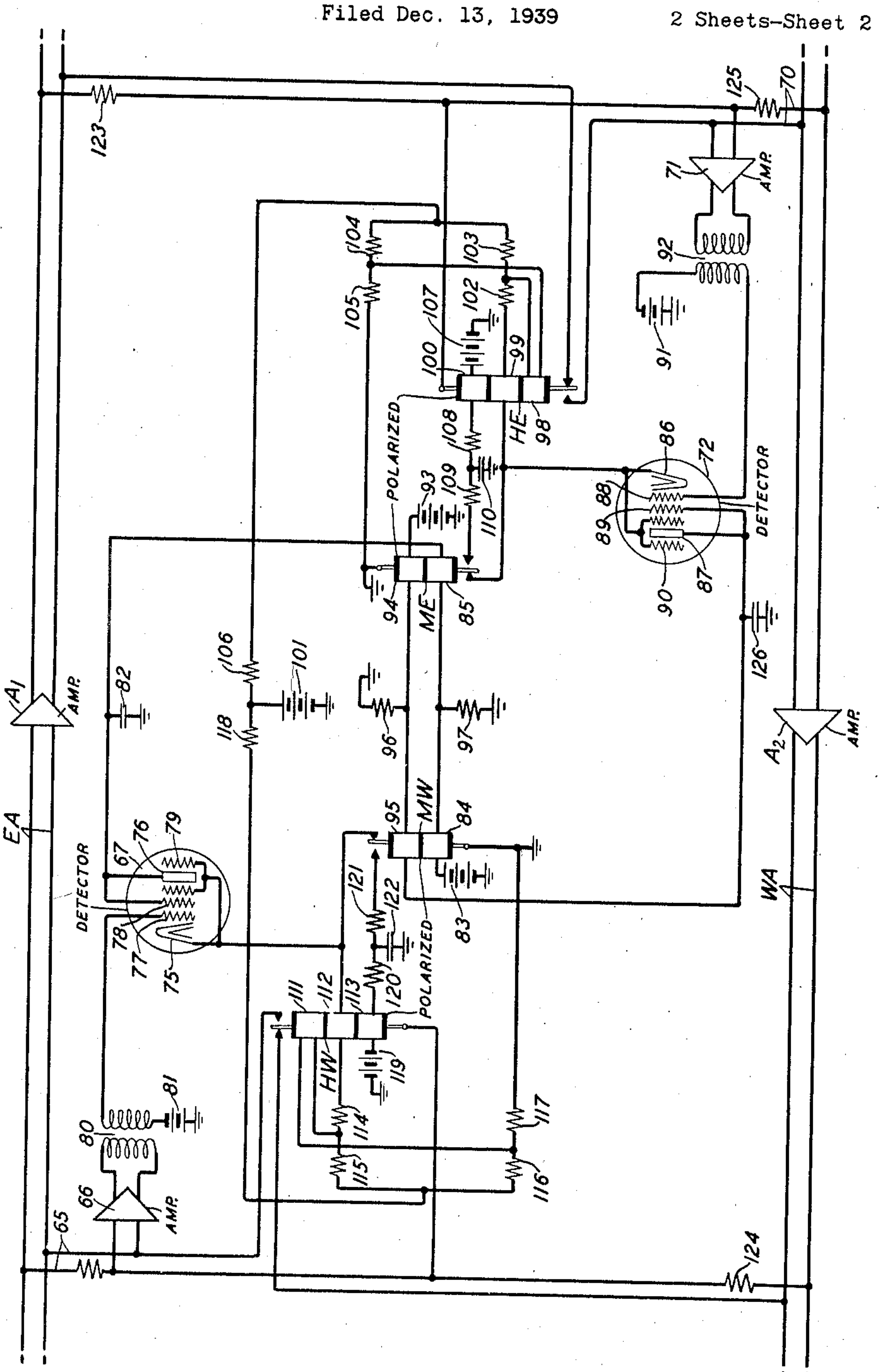
INVENTOR
J. O. SMETHURST
BY
Earl C. Laughlin
ATTORNEY

Dec. 31, 1940. J. O. SMETHURST 2,226,952

SWITCHING CIRCUIT

Filed Dec. 13, 1939 2 Sheets-Sheet 2

FIG. 2



INVENTOR
J. O. SMETHURST
BY
Earl C. Laughlin
ATTORNEY

Patented Dec. 31, 1940 2,226,952

UNITED STATES PATENT OFFICE

2,226,952

SWITCHING CIRCUIT

Joseph O. Smethurst, Bloomfield, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application December 13, 1939, Serial No. 309,029

4 Claims. (Cl. 175—320)

This invention relates to switching circuits and particularly to signal-controlled switching circuits employing electromagnetic relays.

The invention is more specifically directed to, although not limited to, signal-controlled switching circuits employed in connection with the oppositely-directed repeating paths of a two-way signal transmission system, such as a radio or wire telephone system, for suppressing echoes and preventing singing. Such switching circuits usually employ an amplifier-detector for amplifying and detecting the applied signals and electromagnetic relays or other switching devices operated by the detected signals to insert or remove losses in the transmission circuits to provide the desired control of transmission.

An object of the invention is to improve such switching circuits.

This object is attained in accordance with the invention by relatively arranging and controlling the transmission apparatus in the signal-controlled switching circuits so as to provide more efficient operation of these circuits with economy of apparatus.

A feature of the invention is the connection of the windings of one or more switching relays of a signal-controlled switching circuit, in a balanced bridge circuit arrangement and to control the balance of said bridge in such manner as to provide faster operation of the switching relays with desired control of their hang-over characteristics, with a small number of relays.

Other objects and features of the invention will be understood from the following detailed description when read in conjunction with the drawings, Figs. 1 and 2 of which show schematically portions of two-way telephone systems of different types employing switching circuits embodying the invention.

In Fig. 1 the switching circuits of the invention are shown associated with a control terminal for a two-way radio telephone system, only those portions of the terminal apparatus and circuit required to explain the invention being illustrated.

The control terminal of Fig. 1 as shown includes a two-wire transmitting circuit TC leading to a radio transmitter (not shown) and a receiving circuit RC leading from a radio receiver (not shown), the input of the circuit TC and the output of the circuit RC being coupled in well-known manner by a hybrid coil H_1 and associated balancing network N_1 to a two-wire circuit which may be connected by switchboard SW with the two-way telephone line TL. As shown, the transmitting circuit TC includes in its input a volume control device VC_1, which may be a vogad (volume-operated gain-adjusting device) of any of the well-known types, the main function of which is to control the transmitted signal volume level to prevent overloading the radio transmitter. The receiving circuit RC includes in its output a similar volume control device VC_2.

In the absence of outgoing signal transmission the transmitting circuit TC is disabled or blocked at the point 1 by a short-circuiting connection across that circuit, and the receiving circuit RC is normally operative due to the normal break in the short-circuiting connection across that circuit at the point 2.

The short-circuiting connection across the transmitting circuit TC at the point 1 is opened to unblock that circuit for outgoing signals, and the normally open short-circuiting connection across the receiving circuit RC at the point 2 is closed to block or disable that circuit so as to suppress echoes and prevent singing, under control of the transmitting portion TV of a vodas (voice-operated device anti-singing) switching circuit, the input of which is connected across the circuit TC at a point in the output of the volume control device VC_1 by the hybrid coil H_2 and associated balancing network N_2. The transmitting vodas TV includes a sensitivity-adjusting loss pad 3 in its input, the amplifier-detector 4 and a chain of relays including the master relays TM_1 and TM_2 and switching relays S_1, S_2 and S_3, controlled by operation of the amplifier-detector 4.

False operation of the transmitting vodas TV when incoming signals are being received at the terminal is prevented by the receiving portion RV of the vodas, the input of which is connected across the receiving circuit RC at a point 5 to the left of the switching point 2. The receiving vodas RV includes the sensitivity-adjusting loss pad 6 in its input, the amplifier-detector 7 and a chain of relays, including master relay RM and the switching relays S_4 and S_5, controlled from the output of amplifier-detector 7, operating to disable the transmitting vodas TV and the volume control device VC_1 in the transmitting circuit TC in the manner to be described.

The detector portion of the amplifier-detector 4 in the transmitting vodas TV comprises a single electron discharge tube 8 of the pentode type, comprising a heated cathode 9, the anode 10, a control grid 11, a screen grid 12, and a suppressor grid 13 which is connected directly to the cathode. The control grid-cathode circuit of tube 8 is coupled to the output of the amplifier portion of the amplifier-detector 4 through resistance 14, and the tube 8 is normally biased beyond cut-off by a negative potential applied to the control grid 11 from a voltage divider connected across the grid battery 15. Plate current is supplied to the anode 10 of detector tube 8 from plate battery 16 through the normally closed left-hand contacts of the receiving vodas master relay RM, resistance 17 and the operating windings 26 and 25 of the transmitting master relays TM_2 and TM_1 in series.

The detector portion of the amplifier-detector 7 in the receiving vodas RV comprises a single four-electrode electron discharge device 18 comprising a heated cathode 19, an anode 20, a control grid 21, and a suppressor grid 22 connected directly to the cathode 19. The control grid-cathode circuit of the detector tube 18 is coupled to the output of the amplifier portion of amplifier-detector 8 in any suitable manner, and the tube 18 is normally biased beyond cut-off by a negative potential applied to the control grid 21 by the voltage divider across grid battery 24, so as to operate quickly in response to applied signals. Plate current is supplied to the anode 20 of detector tube 18 from plate battery 16 through resistance 23 and the operating winding 42 of the relay RM in series. The screen grid 12 of detector tube 8 in the transmitting amplifier-detector 4 is normally positively biased by plate battery 16 through series resistance 23 so that the detector tube 8 will be quickly operated in response to signal energy applied to the input of amplifier-detector 4 to operatively energize the operating windings 25 and 26 of master relays TM_1 and TM_2, respectively.

In the absence of signal transmission in the transmitting circuit TC, the amplifier-detector 4 in the transmitting vodas TV is unoperated so that the operating windings 25 and 26 of the transmitting master relays TM_1 and TM_2, respectively, are unenergized. Then, the biasing current applied from battery 27 to the biasing windings 28 and 29, respectively, of these relays in series hold the relay armatures on the right-hand contacts. The hold-over windings 30 and 31 of the relays TM_1 and TM_2 are shorted through the resistance 32, condenser 33 and resistance 34 in series. For this condition of the master relays TM_1 and TM_2, the operating windings 35, 36 and 37 of the transmitting switching relays S_1, S_2 and S_3, respectively, connected in series to the open left-hand contact of master relay TM_1, are unenergized, and the biasing current from battery 38 flowing through the biasing winding 39 of relay S_1, the biasing winding 40 of relay S_2, and the biasing winding 41 of relay S_3 in series holds the armatures of these relays respectively on the left-hand, right-hand and left-hand contacts of the relays. The transmitting circuit TC in then blocked at the point 1 by the short-circuiting connection through the closed armature and right-hand contact of relay S_2, and the receiving circuit RC is in the operative condition due to the break in the short-circuiting connection across that circuit at the point 2, provided by the open right-hand contact of relay S_3.

In the absence of signal transmission over the receiving circuit RC, the amplifier-detector 7 of the receiving vodas RV is unoperated, and the operating winding 42 of the receiving master relay RM, connected in the plate circuit of detector tube 18, is unenergized. The biasing current from battery 16 transmitted through resistance 43 and the biasing winding 44 of the relay RM causes the armature of that relay to be held on its left-hand contacts.

The switching relay S_4 has an operating winding 45, a biasing winding 46 and a hold winding 47, and the switching relay S_5 has an operating winding 48, a biasing winding 49 and a hold winding 50. The corresponding windings of the two relays S_4 and S_5 are connected in series so that the relays operate and release in unison. The operating and biasing windings of the relays S_4 and S_5, the battery 16 and resistances 51, 52, 53 and 54 are connected in a Wheatstone bridge circuit. In this bridge circuit, the armature and closed left-hand contact of relay RM, resistance 51 and biasing winding 46 of relay S_4 and biasing winding 49 of relay S_5 in series are connected in one arm, the resistance 52 in a second arm, and the equal resistances 54 and 53 are respectively connected in the other two arms of the bridge. Plate battery 16 is connected across one diagonal of the bridge circuit so that in the unoperated condition of the master relay RM biasing current is supplied from that battery to the biasing winding 46 of relay S_4 and biasing winding 49 of relay S_5 in series. The operating winding 45 of relay S_4 and the operating winding 48 of relay S_5 in series are connected across the other diagonal of the bridge circuit so that in the normal balanced condition of the bridge little current flows through the operating windings of relays S_4 and S_5 and the relay armatures are respectively held on their left-hand contacts due to the biasing effect of the biasing windings of the relays.

The purpose of the other circuit elements shown in Fig. 1 but not previously referred to will be brought out in the following complete description of the operation of the system.

Now let it be assumed that telephone signals received over the telephone line TL from a west subscriber are impressed by the hybrid coil H_1 on the transmitting circuit TC and are transmitted over that circuit towards the disabling point 1, and at that time no east-to-west telephone signals from an east telephone subscriber associated with the east end of the system have reached a corresponding point in the receiving circuit RC.

A portion of the outgoing telephone signals in the transmitting circuit TC will be diverted through hybrid coil H_2 into the input of the transmitting vodas TV. These signals, with a level determined by the initial adjustment of the sensitivity-adjusting loss pad 3, will pass into the amplifier-detector 4 and will be amplified by its amplifier portion. The amplified signals will be impressed on the control grid-cathode circuit of the detector tube 8 across the resistance 14. Because of the normal positive bias on the screen grid 12 of the tube, detector tube 8 will quickly operate to supply energizing current to the operating winding 25 of the relay TM_1 and the operating winding 26 of relay TM_2 in series, causing the operation of these relays to shift their armatures from the right-hand to the left-hand contacts.

Relay TM_1 operated to its left-hand contact short-circuits the hold-over condenser 57, which is normally charged from battery 16, to discharge it through series resistance 58, and connects the operating windings 35, 36, and 37 of the switching relays S_1, S_2 and S_3 in series through the armatures and left-hand contacts of relays TM_1 and S_4 across plate battery 16, causing the relays S_1, S_2 and S_3 to operate.

The purpose of the relay TM_2, condenser 33 and associated resistances is to insure that any speech currents great enough to cause operation of the relay TM_1 to break its right-hand contact will cause it to operate for a long enough time for the hang-over condenser 57 to discharge completely. On release of the master relay TM_1, the relays of the transmitting chain will then be certain to hold operated long enough to allow the weak parts of speech to pass and to prevent trouble being caused by echoes that are received from the radio channels. When relay TM_2 operates to break its right-hand contact, ground is removed from condenser 33, and that condenser will then be charged up to the potential of battery 56 through the resistance 34 and winding 31 of relay TM_2. This kick-up circuit forces the relay TM_2 to operate instantaneously and hold against the left-hand contact for the duration of the charging current. The operation of relay TM_2 also removes the ground from the junction point of resistances 65 and 32 which allows current to flow from battery 56 through resistances 65 and 32 to winding 30 of relay TM_1 to ground, causing a positive operation of TM_1. For every break of the right-hand contact and armature of TM_2 a positive operation of TM_1 is insured to completely discharge the hang-over condenser 57. When energizing current is removed from the operating windings 25 and 26 the master relays TM_1 and TM_2 will release immediately. However, the switching relays S_1, S_2 and S_3 will not release but will be maintained operated for the interval required to charge the condenser 57 through resistances 68 and 58 and relay windings 35, 36 and 37. The final release of relay S_1 will apply a ground through the contacts of S_1 and TM_1 to the junction of resistances 58 and 68, which discharges the condenser 57 to end the hang-over period and restore S_1, S_2 and S_3 to their normal positions.

The operation of relay S_1 to break its left-hand contact will disconnect ground from the right-hand contact of master relay TM_1. The operation of relay S_2 to break its right-hand contact will open the normal short-circuiting connection across the transmitting circuit TC allowing the outgoing signals to be transmitted out over the circuit TC to the radio transmitter, and the simultaneous operation of the relay S_3 to shift its armature from the left to the right-hand contact will connect a short-circuiting connection across the receiving circuit RC at the point 2, disabling that circuit so as to suppress echoes and prevent singing. When the master relay TM_1 breaks its left-hand contact due to cessation of the transmitted signals, the relays S_1, S_2 and S_3 will remain operated for a time, being held up by the charging current to the hold-over condenser 57 flowing from battery 16 through the operating windings of these relays. As this condenser becomes charged, this current decreasing until, its magnetic effect on a particular relay core is exceeded by that of a biasing winding, the relay releases. By proper selection of the circuit constants, this hang-over time interval is made long enough to prevent premature release of the relays S_2 and S_3 so that there is no clipping of the speech signals in the transmitting circuit TC and so that all echoes of the transmitted signals are suppressed in the receiving circuit RC. When the relays S_1, S_2 and S_3 release, the entire circuit returns to its normal condition with the outgoing transmission blocked and the receiving circuit enabled as shown in Fig. 1.

The operation of the circuit of Fig. 1 for the case where incoming signals are received in the receiving circuit RC in the absence of prior outgoing signal transmission in the transmitting circuit TC is as follows.

The receiving circuit RC being in its normal operative condition at the point 2, the received signals will be transmitted over the receiving circuit to the hybrid coil H_1 and will be passed through that coil and switchboard SW to the telephone line TL over which they will be transmitted to the west telephone subscriber. A portion of the east-to-west signals will be diverted from the receiving circuit RC at the point 5 passing into the input of the receiving vodas RV. The diverted speech signals, with a level determined by the adjustment of the sensitivity-adjusting pad 6, will be impressed upon the input of amplifier-detector 7 where they will be amplified and detected. The detected signal currents will be supplied as energizing current to the operating winding 42 of the master receiving relay RM and will cause that relay to operate to shift its armature from the left-hand to the right-hand contacts.

As noted above, with the relay RM in its unoperated condition with its armature held on the left-hand contact, biasing current is supplied to the biasing windings of the switching relays S_4 and S_5 over a circuit extending from ground through plate battery 16, armature and left-hand contact of relay RM, resistance 51, biasing winding 46 of relay S_4, biasing winding 49 of relay S_5 and resistance 52 to ground. Under this condition, there is no current flowing in the operating winding 45 of relay S_4 and the operating winding 48 of relay S_5, as they are connected across the balanced point in the Wheatstone bridge circuit, that is, across the diagonal of the bridge extending from a point between resistances 53 and 54 and a point between resistance 52 and the biasing winding 49 of relay S_5.

When the relay RM operates to break its left-hand contact, the connection between battery 16 and the biasing windings of relays S_4 and S_5 is immediately broken so that biasing current ceases to flow. Then, the bridge being unbalanced, the unbalance current of the bridge will flow through the operating windings of relays S_4 and S_5, over a series circuit extending from the positive terminal of plate battery 16 through resistance 53, operating winding 45 of relay S_4, operating winding 48 of relay S_5, resistance 52 and ground to the negative terminal of battery 16, causing operation of the relays S_4 and S_5. The effect of simultaneously removing the bias and adding operate current to the relays S_4 and S_5 results in fast operation of these relays. Relay S_5 operates to break its left-hand contact disabling the vogad VC_1 in the transmitting circuit as indicated diagrammatically. Relay S_4 operates to remove the battery 16 from the transmitting hang-over circuit, to prevent echoes from falsely operating the transmitting relays.

The operation of relay RM to break its left-hand contact also provides a break in the energizing circuit for the operating windings 25 and 26 of the transmitting master relays TM_1 and TM_2, respectively, from plate battery 16, preventing the subsequent operation of these relays under control of outgoing signals thereafter initiated in the transmitting circuit TC, as long as the receiving master relay RM remains operated by incoming signals.

When the armature of the receiving master relay RM reaches its right-hand contact, current flows through the hold-over windings of the relays S_4 and S_5 over the series circuit extending from the positive terminal of battery 16 through armature and closed right-hand contact of relay RM, resistance 60, holding winding 47 of relay S_4, holding winding 50 of relay S_5 and ground to the negative terminal of battery 16, holding relays S_4 and S_5 in the operated condition. Also, the hold-over condenser 61, normally charged to the potential of battery 16 when relay RM is unoperated, is discharged through the resistance 62.

The disabling of the transmitting vodas relay chain under control of the receiving vodas RV in the manner which has just been described, is not quite positive enough so that there may be a possibility of a receiving volume penalty under certain circuit conditions. When the terminal is set up for zero echo margin, its transmitting amplifier-detector 4, and the receiving amplifier-detector 7 have equal sensitivities as seen from the point 2 in the receiving circuit RC. Under these conditions, the detectors are working on speech levels close to their just operating sensitivities, where operating currents are low and variations in relay adjustment will cause difference in relay operate and release times.

In order to overcome this objection, the circuit arrangement of Fig. 1 is arranged to provide a desensitizing action to the transmitting vodas under control of the receiving vodas in the following manner.

As indicated, the anode 20 of the detector tube 18 in the receiving amplifier-detector 7 is connected through the operating winding 42 of the master receiving relay RM to the screen grid 12 of the detector tube 8 in the transmitting vodas amplifier-detector 4. When the receiving vodas RV is unoperated, a positive voltage is applied to this screen grid from plate battery 16 through the series resistance 23, so that the detector tube 8 is in the condition to be operated quickly in response to applied signals. With the connection of the plate 20 of the receiving vodas detector 18 to the screen grid 12 of the transmitting vodas detector 8 as described above, when an input signal is applied to the receiving vodas detector 18, the plate current flowing through resistance 23 will cause a voltage drop which reduces the voltage on the screen grid 12 of the transmitting vodas detector 8 a like amount, this circuit being proportioned to prevent any plate current flowing in the transmitting master relays TM_1 and TM_2 to more effectively disable them.

When the receiving master relay RM releases with cessation in the supply of received signals to the receiving vodas RV, to restore the relay armature to its left-hand contact, biasing current is again supplied from battery 16 to the biasing windings 46 and 49 of relays S_4 and S_5, respectively, and the bridge being again balanced the current through the operating windings of these relays is again reduced to zero. However, the relays S_4 and S_5 will be maintained operated for a suitable hang-over interval due to the hold-over action provided by charging current flowing to the hold-over condenser 61 over a series circuit extending from the positive terminal of battery 16 through resistance 62, condenser 61, resistance 60, hold winding 47 of relay S_4, hold winding 50 of relay S_5 and ground to the negative terminal of battery 16.

The quick operation of the transmitting vodas TV and of the receiving vodas RV provided respectively by the use of a high normal negative bias on the detector of the transmitting vodas and the fast operating relay circuit in the receiving vodas and by making the operation of the detector in the receiving vodas disable the corresponding detector in the transmitting vodas and the receiving master relay disable the transmitting master relays, provided in the circuit of the invenion shown in Fig. 1, as described above, enables zero echo margin to be maintained at the terminal without resorting to the use of delay circuits in the signal transmission paths. This improvement results in a more satisfactory operation of the terminals in that higher volumes can be delivered to the receiving subscriber.

Fig. 2 shows a modified switching circuit in accordance with the invention associated with a two-way repeating circuited used for switching losses between the two sides of the repeater and suppressing echoes.

As shown, the repeating circuit comprises a west-to-east transmission circuit EA including the one-way amplifier A_1, and an east-to-west transmission circuit WA including the one-way amplifier A_2. These circuits may be oppositely-directed one-way repeating circuits of a two-wire repeater or a four-wire telephone circuit, in which case, the circuits EA and WA would be connected at their terminals in conjugate relation to each other and in energy transmitting relation with a two-wire telephone circuit by a hybrid coil and associated balancing network, or other suitable means (not shown).

Connected across the circuit EA in front of the amplifier A_1 is the input of a switching circuit 65 comprising the one-way amplifying device 66, the detector 67 and a chain of switching relays including the polarized relay ME and the polarized relay HE, controlled by operation of the detector 67. Similarly, connected across the circuit WA in front of the amplifier A_2 is the input of a switching circuit 70 comprising the one-way amplifying device 71, the detector 72 and a chain of switching relays including the polarized relay MW and the polarized relay HW, controlled by operation of the detector 72.

The detector 67 in switching circuit 65 comprises a single electron discharge tube of the pentode type having a cathode 75, which may be of the heater type, supplied with heating current in any suitable manner, the anode 76, a control grid 77, a screen grid 78 and a suppressor grid 79 connected directly to the cathode 75. The control grid-cathode circuit of tube 67 is coupled to the output of the amplifying device 66 by transformer 80, and the tube 67 is normally biased to cut-off by the negative potential applied to the control grid 77 by a grid battery 81 through the secondary winding of transformer 80. But in the presence of sufficient voice frequency voltage applied through the transformer 80 to the control grid 77, plate current will flow in the plate circuit of which the alternating current component is shunted through condenser 82. Plate current is supplied to the anode 76 of detector tube 67 from plate battery 83 through the biasing winding 84 of relay MW and the operating winding 85 of relay ME in series.

Similarly, the detector 72 of the switching circuit 70 connected to the circuit WA comprises a single electron discharge device of the pentode type having a cathode 86, an anode 87, a control grid 88, a screen grid 89 and a suppressor grid

90 connected directly to the cathode. The detector tube 72 is biased to cut-off by the negative potential applied by grid battery 91 through the secondary winding of the input transformer 92. Plate current is supplied to the anode 87 of detector tube 72 from plate battery 93 through the biasing winding 94 of relay ME and the operating winding 95 of relay MW in series, and the alternating current component of the plate current flowing in the plate circuit of detector tube 72, when that tube is operated, is shunted from the relay windings by condenser 126.

The screen grid 78 of detector tube 67 in switching circuit 65 is connected directly to the anode 76 so as to be positively biased to the same potential as the anode by plate battery 83 through the biasing winding 84 of relay MW and the operating winding 85 of relay ME. Similarly, the screen grid 89 of detector tube 72 in switching circuit 70 is connected directly to the anode 87 so as to be positively biased at the same potential as that anode from plate battery 93 through the biasing winding 94 of relay ME and the operating winding 95 of relay MW.

The armature of the polarized switching relay ME is normally held to its left-hand contact by current flowing from the plate battery 93 through biasing winding 94 and resistance 96 to ground, and the armature of polarized relay MW is normally held on its right-hand contact by the biasing current flowing from the plate battery 83 through biasing winding 84 and resistance 97 to ground. The polarized relay HE has three windings, an operating winding 98, a biasing winding 99 and a hold winding 100. The biasing winding 99 and operating winding 98 of relay HE are connected in a balanced Wheatstone bridge circuit with battery 101, resistances 102, 103, 104, 105 and 106 and the contacts of relay ME. In this bridge, the closed armature and left-hand contact of relay ME, biasing winding 99 and resistance 102 are connected in series in one arm, and the resistances 103, 104 and 105 constitute the other three arms. The battery 101 in series with the resistance 106 is connected across one diagonal of the bridge so as to supply the biasing winding 99 of relay HE with biasing current over a circuit extending from the positive terminal of the battery through resistances 106, 103, 102, biasing winding 99, closed lefthand contact and armature of relay ME, and ground to the negative terminal of battery 101. The values of the elements of the four arms of the bridge being selected so as to balance the bridge, the operating winding 98 of relay HE which is connected across the other (balanced) diagonal of the bridge, will normally receive no operating current. The hold winding 100 of relay HE is connected in a circuit which may be traced from ground through battery 107, winding 100, series resistances 108, 109 to the right-hand normally open contact of relay ME, a hold-over condenser 110 being connected from a point between the two resistances 108 and 109 to ground.

Similarly, the polarized relay HW in the switching circuit 70 has an operating winding 111, a biasing winding 112 and a hold winding 113, the operating and biasing windings being connected with battery 101, resistances 114, 115, 116, 117 and 118 and the contacts of relay NW in a balanced Wheatstone bridge circuit. In the latter bridge circuit, one arm comprises the closed armature and right-hand contact of relay MW, the biasing winding 112 of relay HW and resistance 114 in series and the other three arms comprise respectively resistances 115, 116 and 117. The battery 101 is connected in series with resistance 118 across one diagonal of the bridge circuit so that with the armature and right-hand contact of relay MW closed, it supplies biasing current to the biasing winding 112 of relay HW. With the values of the elements in the four arms of the bridge selected to balance the bridge, the operating winding 111 of relay HW, which is connected across the other balanced diagonal, will receive no operating current. The hold winding 113 of relay HW is connected in a circuit which may be traced from ground through battery 119, series resistance 120 and 121 to the open left-hand contact of relay MW, a point between the equal series resistances 120 and 121 being connected through the hold-over condenser 122 to ground.

The switching circuits as described above operate as follows. With signal transmission over the circuit EA, a portion of the signals will be diverted into switching circuit 65 and will be amplified by the amplifying device 66 therein and impressed by transformer on the control grid-cathode circuit of the detector tube 67. When the level of the impressed signal voltages is sufficient to overcome the normal negative bias on the control grid of the detector tube 67, plate current will start to flow in the anode-cathode circuit, the direct current component of which will pass through the operating winding 85 of relay ME and the biasing winding 84 of relay MW in series in such direction as to oppose the normal bias on relay ME produced by the biasing winding 94. This operating current will cause operation of relay ME to shift its armature from the left-hand to the right-hand contact. As soon as the armature of relay ME leaves its left-hand contact the arm of the bridge circuit including the biasing winding 99 of relay HE is opened causing biasing current to be removed from that winding and the bridge to be unbalanced. The unbalance current of the bridge will then flow through the operating winding 98 of the relay HE causing operation of the relay to shift its armature from the right-hand contact to its left-hand contact.

In the idle condition of the repeating circuit of Fig. 2 with no signals being transmitted in either direction, a resistance 123 connected across the transmission circuit EA in the output of the amplifier A_1 through the armature and closed right-hand contact of relay HE provides a loss of, say, about 5 decibels, in that circuit, and the resistance 124 connected across the transmission circuit WA in the output of amplifier A_2, through the normally closed armature and left-hand contact of relay HW provides a loss of equivalent value in the latter circuit.

The breaking of the right-hand contact of relay HE in the manner previously described opens the circuit through resistance 123 normally connected across the circuit EA removing the 5 decibels from that circuit and allowing west's speech currents after amplification by amplifier A_1 to be transmitted with little attenuation out over the circuit EA towards the east subscriber. Because of the fast operation of the switching circuit 65, due to the fast operating relay circuit described, no delay circuit is required with circuit EA in front of the switching point.

When the armature of relay HE reaches its left-hand contact, the resistance 125 is connected across the circuit WA in the input of amplifier A_2, and the input of switching circuit 70 is short-circuited through the left-hand contact and armature of relay HE. The value of resistance 125 is made such that it introduces a desired loss sufficient to suppress echoes in the circuit WA, but because the resistance of the wiring and the left-hand contact of relay HE does not completely disable switching circuit 70 to prevent operation of that circuit by any voice frequency voltages that may be subsequently applied thereto from the path WA. A previous desensitization of switching circuit 70 occurs when direct current first flows in the anode-cathode circuit of detector tube 67 in switching circuit 65 in response to west's speech currents, since the biasing winding 84 of relay MW of switching circuit 70 is in series with the operating winding 85 of relay ME.

When the input level to switching circuit 65 falls below a certain value with cessation in the transmission of signals over the path EA, the energizing current applied to the operating winding 85 of relay ME will be reduced to the point where relay ME will release to return its armature to its left-hand contact. This restores the bias to relay HE by reconnecting battery 101 to the biasing winding 99, and balances the bridge circuit so that unbalance current through the operating winding 98 of that relay is reduced to zero. The operate current previously flowing through hold winding 100 of relay HE, series resistances 108 and 109, and the closed armature and right-hand contact of relay ME to ground is then diverted into condenser 110 and will continue to flow through the hold winding 100 of relay HE and resistance 103 to that condenser until the latter is charged up to the potential of battery 107, thus holding the relay HE operated for a definite hangover time interval after the relay ME has released. At the end of that time interval, relay HE will release connecting resistance 123 across the path EA so as to reinsert the normal loss therein, and simultaneously removing resistance 125 from in shunt of the circuit WA and removing the short circuit from the input of the switching circuit 70 so that the switching circuits are returned to the normal condition shown in Fig. 2.

As the apparatus in switching circuits 65 and 70 are identical, the manner of operation for the case when the east subscriber's speech current arrives at the input of switching circuit 70 over the circuit WA before speech currents are received by the switching circuit 65 over the transmission circuit EA from the west subscriber, will be similar to that previously described for the opposite case, and therefore need not be described here.

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. It should be understood that the specified values for the losses inserted in the transmission path are given by way of example only, and that they may be quite different from the values given depending on the characteristics of the signal transmission circuits with which the switching circuits are used.

What is claimed is:

1. A relay circuit comprising a relay having a biasing winding and an operating winding, a balanced bridge including said biasing winding in one of its arms, a source of current connected across one diagonal of said bridge and normally supplying current to said biasing winding in such direction as to bias said relay against operation, said operating winding being connected across the other diagonal of said bridge so as to be normally unenergized, and means to open said arm of said bridge including said biasing winding to interrupt the current supply to said biasing winding and to cause fast operation of said relay in response to the flow of the unbalance current of said bridge through said operating winding.

2. A relay circuit comprising a relay having a biasing winding, an operating winding and a holding winding, a balanced bridge including said biasing winding in one of its arms, a source of current connected across one diagonal of said bridge, supplying current to said biasing winding in such direction as to bias said relay against operation, said operating winding being connected across the other diagonal of said bridge, and means to open said arm of said bridge including said biasing winding to disconnect said source from said biasing winding, to cause fast operation of said relay by the resulting unbalance current of said bridge through said operating winding, and then to close an energizing circuit for said holding winding to hold said relay in the operated condition.

3. In a signal-operated switching circuit, a relay having an operating winding, a biasing winding, a balanced bridge including said biasing winding in one of its four arms, a source of current connected across one diagonal of said bridge supplying current to said biasing winding in such direction as to bias said relay against operation, said operating winding of said relay being connected across the other diagonal of said bridge, and means responsive to received signals to open said one arm of said bridge to disconnect said source of current from said biasing winding and to unbalance said bridge so that the flow of unbalance current through said operating winding causes quick operation of said relay.

4. A signal-operated switching circuit comprising a control relay having an armature and two contacts, a switching relay having a biasing winding, an operating winding and a holding winding, a plurality of resistances, said biasing winding and said resistances in the unoperated condition of said control relay forming a balanced bridge circuit through the closed armature and one contact of said control relay in one arm, a source of current connected across one diagonal of said bridge normally supplying current to said biasing winding in such direction as to bias said switching relay against operation, said operating winding being connected across the other diagonal of said bridge, and signal-controlled means for operating said control relay from said one to its other contact, the break of said one contact disconnecting said source of current from said biasing winding and unbalancing said bridge to supply operating current to said operating winding causing quick operation of said switching relay, and the make of said other contact of said control relay closing an energizing circuit for said holding winding to hold said switching relay operated.

JOSEPH O. SMETHURST.