Sept. 21, 1937. D. MITCHELL 2,093,525

ECHO SUPPRESSOR APPARATUS

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FIG. 1

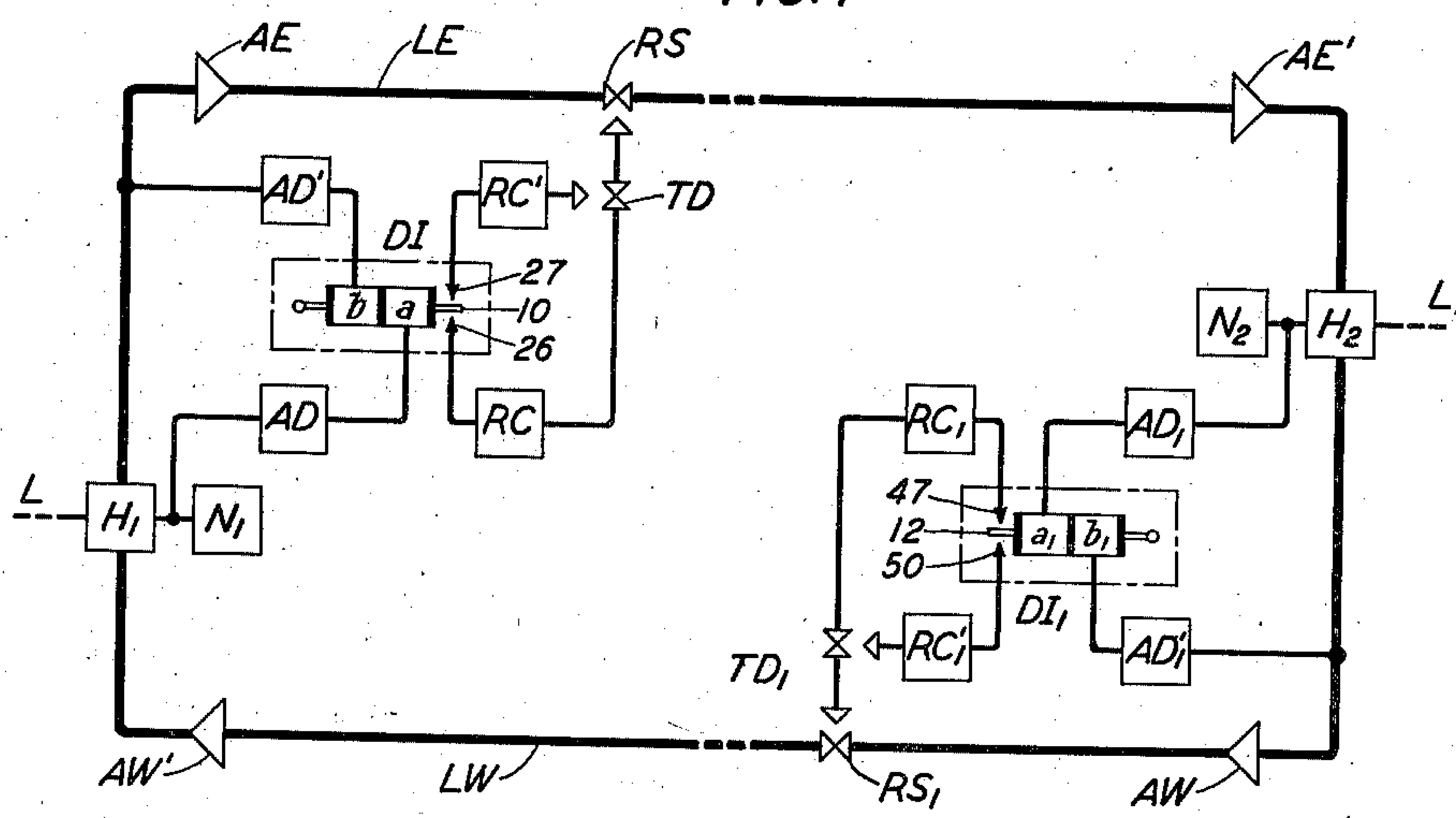

FIG. 2

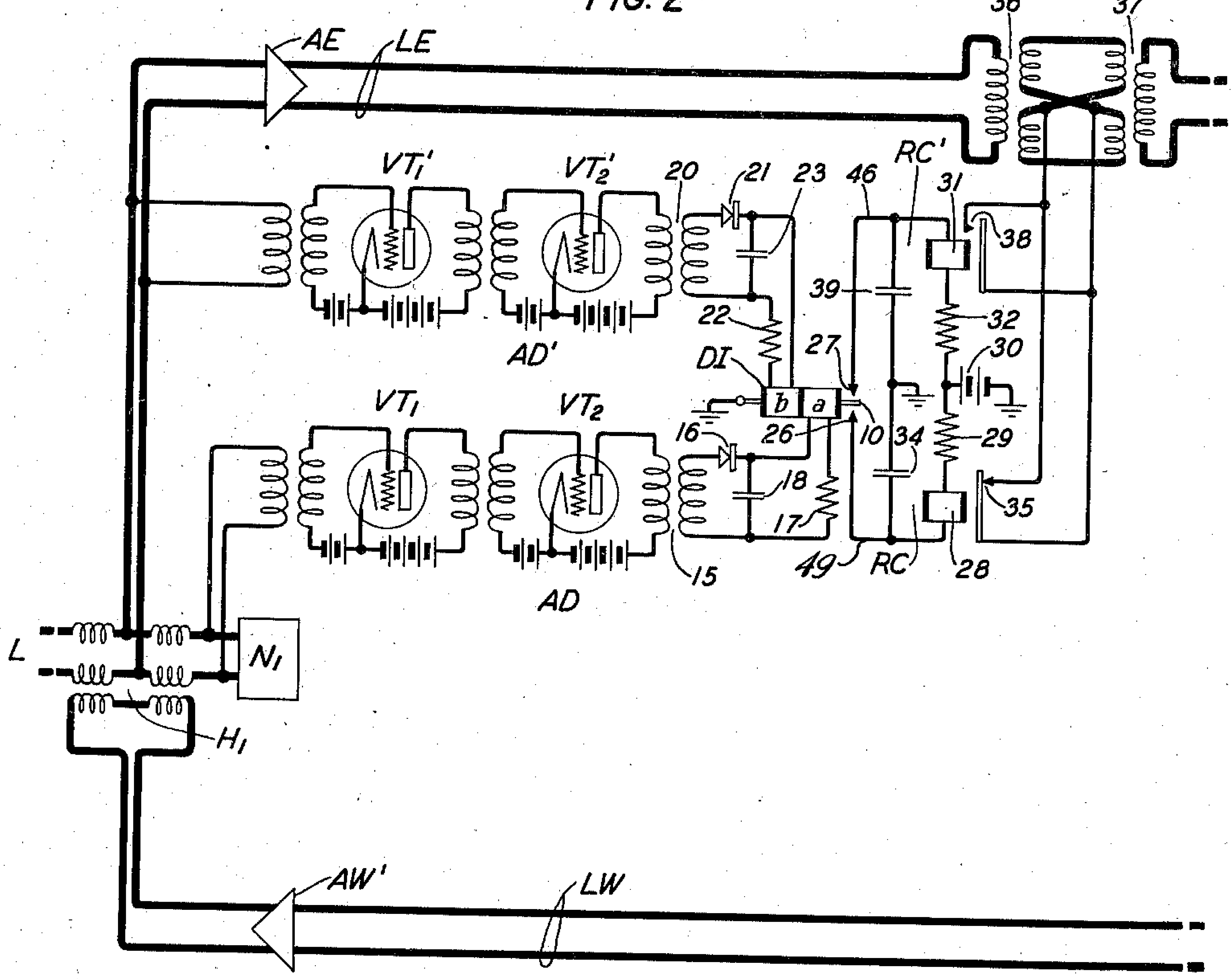

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FIG. 3

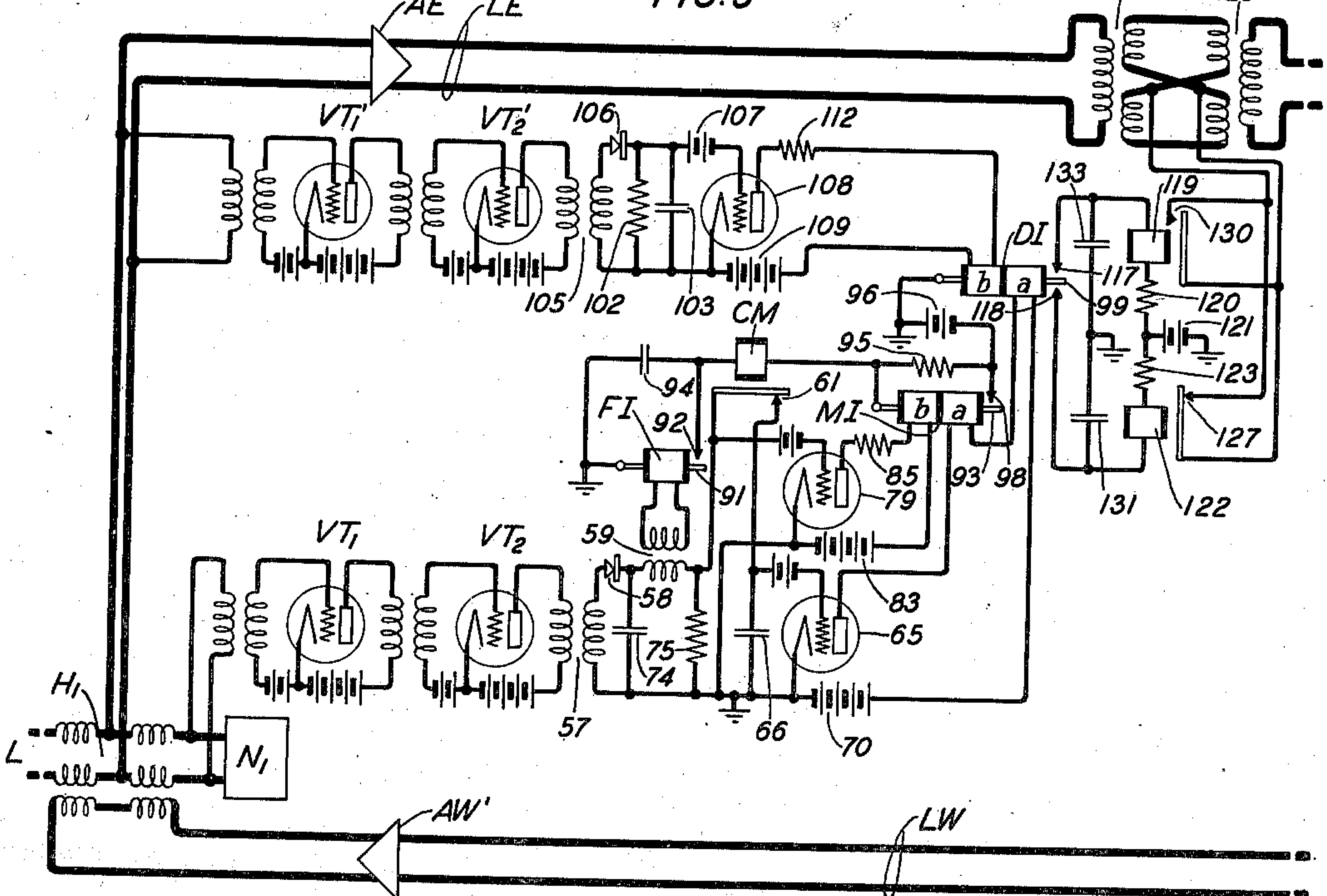
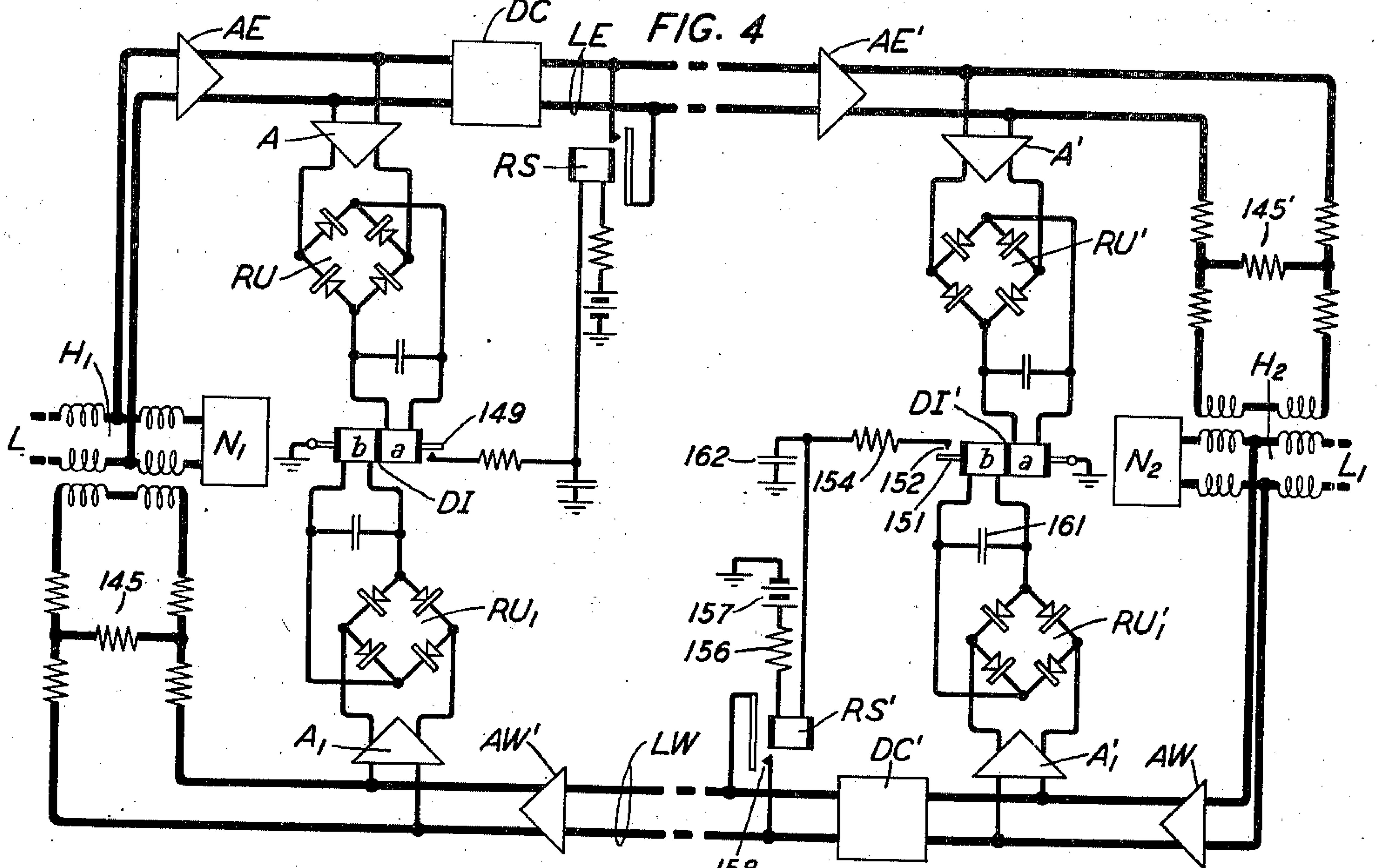


FIG. 4



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ECHO SUPPRESSOR APPARATUS

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10 Claims. (Cl. 178—44)

This invention relates to two-way signaling systems and particularly to the signal-controlled circuits employed for directionally controlling signal transmission in such systems.

An object of the invention is to improve the operation characteristics of long two-way signal transmission systems utilizing therein signal-operated apparatus for suppressing echoes.

In two-way telephone signaling systems in which two paths of a long four-wire circuit are adapted for transmission in opposite directions, it has been found necessary in the past to employ voice-operated switching apparatus for disabling one of the paths while transmission is being effected over the other in order to obtain the best transmission results. Such apparatus serves to prevent echoes of the transmitted voice signals being carried back to the transmitting end of the system and causing a disturbance. The disabling apparatus usually comprises an amplifier-rectifier control circuit connected to each of the two one-way paths of the four-wire circuit, so as to be operably responsive to the initiation of signal transmission therein to disable the other path, the associated control circuit, or both, in any suitable manner. In certain circuits of the prior art, the voice-operated switching apparatus, or echo suppressors as they are called, are located at the terminal ends of the four-wire circuit.

The invention is specifically directed to improvements in such terminal echo suppressors, the improvements consisting in the provision of means for facilitating break-ins by a listening party after the other party has obtained control of the system, and for minimizing transmission lock-outs, without introducing excessive echo difficulties. This is accomplished mainly by special circuit arrangements producing a suitable differential action between the two suppressor units associated with the incoming and outgoing one-way circuit at each terminal of the four-wire circuit.

A more complete understanding of the invention with its various objects and features will be had from the following detailed description when read in connection with the accompanying drawings in which:

Figure 1 is a diagrammatic representation of a four-wire telephone transmission circuit equipped with voice-operated switching apparatus embodying the invention; and

Figs. 2, 3, and 4 illustrate in more detail alternative modifications of the switching apparatus in accordance with the invention which may be used as each terminal of the four-wire circuit shown in Fig. 1.

The diagram of Fig. 1 is not an actual circuit diagram, but rather a single line layout, each line indicating a two-wire circuit. A normal make in a circuit is indicated by contacting arrowheads and a normal break in a circuit by separated arrowheads. An arrow directed at a make point indicates that the circuit will be disabled at that point by operation of the associated control device (amplifier-detector), and an arrow directed at a break point indicates that the circuit will be completed thereat by operation of the associated control device.

Fig. 1 shows connected between the two-way circuits L and L_1 a four-wire circuit comprising a two-wire path LE adapted for transmission from the circuit L to the circuit L_1 in the direction from west to east and a two-wire path LW arranged for transmission from circuit L_1 to circuit L in the direction from east to west. The paths LE and LW are provided with the usual one-way amplifiers AE and AE' and AW and AW', respectively. The hybrid coil transformer H_1 and associated network N_1 connects the input of the path LE and the output of the path LW in substantially conjugate relation with each other and in energy transmitting relation with the two-way circuit L in well known manner. Similarly, the hybrid coil transformer H_2 and associated balancing network N_2 connects the output of the path LE and the input of the path LW in substantially conjugate relation with each other and in energy transmitting relation with the two-way circuit L_1.

Associated with the west end of the four-wire circuit are the amplifier-detectors AD and AD', the inputs of which are respectively connected to the net side of the hybrid coil H_1 and to the input of the path LE, and the outputs of which are respectively connected to the winding *a* and *b* of a differential relay DI having its armature **10** adapted to be engaged with either contact point **26** or contact point **27** associated with relay controls RC and RC', respectively, depending on whether armature **10** is actuated upwardly or downwardly. The energization of the winding *a* tends to pull the armature of the relay DI downwardly and the energization of the winding *b* tends to pull the armature upwardly. When the armature **10** of the relay DI engages the down contact **26**, the relay control RC is operated to actuate switching control RS to disable the path LE, and when the armature **10** engages with the up contact **27**, the relay control RC' is operated to actuate the switching control TD to disable the relay control RC in its output. When the armature 10 separates from contact 26 the control RC releases and the switching control RS returns to its normal condition in which the path LE is operative, and when the armature 10 separates from contact 27 the control RC' releases and switching control TD returns to its normal condition in which switching control RC is operative to actuate RS when armature 10 engages contact 26.

Similarly at the east terminal of the four-wire are the amplifier-detectors AD_1 and AD'_1, the inputs of which are respectively connected to the net side of the hybrid coil H_2 and to the input of the path LW, and the outputs of which are connected to the windings a_1 and b_1, respectively of relay DI_1. The armature 12 of the relay DI_1 is adapted to be engaged with either contact point 47 or 50 associated with relay controls RC and RC', respectively, depending on whether the armature 12 is actuated upwardly or downwardly. The armature 12 is actuated upwardly or downwardly when the relay winding a_1 is energized and downwardly when the relay winding b_1 is energized. When the armature 12 engages the upper contact 47 of relay DI_1 the relay control RC_1 operates to actuate the switching control RS_1 to disable the path LW, and when the armature 12 engages the lower contact 50 the relay control RC'_1 is operated to actuate the switching control TD_1 to disable the relay control RC_1 in its output. When the armature of the relay DI separates from the contact 47 relay control RC_1 releases and the switching control RS_1 returns to its normal condition in which the path LW is operative. Also, when the armature 12 separates from the contact 50, relay control RC_1 releases and the switch control TD_1 returns to its normal condition, wherein the output of relay control RC_1 is operative to actuate switching control RS_1 as soon as the relay control RC_1 is operated.

Referring to Fig. 2 it will be seen that the amplifier portion of the amplifier-detector AD connected across the net side of the hybrid coil H_1 comprises two vacuum tube amplifiers VT_1 and VT_2 (VT_1 is a so-called "voltage" amplifier, while VT_2 is a "power" amplifier) and the detector portion thereof comprises the copper oxide rectifying or detecting unit 16 connected between the output transformer 15 of the amplifier and the winding a of the relay DI in series with the resistance 17. A condenser 18 is connected across the rectifier 16 and the secondary winding of transformer 20 in series so as to be charged from the output of the rectifier.

The amplifier-detector AD' connected across the input of the path LE similarly comprises a vacuum tube "voltage" amplifier VT'_1, a vacuum tube "power" amplifier VT'_2, a copper oxide rectifying unit 21 connected between the output transformer 20 of the amplifier and the winding b of relay DI in series with resistance 22. A condenser 23 is connected across the rectifier 21 and the secondary winding of transformer 20 in series so as to be charged from the output of the rectifier.

As in the system of Fig. 1, the armature 10 of differential relay DI is arranged to engage either the lower contact point 26 or the upper contact point 27 depending on whether the winding a or the winding b is energized. In the absence of received signal currents, when neither winding is energized, the armature is disengaged from either contact. The contact point 26 is connected by lead 49 through the winding of relay 28 and series resistance 29 to the positive terminal of battery 30; and contact point 27 is connected by lead 46 through the winding of relay 31 and series resistance 32 to the positive terminal of battery 30. A condenser 34 is connected across the circuit comprising the winding of relay 28, the resistance 29 and the battery 30 in series, and the condenser 39 is connected across the winding of relay 31, the resistance 32 and battery 30 in series.

The armature and contact 35 of relay 28 are normally closed to connect the two secondary windings of the transformer 36 and the two primary windings of transformer 37 of the transformer network in the path LE in series aiding relation so that signals are normally freely transmitted through the network, and are opened in response to energization of the relay 28 to connect those windings of the transformers 36 and 37 in opposing relation so that transmission of signals through the transformer network over the path LE is substantially blocked. The armature and contact 38 of the relay 31 are normally open, and are closed in response to energization of the relay to reconnect the windings of the transformers 36, 37 in series aiding condition so that signal transmission therethrough over the path LE with little attenuation is permitted.

The transformer network 36, 37 and the connections just described for changing it from the normal low loss condition to the high loss condition, or from the high loss condition to the low loss condition, are disclosed and described in H. C. Silent Patent No. 1,749,841, issued March 11, 1930, and, therefore, need not be described in more detail here.

Relays 28 and 31 and their associated circuits as described above comprise relay controls RC and RC', respectively, in the circuit of Fig. 1. The circuits controlled by relays 28 and 31 described above form the switching control RS and the switching control TD, respectively, in the circuit of Fig. 1. The condensers and resistances associated with the windings of the relay DI, and the windings of relays 28 and 31 provide the usual slow-release circuits therefor.

As will be apparent from the above description, when the armature of relay 28 engages the contact 35 or the armature of relay 31 engages contact 38, or when both contacts engage their respective armatures, the transformer network 36, 37 (corresponding to switching control RS in the system of Fig. 1) is conditioned to allow free transmission of signals therethrough over the path LE, and only when the contacts 35 and 38 are simultaneously disengaged from their associated relay armatures is the transformer network 36, 37 (or transmission control RS) conditioned to block signal transmission over the path LE.

Operation of circuit of Fig. 2

In the circuit of Fig. 2, energy impressed on the input of the circuit AD from the net side of hybrid coil H_1, will be amplified by the amplifiers VT_1 and VT_2 and rectified by the rectifier 16. The rectified currents will charge up condenser 18 to a value dependent on the input and from then on will cause energizing current to flow through the resistance 17 and the winding a of the relay DI, so that the relay tends to pull the relay armature 10 toward the lower contact point 26. Similarly, energy impressed on the input of the circuit AD' from the path LE, will be amplified by the amplifiers VT'_1 and VT'_2 and rectified by the rectifier **22**. The rectified currents will charge up condenser **23** to a value dependent on the input and from then on will cause energizing current to flow through the resistance **22** and the winding *b* of the relay DI, thus tending to cause the relay armature **10** to be pulled toward the upper contact point **17**.

When the pull on the armature **10** exerted by winding *a* prevails over that exerted by winding *b*, the armature closes through contact **26** an energizing circuit for the winding of relay **28** from the battery **30** through resistance **29** and condenser **34** normally charged from battery **30** will discharge. Relay **28** will then operate to separate its armature from contact **35** causing a large disabling loss to be inserted in path LE by transformer network **36**, **37** in the manner previously described. When winding *b* prevails over winding *a* the armature of relay DI closes through contact **27** an energizing circuit for the winding of relay **31** from battery **30** through resistance **32** and condenser **39** normally charged from battery **30** will be discharged. Relay **31** will then operate to close through contact **38** a current causing the transformer network **36**, **37** to be conditioned to remove the loss from the path LE, as previously described.

When the output of the rectifier **16** in the circuit AD or the output of rectifier **21** in AD' ceases, the associated winding *a* or *b* of the relay DI are maintained energized for the desired "hangover" time interval by the discharge of the condenser **18** or **23** through the winding. Also, when an energizing circuit for the winding of relay **28** or **31** is completed through contact point **26** or **27**, these relays will be maintained operated for a desired "hangover" time interval, while condenser **34** or condenser **39** is being charged up by current from battery **30** through resistance **29** or resistance **32** and the relay winding.

Operation of system of Fig. 1

The complete operation of the system of Fig. 1 employing at each terminal the echo suppressor circuits shown in Fig. 2 will now be described referring to Fig. 1.

Let it be assumed that voice currents for transmission in the direction from east to west are being received by the four-wire circuit from the two-way circuit L, and at that time no voice signals are being received by the four-wire circuit over the two-way circuit L_1.

The voice currents from the line L divide in the hybrid coil transformer H_1, the useful part passing out over the path LE and a portion thereof being impressed on the amplifier-detector AD' connected to its input. The received voice currents will have substantially no effect on the amplifier-detector AD connected to the net side of the hybrid coil H_1, because of the balance provided between the transmitting and receiving paths LE and LW by network N_1.

The received voice currents are amplified and detected in AD' and cause winding *b* of the relay DI to be energized. Relay DI operates to close its armature **10** and contact **27** causing the operation of relay control RC'. The latter actuates transmission control TD to disable the output of the relay control RC so that the transmission control RS in the path LE remains in its normal condition permitting transmission of voice signals out over the path LE.

The transmitted voice currents at the east terminal of the four-wire circuit are divided by the hybrid coil H_2, the main portion being transmitted into the line L_1 over which it is transmitted to a listening subscriber, and substantially all of the remaining portion passing into network N_2. The latter voice currents will be impressed on the amplifier-detector AD_1 causing energizing current to be supplied to the winding a_1 of relay DI. The relay DI_1 will then operate to close its armature and contact **47** causing the relay control RC_1 to operate to condition switching control RS, to block transmission over the path LW. The echoes of the west subscriber's voice currents returned from circuit L_1 will be impressed on the amplifier-detector AD'_1 connected to path LW causing energization of winding b_1 of relay DI_1 in its output. The relationship between the amplifier-detector AD_1 and associated circuit and the amplifier-detector AD'_1 and the associated circuit is made such by suitable design that the pull on the armature of relay DI_1 exerted by winding a_1 due to the voice signal impressed on AD_1 is always sufficiently greater than the pull exerted by the winding b_1 due to the echoes impressed on AD'_1 as to hold the relay armature on contact **47**. Thus, the transmission control RS_1 in path LW will remain in condition to block transmission of echoes over that path.

The relationship between the switching circuits associated, respectively, with the outgoing one-way path and the net side of the hybrid coil at each terminal may be expressed as follows:

$$S_N = S_L - (4L + R)$$

Where

S_N=Sensitivity of amplifier-detector bridged on the net side of hybrid coil

S_L=Sensitivity of amplifier-detector bridged on the outgoing one-way path of the four-wire circuit

R=Lowest return loss of the associated two-way circuit

L=Loss of the hybrid coil

Thus, the portion of the west subscriber's voice energy which affects the amplifier-detector AD'_1 after arriving at the hybrid coil H_2, is attenuated by the loss across the hybrid coil plus the return loss of the two-way line L_1 while that portion which affects amplifier-detector AD_1 is attenuated by only the loss from the four-wire to the two-wire side of the hybrid coil H_2. As long as the proper sensitivity relationship between amplifier-detectors AD_1 and AD'_1 is maintained, the influence exerted on amplifier-detector AD_1 due to incoming energy over path LE will always be more effective than that exerted on amplifier-detector AD'_1 solely by echo energy from L_1. Therefore, relay DI_1 will always operate upwardly as a result of the energization of its winding a_1 when the party connected to L_1 is silent.

Now, let it be assumed that the east subscriber connected to line L_1 commences to talk while the west subscriber is talking. The former's voice currents will be divided at hybrid coil H_2, the useful portion of the voice energy entering path LW and being impressed on amplifier-detector AD'_1, and practically none being impressed on AD_1 because of the balance provided by network N_2. This causes an increase in the current flowing through winding b_1 of relay DI_1 which is large enough to cause winding b_1 to prevail over winding a_1, and to shift armature **12** from contact point 47 to contact point 50. Relay control RC'_1 then operates causing control TD to disable relay control RC_1 in its output, thereby returning control RS_1 to its normal condition so as to allow the voice energy of the east subscriber as well as the echoes of the voice energy of the west subscriber to be transmitted over line LW. Accordingly, the voice energy of the east subscriber will eventually reach the west subscriber associated with line L and thus will inform the latter that the east subscriber wants to break in.

It will be noted that the echo suppressor arrangement described above distinguishes from prior art terminal echo suppressors in two important respects; namely, first, the listening subscriber is not required to await a pause in the transmission of the voice energy of the talking subscriber before "breaking in", the circuit conditions requiring only that the wave energy of the former be effectively stronger at the terminal of the four-wire circuit at the listener's end than that of the latter; second, that except in the presence of actual double talking neither party will hear an echo unless the speech is so weak that it fails to operate the proper amplifier-detector. Since echoes can be heard only during actual double talking, the former will be largely masked by the direct speech. In the present circuit arrangement, it is not possible for incoming speech to operate any control other than RS or RS', as the case may be.

Referring to Figs. 1 and 2, let it be assumed that the east subscriber has been talking, and pauses momentarily or stops talking. The relay DI will not immediately release to break the connection between its armature and contact 26, for a current is caused to flow for a brief interval through resistance 17 and winding *a* of relay DI due to the release of the charge that was stored in condenser 18 when current was initially passed through winding *a*. By a proper proportioning of the elements of the discharge circuit current of suitable value may be maintained in coil *a* for a sufficient "hangover" interval of time so that delayed echoes of the east subscriber's speech returning from the two-way line L and causing the energization of winding *b* of the relay cannot cause false operation of that relay to operate relay 31.

Also, in the arrangement shown in Fig. 2, it is apparent that as soon as incoming transmission over path LW ceases, condenser 18 commences to discharge through coil *a* of relay DI, and, thus, the sensitivity of amplifier-detector AD' must be made low enough so that voice energy returning as echoes from line L and impressed on AD' so as to cause energizing current to be supplied to winding coil *b* of relay DI will not be sufficient to enable winding *b* to prevail over winding coil *a* as a result of partial discharge of condenser 18 in AD. Obviously, if the correct value of current could be maintained in winding *a* of relay DI for a time interval equal to the delay of the circuit connected to the two-way line L and, then, is terminated rather abruptly, the above arrangements would be somewhat improved, otherwise a considerably larger charge must be initially built up in condenser 18 so that there will be sufficient charge remaining when the delayed echoes return. In the former case, the sensitivity of amplifier-detector AD' would then be limited only by the loss in the echo path as previously described. Furthermore, there would be no biasing action, occasioned by the trailing out of the discharge of condenser 18, against the operation of relay DI by winding *b* except during the period when the biasing action was actually essential.

Fig. 3 illustrates a modification of the arrangement disclosed in Fig. 2. As in the case of Fig. 2, the apparatus of Fig. 3 would be employed both at the west and east ends of the four-wire transmission circuit represented in Fig. 1. Identical parts appearing in Figs. 1 and 3 are designated by the same reference numeral.

Connected across the circuit intermediate the hybrid coil H and network N_1 is the input of an amplifier comprising the tandem amplifier tubes V_1 and V_2. In the output of the latter is a transformer 57 having one side of its secondary winding connected through a copper-oxide rectifying or detecting unit 58 and primary winding of coil 59 to the grid of the vacuum tube 79, and through rectifier 58, primary winding of coil 59 and normally closed contact 61 of charge maintainer relay CM to the grid of tube 65. A condenser 66 is connected across the grid-filament circuit of tube 65. The other side of the secondary winding of transformer 57 is connected to the filaments of tubes 65 and 79. The plate circuit of tube 65 includes in series battery 70, winding *a* of relay DI and winding *a* of magnitude indicator relay MI. Condenser 74 is connected across the secondary winding of transformer 57 and the rectifying unit 58 in series. Also, a resistance 75 is connected across the secondary winding of transformer 75, rectifier 59 and the primary winding of coil 59 in series.

The plate circuit of tube 79 includes in series plate battery 83, winding *b* of relay MI and resistance 85. The secondary winding of coil 59 is connected to the winding of fall indicator relay FI which is arranged to operate only on a decrease in the current from the rectifying unit 58, and to remain inoperative on an increase of current from the same source. The armature 91 of relay FI is connected to ground and through condenser 94 to the normally open contact point 92 of the relay FI. The contact point 92 is connected through the winding of relay CM to the armature 93 of relay MI, and also through resistance 95 to the normally open contact 98 of relay MI and to the grounded battery 96.

Connected across the input of the path LE is the input of the control circuit including amplifiers VT'_1 and VT'_2. In the output of the latter is a transformer 105 having one side of its secondary winding connected through a copper-oxide rectifying or detecting unit 106 and grid battery 107 to the grid of tube 108, and the other side connected to the filament of tube 108. The plate circuit of tube 108 includes in series plate battery 109, winding *b* of relay DI and resistance 112. A circuit comprising the resistance 102 and parallel condenser 103 is connected across the secondary winding of transformer 105 and the rectifying unit 106 in series.

The grounded armature 99 of relay DI is arranged to engage either contact point 117 or contact point 118, depending on whether the winding *b* or *a* is energized. Contact point 117 is connected through the winding of relay 119 and series resistance 120 to grounded battery 121; and contact point 118 is connected through the winding of relay 122 and series resistance 123 to the grounded battery 121. Contact 127 of relay 122 is normally closed to connect the two secondary windings of transformer 128 and the two primary windings of transformer 129 to enable a transmission of voice energy therethrough over the path LE, and when opened by operation of relay 122 connects these same windings in opposing relation so that the transformer network prevents transmission over the path LE. Contact 130 of relay 119 is normally open and is closed by operation of relay 119 in parallel with contact 127 and the armature of relay 122, to prevent relay 122 from disabling the path LE. Condenser 131 is connected across the circuit comprising the winding of relay 122, resistance 123 and battery 121 in series. Condenser 133 is connected across the circuit comprising the winding of relay 119, resistance 120 and battery 121 in series. The resistances and condensers associated respectively with relays 119 and 122 provide the usual slow-release circuits therefor.

Operation of circuit of Fig. 3

Voice currents originating with the east talking subscriber connected to two-wire line L_1, as described with respect to Figs. 1 and 2, and incoming over line LW are divided in hybrid coil H_1 in the usual way, that is, part of the energy continues on to the subscriber connected to two-wire line L, and another part passes into network N_1. In the latter case, the voice energy is amplified by amplifiers VT_1 and VT_2, and is rectified by rectifying unit 58. The rectified current immediately charges condensers 74 and 66, and at the same time, provides an equal voltage across resistance 75. As long as the input to rectifier 58 continues to increase, the charge on condenser 66 will continue to increase to place a more positive charge on the grids of tubes 65 and 79, thereby effecting corresponding increases in their plate current. The winding *a* of relay DI in the plate circuit of tube 65 is made equal in resistance value to resistance 85 in the plate circuit of tube 79. The tubes 65 and 79 are of a similar type, and, are provided with identical grid batteries and plate batteries 70 and 85. As long as the voltages on the grids of tubes 65 and 79 are equal, relay MI will be unable to operate in either direction. However, as soon as the energy flowing through winding *a* of relay DI is sufficient to effect its operation, relay DI will operate to close armature 99 and contact point 118, thus completing an energization circuit for relay 122 which may be traced from ground through armature 99 and contact point 118 associated with operated relay DI, winding of relay 122, resistance 123 and battery 121 to ground. Relay 122 operates to open contact 127 to break the bridge connection on transformer network 128, 129, so that it blocks transmission over the path LE.

Voice currents returned as echoes from the two-wire line L enter the path LE and are impressed on the associated control circuit. The impressed echoes are amplified by amplifiers VT'_1 and VT'_2 and are then rectified by rectifying unit 106. The rectifier output charges condenser 103 and, thereafter, makes the grid of tube 108 more positive causing plate current to flow through winding *b* of relay DI, tending to operate the latter. The relative sensitivities of amplifiers VT_1—VT_2 and VT'_1—VT'_2 are made such that the amount of current flowing through the *a* winding of relay DI due to incoming speech waves is always larger than that flowing through the *b* winding of the relay due to echoes of that speech only. Under these conditions the armature of the relay DI will always be operated to contact 118 and the transformer network 128, 129 will be conditioned, as previously described, to its high loss condition so as to suppress echoes in the path LE.

As soon as the voice energy incoming over the path LW commences to decrease relay FI operates to close its armature 91 and contact point 92, thereby effecting a discharge of condenser 94 to ground, and, in addition, completing an energization for relay CM from battery 96. This circuit may be traced from ground through armature 91 and contact point 92 of operated relay FI, winding of relay CM, resistance 95, battery 96 to ground. Relay CM then operates to open contact 61 to disconnect condenser 66 from resistance 75. As a result of this the condenser 66 holds its charge and, therefore, maintains the value of current then existing in winding *a* of relay DI and winding *a* of relay MI at the instant immediately prior to the operation of relay CM. If no additional voice currents reach amplifier VT_1 within a given interval of time, relay CM will eventually release due to the fact that condenser 94 will be charged up through resistance 95 and the winding of relay CM from battery 96. The release of relay CM closes contact 61 causing condenser 66 to be rapidly discharged through resistance 75 with the result that the value of current in winding *a* of relay DI will quickly fall to zero breaking contact 118. A short time later after condenser 131 has been completely charged by battery 121, through resistance 123 and the winding of relay 122, the current in relay 122 falls to zero and that relay will release thereby returning the relay contact 127 to the normally closed condition in which the transformer network 128, 129 is in the low loss condition, so that the path LE is in transmitting condition.

However, if voice currents incoming from line LW and being of a value larger than the maximum received heretofore are impressed on amplifier VT_1 before relay CM releases, they will eventually effect a voltage across resistance 75 which will cause the plate current of tube 79 to reach a larger value than the plate current of tube 65, thereby producing a larger current in winding *b* of relay MI than that in its companion winding *a*. Relay MI then operates to its contact 93 short-circuiting resistance 95 and causing condenser 94 to charge up quickly from battery 96, through contact 98 and armature 93 of operated relay MI, and the winding of relay CM. When condenser 94 is charged, current ceases to flow through relay CM so that it releases to close contact 61, thereby enabling condenser 66 to charge up to the proper value in accordance with the larger amount of voice currents being impressed on amplifier VT_1. Thereafter, the echo suppressor apparatus will function as previously described.

While the subscriber associated with the east terminal is talking and the suppressor circuits at the west terminal are conditioned in the manner which has just been described, the west subscriber can "break in" instantly by talking. His voice currents will be impressed on the control circuit connected to the path LE and after being amplified by the amplifiers VT'_1 and VT'_2 and rectified by the rectifier 106 therein will produce sufficient flow of plate current in the output of tube 108 and through the *b* winding of relay DI as to make that winding prevail over the *a* winding. The armature of relay DI will then close through contact 117 an energizing circuit for the winding of relay 119 from battery 121 through resistance 120 and the latter relay will operate to close contact 130. This will, in the manner which has been previously described, connect the windings of the transformer network 128, 127 so that transmission through that network over the path LE may take place.

Fig. 4 illustrates a modified terminal echo suppressor arrangement in which either subscriber can remove the echo suppressor and "break in" on the other subscriber even when the latter has not ceased talking for a time interval of sufficient duration to allow a release of his echo suppressor apparatus. In Fig. 4, between two-wire line L and two-wire line L_1, there is a four-wire circuit having a path LE adapted for transmission from line L to line L_1, and a path LW adapted for transmission from line L_1 to line L. Transmission paths LE and LW are provided with conventional one-way amplifiers AE and AE', and AW and AW', respectively. At the west terminal of the four-wire circuit, a hybrid coil H_1 connects the two-way line L to the paths LE and LW, and a network N balances the line L. Likewise, at the right terminal of the four-wire circuit, a hybrid coil H_2 connects two-way line L_1 to the paths LE and LW, and a network N_2 balances line L_1. The broken portions of paths LE and LW represent long intermediate sections of the four-wire system which may be of any desired length.

The echo suppressor arrangement associated with the west terminal of the four-wire circuit includes amplifier A and full wave copper-oxide rectifying unit RU connected to the outgoing path LE, and an amplifier A_1 and full wave copper-oxide rectifying unit RU_1 connected to the incoming path WE, the former being responsive to outgoing waves in the path LE to supply energizing current to the winding *a* of the differential relay DI, and the latter being responsive to incoming waves in the path LW to supply energizing current to the winding *b* of the same relay. The relay DI controls the operation of the suppressor relay RS which, in turn, controls the loss condition in the path LE in the manner which will be described later in connection with the description of operation of the whole system. A similar echo suppressor arrangement is located at the east terminal of the four-wire circuit for controlling the loss condition of the outgoing path LW thereat. The elements in the latter arrangement bear the same reference characters as the corresponding elements in the echo suppressor arrangement at the west terminal, but followed by a prime (') mark.

Operation of system of Fig. 4

The operation of the system of Fig. 4 is as follows:

Let it be assumed that the west subscriber associated with the two-way line L starts to talk and the east subscriber associated with the east two-way line L_1 is silent. West's voice currents will be divided in the hybrid coil H_1, the useful portion entering the input of path LE and the other portion entering the output of path LW and eventually being dissipated in the output of the amplifier AW' therein. The voice waves in the path LE will be amplified by the amplifier AE and the main portion thereof will be transmitted out over the path LE towards the east terminal.

A small portion of west's waves will be diverted into the control circuit connected near the west terminal, and will be amplified by the amplifier A and rectified by the rectifier RU therein. The rectified currents will energize winding *a* of the differential relay causing its operation to pull its armature 149 upwards. Meanwhile, the portion of west's voice waves entering the output of path LW will be impressed on the associated control circuit, will be amplified by amplifier A_1 and rectified by rectifier RU_1 therein and supplied as energizing current to the winding *b* of relay DI and tend to cause armature 149 to be pulled in the downward direction. Because of the loss encountered in the hybrid coil H_1 and in loss pad 145 in the output of LW the latter energizing current will be so weak as not to have much effect on the operation of the relay DI.

With the armature of relay DI pulled upward, the energizing circuit of the relay RS is broken so that that relay will remain in its normal unoperated condition wherein the loss condition in the path LE is low. The path LE is then operative to transmit freely west's voice currents.

Eventually west's voice currents reach the east end of the four-wire circuit, the main portion passing through the loss pad 145' and being impressed by the hybrid coil H_2 on the two-way line L_1 and being transmitted out over that line to the east subscriber. A portion of the received (west's) voice waves are diverted from the output of LE into the associated control circuit wherein they are amplified by amplifier A', are rectified by rectifier RU' and supplied as energizing current to the *a* winding of the differential relay DI'.

The condenser connected across each winding of the differential relay DI', and those connected across each winding of the relay DI at the west terminal also are provided to by-pass the alternating current components of the rectified waves.

Relay DI' then operates to pull its armature 151 upward making contact with contact point 152 and completing an energization current for the relay RS' from battery 157. This circuit may be traced from ground through armature 151 and contact point 152 of operated relay DI', series resistance 154, winding of relay RS', resistance 156 and battery 157 to ground. Relay RS' then operates to close contact 158, thereby short-circuiting path LW and blocking transmission thereover.

A portion of the voice current passing into the two-wire line L_1 will be returned as echo to the path LW and will be impressed on the control circuit connected to its input. These waves will be amplified by amplifier A'_2, rectified by rectifying unit RU'_1 and applied as energizing current to winding *b* of relay DI'. The energized winding *b* will tend to operate the armature 151 of relay DI' in a downward direction and opposite to that effected by energized winding *a*. However, the sensitivity of receiving amplifier A' and rectifying unit RU' is made sufficiently greater for the received voice currents than that of transmitting amplifier A'_1 and rectifying unit RU'_1 for echo energy returning from line L_1 so that the relay DI' will be maintained actuated upwardly to contact 152. For this reason, therefore, it is readily apparent that false operation of relay DI' by echoes of west's incoming speech transmitted through the coil is entirely prevented In case delayed echo arrives after the direct incoming speech impulse has ceased, it may operate the armature 151 of DI' relay in the down direction momentarily but due to the slow release circuit associated with relay RS' as described below, this echo will still be suppressed.

When relay DI' operates due to the energization of its winding *a*, condenser 162 normally charged by battery 157 discharges through resistance 154, contact point 152 and armature 151 of operated relay DI' to ground, the condenser 162 and resistance 154 forming a slow release circuit for relay RS'. Accordingly, relay RS' remains operated for a short "hangover" interval after relay DI' may have released, thereby blocking any echoes due to trailing weak parts of speech and delayed echoes from the line L_1. As indicated a delay circuit DC' may be inserted in the path LW in front of the disabling point to store initial echo waves until relay RS' has had sufficient time to operate. A delay circuit DC may be inserted in the path LE at the other terminal for this purpose for speech transmission in the opposite direction.

Let it now be assumed that the east subscriber connected to the two-wire line L_1 wishes to "break in" while the west subscriber connected to two-wire line L is talking. The former may commence to talk while the latter's speech currents are still being received, it being unnecessary for him to await a pause in the speech incoming over line LE. It is only required that east's speech wave at the output of the amplifier A'_1 bridging the transmitting path LW be effectively stronger than west's at the output of amplifier A' bridging the receiving path LE. This may be accomplished since the transmitting bridging amplifier A'_1 and rectifying unit RU'_1 may be made considerably more sensitive than receiving bridging amplifier A' and rectifying unit RU' without causing false operation of relay DI' due to echo.

When east's voice currents have caused operation of relay DI' in the down direction due to energization of its winding *b*, relay RS' previously operated by A's speech will subsequently release after a brief interval. After the energization circuit for relay RS' is broken at contact 152, the relay RS' is held operated for this brief "hangover" interval until condenser 162 is completely charged by battery 157 through the winding of relay RS' and resistance 156, and it then releases.

A portion of east's voice currents arriving at the west terminal will be picked up by receiving bridging amplifier A_1 and another portion will pass through hybrid coil H out over line L to the west subscriber. Accordingly, the west subscriber will hear the east subscriber. The relative sensitivities of the two circuits controlling the DI relay at the west terminal is such that east's speech through amplifier A_1 and rectifier RU_1 will not be able to operate the DI relay unless west has stopped talking or is talking considerably weaker than west, so that the energizing current in the winding *b* of relay DI is sufficiently greater than that in winding *a*. Of course, echo will occur during the period of double talking. As soon as A ceases talking the echo suppressors will operate in the manner previously described to suppress the echo.

The sensitivities of the receiving bridging amplifier A' and rectifying unit RU' at the east end of the four-wire circuit and that of the receiving bridging amplifier A_1 and rectifying unit RU_1 at the west end of the four-wire circuit are limited by incoming noises in the usual manner, that is, each of these control circuits must be adjusted so that it will not operate on noise since such a happening would result even under normal conditions in considerable mutilation of the outgoing talker's voice waves. The sensitivities of the transmitting bridging amplifier A and rectifying unit RU at the west terminal and of the transmitting amplifier A'_1 and rectifying unit RU'_1 at the east terminal may be made greater than those of the associated receiving control circuit up to a point where they just prevent an operation of the relay DI or DI' skipped lines in the transmitting direction, the sensitivity will be proportionately lowered. Obviously, the subscriber at the opposite end of the four-wire circuit will then fail to operate the disabling relay RS or RS' unless his speech wave create a stronger pull on relay DI or DI' than the noise. As previously explained, echo from incoming speech never causes as strong a pull on the transmitting side of the DI or DI' relay as the incoming speech waves do on the receiving side. Therefore, it follows that echoes of incoming speech waves which failed to overcome the effect of noise will usually be weaker than the noise. Further, experiments have shown that echoes which are equal to or less than the noise currents are not very objectionable.

It is to be understood that the invention is not limited to the precise details of the circuits illustrated and described for it is apparent that numerous modifications thereof could be made for those skilled in the art within the spirit and scope of the invention.

What is claimed is:

1. In combination in a two-way signal wave transmission system, a four-wire circuit for repeating signals in opposite directions, and means for directionally controlling transmission in said circuit comprising near each terminal of said circuit means for effectively balancing the transmission in the outgoing side against that in the incoming side of said circuit, said balancing means being responsive to a higher transmission level in said incoming side than in said outgoing side to cause said outgoing side to be disabled, and responsive to a higher transmission level in said outgoing side than in said incoming side to prevent said outgoing side from being disabled, and auxiliary means for preventing said balancing means from being falsely operated by signal echoes during pauses in signal transmission.

2. The system of claim 1, in which said balancing means comprises a differential relay operative in one direction in response to wave energy from said outgoing side and in the opposite direction in response to wave energy in said incoming side of said circuit, and said auxiliary means comprises means for making said relay slow-releasing after operation in either direction.

3. In a two-way signaling system, two two-way lines, a four-wire circuit comprising oppositely-directed one-way paths connecting the two-way lines, and an echo suppressor unit associated with the paths near each terminal of the four-wire circuit comprising differential means which when operated in one direction disables the transmitting path and when operated in the opposite direction prevents the transmitting path from being disabled, and control circuits connecting the differential means to the transmitting and receiving paths for effecting operation of the differential means, the sensitivities of the control circuits being relatively adjusted so that the differential means will always be operated in said opposite direction in response to signals outgoing in the transmitting path irrespective of a simultaneous presence of signals incoming in the receiving path, and means associated with said control circuits for making said differential means slow releasing after operation in either direction.

4. In a signaling system, two two-way lines, a four-wire circuit comprising one-way paths for

transmitting signals in opposite directions between the two-way lines, and an echo suppressor unit associated with the paths near each terminal of the four-wire circuit comprising electromagnetic means for disabling the transmitting path, a second electromagnetic means for preventing a disabling of the transmitting path, differential means which when operated in one direction effects an operation of the first-mentioned electromagnetic means and when operated in an opposite direction effects an operation of said second electromagnetic means, and control circuits respectively connected to the transmitting and receiving paths, for effecting operation of the differential means, the sensitivities of the control circuits being relatively adjusted so that the differential means will be operated in said opposite direction when signals are outgoing in the transmitting path regardless of a simultaneous existence of signals incoming in the receiving path.

5. In a two-way signaling system, two two-way lines, a four-wire circuit comprising oppositely-directed one-way paths connecting the two-way lines, and an echo suppressor unit associated with the paths relatively near each end of the four-wire circuit, comprising differential means which when operated in one direction disables the transmitting path and when operated in the opposite direction prevents the transmitting path from being disabled, control circuits connecting said differential means to the transmitting and receiving paths in a manner tending to operate the differential means in one direction in response to signals incoming in the receiving path and in the opposite direction in response to signals outgoing in the transmitting path, the sensitivities of the control circuits being relatively adjusted so that the differential means will be operated in said opposite direction by outgoing signals received in the transmitting path from its associated two-way line whether or not incoming signals are simultaneously present in the receiving path, and auxiliary means for preventing false operation of the differential means by signal echoes during pauses in signal transmission between the two-way lines.

6. The system of claim 5, in which said differential means comprises a differential relay and said auxiliary means comprises means making said relay slow releasing to the required degree.

7. The system of claim 5, in which said differential means comprises a relay having two opposing windings, said control circuits comprise two amplifier-rectifiers, respectively, connected to the transmitting and receiving paths and controlling the energization of a different one of said windings, and said auxiliary means comprises a capacity-resistance arrangement associated with each winding for making said relay slow releasing to the required degree for each direction of operation.

8. The system of claim 5, in which said auxiliary means includes a condenser which is charged up when said differential means is operated and while charged maintains said differential means operated, and means for causing said relay to suddenly discharge a desired time interval after cessation in the supply of controlling signal energy to said differential means.

9. In a two-way signaling system, two two-way lines, a four-wire circuit comprising oppositely-directed one-way paths connecting the two-way lines, and an echo suppressor unit associated with the transmitting and receiving paths near each end of the four-wire circuit, comprising electromagnetic means for disabling the transmitting path, a second electromagnetic means for preventing a disabling of the transmitting path, a mechanical relay having two opposing windings whereby an energization of one winding effects an operation of the first electromagnetic means and an energization of the second winding effects an operation of the second electromagnetic means, amplifier-rectifier units having their outputs connected to a different one of the windings and their inputs respectively connected to the transmitting and receiving path so that said one winding is energized in response to signals incoming in the receiving path tending to operate said first electromagnetic means and said second winding is energized in response to signals outgoing in the transmitting path tending to operate said second electromagnetic means, the sensitivities of the amplifier-detector units being relatively adjusted so that the relay will effect an operation of said second electromagnetic means when outgoing signals are present in the transmitting path irrespective of the simultaneous existence of signals incoming in the receiving path, and a capacity-resistance means connected between the outputs of said amplifier-rectifier units and the windings of the relay for rendering the relay slow releasing after its operation to prevent false operation thereof by signal echoes during pauses in signal transmission between said two-way lines.

10. In a two-way signaling system, a four-wire circuit comprising one-way paths for transmitting signals in opposite directions between two two-way lines, and an echo suppressor unit near each terminal of the circuit, comprising differential means which when operated in one direction disables the outgoing path thereat and when operated in the opposite direction prevents said outgoing path from being disabled, control circuits respectively connected to the outgoing and incoming paths at the terminal and controlling the operation of said differential means, the sensitivities of the two control circuits being relatively adjusted so that said differential means will always be operated in said opposite direction when outgoing signals are present in the outgoing path, and means for preventing false operation of said differential means by signal echoes during pauses in signal transmission comprising a condenser which is charged up in response to incoming signals and when the differential means is operated in said one direction maintains it so operated, and a mechanical relay responsive to cessation in the incoming signals to maintain said condenser charged for a suitable interval of time thereafter and then to cause said condenser to discharge suddenly.

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