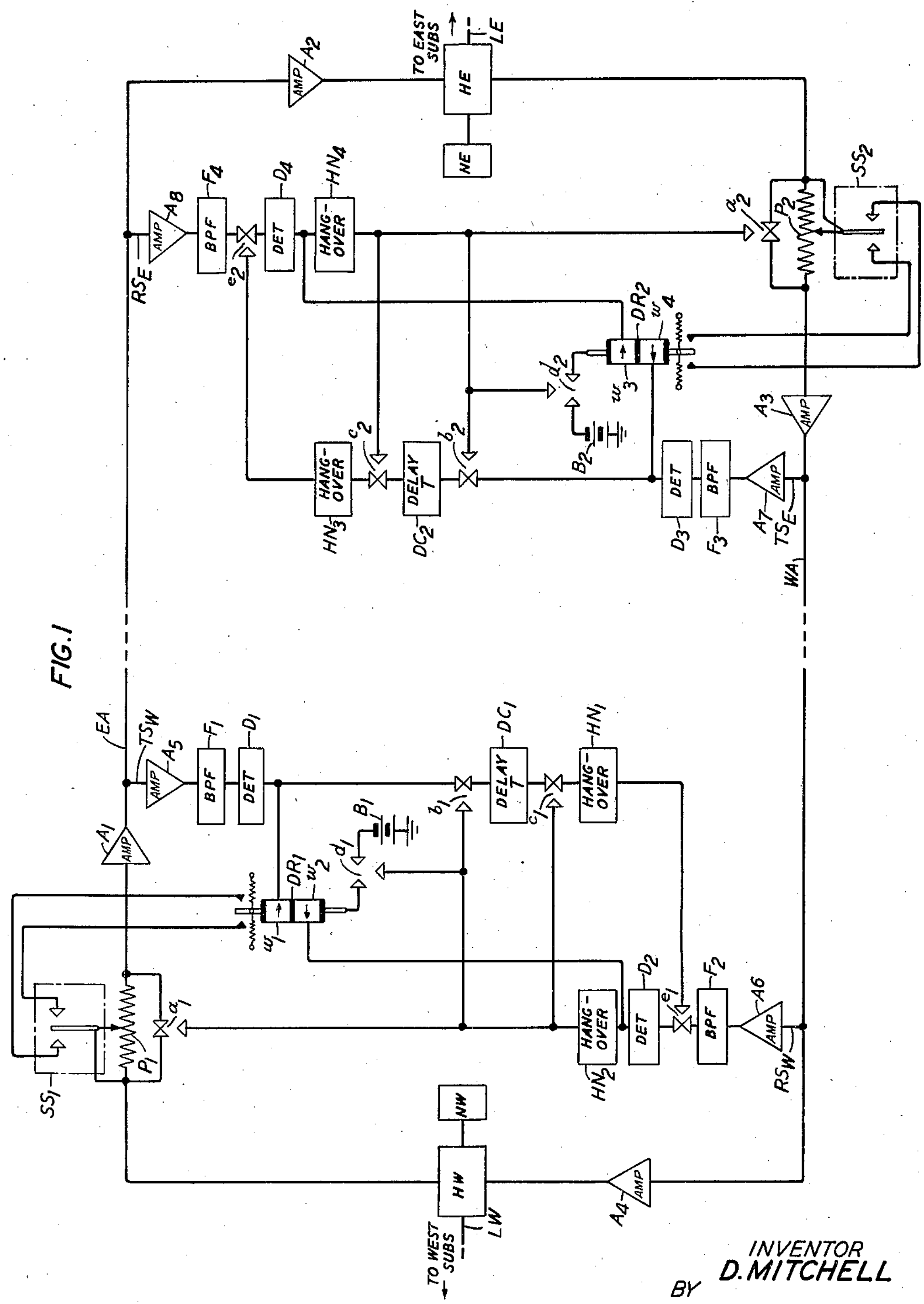
Oct. 7, 1941. D. MITCHELL 2,257,806

ECHO SUPPRESSING CIRCUIT

Filed Nov. 22, 1940 2 Sheets-Sheet 1

FIG. 1



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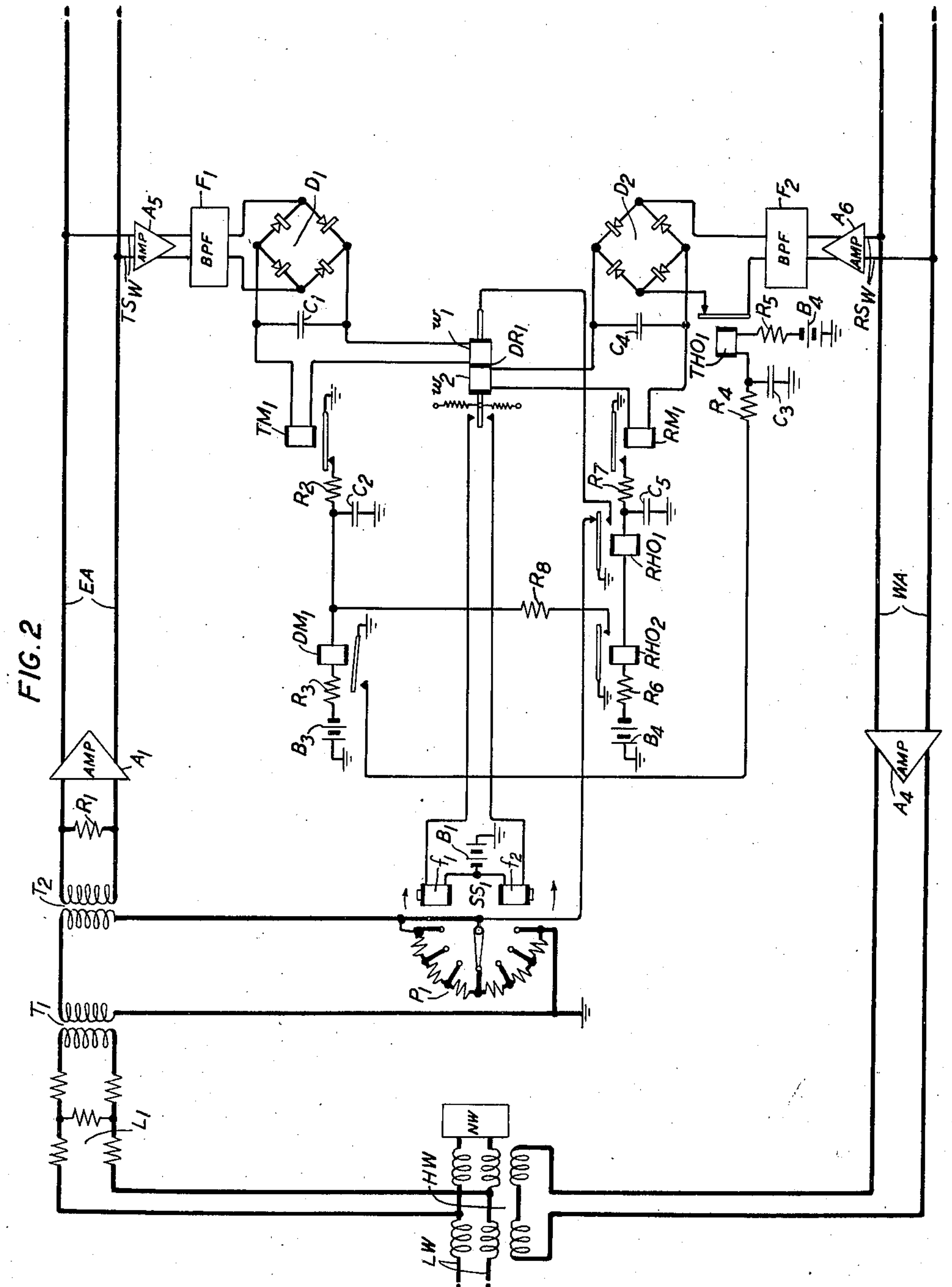

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ECHO SUPPRESSING CIRCUIT

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11 Claims. (Cl. 178—44)

The invention relates to two-way telephone systems and particularly to the switching circuits employed in such systems for suppressing echoes and preventing singing.

The type of echo suppressor most commonly employed in commercial two-way telephone systems operates in response to signal transmission in a transmission path for one direction to insert a loss in the transmission path for the opposite direction, which is of fixed value and sufficiently large to reduce echoes in the latter path to an unobjectionable amount for the worst echo condition which might exist regardless of whether the echo is strong or weak. In another type of echo suppressor the value of the loss inserted in the echo path by its operation is proportional to the magnitude of the talker's voice waves controlling the echo suppressor. The amount of echo from any telephone connection depends to a considerable extent on the return loss at each end of the telephone circuit. If the return loss is high, it is not necessary to put in as much loss to the echo as if the return loss were lower.

An object of the present invention is to automatically adjust the loss inserted by an echo suppressor so that it is never greater than is necessary to properly suppress the echo, thereby providing improved operation particularly from the standpoint of break-ins.

This object is accomplished in accordance with the invention by a circuit arrangement operating under control of the voice currents to adjust the suppression loss in the echo path according to the amount of return loss, so that the total loss to the echo, including the two-wire return loss, is always the same. In one embodiment this circuit arrangement comprises at each terminal of a four-wire telephone circuit, a receiving terminal type of echo suppressor with a delayed action transmitting disabler in combination with a differential circuit which automatically compares the received speech waves with the echoes during the time in which the echo suppressor is operated, and adjusts the loss pad which is inserted in the echo path by operation of the echo suppressor to increase or decrease the suppression loss according to whether the echo is too strong or too weak relative to the received speech waves.

The various objects and features of the invention will be better understood from the following detailed description when read in conjunction with the accompanying drawings in which:

Fig. 1 shows a skeleton diagram of a four-wire telephone circuit with an echo suppressor in accordance with the invention applied to both terminals; and

Fig. 2 shows schematically in more detail the echo suppressor circuits at one terminal of the four-wire telephone circuit of Fig. 1.

In the skeleton diagram of Fig. 1, each of the single lines represents a two-wire transmission path. Contacting arrow-heads at a point in a line indicate that the transmission path is made at that point, and separated arrowheads at a point in a line indicate that the transmission path is broken or disabled at that point. An arrow pointed from a box towards a make point in a transmission path indicates that the transmission path will be disabled at that point in response to the output currents of the transmission device represented by the box, and an arrow pointing from a box to a break point in a transmission path indicates that the transmission path will be enabled at that point in response to the output current of the transmission device represented by the box. Each box containing an armature, connected by an arrow to a point on a variable loss device indicated for convenience as a potentiometer resistance in a transmission path, and two oppositely pointed arrowheads pointing to the armature, respectively connected to different contacts of a differential relay, represents a two-way relay stepping device operating to adjust the potentiometer resistance in one direction or the other depending on the direction of operation of the differential relay. The functions of the other transmission apparatus in the diagram, represented by boxes, are indicated by explanatory legends.

The four-wire telephone circuit of Fig. 1 comprises a west-to-east one-way transmission path EA and an east-to-west one-way transmission path WA coupled at the west terminal by the hybrid transformer HW and associated balancing network NW to a two-way line or circuit LW leading to a west subscriber's telephone circuit (not shown) and coupled at the east terminal by the hybrid transformer HE and associated balancing network NE to a two-way telephone line or circuit leading to an east subscriber's telephone set (not shown). The path EA includes at the west terminal a normally short-circuited potentiometer resistance P_1 and the amplifier A_1, and at the east terminal the amplifier A_2. The path WA includes at the east terminal the normally short-circuited resistance P_2 and the amplifier A_3, and at the west terminal the amplifier A_4.

The transmitting switching control circuit TS_W

of the echo suppressor at the west terminal includes the amplifier A_5 having its input bridged across the outgoing portion of the path EA on the output side of amplifier A_1. The output of the amplifier A_5 connects through the band-pass filter F_1 and the wave detector D_1 to two parallel control branches, one comprising the upper operating winding w_1 of the differential relay DR_1, and the other, in order, the delay circuit DC_1, the hang-over network HN_1 and the switching control e_1.

The receiving switching control RS_W of the echo suppressor at the west terminal includes the amplifier A_6 having its input bridged across the incoming portion of the path WA in front of amplifier A_4. The output of amplifier A_6 connects through the band-pass filter F_2 and the wave detector D_2 to the lower operating winding w_2 of the differential relay DR_1, poled to oppose the operating winding w_1 of that relay. The output of amplifier A_6 also connects through wave detector D_2 and the hang-over network HN_2 in parallel to the four switching controls a_1, b_1, c_1 and d_1. The differential relay DR_1 controls the two-way stepping switch SS_1 which controls the adjustment of the variable loss P_1.

Similarly, at the east terminal the echo suppressor comprises a transmitting portion TS_E and a receiving portion RS_E. The transmitting portion TS_E comprises in order an amplifier A_7 having its input bridged across the outgoing path WA on the output side of amplifier A_3, a band-pass filter F_3 and the wave detector D_3. The output of detector D_3 connects to the lower operating winding w_4 of the differential relay DR_2, and through delay circuit DC_2 and hang-over network HN_3 to the switching control e_2. The receiving echo suppressor portion RS_E includes in order, the amplifier A_8 having its input connected across the incoming portion of the path EA in front of amplifier A_2, the band filter F_4 and the detector D_4. The output of detector D_4 is connected in parallel to the upper operating windinw w_3 of differential relay DR_2, poled to oppose winding w_4, and through the hang-over network HN_4 in parallel to the four switching controls a_2, b_2, c_2 and d_2. The differential realy DR_2 controls the two-way stepping switch SS_2 which controls the adjustment of variable loss P_2.

The function of the differential relays, the various switching controls and the other apparatus of Fig. 1 will be brought out in more detail in the following complete description of operation.

Let is be assumed that the west subscriber associated with the line LW shorts speaking. His speech wave will divide in hybrid coil Hw and the useful part will pass upward into the west-to-east transmission path EA, and will be transmitted over that path through amplifiers A_1, A_2, hybrid transformer HE and line LE to the east subscriber. The loss control P_1 will not be effective to insert any loss in the transmitted waves because control a_1 being in its normally unoperated condition, P_1 is short-circuited.

A portion of west's speech waves at the west terminal will be diverted into TS_W and pass through bridged amplifier A_5 and band-pass filter F_1 and will divide between the winding w_1 of differential relay DR_1 and the input of delay circuit DC_1. The delay circuit DC_1 will delay the transmission of the speech waves for a time T, where T is substantially equal to the transmission time over the path EA between terminals of the four-wire circuit. Thus, at the same instant that west's speech waves reach the east end of the four-wire circuit, the diverted portion at the west terminal passing through delay circuit DC_1 and hang-over network HN_1 will cause the operation of control e_1 to disable the receiving portion RS_W of the echo suppressor at the west terminal at a point in front of the detector D_2.

At the east terminal, a portion of west's speech wave will be diverted into the receiving portion RS_E of the echo suppressor, and will pass through amplifier A_8, band-pass filter F_4 and detector D_4 to energize the upper winding w_3 of differential relay DR_2, and through hang-over network HN_4 will cause the operation of switching controls a_2, b_2, c_2 and d_2. Control a_2 operates to insert the part of the potentiometer resistance P_2, determined by the setting of its variable arm, into the outgoing portion of the path WA at the east terminal to attenuate the echoes of west's speech currents returned from the east subscriber's line LE through hybrid coil HE.

The setting of the variable arm of potentiometer P_2 is controlled by the stepping switch SS_2 the operation of which is controlled by differential relay DR_2, which in turn depends on the relative degree of energization of its two windings w_3 and w_4. Windings w_3 and w_4 are energized respectively by the incoming voice current in EA through the receiving suppressor RS_E, and by the outgoing or echo currents in WA transmitted into the transmitting suppressor TS_E. The differential relay DR_2 cannot cause any adjustment unless the receiving suppressor RS_E is operated to cause the operation of control d_2 to connect battery B_2 to the relay armature. The relay DR_2 may either operate its armature to the right or left contact, or stay in its neutral position. It will operate to the right contact if the incoming speech waves supplied to the upper winding w_3 of the relay are too strong in relation to the echo current supplied to the lower relay winding w_4, and to the left contact if the echo is too strong with relation to the incoming speech waves. The armature of the relay DR_2 will remain in the neutral position if the echo is correct with regard to the incoming wave. Operation of relay DR_2 to the right will cause the loss in P_2 to decrease, as indicated by shorting out more or less of the loss as the case may be and operation in the left direction will cause the loss provided by P_2 in the path WA to increase.

Controls b_2 and c_2 operate in response to the incoming speech waves at the east terminal to disable the transmitting suppressor TS_E at the input and output of delay circuit DC_2, which has a delay of T, respectively. This is necessary to prevent operation of control e_2 by echoes and also to give control to the west subscriber during double talking provided he spoke first. Thus, let it be assumed that the west subscriber started to talk slightly before the east subscriber. The speech waves of both would get started over the respective east-to-west and west-to-each speech transmission path without undergoing any attenuation by the potentiometer resistance at the near terminal, and the diverted speech energy of west and east at the west and east terminals will be started through delay circuit DC_1 and DC_2, respectively. However, since west started talking first, his speech wave would arrive at the east end of the four-wire circuit before east's speech impulse gets through the delay circuit DC_2, and also before the east subscriber's wave gets to the west end of the four-wire circuit. Controls b_2 and c_2 at the east terminal would then operate to prevent operation of control e_2 by east, and would also wipe off any speech impulse started through delay circuit DC_2 by east. Control e_1 at the west end of the circuit would also be operated by west to disable RS_W, thus preventing operation of any of the controls at the west terminal by east's speech when it arrives at the west terminal. A small spurt of east's speech would, however, get through to the west subscriber without attenuation, and if both subscribers continue talking later, later speech from east would arrive at the west terminal attenuated by whatever value of loss which will be inserted in the west-to-east path WA by potentiometer resistance P_2.

It is apparent that breaking would be made appreciably easier by the arrangement of Fig. 1 than in the usual echo suppressor which always puts in a fixed amount of loss which is large enough to suppress echoes under the most severe conditions. Thus, when the return losses are good, the suppression loss provided by the variable loss potentiometer devices P_1 and P_2 might be quite small, and the action of the circuit would not be widely different from that of a circuit with no echo suppressor at all. Only when the return losses are quite poor would the loss have to be as large as it is at all times with most present echo suppressors.

Continued double talking would tend to operate both differential relays DR_1 and DR_2 in the direction to increase the suppression loss at both ends of the circuit. Normally this loss would only have to be adjusted once during a call, however, and thus it is believed that the loss adjustment could be made moderately slow, say, to require two or three seconds to get over its total range. In this case, with the double talking which ordinarily occurs in such circuits, the change in the suppression loss would ordinarily not be very large during double talking and, at any rate, the loss would be adjusted back to its regular value a short time after the double talking had ceased.

Fig. 2 shows the detailed circuit arrangement which could be used at each terminal of the system of Fig. 2 to accomplish the functions described above for Fig. 1. The west terminal of the circuit is illustrated and the corresponding transmission apparatus circuits are designated with similar identification characteristics. The circuit details will be brought out in the following detailed description of operation of the circuit of Fig. 2.

Let it be assumed that the west subscriber connected to the line LW speaks. His speech waves will divide in hybrid coil H_W, part being dissipated in the output of amplifier A_4 and the useful part passing into the input of the west-to-east path EA. West's speech currents will first pass through the loss pad L_1, the function of which is to effectively remove from the two-wire line the effects of the varying impedance of potentiometer resistance P_1, and then will pass through the two repeating coils T_1 and T_2 and amplifier A_1 out over the path EA to the last terminal of the four-wire circuit. If the receiving suppressor relay RHO_1, corresponding to the control a_1 in the system of Fig. 1, is not operated, the potentiometer P_1, the resistance setting of which is controlled by the two-way stepping switch SS_1, comprising the two stepping magnets f_1 and f_2, will be shorted out and there will be no suppression loss applied to west's outgoing speech waves. At the output of amplifier A_1 a part of west's outgoing waves will be diverted into the transmitting portion TS_W of the echo suppressor at the terminal and will be amplified by bridging amplifier A_5 and passed by band-pass filter F_1. This filter is used to select only that portion of the speech waves which is important from the standpoint of producing echoes and at the same time to eliminate unwanted noise waves.

At the output of filter F_1 the waves are detected by the detector D_1 and the pulsating direct current in the output of the detector is smoothed by condenser C_1. This direct current will pass through the winding of the transmitting master suppressor relay TM_1 and the winding w_1 of the differential relay DR_1 and, if strong enough, will operate relay TM_1, and will produce a pull on the relay DR_1 tending to move its armature to the upper relay contact. Let it be assumed that relay TM_1 is operated. This removes the ground from condenser C_2 through resistance R_2 and then allows relay DM_1, normally operated by current from battery B_3 through resistance R_3, to start to release. The relay DM_1 and the associated circuit perform the function of the delay circuit DC_1 in the circuit of Fig. 1. After the desired time interval, T which is equal to the one-way transmission time over the four-wire circuit between terminals, and may be controlled by proper proportioning of the values of condenser C_2 and resistance R_3, relay DM_1 will release, thereby operating relay THO_1, corresponding to control e_1 in the system of Fig. 1, almost immediately due to the discharge of condenser C_3 through R_4 which is comparatively small. Relay THO_1 will be operated by current from battery B_4 transmitted through its winding and resistances R_5 and R_4. Operation of relay THO_1 immediately disables the receiving detector D_2 in its input, thus preventing its operation by echoes from the distant end of the circuit. (With this arrangement, there will always be some echoes, and these echoes may be relatively strong in the case of a very strong local talker.) Relay THO_1 is given sufficient hang-over by the combination of C_3 and R_5, corresponding to hang-over network HN_1 in the system of Fig. 1, so that it holds the receiving detector D_2 disabled for a time sufficiently long to take care of all the delayed echoes.

The differential relay DR_1 will probably be operated very frequently in the up direction by the local talker, but this will have no effect on the stepping of potentiometer P_1, since relay RHO_1 will not be operated at such times, and thus there is no ground on the armature of the differential relay DR_1.

Let it be assumed now that west's outgoing speech has ceased, and incoming speech waves from the east subscriber are present in the path WA. A portion of these waves will be diverted into receiving portion RS_W of the echo suppressor and will be amplified by A_6, filtered by F_2 and detected by detector D_2 which is now operative due to the release of relay THO_1. The pulsating direct current in the output of D_2 will be smoothed by condenser C_4 and will tend to cause a pull in the down direction on relay DR_1 and also to operate the receiving suppressor master relay RM_1.

The operation of relay RM_1 will almost immediately discharge condenser C_5 through R_7, thus causing relay RHO_1 and RHO_2 to operate in response to the current transmitted through their windings and resistances R_6 and R_7 from battery B_4.

The operation of relay RHO_1 immediately inserts loss in the path EA by removing ground from the arm of potentiometer P_1 thereby removing the short from the potentiometer. When the armature of RHO_1 reaches its lower contact, it will also put ground on the armature of the differential relay DR_1 and thus allow adjustment by the stepping magnets f_1 and f_2 under control of differential relay DR_1. Operation of relay RHO_2 immediately discharges condenser C_2 through resistance R_8. Thus, even though the release of relay DM_1 has been initiated by a previous operation of relay TM_1, this action will be completely annulled by operation of relay RHO_2.

The differential relay DR_1 will now be affected by incoming waves through winding w_2 and echo waves attenuated by the loss provided by the variable resistance of potentiometer P_1 through winding w_1. If the echo wave amplitude is too high compared to that of the incoming speech waves, the setting of the differential relay DR_1 will be such that its armature will operate in the up direction. This will cause the potentiometer to step in the clockwise direction thereby increasing the series resistance in the path EA and thus increasing the loss in that path. When the loss is sufficiently increased by successive operations, the currents in w_1 and w_2 will become equal and there will be no further adjustment since the armature of DR_1 will then remain in the center (neutral) position during incoming speech waves.

Now, let it be assumed that a new call comes up in which the return loss is considerably better than that on the one just previous. In this case the loss due to the potentiometer P_1 will be quite high, and during incoming speech the current in winding w_2 of relay DR_1 will be considerably greater than in winding w_1. This will cause operation of the differential relay DR_1 in the down direction and will start a series of stepping operations in a counter-clockwise direction in potentiometer P_1. This will continue until the echoes at the input of amplifier A_5 are increased sufficiently so that the armature of differential relay DR_1 once more stays in the neutral position.

As noted above, double talking while it lasts will produce an effect on the differential relay DR_1 which is similar to loud echoes and thus will probably operate it in the up direction and increase the suppression loss. By making the stepping switch slow-operating by proper design, however, this effect can be made unobjectionable. Another way of making the effect unobjectionable would be to design the stepping switch so that it would not operate at all for very brief pulses. Actually most stepping switches or selectors are such that they do not operate on very brief pulses anyway.

Various modifications of the circuits which have been illustrated and described which are within the spirit and scope of the invention will occur to persons skilled in the art.

What is claimed is:

1. In a two-way signal transmission system including a two-way signal transmission path, one one-way signal transmission path for transmitting to said two-way path and a second one-way signal transmission path for transmitting from said two-way path, an echo suppressor operating in response to incoming signals in said one one-way path to insert an echo suppression loss in said second one-way path, means to automatically compare the level of said incoming signals in said one path with the level of the echoes of said signals returned from said two-way path to said second one-way path during the period in which said echo suppressor is operated by said incoming signals, and means controlled by the comparing means to automatically adjust the value of said echo suppression loss so that its magnitude is just sufficient to properly suppress said returned echoes.

2. The system of claim 1, in which said comparing means compares the level of the signals in said one path with the level of the signal echoes in said second path beyond the point at which said echo suppression loss in inserted therein, said adjusting means is controlled by said comparing means to increase the value of said suppression loss to the required degree when the level of the echoes transmitted through said suppression loss is too large with respect to the level of the received signals in said one path, to decrease the value of said suppression loss when the level of the echoes transmitted therethrough is too small with respect to the level of said received signals, and to make no adjustment of the value of said suppression loss when the comparison of the signals and echoes by said comparing means indicates that the suppression loss is of the correct value.

3. In a two-way signal transmission system, a two-wire line, a four-wire signal transmission circuit connected thereto including one one-way circuit for transmitting to said line and a second oppositely-directed one-way circuit for receiving from said line, an echo suppressor including a portion connected to said one one-way circuit responsive to incoming signals therein to introduce an echo suppression loss in said second one-way circuit, control means for automatically varying the value of said echo suppression loss, during the period in which said portion of said echo suppressor is operated by incoming signals, so that the value of said loss is increased when the ratio of the level of the signal echoes in said one one-way circuit with respect to the level of the incoming signals in said second one-way circuit is greater than a tolerable value and the value of said loss is decreased when the ratio is less than the tolerable value.

4. The system of claim 3 in which said echo suppressor includes a second portion connected to said second one-way circuit at a point beyond said suppression loss, operating in response to outgoing signals in said second circuit but with a delay substantially equal to the overall transmission time over said second one-way circuit between the terminals of said four-wire circuit, to disable the first portion of said echo suppressor.

5. In a two-way signal transmission system including a two-way transmission circuit, one one-way path for transmitting from said circuit and a second one-way path for transmitting to said circuit, means responsive to signal transmission between said second path and said circuit for inserting an echo suppression loss in said one path, auxiliary means responsive to one given ratio of the level of the signal waves in said second path to the level of the signal echoes returned from said circuit to said one one-way path to increase the amount of said suppression loss, and responsive to another given lower ratio of the level of the signal waves in said second path to the level of the echoes in said one path to reduce the amount of said echo suppression loss.

6. The system of claim 5 in which the coupling

between said two-way circuit and said one and said second path comprises a hybrid coil and an associated balancing network, which provides an approximate conjugate relation between said one and said second path, and said auxiliary means comprises a differential circuit for automatically comparing the signals in said second path with the signal echoes in said one path during the period in which said signal responsive means is operated, and means operating automatically to increase or decrease the value of said suppression loss according to whether the echoes are too strong or too weak relative to the signals in said path.

7. In a two-way telephone system including a two-way transmission circuit and incoming and outgoing one-way signal transmission paths connected in approximate conjugate relation with each other and in energy-transmitting relation with said two-way circuit, an echo suppressor comprising a receiving branch connected to said incoming one-way path, responsive to incoming telephone signals therein to insert an echo suppression loss in said outgoing one-way path, and a transmitting branch connected to said outgoing one-way path, responsive to outgoing telephone signals therein to disable said receiving branch, a differential circuit controlled from said outgoing and incoming one-way paths for automatically comparing the signals in said incoming path with the echoes in said outgoing path beyond the point of insertion of said echo suppression loss therein, during a period in which said transmitting branch of said echo suppressor is operated, and means controlled by said differential means for automatically adjusting the value of said suppression loss so that it is never greater than is necessary to properly suppress the echoes.

8. The system of claim 7 in which said differential means comprises a differential relay having two opposing windings, means for energizing one winding in proportion to the level of the signals in said incoming one-way path when said receiving branch of said echo suppressor is unoperated, and means for energizing the other winding in proportion to the level of the echoes transmitted through said suppression loss in said outgoing one-way path, said relay operating in one direction when the signal level exceeds the echo level by a given amount indicating too great a suppression of echoes by said loss, and operating in the opposite direction when the signal level exceeds the echo level by a given lower amount, indicating too little suppression of echoes by said loss, said means controlled by said differential means comprises a two-way stepping switch operating to decrease the value of said echo suppression loss in response to operation of said relay in said one direction until said relay releases, and to increase the value of said suppression loss in response to operation of said relay in said opposite direction until said relay releases.

9. The system of claim 7, in which the echo suppression loss inserted in said outgoing one-way path by operation of the receiving branch of said echo suppressor is a potentiometer resistance, said resistance being short-circuited when said receiving branch is unoperated so as to be ineffective in said outgoing one-way path, and said means for automatically adjusting the value of said suppression loss under control of said differential means comprising a stepping selector switch operating to adjust said potentiometer resistance in a direction to increase the insertion loss in said outgoing path when the comparison by said differential circuit indicates that the loss is smaller than that required to properly suppress the echoes, and operating to adjust said potentiometer resistance in a direction to reduce its insertion loss when the comparison by said differential circuit indicates that the loss is greater than is necessary to properly suppress the echoes.

10. In combination with a four-wire telephone circuit interconnecting two two-way telephone circuits, said four-wire circuit comprising two oppositely directed one-way transmission paths for respectively transmitting telephone signals in opposite directions between said two-way circuits, echo suppressor means at each terminal of said four-wire circuit comprising a voice-operated receiving switching branch connected to the incoming one-way path and responsive to incoming telephone signals therein to insert an echo suppression loss in the outgoing one-way path at the terminal, a voice-operated transmitting switching branch connected to said outgoing one-way path and responsive to outgoing telephone signals, but with a delay substantially equal to the one-way transmission time between terminals of said four-wire circuit, to disable said receiving switching branch, a differential circuit operating automatically to compare the level of the incoming signals in said incoming path with that of the echoes of the signals beyond the point of insertion of said suppression loss in said outgoing path and means controlled by said differential circuit to increase the value of said echo suppression loss when the echoes are too strong and to decrease the value of said suppression loss when they are too weak with respect to the incoming signals.

11. The combination of claim 10, in which the delay in the operation of said transmitting switching branch is attained by the use of a delay circuit of the required value in that branch, said receiving switching branch when operated also disabling said transmitting switching branch on each side of said delay circuit and conditioning said differential circuit for operation.

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