

Oct. 4, 1932.

B. G. BJÖRNSON ET AL

1,880,715

TRANSMISSION CONTROL CIRCUITS

Filed Sept. 10, 1930

2 Sheets-Sheet 1

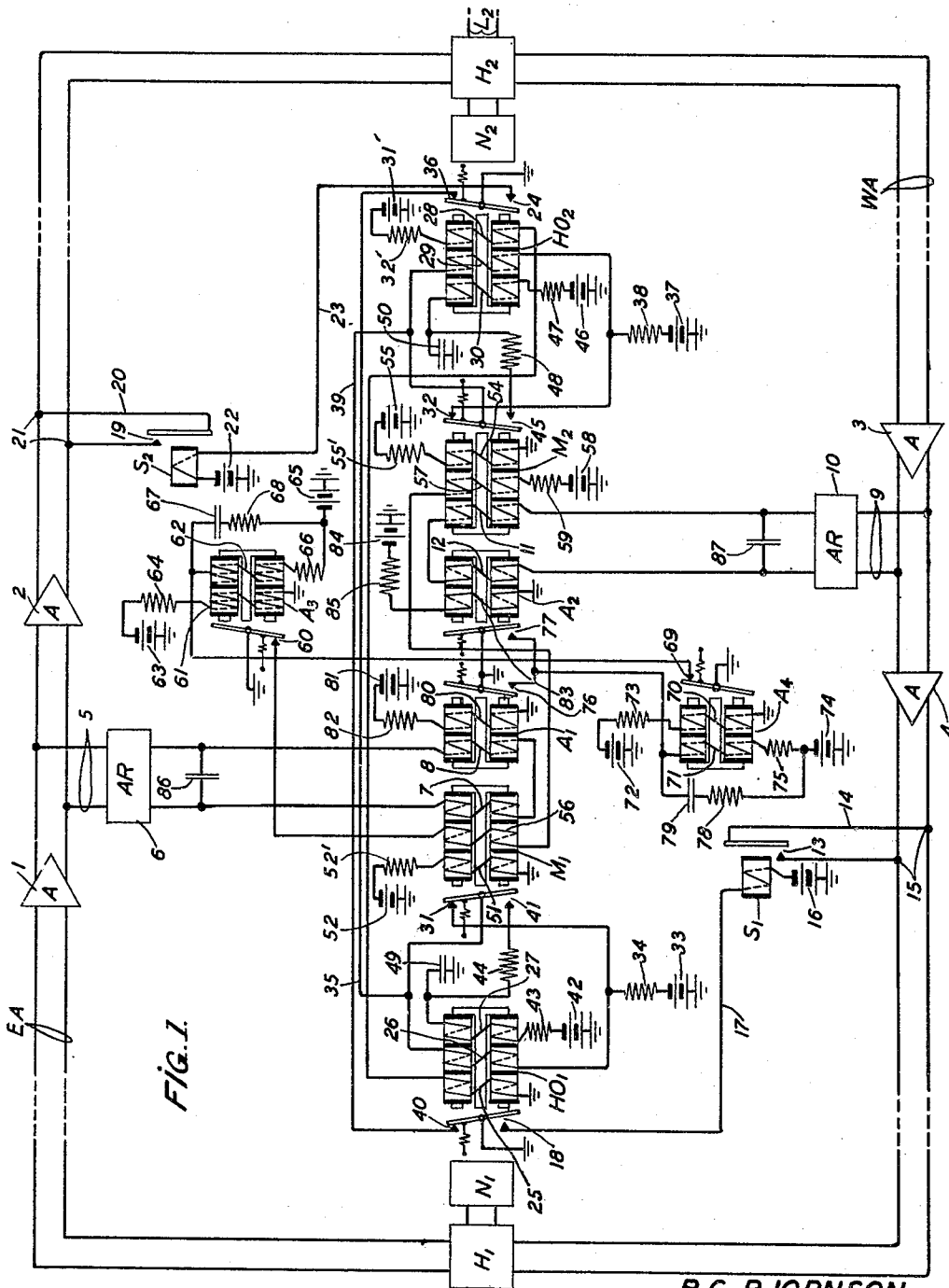


FIG. 1.

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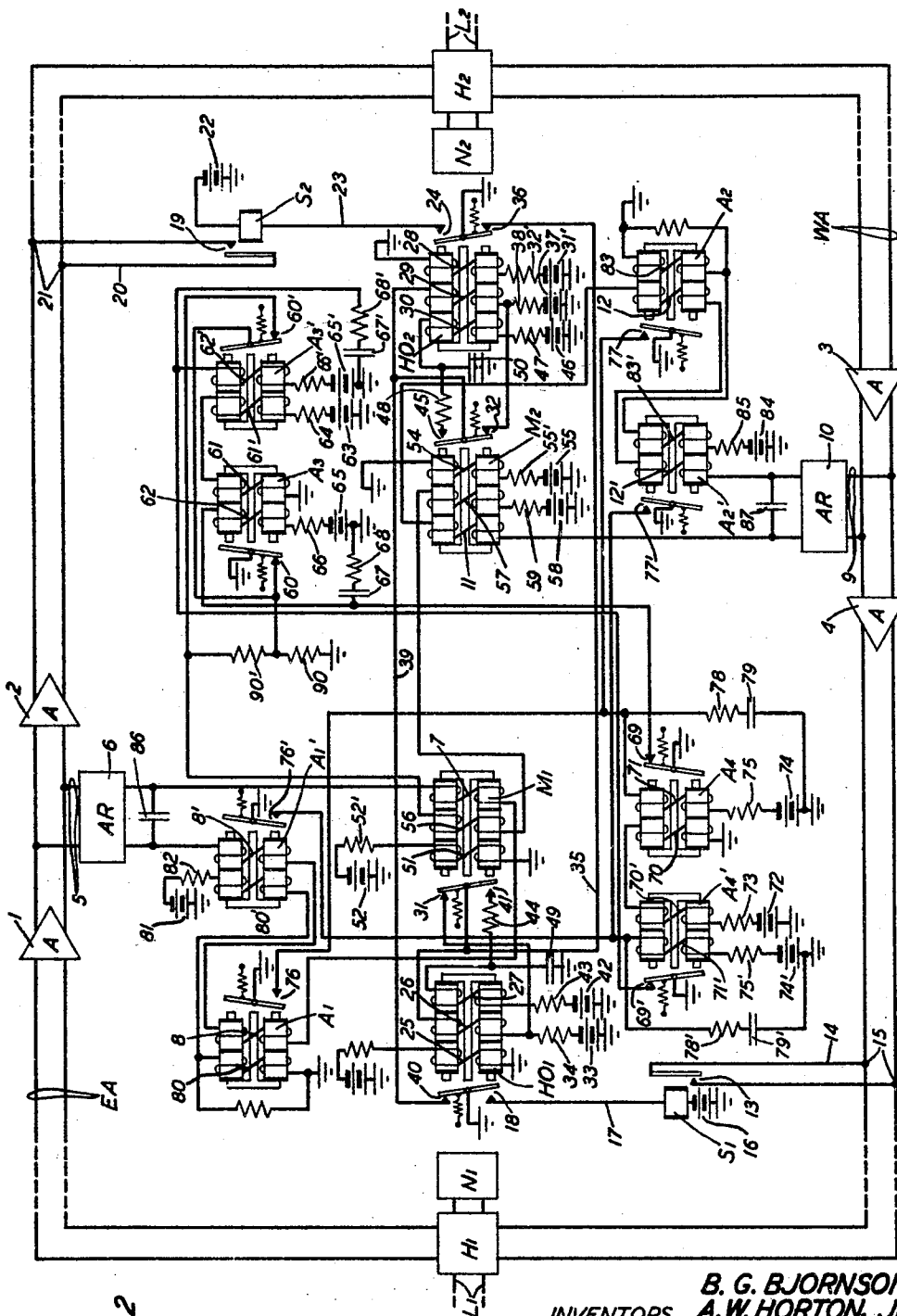


FIG. 2

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TRANSMISSION CONTROL CIRCUITS

Application filed September 10, 1930. Serial No. 480,940.

The invention relates to two-way signaling systems and particularly to the signal controlled means employed in such systems for conditioning the circuits thereof for various purposes such as to suppress disturbances, i. e., echoes, and to prevent singing.

An object of the invention is to improve the operation characteristics of such signal controlled means in two-way signaling systems.

The invention is particularly directed to the signal-controlled means utilized in connection with two-way signaling systems for suppressing echoes, such as echo suppressors, although it is applicable as well to signal controlled means utilized in connection with two-way signaling systems for other purposes, for example, so-called reaction suppressors, anti-singing devices and voice operated repeaters.

An echo suppressor is that type of signal controlled device well-known in the art utilized in connection with two-way signaling systems for effectively disabling one of the associated one-way transmission circuits thereof while signal transmission is taking place over another oppositely directed one-way circuit of the system, thereby preventing echo currents or reflected currents from being transmitted back to the transmitting end of the system and causing a disturbance or singing. The disabling apparatus may comprise, for example, a short circuit which may be closed across one of the one-way circuits by the operation of a mechanical relay in the output of a vacuum tube amplifier-rectifier having its input connected across the one-way circuit for transmission in the opposite direction.

This invention is concerned mainly with improvements in the type of signal controlled circuits employed in connection with two-way signaling systems for the above mentioned purposes, in which the sensitivity is controlled in accordance with the amount of line noise in the system, so as to prevent false operation thereof by line noise, while maintaining at all times the circuits in the most sensitive condition as regards operation by signals. This type of signal controlled circuit when employed for suppressing echoes

is known as a variable sensitivity echo suppressor.

The variable sensitivity echo suppressors of the prior art have certain disadvantages. In the first place, they are usually constructed so that when neither of the echo suppressors associated with the oppositely directed transmission paths is operated by the signals, the sensitivity is determined by the amount of noise on both paths which may result in an over-reduction in sensitivity tending to reduce the efficiency of the system. In the second place, such suppressors are usually constructed so that when the noise is on one one-way transmission path only and the suppressor is operated by signals from the other one-way path, the inputs to both the suppressor and the sensitivity reduction circuit are simultaneously disabled, and the first suppressor is maintained at maximum sensitivity until signal transmission ceases. The suppressors may then be locked up from noise until the sensitivity control circuit has had time to function.

In the variable sensitivity signal controlled system of the invention, the above mentioned disadvantages are eliminated by a construction enabling the sensitivity of the signal controlled suppression devices to be determined by the amount of noise on the one-way transmission path on which the noise is a maximum, and in which the sensitivities of both signal controlled suppression devices associated with the two oppositely directed transmission paths are reduced simultaneously and by the same amount.

A preferred embodiment of the invention is applicable to echo suppressors or anti-singing devices of the type in which mechanical relays are utilized for disabling the one-way transmission paths. The master relays controlling the disabling of the one-way paths are normally biased so as to operate in their most sensitive condition. The master relays are provided with additional windings which, when energized, will reduce the sensitivity of the relays. These additional windings are energized in accordance with the amount of line noise on the one-way transmission path in which noise is a maxi-

num through the consecutive operation of a chain of relays arranged to respond to line noise but not to signals.

The nature of the invention, its purpose and advantages will be clear from the following detailed description thereof when read in connection with the accompanying drawings, Figs. 1 and 2 of which show diagrammatically four-wire telephone repeating systems employing echo suppressors embodying different modifications of the invention.

The four-wire telephone repeating system of Fig. 1 comprises the one-way transmission path EA including the one-way amplifying devices 1 and 2 for repeating telephonic signals in the direction from west to east between a west two-way line section L_1 and an east two-way line section L_2 , and the one-way transmission path WA including the one-way amplifying devices 3 and 4 for repeating telephonic signals in the direction from east to west between the east line section L_2 and the west line section L_1 .

The input of the east path EA and the output of the west path WA are associated in energy transmitting relation with the line section L_1 and in conjugate relation with each other, and the input of the west path WA and the output of the east path EA are connected in energy transmitting relation with the line section L_2 and in conjugate relation with each other, by means of the hybrid coil transformer H_1 and H_2 and associated balancing networks N_1 and N_2 , respectively, in the manner well known in the art.

Connected across the transmission path EA between the output of amplifier 1 and the input of amplifier 2 therein is a control circuit 5 including a wave-controlled, relay-controlling device 6, and the operating winding of the master echo suppressor relay M_1 and the operating winding of an auxiliary relay A_1 connected in series across the output of the device 6. Connected across the transmission path WA between the output of the amplifier 3 and the input of the amplifier 4 is a control circuit 9 comprising the wave-controlled, relay-controlling device 10, and the operating winding 12 of the master echo suppressor relay M_2 and the operating winding 12 of an auxiliary relay A_2 connected in series across the output of the device 10.

Adjacent the transmission path WA is a relay S_1 which, when energized, is adapted to close the normally open contacts 13 in the connection 14 so as to short-circuit the outgoing portion of the path WA at the points 15. Relay S_1 is arranged to be supplied with energizing current from the battery 16 over the conductor 17 when the normally open contacts 18 therein are closed by operation of the holdover relay HO_1 . Adjacent the transmission path EA is the relay S_2 which, when energized, is adapted to operate to close

the normally open contacts 19 in the connection 20 so as to short-circuit the outgoing portion of the path EA at the points 21. The relay S_2 is arranged to be supplied with energizing current from the battery 22 over the conductor 23 when the normally open contacts 24 therein are closed by operation of the holdover relay HO_2 .

The holdover relay HO_1 has three windings, a biasing winding 25, an operating winding 26 and a holdover winding 27. The holdover relay HO_2 has three windings, a biasing winding 28, an operating winding 29 and a holdover winding 30. The biasing winding 25 of holdover relay HO_1 and the biasing winding 28 of holdover relay HO_2 are connected in series and are maintained energized at all times by current from the battery 31' through resistance 32'. The operating winding 26 of holdover relay HO_1 is normally short-circuited through the normally closed contacts 31 of the master echo suppressor relay M_1 . Similarly, the operating winding 29 of holdover relay HO_2 is normally short-circuited through the normally closed contacts 32 of the master echo suppressor relay M_2 . When the master relay M_1 operates to open its normally closed contacts 31 the short circuit around the operating winding 26 of holdover relay HO_1 is removed and the winding is energized by current from the battery 33 over a path extending from ground through battery 33, resistance 34, winding 26 of relay HO_1 , conductor 35 and the normally closed contacts 36 of the holdover relay HO_2 to ground. Similarly, when the master echo suppressor relay M_2 operates to open its normally closed contacts 32, the short circuit around the operating winding 29 of relay HO_2 is removed and that winding is energized by current from the battery 37 over a path extending from ground through battery 37, resistance 38, winding 29, conductor 39 and the normally closed contacts 40 of relay HO_1 to ground.

The holdover winding 27 of holdover relay HO_1 is normally deenergized. When master relay M_1 operates to close its contacts 41, the winding 27 is energized by current from the battery 42 over a path extending from ground through battery 42, resistance 43, winding 27, resistance 44, contacts 41, conductor 35, and the normally closed contacts 36 of holdover relay HO_2 to ground. Similarly, the holdover winding 30 of holdover relay HO_2 is normally deenergized. When the master relay M_2 operates to close its contacts 45, winding 30 is energized by current from the battery 46 over a path extending from ground through battery 46, resistance 47, winding 30, resistance 48, contacts 45, conductor 39 and the normally closed contacts 40 of holdover relay HO_1 to ground.

While the holdover winding 27 of relay HO_1 is being energized, the condenser 49 is

also charged up by current from the battery 42. When relay M_1 releases to break the energizing circuit for winding 27 by opening contacts 41, condenser 49 will discharge slowly through winding 27 and resistance 43 so as to maintain winding 27 energized for an additional interval of time. Therefore the relay HO_1 will remain operated to hold its contacts 18 closed and thus the short-circuiting relay S_1 energized by current from battery 16 for this additional interval of time after the relay M_1 has released. Similarly while the holdover winding 30 of relay HO_2 is being energized the condenser 50 is also being charged up by current from battery 46. When relay M_2 releases to break the energizing circuit for winding 30 by opening contacts 45, the condenser 50 will discharge slowly through winding 30 and resistance 47 to maintain winding 30 energized for an additional interval of time. Therefore, relay HO_2 will remain operated to hold its contacts 24 closed, and thus the short-circuiting relay S_2 energized by current from battery 22 for this additional interval of time after relay M_2 has released.

The resistance 43 and the condenser 49 associated with holdover relay HO_1 are given suitable values so that the additional length of time for which relay HO_1 will be maintained operated after transmission of the west to east speech currents to the control circuit 5 has ceased, is sufficient to insure that the short-circuiting connection across path WA at the points 15 is maintained long enough to block therein any echo or reflected currents due to the preceding west to east speech currents; in other words, the holdover action of holdover relay HO_1 is made such that the line WA is maintained shorted at the points 15 for a period of time at least equal to the transmission time over the path EA between the point of connection of the circuit 5 to the path EA through the hybrid coil H_2 plus the transmission time from the hybrid coil H_2 over the path WA to the points 15 therein. Similarly, the resistance 47 and condenser 50 associated with the holdover winding of relay HO_2 are given such values that the additional length of time for which the relay HO_2 will be maintained operated after the transmission of east to west speech currents over the path WA to control circuit 9 has ceased is sufficient to insure that the short-circuiting connection across the path EA at the points 21 is maintained long enough to block any echoes or reflected current due to the preceding east to west speech current. This latter interval of time will be substantially equal to the transmission time over the path WA between the point of connection of the control circuit 9 to the path WA through the hybrid coil H_1 plus the transmission time over path EA from hybrid coil H_1 to the blocking points 21

in the path EA. It may be desirable to make the holdover periods of relays HO_1 and HO_2 slightly longer than the intervals described to prevent the short-circuiting connections across the paths WA and EA respectively from being removed at the trailing end of a word or syllable.

The master echo suppressor relay M_1 has a biasing winding 51 which is maintained energized at all times by current from the battery 52 through the resistance 52' so that the relay would operate in the least sensitive condition were it not for winding 56. Similarly, the master relay M_2 has a biasing winding 54 which is maintained energized at all times by current from the battery 55 through the resistance 55' so that the master relay M_2 would operate in the least sensitive condition, were it not for winding 57. The master relay M_1 has a third winding 56 so wound as to oppose the action of the operating winding 7 thereof. Similarly, master relay M_2 has a third winding 57 so wound as to oppose the action of the operating winding 11 thereof. The third windings 56 and 57 of relays M_1 and M_2 respectively are utilized to apply back bias to these relays opposing the normal bias produced by the biasing windings 51 and 54, respectively thereof. The winding 56 of master relay M_1 and the winding 57 of master relay M_2 are connected in series so as to be normally supplied with energizing current from the battery 58 through the resistance 59 and the normally closed contacts 60 of the auxiliary relay A_3 . The elements in this series circuit are so chosen that the amount of back bias normally applied is the same for each master relay, and is sufficient to allow the relays M_1 and M_2 to operate in their most sensitive condition. This normally applied, back bias is removed in one step when auxiliary relay A_3 releases to open its contacts 60 causing the sensitivity of each master relay M_1 and M_2 to be reduced by an equal amount to the point where these relays will just not be operated by the noise received by them from the paths EA and WA, respectively, although responsive to the speech waves received from these paths.

The auxiliary relay A_3 has two windings, a biasing winding 61 and an operating winding 62. The biasing winding 61 is at all times energized by current from battery 63 through the resistance 64. The operating winding 62 of relay A_3 is normally energized by current from the battery 65 over a path extending from ground through battery 65, resistance 66, winding 62 and the normally closed contacts 69 of the auxiliary relay A_4 to ground, so as to hold the relay contacts 60 closed.

A condenser 67 and a resistance 68 are connected in series across the winding 62 and the resistance 66, so that condenser 67 will be normally charged by current from battery

65 through resistance 68. When the normally closed contacts 69 of the auxiliary relay A_4 are opened by operation of that relay, the normal energizing circuit for the operating winding 62 of relay A_3 is broken, but the relay A_3 will not release for a definite time thereafter because the winding 62 will be maintained energized while the condenser 67 discharges through that winding and the resistances 66 and 68. This definite period of time may be made of any desired length by proper choice of the values of condenser 67, resistances 66 and 68 to regulate the time constants of the relay A_3 . The time constants of relay A_3 are made such that the relay will not release unless the contacts 69 of auxiliary relay A_4 remain open for a time longer than the duration of the average speech syllable plus the holdover period for relay A_4 . Thus, the contacts 69 will never be closed long enough by operation of relay A_4 when speech energy alone is supplied to the preceding relays (A_1 and A_2) in the chain to cause relay A_2 to release. The speech waves applied to relay A_1 or A_2 , therefore, will not be effective to cause any reduction in the sensitivity of the master suppressor relays M_1 and M_2 through relays A_4 and A_3 .

Auxiliary relay A_4 , which is controlled by operation of either auxiliary relay A_1 or A_2 , is provided to bridge the periods between peaks of noise in order to release auxiliary relay A_3 on intermittent noise. It controls relay A_3 through its contacts 69 when auxiliary relay A_1 or A_2 operates frequently enough so that the holdover of auxiliary relay A_4 allows auxiliary relay A_3 to release.

Auxiliary relay A_4 has two windings, a biasing winding 70 and an operating winding 71. The biasing winding 70 is always energized by current from battery 72 through resistance 73. The operating winding 71 is arranged to be energized by current from the battery 74 through resistance 75 when either the normally open contacts 76 of auxiliary relay A_1 or the normally open contacts 77 of relay A_2 are closed by operation of the respective relays.

A resistance 78 and a condenser 79 are connected in series across the winding 71 of relay A_4 and the resistance 75. When the contacts 76 of relay A_1 or contacts 77 of relay A_2 are closed, the current from battery 74, besides energizing winding 71, also charges the condenser 79. When the energizing circuit for winding 71 on relay A_4 is broken by the opening of contacts 76 of relay A_1 or contacts 77 of relay A_2 , the condenser 79 slowly discharges through the resistances 78 and 75 and the winding 71, causing the winding 71 to be maintained energized, and thus the relay A_4 to be maintained operated to hold its contacts 69 open, for a definite holdover period of time after the supply of energizing current to winding 71 from battery 74 ceases.

The value of the condenser 79 and of the resistances 78 and 75 are chosen so as to give the relay A_4 a holdover in its operation sufficient to bridge the interval between peaks of intermittent noise of a particular type which will be referred to below.

The auxiliary relay A_1 has, in addition to its operating winding 8, a biasing winding 80 which is always maintained energized by current from the battery 81 through the resistance 82. The value of resistance 82 is preferably so chosen that the relay A_1 is about 3 decibels more sensitive than the master echo suppressor relay M_1 . Similarly, the auxiliary relay A_2 has in addition to its operating winding 12 a biasing winding 83 which is always maintained energized by current from the battery 84 through the resistance 85. The value of the resistance 85 is also preferably so chosen that the relay A_2 is about 3 decibels more sensitive than the master relay M_2 . As the two relays A_1 and A_2 have equal sensitivities, the one supplied with currents of the greater amplitudes will operate first.

A condenser 86 of suitable value is connected across the series circuit comprising the winding 7 of relay M_1 and the winding 8 of relay A_1 to prevent chattering of the contacts of these relays. Similarly, a condenser 87 of suitable value is connected across the winding 11 of relay M_2 and the winding 12 of relay A_2 to prevent chattering of the contacts of these relays.

The wave-controlled, relay-controlling devices 6 and 10 may be vacuum tube, amplifier-rectifier, circuits of the type well known in the art or any other devices which will respond to alternating current impressed upon their inputs to operate mechanical relays in their outputs.

The operation of the system of Fig. 1 as a whole will now be described.

As the operation of the system when speech waves are being transmitted in the direction from west to east is similar to the operation when speech waves are being transmitted in the direction from east to west, only the former case need be described. It will be assumed that speech waves are being transmitted from west to east over the transmission path EA between lines sections L_1 and L_2 , and that at that time no speech waves are being transmitted in the direction from east to west over the transmission path WA. It will also be assumed that there is noise on both the path EA and the path WA and that the amount of noise on the path EA is greater than that on the path WA at this time.

The speech currents transmitted over the path EA will be amplified by the amplifier 1 therein and the amplified waves divided between the input of the amplifier 2 in the path EA and the input of control circuit 5. The main portion of the speech waves in the output of amplifier 1 in the path EA will be

amplified by the amplifier 2, and the amplified waves will be impressed by the hybrid coil H_2 upon the line section L_2 and transmitted thereover to the listening subscriber.

A portion of the amplified speech waves in the output of the amplifier 1 in the path EA together with a portion of the noise waves which are present in the output of amplifier 1 will be impressed upon the input of the wave-controlled, relay-controlling device 6 in control circuit 5 causing that device to be operated to energize the operating winding 7 of relay M_1 and the operating winding 8 of auxiliary relay A_1 . The master relays M_1 and M_2 and the auxiliary relays A_1 and A_2 are designed to operate at a syllabic frequency. The frequency of their operation depends upon the sensitivity of the associated amplifier-rectifier devices, the type of the impressed waves and their rapidity and various other factors including the relay design. Auxiliary relay A_1 being more sensitive than relay M_1 , will operate in advance of M_1 to start the chain of operations which will be described later.

Relay M_1 will then operate to close its normally open contacts 41 and to open its normally closed contacts 31. The opening of contacts 31 will cause the short circuit around the operating winding 26 of relay HO_1 to be removed, allowing that winding to be energized by current from battery 33. The closing of contacts 41 causes the holdover winding 27 of relay HO_1 also to be energized by current from battery 42.

Relay HO_1 will operate to close its contacts 18 in conductor 17, and to open its contacts 40 in the conductor 39. The opening of contacts 40 in conductor 39 will effectively disable the energizing circuit for winding 29 of relay HO_2 , thus preventing that relay from being thereafter operated to cause the short-circuiting of path EA by operation of the relay S_2 due to later false operation of relay M_2 . The closing of contacts 18 in conductor 17 will cause the windings of relay S_1 to be energized by current from battery 16. Relay S_1 will then operate to close the normally opened contacts 13 in the connection 14 causing the outgoing portion of the transmission path WA to be short-circuited thereby at the points 15. The path WA will be maintained short-circuited as long as speech waves are being received by the relay M_1 from the transmission path EA, and due to the holdover action of the relay HO_1 , will be maintained short-circuited for a definite interval after that time, while condenser 49 which was charged by current from battery 42 through resistance 43 and winding 27 during the time of energization of the holdover winding 27 of relay HO_1 , is discharging through the resistance 43. As stated above, this holdover period is made long enough to insure that the path WA is blocked long enough to prevent all

echoes or reflected currents in the path WA due to the preceding west to east speech currents in the path EA from getting through to hybrid coil H_1 .

Because of its greater sensitivity the relay A_1 will operate in response to speech or noise waves impressed on its operating winding 8 from the output of the device 6, slightly before the master relay M_1 . When the amount of noise impressed on the relay A_1 is above a predetermined value, that relay will operate to close and maintain closed its contacts 76. When contacts 76 are closed the operating winding 71 of relay A_4 is energized by current from battery 74 over a path extending from ground through battery 74, resistance 75, winding 71 and contacts 76 of relay A_1 to ground. Relay A_4 will then operate to open its contacts 69 to break the energizing circuit for the operating winding 62 of relay A_3 .

By proper selection of the values of the condenser 79 and the resistances 78 and 75 comprising the holdover circuit of relay A_4 , and the values of condenser 67 and resistances 68 and 66 comprising the holdover circuit for relay A_3 , the holdover of these two relays are made such that relay A_3 will not release for operation of relay A_4 by the syllabic variations in speech but will release for operation of relay A_4 on intermittent noise of a certain type.

The A_4 relay is provided to introduce a holdover action to take care of certain types of noise especially those with pronounced low frequency components which would cause auxiliary relay A_1 or auxiliary A_2 to vibrate freely without effecting operation of the auxiliary relay A_3 . The elements in the holdover circuit are preferably such that auxiliary relay A_4 gives a holdover action somewhat less than that of relay HO_1 or relay HO_2 and yet sufficiently long to bridge the intervals between peaks of noise of the above mentioned type. The holdover time of auxiliary relay A_4 preferably should be greater than .01 seconds to bridge the intervals between 60 cycle noise peaks. A holdover time for relay A_4 of between .05 and .10 seconds was found to give the best results with most noises. To prevent undue operation by speech the release time of auxiliary relay A_3 preferably should be greater than .75 seconds.

The noise waves impressed with the speech waves from the output of the device 6 upon the operating windings of auxiliary relay A_1 are steady compared with the fluctuating speech waves. They will cause the contacts 76 of that relay to be maintained closed long enough to cause such operation of auxiliary relay A_4 that its contacts 69 will remain open for a sufficient length of time to enable relay A_3 to release to open its contacts 60. The opening of the contacts 60 will break the energizing circuit for winding 56 of master relay

M_1 and winding 57 of master relay M_2 , thus removing the normal back bias from these relays. The removal of the back bias from the relays M_1 and M_2 in response to the noise waves in the manner pointed out will cause the relays M_1 and M_2 to be made sufficiently less sensitive so as just not to be falsely operated by the noise impressed on their operating windings, while still being responsive to the impressed speech waves. Increased noise on a telephone line will generally permit operation of the suppressor relays at reduced sensitivity due to the fact that the talkers tend to raise their voices to get through the noise and due to the masking effect of the noise on the weak echoes.

A part of the noise which is present in the output of amplifier 3 in the transmission path WA at the time speech waves are being transmitted over the path EA, and which according to our assumption is of less magnitude than the noise on path EA, will be diverted into the control circuit 9 causing the operation of the wave-controlled, relay-controlled device 10 to energize the operating windings 12 and 11 of the auxiliary relay A_2 and the master echo suppressor relay M_2 , respectively. The energization of the winding 11 of master relay M_2 by the noise waves will not cause operation of the relay M_2 because it has been readjusted by operation of A_1 to be inoperative by noise. Auxiliary relay A_2 , which is more sensitive than master relay M_2 , may operate to close its normally opened contacts 77 causing a circuit extending from ground through battery 74, resistance 75, winding 71 of relay A_4 and contact 77 of relay A_2 to ground, to be set up. This, however, will have no effect on the relay A_4 as that relay has already been operated to close its contacts 67 in response to the previous operation of relay A_1 closing an energizing circuit for the winding 71 of relay A_4 through contacts 76 of relay A_1 . The reduction in the sensitivity in the master echo suppressor relays M_1 and M_2 has been controlled, therefore by the greater noise on the path EA alone. If, however, the noise on the transmission path WA had been greater than the noise on the transmission path EA the auxiliary relay A_2 would have been responsive thereto to cause the operation of relay A_4 and the release of relay A_3 to remove the normal back bias and thus to decrease the sensitivity of these relays in a manner similar to that described in connection with relay A_1 .

When the transmission of speech waves over path EA ceases, the wave-controlled, relay-controlling device 6 in control circuit 5 connected thereto, will release its energization due to speech but retain that due to noise, partially deenergizing the operating windings 7 and 8 of master relay M_1 and auxiliary relay A_1 , respectively. Relay M_1 will release but A_1 will remain operated by

noise, if it is sufficiently high. The contacts 31 of relay M_1 will then return to their normally closed condition causing the operating winding 26 of holdover relay HO_1 to be again short-circuited. The contacts 41 of relay M_1 will simultaneously return to their normally opened condition thus breaking the energizing circuit for holdover winding 27 of relay HO_1 . The condenser 49 which has been charged up during the energization of winding 27 by current from battery 42 will then start to discharge slowly through winding 27 and resistance 43 maintaining the winding 27 energized for the additional holdover period defined above which is determined by the value of the condenser 49 and the value of the resistance 43. Relay HO_1 will therefore remain operated for that additional period. Therefore, the short-circuiting connection 14 across the outgoing portion of the path WA will remain closed, and the energizing of the operating winding 29 of the relay HO_2 by false operation of relay M_2 , by the continued open condition of the contacts 40 of relay HO_2 , is prevented, for the same interval of time. At the end of this holdover interval of time, the relay HO_1 will release closing contacts 40 and opening contacts 18. The opening of contacts 18 of relay HO_1 deenergizes the relay S_1 causing the short-circuiting connection across the transmission path WA at the points 15 to be broken by the opening of the contacts 13 in the connection 14. The closing of the contacts 40 removes the break in the energizing circuit for the operating winding 29 of relay HO_2 thus returning that relay to the condition where it may be operated under control of master echo suppressor relay M_2 .

In the manner which has just been described, the combinations of relays shown in the drawings operate, when there is noise present in either the transmission path EA or the transmission path WA, or both to reduce in one step the sensitivity of the relays of both master relays M_1 and M_2 to the point where they will just not be operated by impressed noise corresponding in magnitude to that on the transmission path on which it is a maximum. The effect of the control circuits upon sensitivity is not additive but the sensitivity is determined by whichever control circuit receives the maximum amount of noise. The sensitivity of both sides of the echo suppressor are reduced simultaneously and by the same amount, thereby preventing false operation.

It is apparent, of course, that a closer approximation of continuous variation of the sensitivity of the master echo suppressor relays with noise could be obtained by using additional relays to cause the sensitivity to be changed in small steps. This may be obtained, as shown in Fig. 2, by providing

additional steps in back bias on the master echo suppressor relays M_1 and M_2 controlled by a set of auxiliary relays A_1' to A_4' corresponding to auxiliary relays A_1 to A_4 in the circuit which has just been described, each set of relays having the required design to produce a different proportion of the reduction in the sensitivity of the master echo suppressor relays. In Fig. 2, the relays A_1' to A_4' are identical with the relays A_1 to A_4 except that by suitable choice of the biasing elements, the relay A_1' is made less sensitive than relay A_1 and relay A_2' is made less sensitive than relay A_2 . The elements of relays A_1' to A_4' corresponding to those of relays A_1 to A_4 respectively are identified in Fig. 2 with the same reference characters identifying the elements of the latter relays but followed by a prime (') mark.

The operating winding 8' of auxiliary relay A_1' is connected in series with the operating winding 8 of relay A_1 and the operating winding 7 of the master relay M_1 across the output of the amplifier-rectifier 6 in control circuit 5. Similarly, the operating winding 12' of auxiliary relay A_2' is connected in series with the operating winding 12 of auxiliary relay A_2 and the operating winding 11 of master relay M_2 across the output of the amplifier-rectifier 10 in control circuit 9.

The biasing winding 70' of relay A_1' is energized in series with the biasing winding 70 of relay A_1 by current from battery 72 through resistance 73. The operating winding 71' of relay A_1' is arranged to be energized by current from the battery 74' through resistance 75' when either the normally open contacts 76' of auxiliary relay A_1' or the normally open contacts 77' of relay A_2' are closed by operation of the respective relays.

The biasing winding 61' of auxiliary relay A_3' in series with the biasing winding 61 of auxiliary relay A_3 is energized by current from battery 63 through the resistance 64. The operating winding 62' of relay A_3' is normally energized by current from the battery 65' over a path extending from ground through battery 65', resistance 66', winding 62' and the normally closed contacts 69' of the auxiliary relay A_4' to ground, so as to hold the relay contacts 60' of relay A_3' closed. Similarly, the operating winding 62 of relay A_3 is normally energized by current from the battery 65 over a path extending from ground through battery 65, resistance 66, winding 62 and the normally closed contacts 69 of the auxiliary relay A_4 to ground, so as to hold the relay contacts 60 of relay A_3 closed.

As in Fig. 1, the biasing winding 51 of master echo suppressor relay M_1 is maintained energized at all times by current from the battery 52 through the resistance

52' so that the relay would operate in the least sensitive condition were it not for winding 56, and the biasing winding 54 of master relay M_2 is maintained energized at all times by current from the battery 55 through the resistance 55' so that the master relay M_2 would operate in the least sensitive condition, were it not for winding 57. The third winding 56 of relay M_1 so wound as to oppose the action of the operating winding 7 thereof, and the third winding 57 of relay M_2 so wound as to oppose the action of the operating winding 11 thereof, are normally energized in series by current from battery 58 over a path extending from ground through battery 58, resistance 59, winding 57 of relay M_2 , winding 56 of relay M_1 , normally closed contacts 60' of relay A_3' and normally closed contacts 60 of relay A_3 to ground, thus applying back bias to these relays opposing the normal bias produced by the biasing windings 51 and 54 of the respective relays. The values of the elements in this series circuit are so chosen that the amount of back bias normally applied is the same for each master relay, and sufficient to allow the relays M_1 and M_2 to operate in their most sensitive condition.

The sensitivities of the auxiliary relays A_1 , A_2 are adjusted by proper choice of the elements in their circuits so that each relay will operate to close and maintain closed its contacts 76, 77 respectively whenever the amount of noise impressed on its operating winding 8 or 11 from the output of the associated amplifier-rectifier device 6 or 10 exceeds a given low value. Also, the sensitivities of the auxiliary relay A_1' , A_2' are respectively adjusted so that each relay will operate to close its contacts 76' or 77' whenever the amount of noise impressed upon its operating winding 8' or 11', exceeds a given higher value. Let it be supposed that noise is present on the path EA in sufficient amount so that when it is amplified and rectified by the amplifier-rectifier device 6 in control circuit 5, it will cause the operation of relay A_1 but not the operation of relay A_1' . This will start the chain of operations, as described above in connection with Fig. 1, culminating in the release of the relay A_3 to open its normally closed contacts 60. The opening of contacts 60 will remove the normal short circuit around the resistance 90, thus connecting that resistance 90 in the energizing circuit for the third windings 56 and 57 of the master relays M_1 and M_2 , respectively, the energizing circuit for these windings now extending from ground through battery 58, resistance 59, winding 57 of relay M_2 , winding 56 of relay M_1 , normally closed contacts 60' of relay A_3' and resistance 90 to ground. The value of the resistance 90 is so selected that the amount of back bias removed from the re-

lays M_1 and M_2 by its inclusion in the energizing circuit for their third windings is just sufficient to prevent operation of the latter relays by the noise waves of said given lower amount impressed on their operating windings while allowing operation by the speech waves whenever speech overrides the noise.

Now let it be supposed that the amount of noise impressed from the output of the amplifier-rectifier 6 in control circuit 5 on the series circuit comprising the operating winding 7 of relay M_1 , the operating winding 8 of auxiliary relay A_1 and operating winding 8' of auxiliary relay A_1' increases to such value as will cause the operation of relay A_1' in addition to the relay A_1 , so as to cause the contacts 76' of relay A_1' to close. This will start the chain of operations culminating in the opening of normally closed contacts 60' of auxiliary relay A_3' through the operation of relay A_1' and the consequent release of relay A_3' .

The opening of contacts 60' of auxiliary relay A_3' will remove the normal short circuit around resistance 90 causing the resistance 90' to be connected in the energizing circuit for the third windings 56 and 57 of relays M_1 and M_2 respectively, in series with the resistance 90', the energizing circuit for these windings now extending from ground through battery 58, resistance 59, winding 57 of relay M_2 , winding 56 of relay M_1 , resistance 90' and resistance 90 to ground. The value of the resistance 90' is so selected that its inclusion in the energizing circuit for the third windings of relays M_1 and M_2 in series with the resistance 90, will cause the amount of back bias removed from the relays M_1 and M_2 to be just sufficient so that these relays will not be operated by said greater amount of noise impressed upon their operating windings. By using additional chains of relays corresponding to relays A_1' to A_4' and additional resistances corresponding to resistances 90' and 90 and connected in similar manner, it may be seen that the sensitivity of the master relays M_1 and M_2 may be changed in still smaller steps so as to obtain a closer approximation of continuous variation in sensitivity with the amount of noise.

The auxiliary relays A_4 , A_4' may be dispensed with in systems not subject to noises of the type for which those relays were provided, that is, noises which have pronounced low frequency components. If the relays A_4 , A_4' are not used, the windings of the auxiliary relay A_3 would be controlled directly from the contacts of the auxiliary relay A_1 or A_2 , and the windings of the auxiliary relay A_3' would be controlled directly from the contacts of the auxiliary relays A_1' or A_2' .

In the system of the invention which has been illustrated and described, an additional

one-way amplifying device (2 or 4) is connected in each transmission path between the input of the associated control circuit (5 or 9) and the blocking points (21 or 15) in that path. These one-way devices besides providing additional amplification in the transmission paths, are utilized also for the purpose of preventing the short-circuiting of the outgoing portion of each path under control of the echo suppressor connected to the oppositely directed transmission path from affecting the input to the echo suppressor associated with the first path. This can be accomplished in other ways, for example, by associating the output of the first amplifying device in each path (1 or 3) with the input of the associated control circuit and the outgoing portion of the same path through a hybrid coil transformer and associated balancing network, or through a special bridge transformer network such as is disclosed in the copending application of B. G. Björnson, Serial No. 471,520, filed July 29, 1930. Other modifications of the circuits which have been illustrated may be made by persons skilled in the art without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. In a two-way signal transmission system, two one-way signal transmission paths for transmitting the signals in opposite directions in said system, means connected to each path and responsive to signal transmission therein effectively to disable the other path, and means for varying the sensitivity of both of said disabling means to operation in accordance with the amount of noise in the particular one of said paths in which the noise is a maximum so as to maintain at all times said disabling means in the most sensitive condition possible as regards operation by signals while preventing false operation by noise.

2. In a two-way signal transmission system, two one-way signal transmission paths subject to disturbing noise, means connected to each of said paths and responsive to signal transmission therein effectively to disable the other path, means for preventing false operation of either of the disabling means by the noise transmitted over said paths, and means responsive to the noise on the transmission path on which the noise is a maximum to vary the sensitivity of both disabling means.

3. In a system for suppressing echoes in a two-way signal transmission circuit comprising one-way paths for transmitting signals in opposite directions, a control device, connected to each of said one-way paths and responsive to waves transmitted thereover, relay means controlled by the device connected to each path and adapted to disable effectively the oppositely directed path, and

means responsive to the noise on the path only in which it is a maximum, to reduce the operating sensitivity of both of said relay means so as to prevent false operation by noise.

means controlled by operation of said third relay to vary the sensitivity of said controlling means in accordance with the level of the noise on said one path.

4. The system of claim 3 and in which the last-mentioned means comprises means for varying the sensitivity of both relay means simultaneously and by the same amount.

11. In a system for suppressing echoes in a two-way signal transmission system comprising one-way paths for transmitting signals in opposite directions, a wave-controlled, relay-controlling device connected to each path and operating in response to waves transmitted thereover, means controlled by operation of said device to disable effectively the oppositely directed one-way path, and means for preventing at all times operation of said disabling means by noise while reducing its sensitivity to operation in accordance with the level of noise in said paths, said means comprising a noise master relay in the output of each relay-controlling device and adapted to operate whenever the noise on the associated path rises above a certain level, a second relay adapted to be operated by operation of either noise master relay, and having a given holdover in its time of operation, a third relay adapted to be operated if said second relay remains operated for a predetermined length of time, and means controlled by operation of said third relay to reduce the sensitivity of both disabling means to operation.

5. The system of claim 3 and in which the last-mentioned means is designed to be inoperative by speech waves.

In witness whereof, we hereunto subscribe our names this 9th day of September, 1930.

6. The system of claim 3 and in which the last-mentioned means comprises a chain of relays operated in sequence in response to the noise received from said paths above a certain amplitude level, and having different operating and holdover times determined by the type of noise against which protection is desired, to apply biasing potentials to windings of said relay means to reduce their sensitivity so as to prevent false operation by said noise.

7. The system of claim 3 in which last-mentioned means comprises a plurality of relays of different operating sensitivities, responsive to the noise received from said paths to provide successive steps of reduction of the sensitivity of said relay means as the amount of said noise increases to maintain said relay means at maximum sensitivity as regards operation by speech at all times while preventing operation by said noise.

8. The system of claim 3 and in which the last-mentioned means comprises a chain of relays operated in sequence in response to noise waves received from said paths to bias said relay means so as to vary their sensitivity in accordance with the amplitude of said noise waves.

9. The system of claim 3 and in which the last-mentioned means comprises a chain of relays operated in sequence in response to noise waves received from said paths to bias said relay means so as to vary their sensitivity in accordance with the amplitude of said noise waves, said relays having such operating and holdover times as to prevent operation of the last relay in the chain by said signals.

10. In combination, means connected to one signal transmission path and responsive to signals transmitted thereover for controlling the transmitting efficiency of another transmission path, and means for controlling the sensitivity of said controlling means in accordance with the level of noise on said one path comprising a noise master relay connected to said one path and adapted to be operated whenever the noise level therein exceeds a certain level, a second relay adapted to be operated by operation of said master relay and having a given holdover operation time, a third relay adapted to be operated when said second relay is maintained continuously operated for a predetermined time, and

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