July 3, 1945. K. G. VAN WYNEN 2,379,768

TRANSMISSION CONTROL IN TWO-WAY SIGNALING SYSTEM

Filed Oct. 1, 1942 3 Sheets-Sheet 1

FIG. 1

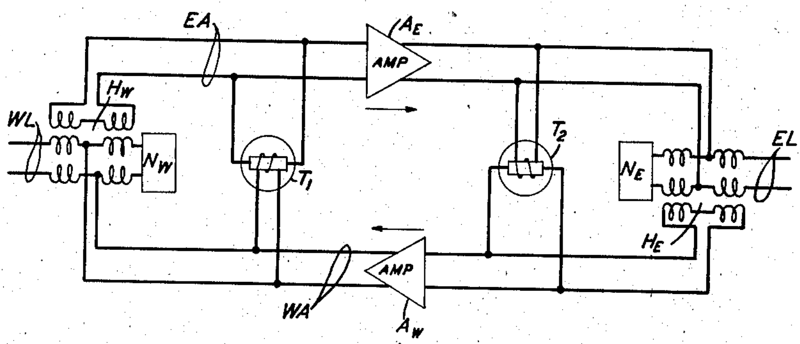

FIG. 2

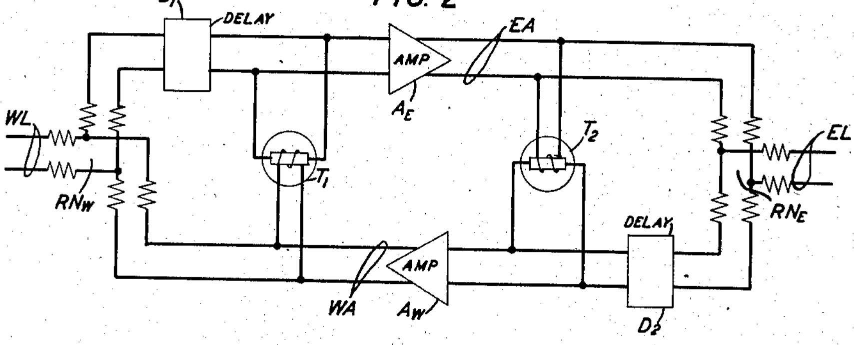

FIG. 3

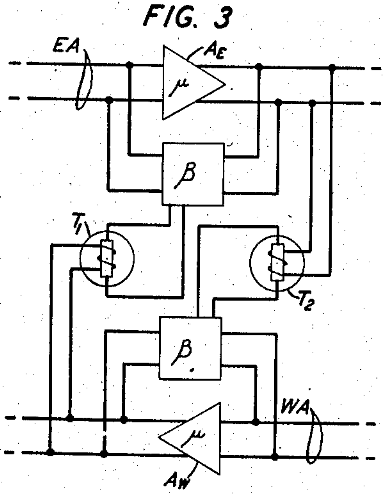

FIG. 4

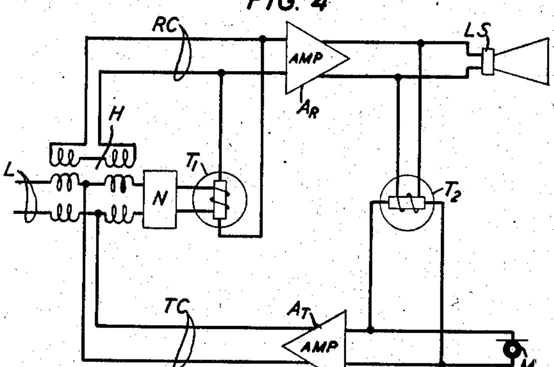

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FIG. 5

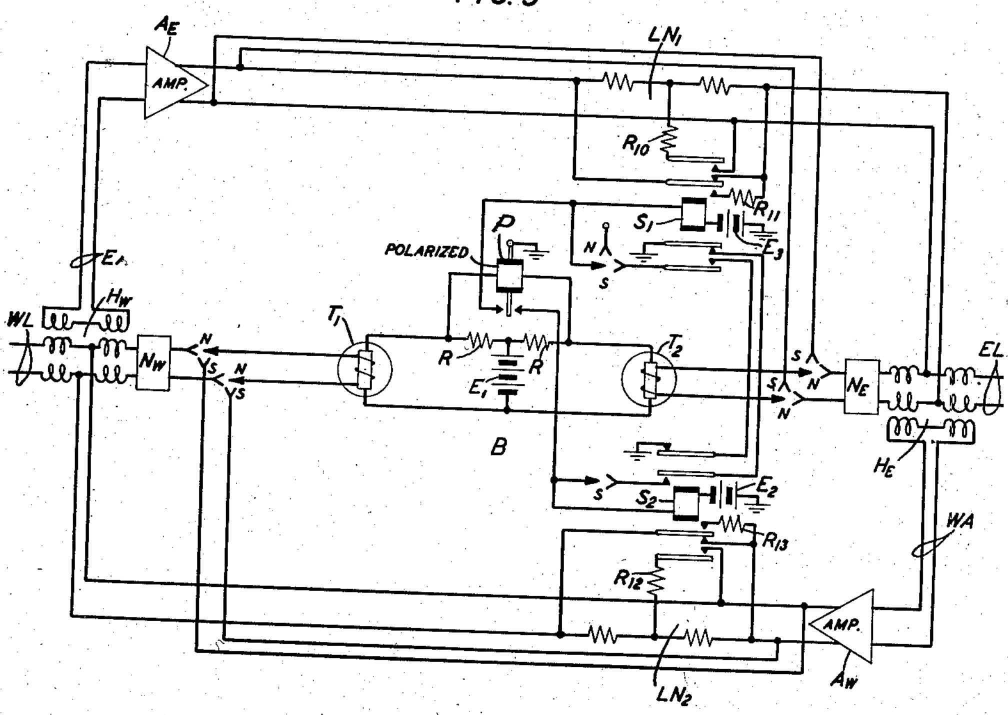

FIG. 5A

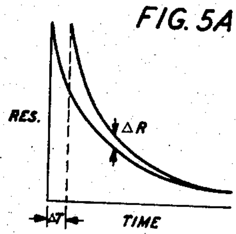

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FIG. 6

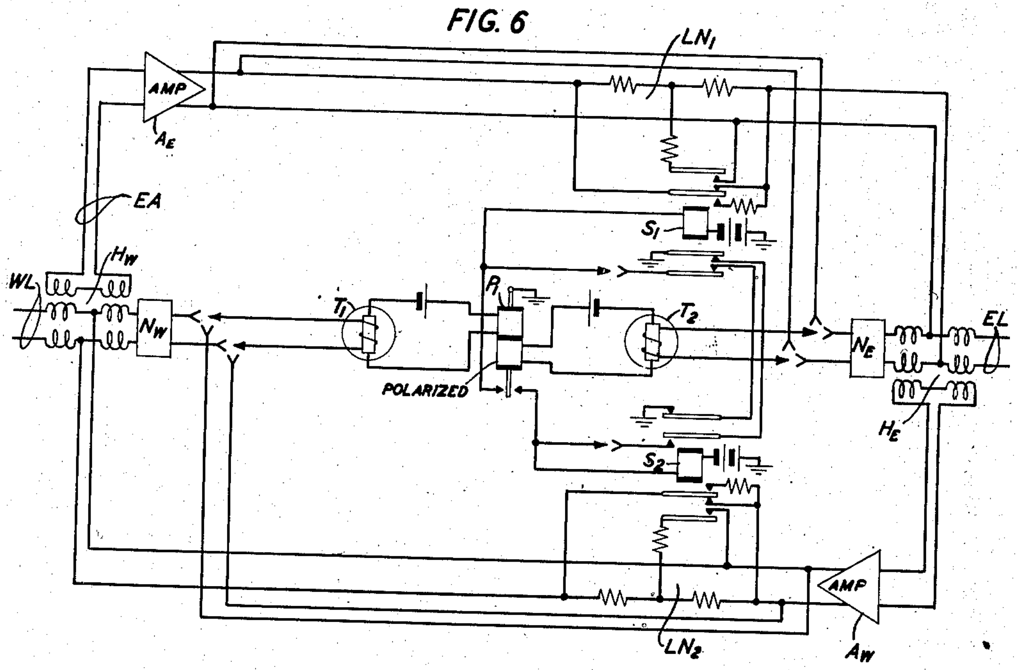
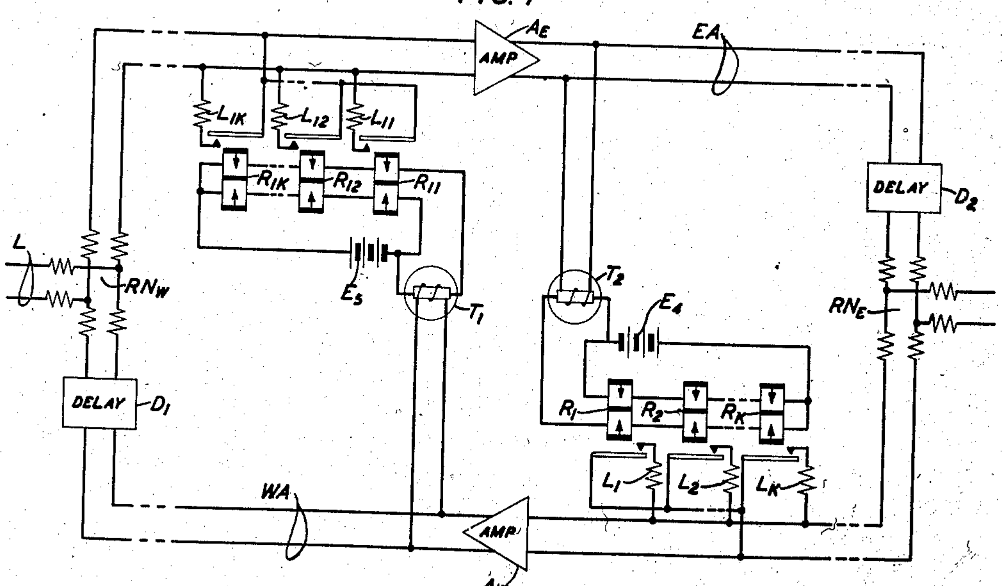


FIG. 7



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TRANSMISSION CONTROL IN TWO-WAY SIGNALING SYSTEM

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Application October 1, 1942, Serial No. 460,374

8 Claims. (Cl. 178—44)

This invention relates to two-way telephone systems, and particularly to circuits for directionally controlling signal transmission in such systems while suppressing echoes and preventing singing.

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

A more specific object is to improve the singing margin and reduce echoes in two-way telephone repeater circuits.

These objects are attained in accordance with the invention by the application of thermistors to a two-way telephone repeater in such manner as to increase the loss in the singing path thereby enabling a greater reduction in the amount of echo for a given amount of amplification, or increased amplification for a given amount of echo to be attained. This is accomplished in accordance with one embodiment of the invention by using a portion of the signal output energy of the amplifier in each repeating path to heat a thermistor element connected in the input of the amplifier in the oppositely directed repeating path so as to insert additional loss in the latter path.

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:

Figs. 1 to 7 show schematically telephone repeater circuits employing different modifications of the invention; and

Fig. 5A shows curves illustrating the operation of the modification shown in Fig. 5.

The telephone repeater circuit of Fig. 1 includes a two-wire, one-way transmission path EA including the one-way amplifier A_E, for transmitting signals in the direction from west to east between a west two-way line WL and an east two-way line EL, and a two-wire, one-way transmission path WA including the one-way amplifier A_W, for transmitting telephone signals in the direction from east to west between the same two-way lines. The input of the path EA and the output of the path WA are coupled in conjugate relation with each other and in energy transmitting relation with the two-way line WL by the hybrid coil H_W and associated line balancing network N_W, and the output of the path EA and the input of the path WA are coupled in conjugate relation with each other and in energy transmitting relation with the line EL by the hybrid coil H_E and associated line balancing network N_E. Without auxiliary equipment, proper operation of this circuit requires that the sum of the losses across the two hybrid coils, L_E+L_W, together with any loss in the conductors must be greater than the sum of the gain in the amplifiers A_E and A_W.

In accordance with the invention the two thermistors T_1 and T_2 are applied to this circuit. Each thermistor consists of an element the electrical resistance of which decreases rapidly when its temperature is increased above a given value and a heating element electrically isolated from the resistance element. The heating element of the thermistor T_1 is bridged across the output of the amplifier A_W in the path WA and its variable resistance element is bridged across the input of the oppositely directed amplifier A_E in the path EA. The heating element of the thermistor T_2 is bridged across the output of the amplifier A_E in the path EA and its variable resistance element is bridged across the input of the amplifier A_W in the path WA.

Now, when speech waves from a west subscriber associated with the line WL are impressed on the hybrid coil H_W, they will be divided by it in a predetermined ratio (which is usually 1:1), part going into the path EA directed towards the listener associated with the east line EL and the other part into the path WA directed towards the talker associated with the line WL. The portion of the west talker's speech energy passing into the output of the path WA will be dissipated in the output of amplifier A_W. A portion of this energy will be impressed as heating current upon the heating element of the thermistor T_1, but with proper design of the thermistor will be of insufficient level to raise the temperature of its variable resistance element appreciably, so that the loss in the input of the amplifier A_E in the path EA remains low. The other portion of the west talker's speech energy passing into the path EA will be amplified by the amplifier A_E and transmitted over that path and line EL to the east subscriber. Since the amplifier A_E has a high gain, the high amplitude level of the portion of its output applied to the heating element of the thermistor T_2 will heat its variable resistance element sufficiently to reduce its resistance to a low value, thereby inserting a large loss into the input of the amplifier A_W in the path WA.

Since the magnitude of the echo returned to the west talker through hybrid coil H_E and the path WA depends, among other factors, upon the loss L_E across the hybrid coil H_E, the loss inserted into the input of the path WA by thermistor T_2 acts as an increase in L_E and, therefore, decreases the magnitude of this echo. Since the thermistor loss is also in the singing circuit, an alternate use would be to provide a corresponding increase in gain in the amplifier A_E to reduce the over-all equivalent from talker to listener. The echo then would remain the same as before the application of the thermistor.

Similarly, when speech waves from the east talker associated with the line EL are impressed upon the hybrid coil H_E, they will be divided by it in a predetermined ratio, part going into the path WA directed to the listener and the other part into the path EA directed toward the talker. The portion of east's speech energy passing into the output of the path EA will be dissipated in the output of amplifier A_E. The portion of that energy impressed as heating current upon the heating element of the thermistor T_2, if that thermistor is properly designed, will be of insufficient level to cause an appreciable reduction in the resistance of its variable resistance element so that the loss in the input of the amplifier A_W will remain low. The main portion of the east talker's speech energy in the path EA will be amplified by amplifier A_W and will pass through hybrid coil H_W and line WL to the east subscriber. Since the amplifier A_W in the path WA has a high gain, the portion of the east talker's speech energy in the output of that amplifier applied to the heating element of the thermistor T_1 will cause sufficient heating of its variable resistance element to decrease the resistance shunting the input of amplifier A_E to a low value and thus insert a large loss into the input of the path EA.

The circuit arrangement of Fig. 2 is similar to that of Fig. 1 except that the hybrid coils H_W and H_E and their associated balancing networks N_W and N_E have been replaced with three-branch resistance networks RN_W and RN_E, respectively, and the delay networks D_1 and D_2 have been inserted in the input of the paths EA and WA, respectively. Now, when speech waves from the west talker associated with the line WL are impressed on the resistance network R_W, half will then enter the output of the path WA and will be dissipated in the output of the amplifier A_W, the level of the portion of these speech waves applied to the heating element of thermistor T_1 being insufficient to cause operation of that thermistor to insert loss into the path EA. The speech waves entering the path EA will pass through the delay circuit D_1 and will be amplified by the amplifier A_E. The amplified energy delivered to the resistance network RN_E will divide equally between the line EL leading to the east subscriber and the input of the path WA where it passes through the delay circuit D_2. A portion of the amplified speech waves in the output of the amplifier A_E in the path EA will be applied to the heating element of the thermistor T_2 heating it sufficiently to cause an appreciable reduction in the resistance shunting the path WA in the input of the amplifier A_W, thereby inserting a large loss in that path. Due to the delay in the delay circuit D_2, the thermistor T_2 acts to place the low resistance across the input of amplifier A_W before the echo waves arrive at that point, thereby effectively reducing them when they do arrive.

There are two possible ways in which the thermistor T_2 or T_1 may affect the circuit operation. If the resistance of T_2 or T_1 is so low that the loss inserted by it is considerably greater than the sum of the gains of the amplifiers A_W and A_E, than the circuit operates essentially as a one-way amplifier pointed from talker to listener. If the resistance of T_2 or T_1 is such that the inserted losses are less than the sum of the two amplifier gains, then the circuit will have the configuration of a feedback amplifier in which T_2 and the amplifier A_W, or T_1 and the amplifier A_E, combine to appear as a loss in the β circuit. Converting this circuit configuration to that of a feedback amplifier would, of course, require meticulous care in design and would be limited by the performance of thermistors T_1 and T_2, the impedances looking towards the talker and the listener, and the delay circuits D_1 and D_2.

Such circuits as that of Fig. 2 would tend to be unstable when not in use. However, there would be a definite limit to the level of oscillations since both thermistors would operate as soon as the level increases sufficiently. When a signal is applied by the talker this oscillation would be broken since the thermistor T_2 or T_1 controlled from the output of the amplifier in the talking path goes to a still lower resistance, thereby taking control and conditioning the circuit for transmission in one direction only.

In the arrangements of the invention in Figs. 1 and 2, the thermistors have been so applied as to produce a shunting effect on a voice transmission path when supplied with sufficient heating energy from the other voice transmission path. An equivalent effect could, of course, be obtained by applying the thermistors at other places in the circuit. For example, as shown in Fig. 3, if the amplifier A_E in the path EA and the amplifier A_W in the path WA are feedback amplifiers, the variable resistance elements of the thermistors T_1 and T_2 could be respectively inserted in the β path of the amplifiers A_E and A_W, so as to effectively lower the feedback and thus the gain of the associated amplifier when the thermistor is heated by the speech output of the other amplifier.

Fig. 4 shows a modified arrangement in accordance with the invention applied to a two-way loud-speaking telephone set in which a transmitting circuit TC including the microphone M and the transmitting amplifier A_T, and the receiving circuit RC including the receiving amplifier A_R and the loud-speaker LS, are coupled to the two-way line L by the hybrid coil H and associated line network N, and are also coupled to each other by the acoustic path between loud-speaker LS and microphone M. One limitation in the use of such a loud-speaking telephone set lies in the reverberation of the room in which the loud-speaker and microphone are located. In this circuit, the heating element of the thermistor T_1 constitutes a part of the balancing network N and absorbs some predetermined portion of the energy impressed on the hybrid coil H from the transmitting circuit TC, which is ordinarily absorbed by the network N, and the variable resistance element of that thermistor is bridged across the input of the receiving amplifier A_R. The heating element of the thermistor T_2 is bridged across the output of the amplifier A_R which drives the loud-speaker LS, and the variable resistance element of that thermistor is connected across the transmitting circuit TC between the microphone M and the transmitting amplifier A_T. Then, if speech waves are received over the line L and are impressed by hybrid coil H on the receiving circuit RC, the amplified speech waves in the output of the amplifier A_R will heat the thermistor T_2 to insert a loss in the microphone circuit. This, in turn, reduces the amplitude of the waves transmitted back over the circuit TC and the line L to the talker, due to the acoustic feedback from the loud-speaker LS to the microphone M. This returned speech (echo) from a reverberant room is very disturbing to the talker and, therefore, any reduction which the thermistor T_2 provides will increase the usefulness of this loud-speaking telephone circuit.

When the microphone M is activated by the speech of a local talker, the amplified speech waves in the output of amplifier A_T transmitted through hybrid coil H to balancing network N and the associated heating element of the thermistor T_1, will activate the latter to insert a large loss in the input of the receiving amplifier A_R thereby effectively reducing the acoustic sidetone, which benefits both the talker at the microphone and the listener at the far end of the line.

Fig. 5 shows a modified arrangement in accordance with the invention operating to provide a differential echo suppressor. Fig. 5 includes a four-wire repeating circuit like that of Fig. 1 as indicated by the use of the same identification characters for corresponding component elements. The heating elements of the thermistors T_1 and T_2, respectively, constitute part of the line balancing network N_W and of the balancing network N_E, and absorb some predetermined portion of the energy ordinarily absorbed by these networks from the transmission received over the paths WA and EA, respectively. The variable resistance elements of the thermistors T_1 and T_2 are arms of the resistance bridge B whose fixed arms are the equal resistances R, and which is energized by the battery E_1 connected across one diagonal of the bridge. The winding of a polarized relay P is connected across the other diagonal of the bridge, this relay when operated in one direction causing the operation of the switching relay S_1 and when operated in the other direction causing the operation of a switching relay S_2. The relays S_1 and S_2, respectively, control the loss values of the unbalanced 600-ohm bridged-T loss networks LN_1 including the resistance elements R_{10} and R_{11}, and LN_2, including resistance elements R_{12} and R_{13}, in the output of the amplifier A_E in the path EA and in the output of the amplifier A_W in the path WA, respectively. With relays S_1 and S_2 in their normal unoperated condition, with bridge B balanced, the networks LN_1 and LN_2 are effectively removed from the paths EA and WA, respectively, and the transmission efficiencies of these paths are high.

Two alternative wiring arrangements are indicated by the character N and S, respectively.

Considering the N wiring, speech waves from a west subscriber incoming over the line WL pass through the hybrid coil H_W and over the path EA to the hybrid coil H_E, being amplified by the amplifier A_E en route. A portion of these waves pass through hybrid coil H_E to line EL and over that line to the east subscriber. Another portion of these speech waves pass through the hybrid coil H_E into the network N_E causing heating of the thermistor T_2 to thereby reduce the resistance of its variable resistance portion in bridge B. A portion of the west subscriber's speech waves will be reflected at hybrid coil H_E into the path WA and with the amplification provided by the gain setting of the amplifier A_W will pass over the path WA to the hybrid coil H_W where part will enter the network N_W and thus supply heating current to the associated thermistor T_1 causing the resistance value of T_1 to be reduced. Since, however, there is less energy in the thermistor T_1 than in the thermistor T_2, by the amount of the return loss at H_E, the thermistor T_2 will be converted to a lower resistance than the thermistor T_1. Hence the bridge B will be unbalanced in such manner that the polarized relay P operates to its right-hand contact connecting ground to the winding of switching relay S_2 and causing the latter relay to be operated from battery E_2. The operation of relay S_2 will connect resistances including resistances R_{12} and R_{13} into the bridged-T loss network LN_2 thereby inserting a high loss into the path WA in the output of the amplifier A_W. This high loss in WA will cause a reduction in the magnitude of the echoes of west's speech waves returned over that path. When the speech waves received from the west subscriber over the line WL cease, the consequent removal of heating current from the thermistors T_1 and T_2 will cause the bridge B to be balanced, and, therefore, the polarized relay P and the switching relay S_2 to fall back so as effectively to remove the network LN_2 from the path WA.

When speech waves are received over the line EL from an east subscriber, and at that time the west subscriber associated with the line WL is not talking, part of east's speech waves pass through the hybrid coil H_E into the path WA and pass over that path with the amplification provided by the amplifier A_W to the hybrid coil H_W. A portion of these speech waves will pass into the line WL and will pass over that line to the west subscriber. Another portion of these waves will pass through the hybrid coil H_W into the network N_W and will cause heating of the associated thermistor T_1 to reduce its resistance. Another portion of the speech waves will be reflected at the hybrid coil H_W and will return as echoes over the path EA with an amplification provided by the amplifier A_E to the hybrid coil H_E where part of it will enter the network N_E and thus the heating element of the thermistor T_2 causing the resistance of that thermistor to be reduced. Because of the return loss at the hybrid coil H_W, the resistance of thermistor T_1 will be lower than that of the thermistor T_2, so that the bridge B will be unbalanced in the opposite direction causing the operation of the polarized relay P to its left-hand contact. This will cause ground to be supplied to the winding of the switching relay S_1 completing an energizing circuit for that relay from battery E_3. The consequent operation of the relay S_1 will connect the resistances R_{10} and R_{11} into the bridged-T loss network LN_1 thereby placing a loss in the path EA which will reduce the magnitude of echo of east's speech currents returned over the path EA. When East ceases talking, the consequent removal of the heating current from the thermistors T_1 and T_2 will cause the birdge B to be balanced again and relays P and S_1 to fall back to effectively remove the loss network LN_1 from the path EA.

It will be noted that when West is talking and has caused operation of the thermistor control arrangement to insert the echo suppressing loss network LN_2 into the path WA, East can cause the loss to be transferred from the east-to-west transmission path WA to the west-to-east path EA by talking at a level greater than West by the amount of loss in the network LN_2 to change the ratio of the resistances of the thermistors T_1 and T_2 so as to unbalance the bridge B in the proper direction to operate the polarized relay P to its left-hand contact. This will cause the release of relay S_2 to remove network LN_2 from WA and the operation of S_1 to insert network LN_1 in EA.

Similarly, when East has directional control of the circuit, West can obtain control by talking louder than East by the amount of loss in the loss network LN_1 then inserted in the path EA. The operation and release of the relay P will be delayed for the time required for the thermistor to heat and cool.

If the hybrid coils H_E and H_W are remote from each other as in the case of a four-wire repeater, wiring S would be employed, in which case the amplifiers A_E and A_W are assumed close to each other. The action of the thermistors T_1 and T_2 in the case of S wiring is similar to that just described for the N wiring except that the heating energy for the two thermistors is then derived directly from the outputs of the amplifier in the path WA and EA, respectively, at a point in front of the inserted loss pads LN_2 and LN_1 instead of from the net side of hybrid coils. In this case, when the relay S_2 or S_1 operates in response to operation of the polarized relay P to its right-hand or left-hand contact, it locks up through a back contact of the other switching relay S_1 or S_2, thereby keeping the loss in the path WA or EA until such time as East or West, respectively, talks. Since the thermistors derive their heating energy directly from the outputs of the amplifiers and ahead of the inserted loss, and since these are equal level points in the circuit, East can always transfer the loss by talking at a higher level than West.

In the differential action of the thermistors T_2 and T_1, there are two separate actions possible with the S wiring. One is the differential action due to the return loss across the hybrid coil and the second is the time differential due to the transit time from amplifier A_E through hybrid coil H_E and back to amplifier A_W or from amplifier A_W through hybrid coil H_E and back to amplifier A_E. Now, if the level is the same at the two points there will still be a resistance differential ΔR during the heating time of the thermistors due to the time differential Δt. This is shown by the curves of Fig. 5A in which the resistance variations of the two thermistors are plotted against time. On cooling of the thermistors, the action would be in the reverse direction and might be considered in the nature of an anticipatory action. If this were undesirable, relays S_1 and S_2 could be made to include a slow-operate or release arrangement, in which case the bridge B will return to balance on cooling without transferring the network loss. Ordinarily, this latter feature of time differential would be overshadowed by the level differential.

The circuit arrangement of Fig. 6 is similar to that of Fig. 5 in every respect except for the type of differential action. In Fig. 6, the variable resistance elements of the two thermistors T_1 and T_2 are inserted in series respectively with the two oppositely poled biased windings of the polarized relay P_1, and the differential action is obtained from the magnetic circuit of that relay. The relay P_1 operates to its right-hand contact in response to a greater amount of biasing current supplied to its lower winding than to its upper winding from the associated batteries due to a greater reduction in the resistance of the variable resistance element of the thermistor T_2 having its heating element associated with network N_E, than in the resistance of the variable resistance element of the thermistor T_1 having its heating element associated with the network N_W, when the west subscriber talks first, or talks louder than the east subscriber by an amount equal to the loss value of the resistance loss network LN_1. This will cause the switching relay S_2 to be operated to effectively insert the full loss value of the loss network LN_2 into the path WA to suppress the echoes of West's speech waves and to give directional control of the circuit to West. Similarly, the operation of the polarized relay P_1 to its left-hand contact when the biasing current supplied to the upper winding of that relay is greater than that supplied to the lower winding of the relay due to a greater reduction in the resistance of the variable resistance element of the thermistor T_1 than in the resistance of the variable resistance element of the thermistor T_2, when East starts talking first or talks louder than West by an amount at least equal to the loss value of the loss network LN_2 in the path WA, will cause the operation of the relay S_1 to insert the full loss value of the loss network LN_1 into the path EA to suppress echoes of East's speech waves and to give him directional control of the circuit.

Fig. 7 shows a modified arrangement of the invention which is essentially similar to that shown in Fig. 2 except that relays controlled by the variation of the resistance value of the variable resistance elements of the thermistors T_1 and T_2 are used to insert the required echo suppression loss into the paths EA and WA, respectively.

The relays R_1, R_2 . . . R_K are marginal relays of different sensitivities having their upper (biasing) windings supplied in series with biasing current from battery E_4 and their lower (operating) windings supplied in series with the variable resistance element of thermistor T_2 with operating current also from the battery E_4, the heating element of the thermistor T_2 being connected across the output of the amplifier A_E in the west-to-east transmission path EA. Similarly, relays R_{11}, R_{12} . . . R_{1K} are marginal relays of different sensitivities having their lower (biasing) windings supplied in series with biasing current from the battery E_5 and their upper (operating) windings supplied in series with the variable resistance element of the thermistor T_1 with operating current also from the battery E_5, the heating element of the thermistor T_1 being bridged across the output of the amplifier A_W in the east-to-west transmission path WA. The relays R_1, R_2, R_K are arranged not to operate with the normal bias, but when the resistance of thermistor T_2 is reduced in response to the output waves of the amplifier A_E applied to its heating element, when signal transmission is taking place over the path EA, the increased operating current flowing in series through the operating windings of relays R_1, R_2 . . . R_K first cause the most sensitive relay R_1 to operate to insert the loss L_1 into the transmission path WA in front of amplifier A_W. Further reduction in the resistance of the variable resistance element of thermistor T_2 in response to higher level speech waves supplied to its heating element from the output of amplifier A_E, causes the relay R_2 to operate to insert the loss L_2 into the path WA in front of amplifier A_W, and still further reduction in the resistance of the variable resistance element of thermistor T_2 in response to higher level speech waves applied to its heating element will cause the least sensitive relay R_K to operate to insert the additional loss L_K into the path WA in front of amplifier A_W.

In a similar manner when speech waves are being transmitted over the path WA the amplified waves in the output of the amplifier A_W applied to the heating element of the thermistor T_1 will cause the reduction of its resistance to operate relays R_{11}, R_{12} . . . R_{1K} in turn as the level of the speech current increases to insert the losses L_{11}, L_{12} . . . L_{1K} in the path EA in the input of the amplifier A_E, the total loss inserted being proportional to the level of the east-to-west speech current flowing over the path WA. The loss elements L_1, L_2 . . . L_K and L_{11}, L_{12} . . . L_{1K} may be elements of bridged-T loss networks such as illustrated in Figs. 6 and 7.

As described in connection with the similar repeater of Fig. 2 employing three-branch resistance coupling networks RN_W and RN_E and delay circuits D_1 and D_2, the repeater circuit of Fig. 7 when not in use for transmitting speech waves would be in the condition of stabilized oscillation which would cause certain of the relays R_1 . . . R_K and R_{11} . . . R_{1K} to be operated. The transmission of speech waves in the direction from west to east over the path EA will cause the thermistor T_2 to go to a lower resistance and, therefore, will cause more loss to be inserted in the oppositely directed repeating path WA. The consequent reduced output of the amplifier A_W in the path WA would in turn cause certain relays in the R_{11} . . . R_{1K} chain to fall back removing loss from the path EA and pointing transmission from west to east. The action will be similar in case the east subscriber talks first, the relay chain R_{11} . . . R_{1K} operating to insert the required echo suppression loss in the path EA and the consequent reduced output of the amplifier A_E causing certain relays in the chain R_1 . . . R_K to fall back to remove loss from the path WA and pointing transmission from east to west. By suitably choosing the values of the losses L_1 . . . L_K and L_{11} . . . L_{1K}, the repeater circuit can be made to cease oscillating and become a stable amplifier pointing in one direction at a time when speech is applied. When no speech is applied the circuit returns to oscillation which is not necessarily a severe penalty if the level and frequency are controlled.

In the practical application of the schemes discussed above in connection with Figs. 1, 3 and 4, the variable resistance elements of the thermistors might not be placed directly across the voice transmission paths as illustrated because of the undesirable change in impedance which it would bring about. Preferably, the variable resistance elements of the thermistors would be placed in series with a marginal relay which would in turn insert a loss pad in the transmission path in the manner similar to that illustrated in connection with Fig. 7. It might also be preferable to have the effect introduced by the thermistors on an "either or" basis rather than have both act independently. Various other modifications of the circuits illustrated and described which are within the spirit and scope of the invention will occur to those skilled in the art.

What is claimed is:

1. In a two-way telephone system including two oppositely directed one-way transmission paths for the telephonic signals in opposite directions, each including amplifying means, means to prevent singing and suppress echoes in said system during signal transmission thereover in either direction, comprising two variable resistance devices the resistances of which vary nonlinearly with temperature, means responsive to the amplified signal output of the amplifying means in each of said paths to heat a different one of said variable resistance devices to a temperature which will produce a given change in the resistance thereof, and means responsive to said given change in the resistance of a variable resistance device in response to the amplified signal output of the amplifying means in one path when it is transmitting signals, to effectively insert an appreciable loss in the other path.

2. The system of claim 1, in which each of said variable resistance devices is a thermistor having a variable resistance element and a heating element therefor, the heating element of each thermistor being connected across the output of the amplifying means in a different one of said paths, and the variable resistance element thereof being associated with the other path so as to insert said appreciable loss therein in response to said given change in its resistance.

3. The system of claim 1, in which each of said variable resistance devices is a thermistor having a variable resistance element the resistance of which decreases with temperature, and a heating element therefor, the heating element of each thermistor being connected to the output of the amplifying means in a different one of said paths so as to be heated in accordance with the amplitude level of the amplified signals in that path, and the variable resistance element of that thermistor being connected effectively in shunt with the other path in front of the amplifying means thereon, each thermistor being such that its resistance value will be substantially unaffected by waves applied to the heating element of a level corresponding to signal echoes.

4. The system of claim 1, in which each of said amplifying means comprises a feedback amplifier and each said variable resistance device is a thermistor having a variable resistance element and a heating element therefor, the heating element of each thermistor being connected across the output of the amplifying means in a different one of said paths so as to be heated by the amplified signal output thereof, and the variable resistance element thereof being connected in the feedback path in the amplifier in the other path in such a manner as to reduce the amplifier gain in proportion to the change in its resistance when heated above a given temperature.

5. In combination, in a two-way telephone transmission system, two two-way lines, two oppositely directed one-way signal transmission paths, each including an amplifying means, connecting said lines, and means to prevent singing and to suppress echoes in said system during signal transmission in either direction thereover, comprising two thermistors each consisting of a variable resistance element the resistance of which decreases rapidly when its temperature is increased above a given value, and a heating element therefor electrically isolated from the variable resistance element, the heating element of each thermistor being bridged across the output of the amplifying means in a different one of said paths, and its variable resistance element being associated with the other path in such a manner that when its temperature is increased above said given value an appreciable loss is inserted in said other path, the thermistors being proportioned and the gain of the amplifying means in said paths being selected so that the level of amplified signals applied to a heating element of a ther-

mistor when a path is transmitting signals is sufficient to raise the temperature of its associated variable resistance element above said given value but the level of amplified signal echoes in the non-transmitting path applied to a heating element of a thermistor is insufficient to raise the temperature of the variable resistance element thereof to said given value.

6. The system of claim 5, in which the variable resistance element of each thermistor is placed in series with the operating winding of a relay in a direct current circuit, the increase in current flow in said winding with the reduction in resistance of said variable resistance element when it is heated to said given temperature in response to the amplified signal output of the amplifying means in one path causing operation of said relay to insert said appreciable loss in said other path.

7. The system of claim 5, in which the variable resistance elements of the two thermistors are respectively included in a different arm of a balanced bridge circuit, and the unbalance of said bridge circuit when the resistance of the variable resistance element in one arm is substantially reduced with respect to that of the variable resistance in the other arm when one path is transmitting direct signals and the other is not, causes said appreciable loss to be inserted in said other path.

8. The system of claim 5, in which said transmission paths are coupled in conjugate relation with each other and in energy transmitting relation with one of said two-way lines by a hybrid coil and associated line balancing network, the heating current supplied to the heating element of each thermistor being derived from the signal current fed into a different one of the networks when the path connected thereto is transmitting direct signals, and the variable resistance elements of the two thermistors are connected in a differential circuit, the unbalance in said differential circuit when one of said variable impedance elements is heated above said given temperature and the other below said given temprature in response to direct signal transmission in one path only causing said appreciable loss to be inserted in said other path.

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