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TRANSMISSION CONTROL IN SIGNALING SYSTEMS

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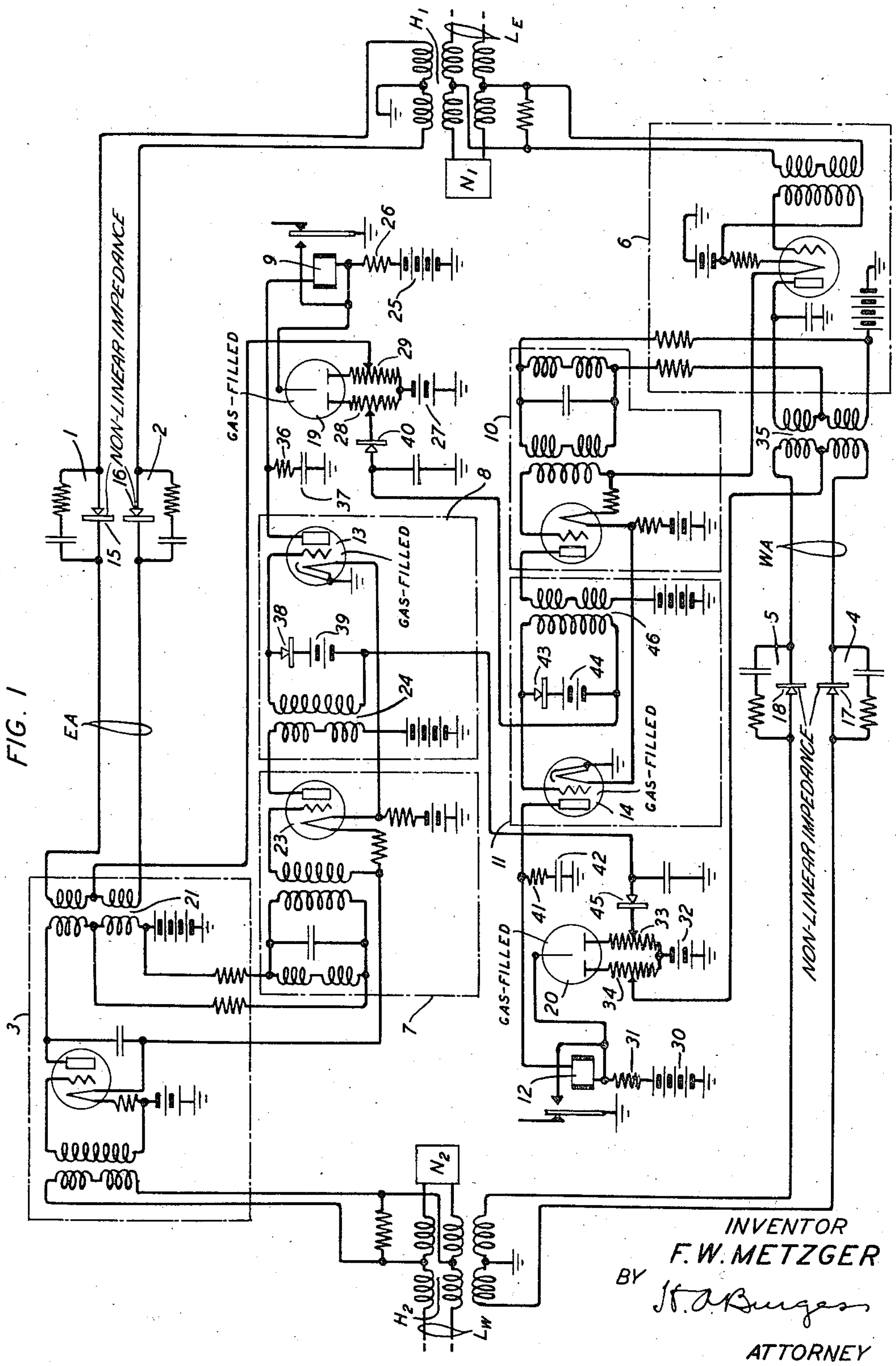

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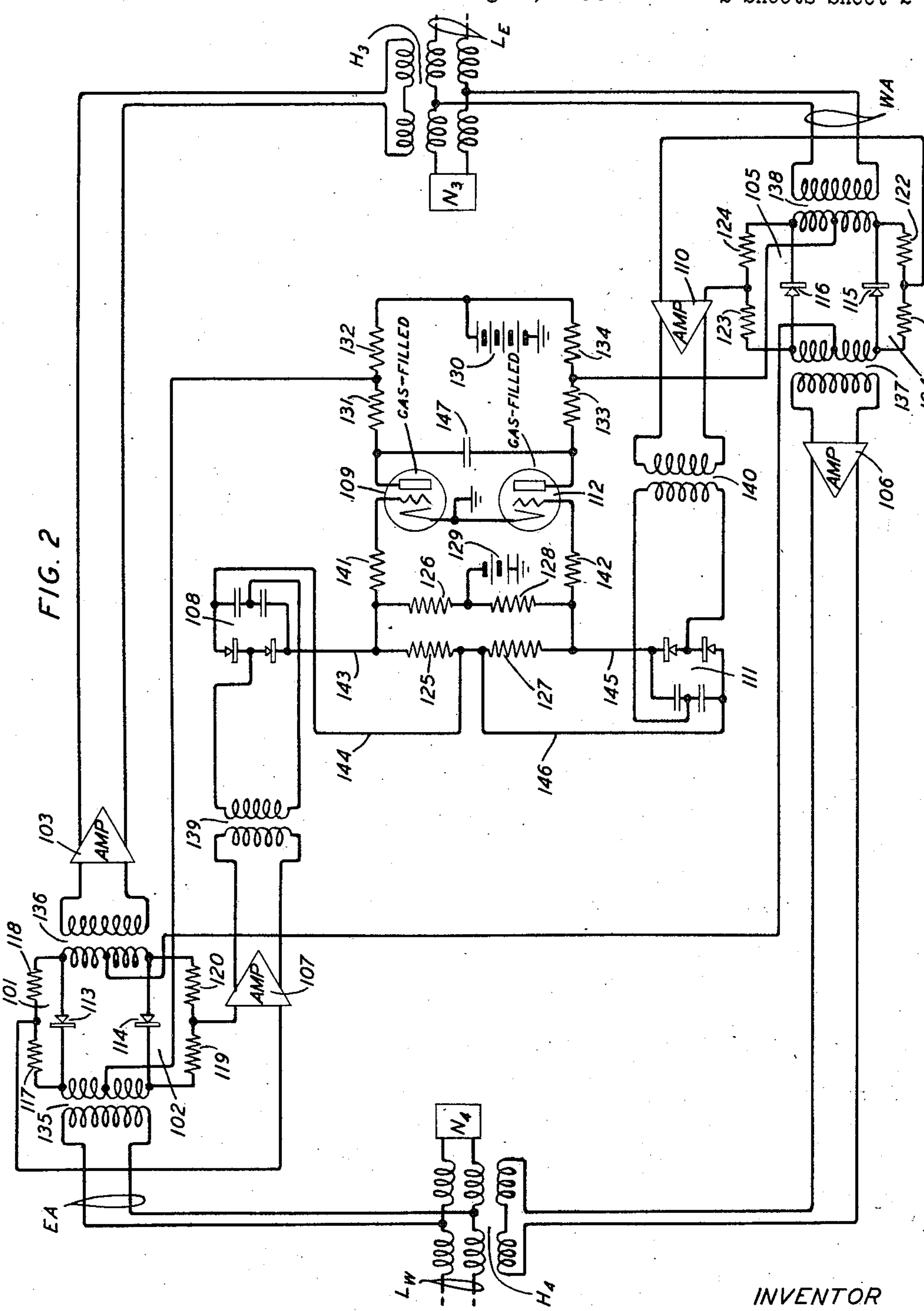

FIG. 2

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TRANSMISSION CONTROL IN SIGNALING SYSTEMS

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6 Claims. (Cl. 179—170)

The invention relates to two-way signal transmission systems and particularly to circuits for directionally controlling transmission in such systems.

An object of the invention is to improve the operation of two-way repeaters in signal transmission systems.

It has been frequently found desirable to insert repeating or amplifying circuits between two-way transmission lines in a two-way signaling system, to compensate for attenuation in the signals transmitted in opposite directions thereover. In the prior art one form of repeating circuit comprises two oppositely-directed one-way repeating paths which, to enable amplification of the signals for both directions of transmission, are coupled to each other and to the two-way transmission lines by three-winding transformers or hybrid coils in such a manner as to form a Wheatstone bridge circuit. As is well known, the balanced condiiton of such a bridge circuit is attained by providing a balancing network in one arm thereof to closely simulate the impedance of the associated transmission line in another arm. Unless a high degree of balance is maintained by the balancing networks so that the repeating paths are substantially conjugate, there is a critical amount of amplification which cannot be exceeded without setting up a local circulation of energy in the form of a sustained tone known as singing. In another form of circuit in the prior art, repeating of the signals in opposite directions without necessitating close balancing of the impedances of the transmission lines to avoid singing is attained by utilizing switching means responsive to the transmission of voice currents or other signals in either direction to render operative the repeating path for that direction only. In certain of such circuits this may be accomplished by making the switching apparatus responsive to the signals to remove effectively a loss (attenuation) from the signaling or talking path, to switch a loss into the other path, or to do both.

In accordance with the present invention, in a system of the last mentioned type, one or more loss elements having a non-linear resistance-direct current voltage characteristic, such as copper-oxide rectifiers, are connected in the repeating paths, and signal-controlled means are provided for applying suitable direct current voltages to these elements to so control the losses inserted thereby in the repeating paths as to provide efficient transmission of signals in one repeating path while effectively blocking the other path.

In one embodiment of the invention the non-linear resistance elements in the networks are connected in series in the repeating paths and are normally biased so as to provide a high resistance to the signals, and the resistances of the non-linear resistance elements in either path are changed to a low value by the application of suitable direct current voltages in response to transmission of signals in that path.

In a second embodiment of the invention, the non-linear resistance elements in both repeating paths are connected in series therewith and are normally biased in such a manner that the elements in one path have a high resistance while the elements in the oppositely-directed path have a low resistance. In response to transmission of signals in either path, suitable direct current voltages are supplied to the elements therein which change their resistances to a low value if they normally have a high resistance, and, simultaneously change the resistance of the elements in the opposite repeating path to a high value so as to allow efficient transmission of signals in the first path only.

The objects and advantages of the invention will be better understood from the following detailed description thereof when read in connection with the accompanying drawings in which Figs. 1 and 2 show schematically different modifications of the invention embodied in a two-way telephone repeater.

The two-way telephone repeater circuit of Fig. 1 comprises a transmission path EA including the loss networks or pads **1** and **2** and the one-way amplifying device **3**, for repeating telephone signals in the direction from west to east between the west two-way line section L_W and the east two-way line section L_E, and a transmission path WA including the loss networks or pads **4** and **5** and the one-way amplifying device **6** for repeating signals in the direction from east to west between the line section L_E and the line section L_W. The oppositely-directed one-way repeating paths EA and WA are connected in conjugate relation with each other and in energy transmitting relation with the line sections L_W and L_E by the hybrid coil transformers H_1 and H_2 and associated balancing networks N_1 and N_2 in well known manner.

Connected to the output of the one-way amplifier **3** in the repeating path EA is the input of a control circuit comprising in order a wave amplifier **7**, a wave rectifier **8** and a relay **9**, the winding of which is connected to the output of rectifier **8**. Similarly connected to the output circuit of the amplifier 6 in the path WA is the input of a control circuit comprising in order a wave amplifier 10, a wave rectifier 11 and a relay 12, the winding of which is connected to the output of rectifier 11. In rectifiers 8 and 11, respectively, the rectifying tubes 13 and 14 are preferably three-element tubes of the hot-cathode, gas-filled type which break down and become conducting when the potential on the grid or control electrode therein is raised sufficiently above a critical value. In addition to the elements mentioned, the control circuits respectively contain two other three-element tubes 19 and 20 of the cold-cathode, gas-filled type which break down and become conducting when certain potential conditions are applied to their electrodes.

The loss networks or pads 1, 2, 4, and 5 each comprises one or more copper-oxide rectifying units shunted by a resistance element in series with a condenser. The copper-oxide rectifying unit 15 in the pad 1 is connected in series with the upper conductor of the path EA, the unit 16 in pad 2 in series with the lower conductor of the path EA, the unit 17 in pad 4 in series with the lower conductor of the path WA and the unit 18 in pad 5 in series with the upper conductor of the path WA. Each copper-oxide rectifying unit is so poled in the conductor in which it is connected that when biased by a direct current voltage in the manner which will be described below, it offers a resistance of high value to the signal currents transmitted in the direction opposite to the direction in which the arrow head of the unit points and, when unbiased or biased by a direct current voltage of opposite polarity, it offers a resistance of very low value to signal currents transmitted in the direction opposite to that in which the arrow head points. The value of the resistance elements in shunt with the copper-oxide rectifying elements in the pads in each path determines the amount of loss inserted in the path when the associated copper-oxide rectifying units are biased. The values of the resistance elements would be selected so that the losses inserted in the paths in which they are connected would be sufficient to block the transmission of signals thereover for the latter condition. Each resistance element is short-circuited by the low resistance path through the associated copper-oxide rectifying units when the latter are unbiased so that for the latter condition, the pad is effectively removed from the transmission path as regards any appreciable effect on the transmission of signals thereover. The condenser in series with each resistance element in each pad is provided to prevent transmission of direct current therethrough when the associated copper-oxide rectifying unit is biased with the direct current voltage. In some cases the condensers may be omitted without deleteriously affecting the operation of the system. Any other elements having similar non-linear resistance-direct current voltage characteristics may be substituted for the copper-oxide rectifying units in each pad.

The nature and functions of the other apparatus and circuits illustrated in the system of Fig. 1 will be described in connection with the following complete description of operation of the system.

The positive potential impressed on the anode of tube 19 by the battery 25 through resistance 26 is such that tube 19 is normally ionized and in the conducting condition and current flows therethrough over a circuit which may be traced from the positive terminal of battery 25 through resistance 26 to the anode of tube 19 and through the discharge path to both cathodes of the tube and from the cathodes through potentiometer resistances 28 and 29, the negative to the positive terminal of battery 27 to ground to the negative terminal of battery 25.

The contact arm of potentiometer 29 is connected to the mid-point of the secondary winding of the output transformer 21 for amplifier 3 in the path EA, and is adjusted so that the potential of that mid-point is approximately 5 volts above ground potential. The sides of the copper-oxide rectifying units 15 and 16 connected through the conductors of the path EA and the upper and lower halves, respectively, of the secondary winding of transformer 21 to said mid-point, are therefore also at 5 volts above ground potential. The other sides of the elements 15, 16 are connected to ground through the outgoing conductors of the path EA and the windings of the hybrid coil transformer H_1. With these potential conditions the bias on each copper-oxide rectifying element 15 and 16 is such that its resistance is of very high value due to the non-linear resistance-voltage characteristics as pointed out above. Thus, the resistance elements in parallel with the copper-oxide rectifying elements in the two pads 1 and 2 are normally effective to insert such a high loss in the path EA as effectively to block that path as regards transmitting signals from the output of amplifier 3 to the line section L_E.

Similarly, the biasing potential produced on the anode of tube 20 by battery 30 through resistance 31 is such that tube 20 is normally ionized and in the conducting condition and current flows therethrough over a circuit which may be traced from the positive terminal of battery 30 through resistance 31, the anode to the two cathodes of tube 20, through potentiometer resistances 33 and 34, negative to positive terminal of battery 32 to ground to the negative terminal of battery 30.

The contact arm of the potentiometer 34 is connected to the mid-point of the secondary winding of output transformer 35 for amplifier 6 in the path WA. It is adjusted so that the potential of that mid-point is approximately 5 volts above ground potential. The sides of each copper-oxide rectifying element 17 and 18 in the pads 4 and 5 connected through the conductors of the path WA and the upper and lower halves of the secondary winding of transformer 35 to the mid-point of that winding therefore are also 5 volts above ground potential. The other sides of the elements 17 and 18 are connected to ground through the outgoing conductors of the path EA and the windings of hybrid coil transformer H_2. Thus, the copper-oxide rectifying elements 17 and 18 are biased due to these potential conditions to provide a very high resistance in both sides of the path WA and the resistance elements in shunt with said copper-oxide rectifying elements are normally effective to insert their loss value in the path WA so that the path is effectively blocked for transmission of signals.

Let it be assumed that telephone signals are being received over the west line section L_W and that no signals are being simultaneously received from the east line section L_E. The incoming signals are impressed on path EA by hybrid coil transformer H_2 and are amplified by the one-way amplifier 3 in that path. A portion of the amplified signals will be diverted from output transformer 21 into the associated control circuit and after amplification by the tube 23 in amplifier 7 therein will be impressed by transformer 24 on the grid electrode of tube 13 of rectifier 8. In response to the impressed potential, the gas-filled tube 13 ionizes and becomes conducting. Normally, that is when tube 13 is in the de-ionized condition, the condenser 37 in the plate circuit of the tube is charged from battery 25 through resistances 26 and 36 and the winding of relay 9. When tube 13 becomes conducting, it completes a circuit from ground over its cathode-anode circuit to one side of the condenser 37 through resistance 36 and also to the positive terminal of battery 25 through the winding of relay 9 and resistance 26. Now condenser 37 partially discharges through tube 13, thereby immediately lowering the potential on the anode of the normally ionized, cold-cathode, gas-filled tube 19 to a point where tube 19 de-ionizes and becomes non-conducting. Since no current now flows through tube 19, the positive 5 volt potential normally maintained on one side of the rectifying elements 15 and 16 in pads 1 and 2 in the path EA through potentiometer 29 is removed. A negative potential of 24 volts is now applied to elements 15 and 16 over a circuit extending from the negative terminal of the 24 volt battery 27 through potentiometer 29, the two halves of the secondary winding of transformer 21 and the conductors of the path EA. This reversal of potential causes direct current from battery 27 to flow through the rectifying elements 15 and 16 reducing the resistance of these elements to a low value and thereby short-circuiting the resistances in pads 1 and 2 through these elements. This effectively removes the normal loss from the two conductors of path EA and the signals incoming from the west line section L_E after amplification by the one-way amplifier 3 will be transmitted with little attenuation through the elements 15 and 16 to the output of the path EA where they will be impressed on the east line section L_E by hybrid coil transformer H_1.

Also, when tube 13 ionizes in response to the applied signals, current is transmitted from battery 25 through resistance 26, the winding of relay 9 and tube 13. The current through the winding of relay 9 causes operation of that relay to connect ground through its armature and front contact to the anode of tube 19, and to one side of the relay winding, thereby short-circuiting the battery 25 through resistance 26 and the relay contacts. Condenser 37 now completely discharges and, since both the cathode and anode of tube 13 are now at ground potential, tube 13 de-ionizes. Relay 9 also then releases and removes the short circuit around battery 25 and resistance 26. Tube 19 does not immediately re-ionize after the ground is removed from its anode by the release of relay 9 since condenser 37 must first be charged by battery 25 to a point where the potential on the anode of tube 19 is sufficient to cause ionization to take place. Tube 13 does not ionize immediately upon the closure of its anode circuit, even though signals are being impressed on its grid, since the anode potential does not reach the ionization value until condenser 37 is charged to a certain point. This delay interval in the re-ionization time of tubes 13 and 19 is controlled by the charging time of condenser 37 and is therefore dependent upon the values of resistances 26 and 36 and on the capacitance of condenser 37. This delay interval is provided to prevent a continuous cycle of ionization and de-ionization of the tube 19 which would result in the repeated raising and lowering of the resistance value of the rectifying elements 15 and 16 in path EA during a train of signals from the west line section L_W. By controlling the charging time of condenser 37 so as to insure that tube 19 does not re-ionize in the interval between syllables, the mutilation of the syllables of speech which is known as clipping may be guarded against.

The devices 38, 40, 43, and 45 in the system of Fig. 1 are illustrated as copper-oxide rectifying elements, similar to the elements 15, 16, 17, and 18, but may consist of any other elements having similar non-linear resistance-direct current voltage characteristics. The rectifying element 38 in series with a 9 volt battery 39 is connected across the secondary winding of the transformer 24 coupling the amplifier tube 23 to the rectifier tube 13. Element 38 is so connected with respect to its polarity that when the grid or control electrode of tube 13 goes positive in response to the impressed signals incoming over the west line section L_W, the element tends to become of low resistance. If the potential induced in the secondary winding of transformer 24 is less than 9 volts, element 38 will have a high resistance since the induced potential is insufficient to overcome the fixed bias of 9 volts maintained on the element by battery 39. Regardless of the level of the incoming signals, the maximum potential which can develop across the secondary winding of transformer 24 and on the grid of tube 13 is, therefore, 9 volts. The grid of tube 13 is normally negatively biased by battery 32 over a circuit extending from battery 32 through potentiometer 33, copper-oxide rectifying element 45 and the secondary winding of transformer 24 to the grid of tube 13. Since tube 20 is normally ionized and in the conducting condition, current is flowing through the tube and through potentiometers 33 and 34 as previously set forth. The contact arm of potentiometer 33 is so adjusted that the negative bias on the grid of tube 13 is of such a value that an impressed positive potential of 8 volts thereon is necessary to cause that tube to ionize.

Similarly, rectifying element 43 in series with a 9 volt battery 44 is connected across the secondary winding of transformer 46 coupling the amplifier tube 46 in amplifier 10 to the rectifier tube 14 in rectifier 11. Element 43 is so connected with respect to its polarity that when the grid of tube 14 goes positive in response to the impressed signals incoming from the east line section L_E, the element 43 tends to become of low resistance. If the potential induced in the secondary winding of transformer 46 is less than 9 volts, element 43 will have a high resistance since the induced potential is not sufficient to overcome the fixed bias of 9 volts maintained on the element by battery 44. A maximum potential of 9 volts, therefore, is all that can develop across the secondary winding of transformer 46 on the grid of tube 14. The grid of tube 14 is normally negatively biased by battery 27 over a circuit extending from the battery through potentiometer 28, copper-oxide rectifying element 40 and the secondary winding of transformer 46 to the grid. Since tube 19 is normally ionized and conducting, current is flowing through the tube and through potentiometers 28 and 29 as previously set forth. The contact arm of potentiometer 28 is so adjusted that the potential placed on the grid of tube 14 is of such a value that an impressed positive potential of 8 volts is necessary on the grid of the tube to cause that tube to ionize.

When tube 13 ionizes in response to a signal incoming from the west line section L_W and deionizes tube 19, as previously described, current ceases to flow through tube 19 and potentiometer 28 thereby removing the normal biasing potential on the grid of tube 14. The negative terminal of the 24 volt battery 27 is now connected to the grid of tube 14 in a circuit extending through potentiometer 28, rectifying element 40 and secondary of transformer 46. With this negative 24 volt bias, a swing of 18 volts on its grid is now necessary to cause tube 14 to ionize. Since the maximum potential of 9 volts is all that can develop across the secondary winding of transformer 46, rectifier tube 14 cannot ionize to become conducting as long as signals are continuously incoming from the west line section L_W. Since tube 14 cannot ionize, tube 20 remains ionized thereby maintaining the proper potential conditions on rectifier elements 17 and 18 to keep these elements at a high resistance value which means that the full value of the shunting resistances in the pads 4 and 5 are effective in the path WA. Thus the east to west transmission path WA is maintained blocked as long as the west-to-east signals are being received from the west line section L_W substantially continuously.

In a manner similar to that just described for the elements of the control circuit connected with the path EA in the case where signals are first applied to the repeating circuit from the west line section L_W, the corresponding elements of the control circuit connected to the path WA operate when signals are first impressed upon the repeating circuit from the line section L_E to change the bias of the rectifying elements 17 and 18 in the pads 4 and 5 in the path WA so that they provide a very low resistance in that path and thus allow efficient transmission of the signals from the line section L_E to the line section L_W. Also, the elements in the control circuit connected to the path WA operate in response to the signals received from the line section L_E to maintain the proper potential conditions on the rectifying elements 15 and 16 in the pads 1 and 2 in the path EA to hold that path blocked during the substantially continuous transmission of the east to west signals from the line section L_E in a manner similar to that described for the corresponding elements in the control circuit connected to the path EA described above.

Referring now to the modification of the invention shown in Fig. 2, the two-way telephone repeater circuit shown therein comprises a transmission path EA including the loss networks 101 and 102 and the one-way amplifying device 103 for repeating telephonic signals in the direction from west to east between the west two-way line section L_W and the east two-way line section L_E, and a transmission path WA including the loss networks 104 and 105 and the one-way amplifying device 106, for repeating signals in the direction from east to west between the line section L_E and the line section L_W. The oppositely-directed one-way repeating paths EA and WA are connected in conjugate relation with each other and in energy transmitting relation with the west line section L_W and the east line section L_E by the hybrid coil transformers H_3 and H_4 and associated balancing networks N_3 and N_4 in well known manner.

The loss networks or pads 101, 102, 104, and 105 each comprises one or more copper-oxide rectifying units shunted by resistances. The copper-oxide rectifying unit 113 in the pad 101 is connected in series with one side of a portion of the path EA located between the transformers 135 and 136 in front of the amplifying device 103 and the copper-oxide rectifying unit 114 in the pad 102 is connected in series with the other side of the portion of the path EA located between the transformers 135 and 136 in front of the amplifying device 103. The copper-oxide rectifying unit 115 is connected in series with one side of the portion of the path WA located between the transformers 137 and 138 in front of the amplifying device 106, and the copper-oxide rectifying unit 116 is connected in series with the other side of the portion of the path WA located between the transformers 137 and 138 in front of the amplifying device 106. Each copper-oxide rectifying unit is so poled in the side of the repeating path in which it is connected that when biased by a direct current voltage in the manner which will be described below it offers a resistance of high value to signal currents transmitted in the direction opposite to the direction in which the arrow head points and when unbiased or biased by a direct current voltage of opposite polarity it offers a resistance of very low value to signal currents transmitted in the direction opposite to which the arrow head points.

The rectifying unit 113 in the pad 101 is shunted by the equal resistances 117 and 118 in series, the rectifying unit 114 in the pad 102 is shunted by the equal resistances 119 and 120 in series, the rectifying unit 115 in the pad 104 is shunted by the equal resistances 121 and 122 in series, and the rectifying unit 116 in the pad 105 is shunted by the equal resistances 123 and 124 in series. The values of the resistance elements 117, 118 in pad 101; 119, 120 in pad 102; 121, 122 in pad 104; and 123, 124 in pad 105 determine the amount of loss inserted in the transmission path in which they are connected when the copper-oxide rectifying units in the pads are unbiased or are biased so as to offer a resistance of high value in the signal transmitting direction in the path. The values of the resistances would be so selected that the loss inserted in the repeating paths would be sufficient to block transmission of signals or echoes therein for the latter condition. The series resistance elements in each pad are short-circuited by the low resistance paths through the associated copper-oxide rectifying units when the latter are biased to offer a low loss in the repeating path in which connected in the signal transmitting direction so that for the latter condition the pad is effectively removed from the transmission path as regards any effect on the transmitted signals. Any other elements having similar non-linear resistance-direct current voltage characteristic may be substituted for the copper-oxide rectified elements in the loss networks or pads.

Connected across the loss networks 101 and 102 in the repeating path EA, between the mid-point of resistances 117 and 118 and the mid-point of resistances 119 and 120 is the input of a control circuit comprising in order an amplifier 107, a rectifier 108 and a gas-filled discharge tube 109. Similarly connected across the loss networks 104 and 105 in the repeating path WA between the mid-point of resistances 123 and 124 and the mid-point of resistances 121 and 122 is the input of a control circuit comprising in order an amplifier 110, a rectifier 111 and a gas-filled discharge tube 112.

The amplifiers 103, 106, 107, and 110 may be of any of the well known types, for example, of the type employing three-electrode vacuum tubes. The rectifiers 108 and 111 may be of any of the well known types but are preferably all of the type employing copper-oxide rectifying elements. The gas-filled discharge tubes 109 and 112 are preferably three-element tubes of the hot-cathode gas-filled type which break down and become conducting when the potential on the grid or control electrode therein is raised sufficiently above a critical value.

The rectifier 108 comprises two oppositely poled copper-oxide rectifying units in series shunted by two condensers in series, the output of the control amplifier 107 being coupled by transformer 139 across the junction point between the two copper-oxide rectifying units and the junction point between the two condensers in rectifier 108. Similarly, the rectifier 111 comprises two oppositely poled copper-oxide rectifying units in series shunted by two condensers in series, the output of the control amplifier 110 being coupled by transformer 114 across the junction point between the two copper-oxide rectifying units and the junction point between the two condensers in rectifier 111. A resistance 125 is connected across the output of rectifier 108, that is, across the two rectifying units therein in series, and an equal resistance 127 is connected across the output of rectifier 111, that is, across the two rectifying units therein in series. The two resistances 125 and 127 are connected in series and are shunted across the two resistances 126 and 128 in series, respectively, in the individual portions of the input circuits of the gas-filled discharge tubes 109 and 112.

The input and output circuits of the gas-filled rectifier tubes 109 and 112 are respectively connected in push-pull relation. The anode-cathode circuit of the rectifier tube 109 includes in series the plate battery 130 and the series resistance 131 and 132, and the anode-cathode circuit of rectifier tube 112 includes in series plate battery 130 and resistances 133 and 134. The grid-cathode circuit of gas-filled tube 109 comprises in series grid battery 129 and the series resistances 126 and 141, and the grid-cathode circuit of the gas-filled tube 112 comprises in series the grid battery 129 and the series resistances 128 and 142.

The junction point between the series resistances 131 and 132 in the output circuit of the gas-filled tube 109 is connected to the mid-point of the secondary winding of transformer 135 in the path EA, and thus to one side of each copper-oxide rectifying element 113 and 114 in the pads 101 and 102, respectively, through the respective halves of said secondary winding. Similarly, the junction point between the series resistances 133 and 134 in the plate circuit of gas-filled tube 112 is connected to the mid-point of the secondary winding of the transformer 138 in the path WA and thus to one side of each copper-oxide rectifying element 115 and 116 in pads 104 and 105, respectively, through the two halves of said secondary winding.

By the connections detailed above, the input circuits of the gas-filled discharge tubes 109 and 112 and the output circuits of the rectifiers 108 and 111 are connected together in a differential circuit in such manner that the output of the rectifiers determines the voltages in the differential circuit. As will be explained below in connection with the operation of the system of Fig. 2, the voltages in the differential circuit control the ionization of tubes 109 and 112, which, in turn control the potential conditions on the copper-oxide rectifying elements 113, 114 in loss networks 101 and 102, and on copper-oxide rectifying elements 115, 116 in the loss networks 104 and 105.

The nature and functions of the other apparatus and circuits illustrated in the system of Fig. 2 will be described in connection with the following complete description of the operation of that system.

With the filaments or cathodes of tubes 109 and 112 energized by an individual or a common battery (not shown), either tube 109 or tube 112 is ionized and in the conducting condition depending upon the direction of the last previous signal impressed upon the repeater. If these previous signals were in the direction from east to west having been applied to the repeater from the east line section L_E, the conditions disclosed in the differential circuit comprising the output circuits of rectifiers 108 and 111 and the input circuits of gas-filled discharge tubes 109 and 112 will be such as to put the tube 112 in the ionized condition and the tube 109 in the de-ionized condition. On the other hand, if the previous signals were in the direction from west to east having been applied to the repeater from the west line section L_W, the tube 109 is ionized and the tube 112 is de-ionized.

Let it be assumed that the last previous signals impressed on the repeater circuit were in the east to west direction and that, therefore, tube 112 is ionized and tube 109 is de-ionized. With tube 112 ionized and in the conducting condition, current flows from the plate battery 130 through resistances 133 and 134. Due to the drop in voltage caused by the current flow through resistances 133 and 134, the junction point of the latter resistances is at a lower potential than the junction point of resistances 131 and 132 in the anode-cathode circuit of tube 109. This difference in potential results in a flow of biasing current through the copper-oxide rectifying elements 113, 114, 115 and 116 over a circuit which may be traced from the junction point of resistances 131 and 132 to the mid-point of the secondary winding of transformer 135, through copper-oxide rectifying elements 113 and 114 in parallel with the resistances 117, 118, 119 and 120, respectively, each half of the primary winding of transformer 136, from the mid-point of said primary winding to the mid-point of the primary winding of transformer 136 in the path EA through copper-oxide rectifying elements 115 and 116 in parallel with resistances 121, 122 and 123, 124, respectively, each half to the mid-point of the secondary winding of transformer 138 and thence to the junction point of resistances 133 and 134. This current flows through elements 115 and 116 in the conducting directions causing their resistances to be reduced to low values. However, the biasing current flows through the copper-oxide rectifying elements 113 and 114 in the direction in which their resistance is very high. The latter elements, therefore, insert a high loss in the repeating path EA. In addition, due to the high resistance of copper-oxide rectifying elements 113 and 114, the resistances

117 and 119 in parallel therewith are effective to insert their full resistance value in series with the input of amplifier 107 effectively preventing transmission subsequently of signal currents from the line section L_W to the control circuit having its input connected across the path EA. Since the copper-oxide rectifying elements 115 and 116 are low in resistance at this time, resistances 121 and 122 and the resistances 123 and 124 are effectively in parallel and provide a loss in the input to amplifier 110 which is less than the loss in the input to amplifier 107.

With the repeater in the condition hereinbefore set forth, that is, with a high loss in the path EA due to the high resistance of elements 113 and 114 and with a low loss in the path WA due to the low resistance of elements 115 and 116, let it be assumed that signals are applied to the repeater from the west line section L_W, no signals being simultaneously applied thereto from the east line section L_E.

The signals will be impressed on path EA by the hybrid coil transformer H_4 and will be passed by transformer 135 and by-passed around the high resistance copper-oxide elements 113 and 114 through the shunting resistance circuits. A portion of the incoming signals will be diverted at the mid-points between resistances 117, 118 and between resistances 119, 120 into the control circuit where it will be amplified by the amplifier 107 and then rectified by the rectifier 108, causing a direct current potential to be applied across the conductors 143 and 144.

This application of a direct potential across the conductors 143 and 144 in response to the rectified signals causes current to flow in the differential circuit comprising resistances 125, 126, 127 and 128 in the direction which lowers the negative potential on the grid of tube 109 and increases the negative potential on the grid of tube 112. This decrease in the negative potential on the grid of tube 109 causes that tube to ionize and become conducting. Upon the ionization of tube 109, a circuit is completed from ground on the cathode of tube 109 through the cathode-anode circuit of the tube to one side of the condenser 147 connected between the plates of tubes 109 and 112, and to the positive terminal of battery 130 through resistances 131 and 132. Condenser 147 partially discharges, causing a surge of current through condenser 147 which momentarily reduces the potential on the anode of tube 112 to a value below that required to maintain ionization of that tube. Tube 112 de-ionizes and, since its cathode-anode circuit is opened, current ceases to flow in the circuit from the positive terminal of battery 130, through resistances 134 and 133, to ground at the cathode of tube 112. The junction point of resistances 133 and 134 therefore assumes the full potential of battery 130.

Since tube 109 is ionized, current flows from the positive terminal of battery 130 through resistances 132 and 131 to ground over the anode-cathode discharge path of tube 109. Due to the voltage drop caused by the current flow through resistances 131 and 132, the junction point of these resistances is at a lower potential than the junction point of resistances 133 and 134. The potentials at these junction points are now the reverse of those which obtained before signals were impressed on the path EA. The biasing current through the non-linear resistance elements 113, 114, 115, and 116 is therefore flowing in the direction opposite to the previous current flow through these elements, being now in the conducting direction through elements 113 and 114 and in the non-conducting direction for elements 115 and 116. Due to this reversal of biasing current, elements 113 and 114 become low in resistance value and effectively short circuit resistances 117, 118 and 119, 120, respectively, reducing the loss in path EA while elements 115 and 116 become high in resistance value so that the resistances 121, 122 and 123, 124 in parallel therewith become effective to insert a high loss in path WA. Elements 113 and 114, being low in resistance value, the resistances 118 and 120 are effectively placed in parallel with resistances 117 and 119, respectively, thereby reducing the loss in the input circuit to the control circuit amplifier 107. Since elements 115 and 116 are now high in resistance value, resistances 121 and 123 are removed, in effect, from in parallel with resistances 122 and 124, respectively, thereby increasing the loss in the input circuit to the control circuit amplifier 110.

The increase in the loss in the input to the amplifier-rectifier associated with the path opposite to that in which signals are being repeated, serves to prevent the ionization of the gas tube controlled by the then non-repeating path in the event of an unbalanced line. For example, with signals being impressed on path EA and the repeater functioning as hereinbefore set forth, let it be assumed that the east line section L_E is not in close balance. A portion of the signals in path EA, after amplification by amplifier 103, are fed back into path WA through the hybrid coil transformer H_3. However, since the loss in the input to amplifier 110 is greater than that in the input to amplifier 107, the level of the waves in the output of rectifier 111 is lower than that of the waves in the output of rectifier 108. Having the greater output, rectifier 108 therefore maintains control of the gas tubes, keeping tube 109 ionized and preventing the ionization of tube 112. In this manner the repeater functions properly even though one or both associated lines are not in close balance.

In the foregoing description it was assumed that tube 112 was ionized and tube 109 de-ionized prior to the application of signals to path EA over the west line section L_W. Assume, instead, that tube 109 is ionized and tube 112 de-ionized prior to the application of the signals to path EA. Under this condition the flow of biasing current through the copper-oxide rectifying elements is in such direction that elements 113 and 114 are low in resistance value, while elements 115 and 116 are high in resistance value. When signals are now impressed on path EA over the west line section L_W, no action takes place in the signal-controlled gaseous tube circuits other than that the output of rectifier 108, under control of the incoming signals, maintains the proper potentials on the grids of tubes 109 and 112 so that tube 109 remains ionized and tube 112 de-ionized.

Assume now that the signals incoming over the west line section L_W have ceased, and that, with tube 109 remaining ionized and tube 112 de-ionized, signals are impressed on path WA over the east line section L_E by the hybrid coil transformer H_3. These signals will be passed by the transformer 138 and a portion thereof will be diverted through resistances 122 and 124 into the associated control circuit and will be amplified by amplifier 110 therein. The amplified signals will be impressed by the transformer 140 on the rectifier 111. The rectified signals in the output of rectifier 111 will then be applied to the differential control circuit for the gaseous tubes 109 and 112 over conductors 143 and 144. Due to this applied potential, current flows through the differential circuit in the direction which reduces the negative potential on the grid of tube 112 and increases the negative potential on the grid of tube 109. Tube 112 ionizes and becomes conducting in response to the lowering of the negative potential on its grid.

With tube 112 ionized, a circuit is completed from ground on its cathode through the cathode-anode circuit to one side of condenser 147, and to the positive terminal of battery 130 through resistances 133 and 134. Condenser 147 partially discharges, causing a surge of current through the condenser which momentarily lowers the potential on the anode of tube 109 below the value required to maintain ionization, and tube 109 therefore de-ionizes. In de-ionizing, tube 109 opens the circuit from battery 130 through resistances 132 and 131 to ground on its cathode. Since current ceases to flow through resistances 131 and 132, the junction point of these resistances assumes the full potential of battery 130. Tube 112 now being ionized, current flows from the positive terminal of battery 130 through resistances 134 and 133, to ground over the anode-cathode circuit of the tube. Due to this current flow, the junction point of resistances 133 and 134 is at a lower potential than the junction point of resistances 131 and 132. Due to this difference in potential, biasing current now flows through the copper-oxide rectifying elements in a circuit hereinbefore traced in connection with the description of operation for the case where signals are repeated from west to east, but in the direction opposite to that which flowed through these elements when tube 109 was ionized and tube 112 de-ionized. This current flow is now in the conducting direction through elements 115 and 116, reducing their resistance to a low value and is in the non-conducting direction through elements 113 and 114 thereby increasing the resistance of these latter elements to a high value so as to insert a loss in path EA. Since the resistance of elements 115 and 116 is now low in value, resistances 121 and 123 are effectively placed in parallel with resistances 122 and 124. This lowers the loss in the input circuit to amplifier 110. Elements 113 and 114 being high in resistance value, resistances 118 and 120 are effectively removed from in parallel with resistances 117 and 119, respectively, thereby increasing the loss in the input circuit to amplifier 107. This regulation of the input to the signal-controlled amplifier-rectifiers insures the proper functioning of the repeater circuit under unbalanced line conditions as previously set forth.

As long as signals continue to be impressed on path WA over the east line section L_E, tube 112 remains ionized and tube 109 de-ionized. Upon the cessation of the east line signals, tubes 112 and 109 remain in their foregoing respective conditions until signals are impressed on path EA over the west line section L_W, at which time tube 109 ionizes and tube 112 de-ionizes, causing the repeater circuit to function in the manner similar to that set forth in connection with the description of operation for transmission of west to east signals.

Should the cathode circuits of tubes 109 and 112 be opened during maintenance of the repeater or for any other reason, the tube which is ionized at that time will de-ionize. When the cathode circuits of the tubes are again closed, both tubes may remain de-ionized. The first signal impresssed over either line section will, however, cause the tube associated with the repeating path of that signal to ionize, after which the repeater circuit functions as previously described, one or the other of tubes 109 and 112 remaining ionized depending upon the direction of the last repeated signal.

Many modifications of the circuits illustrated and described within the spirit and scope of the invention will be apparent to persons skilled in the art. The invention is to be limited only within the scope of the appended claims.

What is claimed is:

1. In combination, two oppositely-directed one-way circuits for transmitting alternating current signals in opposite directions between stations, a loss pad in each circuit including one or more elements having a non-linear resistance-direct current voltage characteristic which when biased by a direct current voltage of one polarity and of the proper value will condition the pad to offer a high loss to the transmitted signals in said circuit and when biased by a direct current voltage of the opposite polarity and of the proper value will condition the pad to offer a low loss to the transmitted signals, means normally applying the first-mentioned voltage to said elements in each pad so that both pads are in the high loss condition, means responsive to the initiation of signal transmission in either circuit to remove the normally-applied voltage from the elements in that circuit and to apply thereto the second-mentioned voltage to put the pad in the low loss condition, and means responsive to signals in the circuit in which they are first initiated to prevent later-initiated signals in the other circuit from causing a change in the loss conditions of the pads in either circuit during the substantially continuous signal transmission in the first circuit.

2. The combination of claim 1 and in which the application of the normal biasing voltage to the elements of the pad in each circuit is controlled by a normally-ionized gas-filled discharge device, and the removal of the normal biasing voltage and the application of the proper voltage to put that pad in the low loss condition is caused by the de-ionization of said device in response to initiation of signal transmission in that circuit.

3. In combination in a signal transmission system, two oppositely-directed one-way circuits for transmitting alternating current signals in opposite directions between stations, a loss pad in each circuit including one or more elements having a non-linear resistance-direct current voltage characteristic which when biased by a direct current voltage of one polarity and of the proper value will condition the pad to provide a high loss to transmitted signals in said circuit and when biased by a direct current voltage of the opposite polarity and of the proper value will condition the pad to provide a low loss to transmitted signals in that circuit, means normally applying to the elements of the pad in one circuit the first-mentioned voltage and to the elements of the pad in the other circuit the second-mentioned voltage, control means responsive to the initiation of signal transmission in either circuit to so control the voltages on the elements of the pads in said circuits that the pad in the circuit in which said transmission is initiated is maintained or put in the low loss condition and the pad in the other

circuit is put or maintained in the high loss condition, and means responsive to signal transmission in the circuit in which first initiated to prevent later-initiated signals in said other circuit from changing the loss condition of the pad in either circuit during substantially continuous transmission of the first-initiated signals in the first circuit.

4. The system of claim 3 and in which said means normally applying said first-mentioned voltage to the elements of the pad in one circuit and said second-mentioned voltage to the elements of the pad in the other circuit comprises a differential circuit including a normally ionized and a normally de-ionized gas-filled discharge device, and the means responsive to signal transmission in either circuit for so controlling the voltages on the elements of the pads in the two circuits that the pad in the circuit transmitting signals is in the low loss condition and the other pad is in the high loss condition, comprises means for rectifying a portion of the transmitted signals and for applying the rectified signals to the differential circuit in such manner as to properly control the ionization in the two discharge devices.

5. The system of claim 3 in which the means normally applying the voltages to the elements of the pads in said one-way circuits comprises a differential circuit consisting of two electric discharge devices connected in push-pull relation, the output of which is connected across the nonlinear resistance elements in the pads in both one-way circuits, and the means responsive to the initiation of signal transmission in either one-way circuit to so control the voltages on the pads in said circuits that the pad in the circuit in which signal transmission is initiated is maintained or put in the low loss condition and the pad in the other circuit is maintained or put in the high loss condition comprises means for rectifying a portion of the transmitted signals and for applying the rectified signals to the differential circuit in such manner as to produce the proper potential conditions in its output.

6. In combination, two oppositely-directed one-way circuits for transmitting alternating current signals in opposite directions between stations, a loss pad in each circuit comprising one or more impedance elements in series therewith and of such values as to offer a high loss to transmitted signals, one or more copper oxide rectifying units effectively in shunt with the series impedance elements in each paid and in series relation with said circuit, said copper oxide rectifying units being normally biased by direct current in such manner as to offer a resistance of high value in the direction of transmission of said signals, and switching means connected to each one-way circuit and responsive to initiation of signal transmission therein to change the direct current bias on the rectifying units shunting the impedance elements in the pad in that circuit so that said units offer a low resistance to the transmitted signals, and to disable the switching means connected to the other one-way circuit.

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