Oct. 15, 1929. P. B. FLANDERS 1,731,656

REPEATER CIRCUITS

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FIG. 1

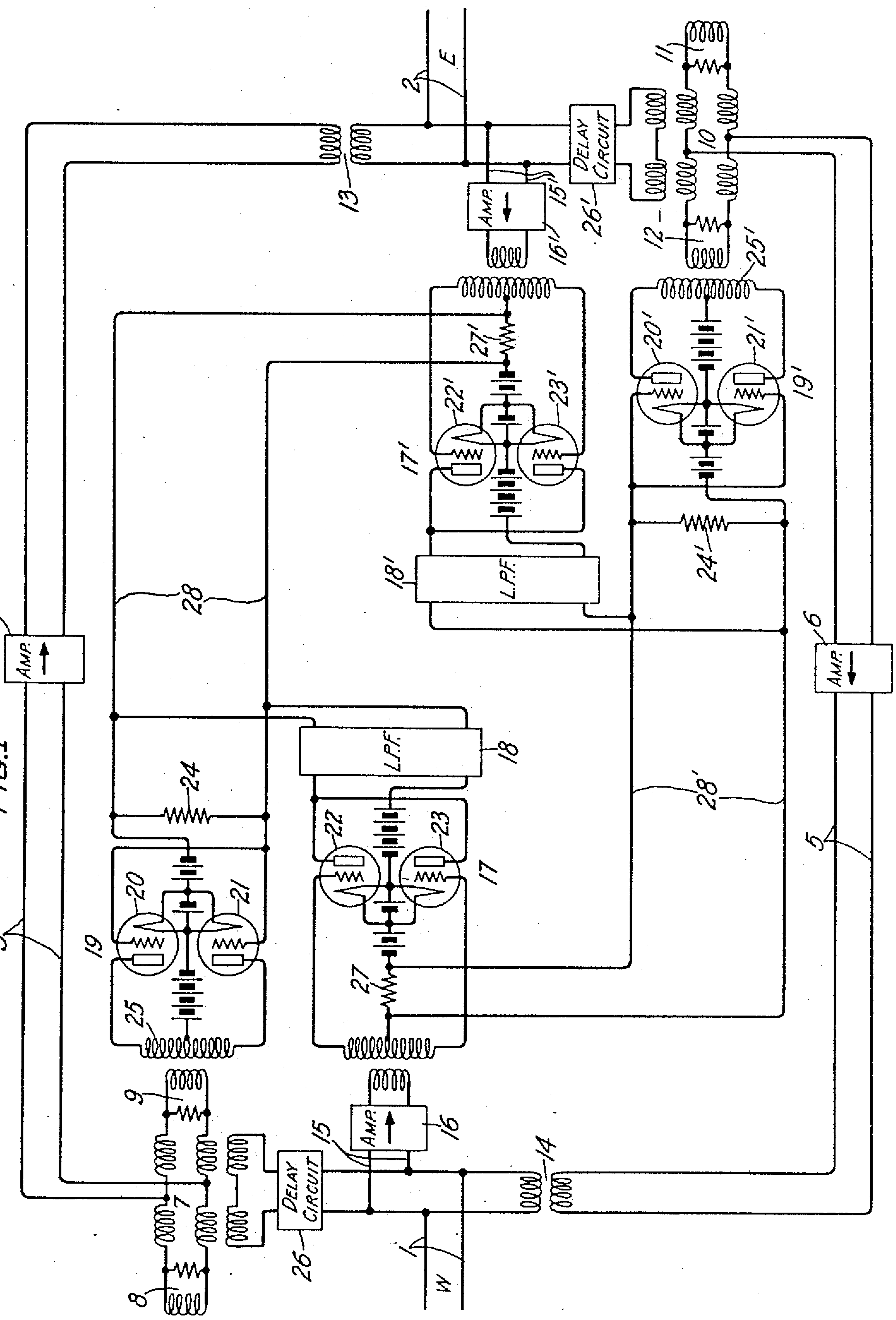

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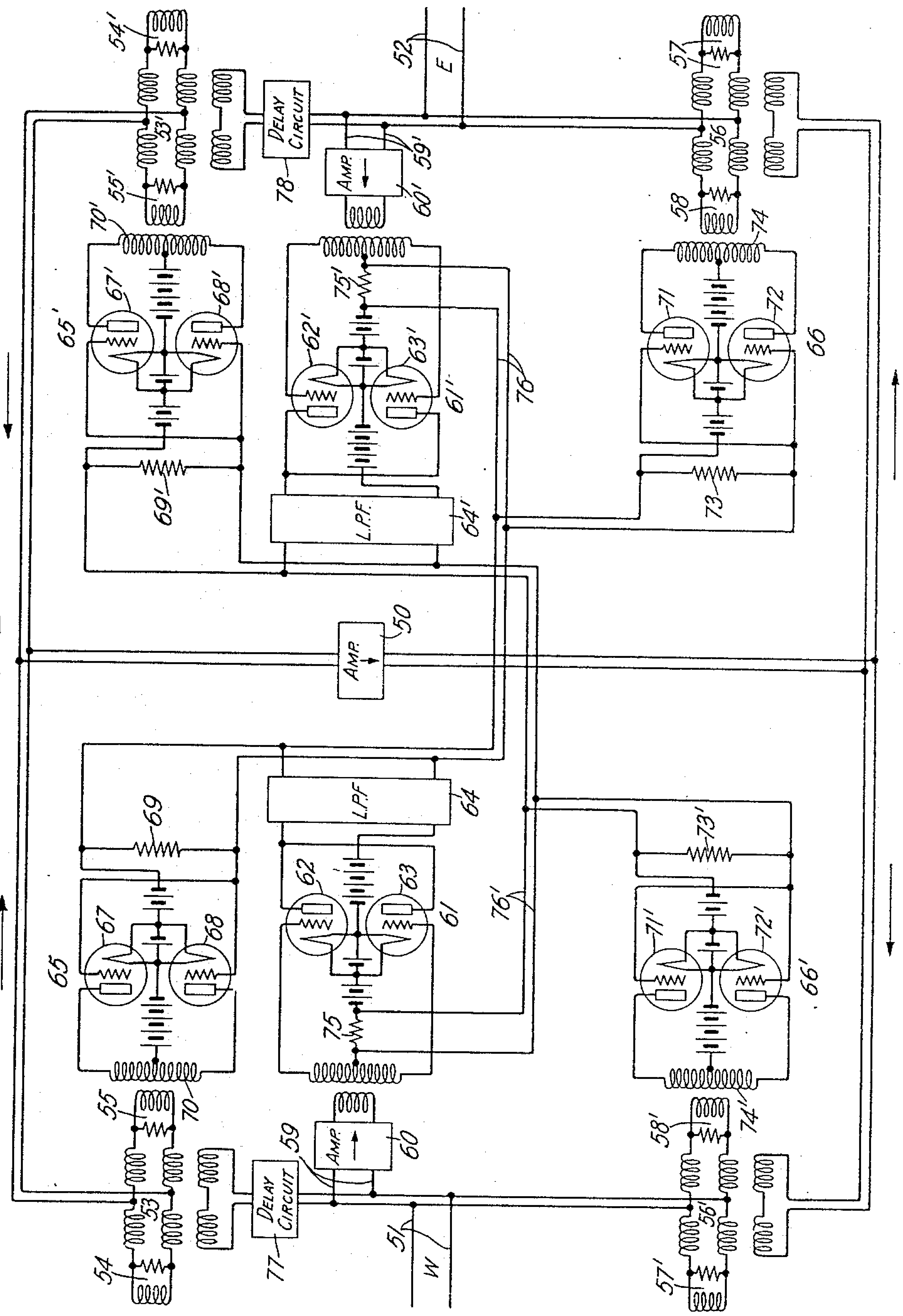
FIG. 2



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UNITED STATES PATENT OFFICE

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REPEATER CIRCUITS

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This invention relates to the transmission of electric currents and particularly to circuits for repeating such currents.

The invention has special reference to signal-operated repeater circuits of the type in which, between periods of transmission, the repeater is not in condition to transmit efficiently in either direction, but flow of signaling currents in either direction controls apparatus to condition the repeater for efficient transmission in that direction.

An object of the invention is to provide improvements in the two-way transmission of electric currents, for instance, in the two-way repeating of telephonic currents.

In accordance with the invention, a two-way signal-operated repeater of the type defined above is provide in which efficient operation is obtained without necessitating the use of movable switching elements for conditioning the repeating paths.

In a specific embodiment, the repeater of the invention comprises two oppositely directed unilateral paths for repeating signaling currents in opposite directions between two two-wire circuits. The input of each unilateral path is connected to its associated two-wire circuit through a conjugate connection comprising a hybrid coil transformer and balancing networks forming a bridge circuit, one of which networks includes the output impedance of a three-electrode space discharge amplifying device, which device in the following discussion will be referred to as the control device. The two bridge circuits are preferably initially balanced so that the transmission loss through each hybrid coil from a two-wire circuit to the unilateral repeating path is substantially infinite, thus normally preventing transmission in either direction between the two-wire circuits.

To enable transmission of received signaling energy between the two-wire circuits in a given direction, a portion of the received energy is utilized to unbalance the bridge circuit connected to the unilateral repeating path for that direction, so as to decrease the transmission loss through the hybrid coil portion of the bridge circuit, and allow signaling energy to be transmitted therethrough to the amplifier in the associated unilateral repeating path. This is accomplished by diverting a portion of the received signaling energy through an auxiliary control path, amplifying and rectifying the diverted energy and impressing it on the input circuit of the control device so as to vary its output impedance and thus the balance of the bridge circuit including that impedance. To prevent the amplified energy transmitted through the repeating path for either direction from being effective to unbalance the bridge circuit of the repeating path for the opposite direction, a portion of the rectified energy in the input of the control device in one auxiliary control circuit is utilized to neutralize the effect of the amplified energy incident on the other auxiliary control path.

A feature of the invention is a two-way signal-operated repeater in which echoes are effectively suppressed without necessitating the use of movable switching elements.

The invention itself in its objects and advantages will be best understood by reference to the following detailed description taken in connection with the accompanying drawings, Fig. 1 of which shows the invention applied to a two-way signal repeater circuit utilizing separate amplifiers for transmission in the opposite directions, and Fig. 2 of which shows the invention applied to a two-way signal repeater circuit utilizing a single amplifier for transmission in both directions.

The two-way repeater circuit of Fig. 1 comprises two two-way transmission lines 1 and 2 connected through an eastwardly directed one-way circuit 3 including an amplifying device 4 and the westwardly directed one-way circuit 5 including an amplifying device 6. A bridge circuit comprising a hybrid coil 7 having the usual series and line windings, and impedance networks 8 and 9 is connected between the amplifying device 4 in repeating path 3 and line 1, the input of the amplifying device 4 being connected directly across the bridge points of the hybrid coil, and line 1 being connected effectively across the other diagonal of the bridge circuit by being connected to the terminals of the series winding of hybrid coil 7. Another bridge circuit comprising hybrid coil 10 having the usual series and line windings, and balancing networks 11 and 12 is connected between amplifying device 6 in repeating path 5 and line 2 the input of device 6 being connected directly across the bridge points of hybrid coil 10, and line 2 being connected effectively across the other diagonal of the bridge circuit by being connected to the terminals of the series winding of hybrid coil 10. The output of amplifier 4 in repeating path 3 is coupled by transformer 13 across transmission line 2, and the output of amplifier 6 in repeating path 5 is coupled by transformer 14 across transmission line 1.

The balancing networks 8, 9, 11 and 12 may comprise any desired combination of impedance elements, but, as illustrated, each preferably comprises a parallel combination of resistance and inductance.

Bridged across the transmission line 1 in front of the series winding of hybrid coil 7 is an auxiliary control circuit 15 comprising a plurality of transmission devices connected in cascade including in order, an amplifier 16, a rectifier 17, a low pass filter 18 and a control device 19. The rectifier 17 may comprise one or more space discharge devices but preferably comprises two three-electrode vacuum tubes 22 and 23 connected in push-pull relation. The control device 19 preferably comprises the three-electrode space discharge devices 20 and 21 connected in push-pull at their outputs and having a portion of their grid circuits in common. The output of filter 18 is connected to the common branch of the grid circuits of tubes 20 and 21 across a resistance 24, in such manner that the potential variations in the output of filter 18 are applied to the two tubes symmetrically. The output circuits of tubes 20 and 21 are coupled to the inductive element in the balancing network 9 by an output winding 25, so that the control device 19 effectively controls the impedance of network 9 as viewed from the hybrid coil 7.

A control circuit 15′ similar to the control circuit 15 just described and comprising elements similar to those of the latter control circuit and similarly connected, is bridged across transmission line 2 in front of the series winding of hybrid coil 10. The elements of control circuit 15′ are identified by characters similar to those of the corresponding elements of circuit 15 with the addition of a prime (′) mark. The output of control channel 15′ is coupled by the output winding 25′ of control device 19′ to the inductive element in balancing network 12, so that the control device 19′ will effectively control the impedance of network 12 as viewed from hybrid coil 10.

A resistance 27′ in the common portion of the grid circuits of rectifier 17′ in control circuit 15′ is connected by connections 28 across the output of filter 18 in control circuit 15 in such manner that the portion of the rectified current from filter 18 flowing through resistance 27′ will produce a voltage drop therein which will make the potentials applied to the grids of tubes 22′ and 23′ of rectifier 17′ more negative. Similarly, a resistance 27 in the common portion of the grid circuits of rectifier 17 in control circuit 15 is connected by connections 28′ across the output of filter 18′ in control circuit 15′ in such manner that the portion of the rectified current from filter 18′ flowing through resistance 27 will produce a voltage drop therein which will make the potentials applied to the grids of tubes 22 and 23 of rectifier 17 more negative.

Delay circuits 26 and 26′ of suitable type are connected respectively in transmission line 1 between the connection thereto of control circuit 15 and the series winding of hybrid coil transformer 7 and in transmission line 2 between the connection thereto of control circuit 15′ and the series winding of hybrid coil 10, for the purpose of delaying propagation of signaling waves from line 1 and line 2, respectively, to hybrid coils 7 and 10.

The operation of the system of Fig. 1 is as follows: The circuits of control device 19 comprising tubes 20 and 21, and the circuits of control device 19′ comprising tubes 20′ and 21′ are initially adjusted so that when no signaling variations are applied to the inputs of these tubes, the output impedances of the control devices 19 and 19′ are of such values that the bridge circuits comprising, respectively, hybrid coil 7 and networks 8 and 9, and hybrid coil 10 and networks 11 and 12 are balanced. For example, the output impedance of tubes 20, 21, 20′ and 21′ may be made infinite by adjusting the tube circuits so that no space current flows therein, as by adjusting the negative potentials on the grids of the tubes so as to neutralize the effects of the potentials applied to the plates of the tubes, the values of the impedance elements in balancing network 8 are initially relatively adjusted with respect to the impedances of network 9 including the initial output impedance of control device 19 to balance the bridge circuit comprising hybrid coil 7 and networks 8 and 9, and thus make the transmission loss through the hybrid coil 7 substantially infinite. Similarly, the values of the impedance elements in balancing networks 11 and 12 associated with hybrid coil 10, may be relatively adjusted so that the bridge circuit comprising hybrid coil 10 and balancing networks 11 and 12, is initially balanced and the transmission loss through hybrid coil 10 is therefore substantially infinite. This means that in the absence of transmission in one direction in the system, the repeating path for that direction is inoperative to repeat signaling variations between transmission lines 1 and 2.

Now, if signaling variations are received over transmission line 1 in the direction from west to east, a portion of these variations will be diverted from line 1 through control circuit 15, amplified in amplifier 16 and rectified in rectifier 17. The rectified variations which pass through the low pass filter 18 are applied symmetrically to the grids of tubes 20 and 21 of control device 19 across resistance 24. The applied variations will cause the potentials on the grids of tubes 20 and 21 to rise to such value as to make space current flow in each of these tubes. The resulting output currents of tubes 20 and 21 will flow through output winding 25 in the same direction and reduce the plate impedances of these tubes from an infinite value to a finite value, thus decreasing the effective impedance of network 9 as viewed from the hybrid coil 7. The bridge circuit comprising hybrid coil 7 and networks 8 and 9, therefore, will be unbalanced, so as to decrease the transmission loss through hybrid coil 7 from an infinite value to a finite value. The signaling energy from line 1, the transmission of which to hybrid coil 7 has been delayed for the interval of time necessary for operation of control device 19 by proper design of delay circuit 26 then will be transmitted through hybrid coil 7 to amplifier 4 in repeating path 3.

The amplified variations in the output of amplifying device 4 are impressed by means of transformer 13 upon the outgoing transmission line 2. As the bridge circuit comprising hybrid coil 10 and networks 11 and 12 coupling the input of the oppositely directed repeating path 5 to transmission line 2, is normally balanced, substantially no part of the amplified variations will be transmitted through the hybrid coil 10 into the repeating path 5. However, a portion of the amplified variations transmitted through transformer 13 will be diverted into control circuit 15′ and amplified by amplifier 16′. The resistance 27′ in the common portion of the grid circuits of rectifier 17′ is of proper value, so that the portion of the rectified variations transmitted thereto from the output of filter 18 in control circuit 15 over connections 28 will produce a voltage drop in resistance 27′ of such magnitude as to neutralize the effect of the amplified variations in the output of amplifier 16′ on the grids of rectifier 17′. The rectifier 17′, therefore, will remain in its normal condition, and the amplified variations impressed thereon will be prevented from unbalancing the bridge circuit comprising hybrid coil 10 and networks 11 and 12.

When the transmission of signaling variations from west to east over transmission line 1 ceases, tubes 20 and 21 of control circuit 19 will return to their normal condition, and the bridge circuit comprising hybrid coil 7 and networks 8 and 9, will again become balanced so that the loss through hybrid coil 7 is again substantially infinite. The delay circuit 26, of course, is relatively designed with respect to control circuit 15 so that all received signaling energy from line 1 is transmitted through hybrid coil 7 before the bridge circuit becomes unbalanced.

The operation of the system when transmission is in the direction from east to west is similar to that when the transmission is in the direction from west to east and therefore need not be described.

The push-pull connection of tubes 20 and 21 of control device 19 in control channel 15 and of tubes 20′ and 21′ of control device 19′ in control circuit 15′, is for the purpose of preventing the introduction of even harmonics of the signal waves into the main repeating paths because of the action of tubes 20 and 21 or tubes 20′ and 21′, on path 3 and 5, respectively. A single tube may, however, be used in the control devices instead of the push-pull tubes, in which case, if the circuit of each control tube is so adjusted that its plate resistance is reduced to its lowest value by the control energy impressed on the input of the tube, the variation of the plate resistance with the impressed alternating voltage will be small, and the harmonics introduced by the control circuits in the main repeating paths will not cause objectionable interference therein.

The purpose of low pass filters 18 and 18′ in control circuits 15 and 15′, respectively, is to filter out large variations in the control currents which might cause difficulty in obtaining smooth operation of the control devices in unbalancing the bridge circuits.

The elements in the control circuits 15 and 15′ and the hybrid coil transformers 7 and 10 should be so selected that the loss through the hybrid coils will not vary sensibly with variations in amplitude of the received signaling variations. One way of aiding this would be to use for the rectifier tubes 22, 23 in control circuit 15, and for the rectifier tubes 22′, 23′ in control circuit 15′, respectively, tubes which have such a saturation characteristic that received waves above a given amplitude value will not cause any increase in the amplitude of the control waves applied to the control devices in the two control circuits.

Fig. 2 shows a modification of the two-way repeating system of Fig. 1, in which a single amplifier 50 is employed for repeating signaling energy between the two-way transmission lines 51 and 52 in both directions. A bridge circuit comprising a hybrid coil transformer 53 having the usual series and line windings, and balancing networks 54 and 55, is connected between amplifier 50 and transmission line 51, the input of amplifier 50 being connected directly across the bridge points between the line windings of hybrid coil 53, and line 51 being connected effectively across the other diagonal of the bridge circuit by being connected to the terminals of the series winding of hybrid coil 53. A second bridge circuit comprising hybrid coil 53′ having the usual series and line windings, and balancing networks 54 and 55′, is connected in a similar manner between the input of amplifier 50 and transmission line 52.

A third bridge circuit comprising a hybrid coil 56 and balancing networks 57 and 58 is connected between the output of amplifier 50 and transmission line 52, the output of the amplifier 50 being connected effectively across one diagonal of the bridge circuit by being connected to the terminals of the series winding of hybrid coil 56, and transmission line 52 being connected directly across the other diagonal of the bridge circuit at the bridge points between the line windings of hybrid coil 56. In similar fashion, a fourth bridge circuit comprising the hybrid coil 56′, and balancing networks 57′ and 58′ is connected between the output of amplifier 50 and transmission line 51.

The balancing networks 54, 55, 54′, 55′, 57′, 58, 57′ and 58′ may comprise any desired combination of impedances, but preferably each comprises, as illustrated, a parallel combination of resistance and inductance.

Bridged across the transmission line 51 in front of the series winding of hybrid coil 53 is a control circuit 59 including a plurality of transmission elements comprising in order an amplifier 60, a rectifier 61, a low pass filter 64 and the control devices 65 and 66. The control device 65 preferably comprises two three-electrode space discharge devices 67 and 68 connected in push-pull relation at their outputs and having a portion of their grid circuits in common. Similarly, the control device 66, preferably comprises two three-electrode space discharge devices 71 and 72 connected in push-pull relation at their outputs and having a portion of their grid circuits in common.

The output of filter 64 is connected to the common branch of the grid circuits of tubes 67 and 68 of control device 65 across a resistance 69, and to the common branch of the grid circuits of tubes 71 and 72 of control device 66 across a resistance 73, in such manner that any potential variations in the output of filter 64 will be applied symmetrically to the inputs of tubes 67 and 68, and to the inputs of tubes 71 and 72. The outputs of tubes 67 and 68 of control device 65 are coupled by means of output winding 70 to the inductive element in network 55, so that control device 65 effectively controls the impedance of network 55 as viewed from hybrid coil 53. Similarly, the outputs of tubes 71 and 72 of control device 66 are coupled by means of output winding 74 to the inductive element in impedance network 58 so that control device 66 effectively controls the impedance of network 58 as viewed from hybrid coil 56. The rectifier 61 may comprise one or more space discharge devices, but preferably comprises the two three-electrode space discharge devices 62 and 63 connected in push-pull relation.

A control circuit 59′ similar to the control circuit 59 just described and comprising elements similar to those of the latter circuit and similarly connected, is bridge across transmission line 52 in front of the series winding of hybrid coil 53′. The elements of control circuit 65′ are identified by characters similar to those of the corresponding elements in control circuit 65, but with the addition of a prime (′) mark. The output of control device 65′ in control channel 59′ is coupled by output winding 70′ to the inductive element in balancing network 55′, and the output of the control device 66′ is connected by output winding 74′ to the inductive element in balancing network 58′, so that control devices 65′ and 66′ respectively, control the impedance of networks 55′ and 58′ as viewed from hybrid coils 53′ and 56′, respectively.

A resistance 75′ in the common portion of the grid circuits of tubes 62′ and 63′ of rectifier 61′ in control circuits 59′ is connected by connection 76 across the output of filter 64 in control circuit 59 in such manner, that the portion of the rectified current from filter 64 flowing through resistance 75′ will produce a voltage drop therein which will make the potentials applied to the grids of tubes 62′ and 63′ of rectifier 61′ more negative. Similarly, a resistance 75 in the common portion of the grid circuits of tubes 62 and 63 of rectifier 61 in control channel 59 is connected by connections 76′ across the output of filter 64′ in control channel 59′, in such manner that the rectified currents from filter 64′ flowing through resistance 75 will produce a voltage drop therein which will make the potentials applied to the grids of tubes 62 and 63 of rectifier 61 more negative.

Delay circuits 77 and 78 of any suitable type are connected, respectively, in transmission line 51 between the connection thereto of control circuit 59 and the series winding of hybrid coil 53, and in transmission line 52 between the connection thereto of control circuit 59′ and the series winding of hybrid coil transformer 53′, for the purpose of delaying the propagation of signaling currents from line 1 and line 2, respectively, to hybrid coil 53 and 53′.

The operation of the system of Fig. 2 will be clear from the description of its operation in transmission from west to east, as the operation in transmission from east to west is similar.

The circuits of control device 65, comprising tubes 67 and 68, of control device 66 comprising tubes 71 and 72, of control device 65′ comprising tubes 67′ and 68′ and a control device 66′ comprising tubes 71′ and 72′, are initially adjusted so that when no signaling variations are applied to the inputs of these tubes, their output impedances are such that the bridge circuits associated therewith are balanced, and the transmission losses through hybrid coils 53, 56, 53′ and 56′, respectively are, therefore, substantially infinite. This may be accomplished in a manner similar to that described in connection with hybrid coils 7 and 10 in the system of Fig. 1. This means that in the absence of transmission in either direction in the system, the repeating path for that direction is inoperative to transmit signaling variations between transmission lines 51 and 52.

Now, if signaling variations are received over transmission line 51 in the direction from west to east, a porton of these variations will be diverted from line 51 through control circuit 59, amplified in amplifier 60 and rectified in rectifier 61. The portion of the rectified variations which is transmitted through low pass filter 64 is impressed on the input circuits of control devices 65 and 66 in parallel cross resistances 69 and 73. The impressed variations are effective to raise the potentials applied to the grids of the tubes of control devices 65 and 66, respectively, to such value as to make space current flow in the tubes thereof. The resulting output currents in tubes 67 and 68 of rectifier 65 will flow through the output winding 70 in the same direction and reduce the plate impedances of these tubes from an infinite value to a finite value, thus decreasing the impedance of network 55 as viewed from hybrid coil 53. The normally balanced bridge circuit comprising hybrid coil 53 and networks 54 and 55, will therefore, be unbalanced so as to decrease the transmission loss through hybrid coils 53 from an infinite to a finite value. The signaling variations from transmission line 51, which have been delayed for the interval of time required for unbalancing hybrid coil 53 by proper design of delay circuit 77, therefore will pass through hybrid coil 53 to the input of amplifier 50 and be amplified therein.

Similarly, the output currents of tubes 71 and 72 of control device 66, due to the rectified signaling variations impressed symmetrically on their input circuits across resistance 73 will flow in the same direction through output coil 74 and reduce the plate impedances of tubes 71 and 72 from an infinite value to a finite value, thus effectively decreasing the impedance of that network as viewed from hybrid coil 56. This will result in the unbalancing of the bridge circuit comprising hybrid coil 56 and networks 57 and 58, and a decrease in the transmission loss through hybrid coil 56 from an infinite to a finite value allowing the amplified variations in the output of amplifier 50 to be transmitted through hybrid coil 56 to the outgoing line 52.

Because the bridge circuits comprising, respectively, hybrid coil 53′ and balancing networks 54′ and 55′, and hybrid coil 56′ and balancing networks 57′ and 58′ are normally balanced, the amplified variations from the output of amplifier 50 cannot be transmitted through hybrid coil 53′ to the input of amplifier 50, or through hybrid coil 56′ to transmission line 51. However, a portion of the amplified variations transmitted through hybrid coil 56 will be diverted into control circuit 59′ and amplified in amplifier 60′. The resistance 75′ in the common portion of the grid circuits of rectifier 61′ is of proper value, so that the voltage drop therein due to the portion of the rectified variations from the output of filter 64 transmitted thereto over connections 76, will be of such magnitude as to neutralize the effect on the grids of the tubes of rectifier 61′ of the amplified variations in the output of amplifier 60′. The unbalance of the bridge circuits including hybrid coil 53′ and the bridge circuit including hybrid coil 56′ by the amplified variations from the output of amplifier 50 is thereby prevented.

As in the case of the control devices in the system of Fig. 1, the push-pull connection of the outputs of the tubes in control devices 65, 66, 65′ and 66′ is for the purpose of preventing the introduction of even harmonics of the signal waves into the repeating paths, but single tubes may be used in place of the push-pull tubes if the circuits thereof are adjusted in the manner described in connection with the system of Fig. 1, so that the variations of the plate resistances with the alternating voltages impressed on their input circuits are small. Low pass filters 64 and 64′ are for the purpose of filtering out large variations in the control potentials applied to the inputs of control devices 65, 66, 65′ and 66′.

While the invention has been described as applied to certain typical systems including certain particular combination of apparatus, it is to be understood that it is not limited to the systems or the particular combinations of apparatus described, but only by the scope of the appended claims.

What is claimed is:

1. A transmission system comprising two two-way transmission circuits, a path for repeating signaling waves between said two-way circuits, a bridge circuit connected in said repeating path, said bridge circuit being normally balanced so as to effectively prevent transmission between said two-way circuits over said repeating path, and means responsive to transmission of signaling waves in one of said two-way circuits for unbalancing said bridge circuit so as to enable transmission of

said signaling waves between said two-way circuits over said repeating path.

2. A transmission system comprising two two-way transmission circuits, two oppositely directed unilateral paths adapted for repeating signaling waves in opposite directions between said two-way circuits, a bridge circuit connected between the input of each unilateral path and a different one of said two-way circuits and normally balanced so as to effectively prevent transmission between said two-way circuits in either direction, and means responsive to the transmission of signaling waves in said system in one direction for unbalancing one of said bridge circuits to allow transmission of signaling waves between said two-way circuits over the repeating path for said one direction.

3. A transmission system in accordance with claim 2, and in which each of the balanced bridge circuits comprises a hybrid coil transformer and associated balancing impedance networks, and said means for unbalancing said one of said bridge circuits comprises means responsive to transmission in said system for varying the impedance of one of said networks.

4. A transmission system in accordance with claim 2 and in which each of said balanced bridge circuits comprises the windings of a hybrid coil transformer and associated balancing impedance networks, one of said impedance networks comprising the output circuit of a space discharge device, and said means for unbalancing one of said bridge circuits comprises means for varying the impedance of said output circuit of said space discharge device.

5. A transmission system in accordance with claim 2 and in which each of said balanced bridge circuits has for its respective arms the windings of a hybrid coil transformer, a constant impedance device and a variable impedance device, and the means for unbalancing said bridge circuit comprises means responsive to transmission in said system for controlling the impedance of said variable impedance device.

6. A transmission system in accordance with claim 2 and in which the input of one unilateral path is effectively connected across one diagonal of one of said bridge circuits, and one of said two-way circuits and the output of the other of said unilateral paths connected effectively across the other diagonal of said balanced bridge circuit.

7. A transmission system in accordance with claim 2 and in which each of said bridge circuits includes in one of its arms the effective output impedance of a space discharge device having an input circuit, and said means for unbalancing said bridge circuit comprises means for applying a portion of the signaling currents transmitted over one of said two-way circuits to said bridge circuit, to the input circuit of said space discharge device so as to change the effective output impedance thereof.

8. A repeating system comprising two two-way transmission circuits, two oppositely directed unilateral paths including amplifying means, means for effectively connecting each two-wire circuit with the input of one of said unilateral paths and the output of the other unilateral path, said means including a bridge circuit coupling the input of each unilateral path with the two wire circuit, each of the bridge circuits being normally balanced so as to normally prevent transmission of signaling variations between said two-wire circuits, means connected to each two-wire circuit and responsive to transmission in one direction therein for unbalancing the bridge circuit coupled thereto so as to allow transmission of signaling energy from one two-wire circuit to the other over the unilateral path for said one direction, and means to prevent the transmitted energy from unbalancing the bridge circuit connected to said other two-wire circuit.

9. A repeating system, comprising a repeater path between two line sections, said path containing impedance balancing means normally balanced to prevent transmission through the repeater path, and means controlled by signal waves received over a line section for upsetting the impedance balance of said first means and thereby rendering the repeater path operative to repeat said signals into the opposite line section.

In witness whereof, I hereunto subscribe my name this 16th day of May, 1928.

PAUL B. FLANDERS.