

Feb. 11, 1936.

V. E. ROSENE

2,030,400

CONTROL CIRCUIT

Filed Feb. 21, 1935

4 Sheets-Sheet 1

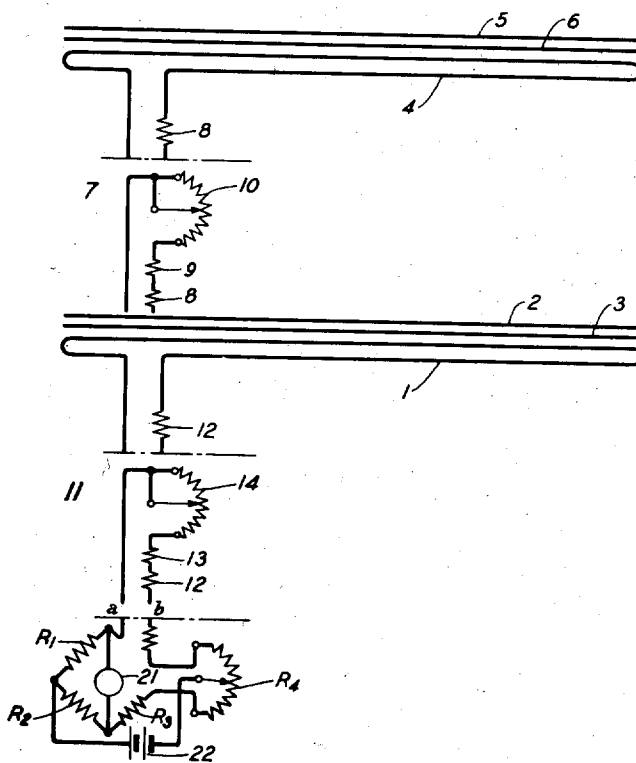
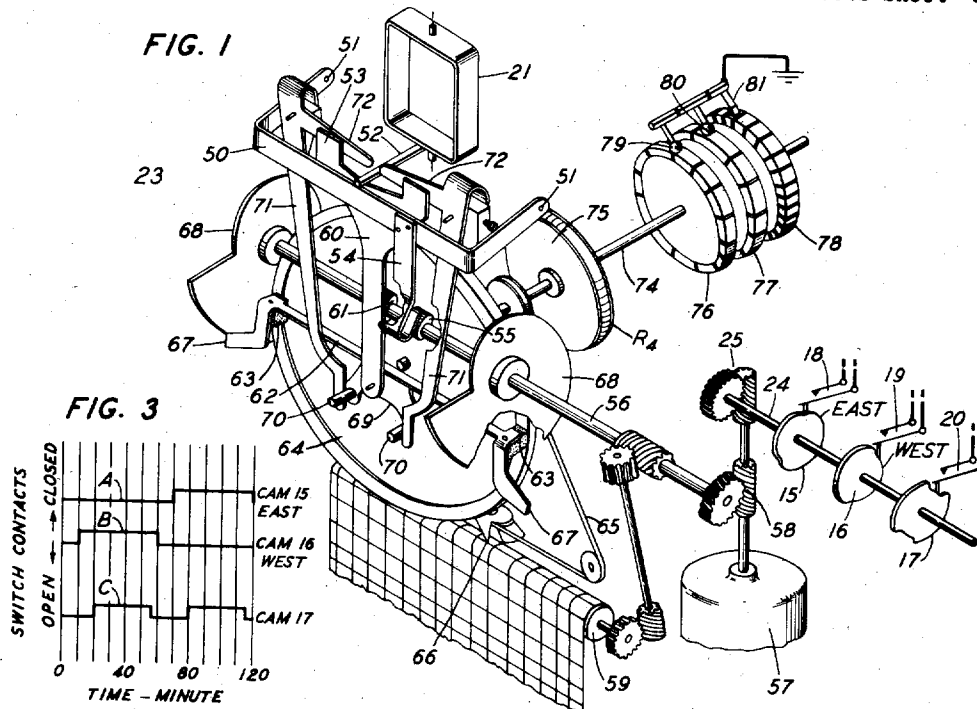


FIG. 2

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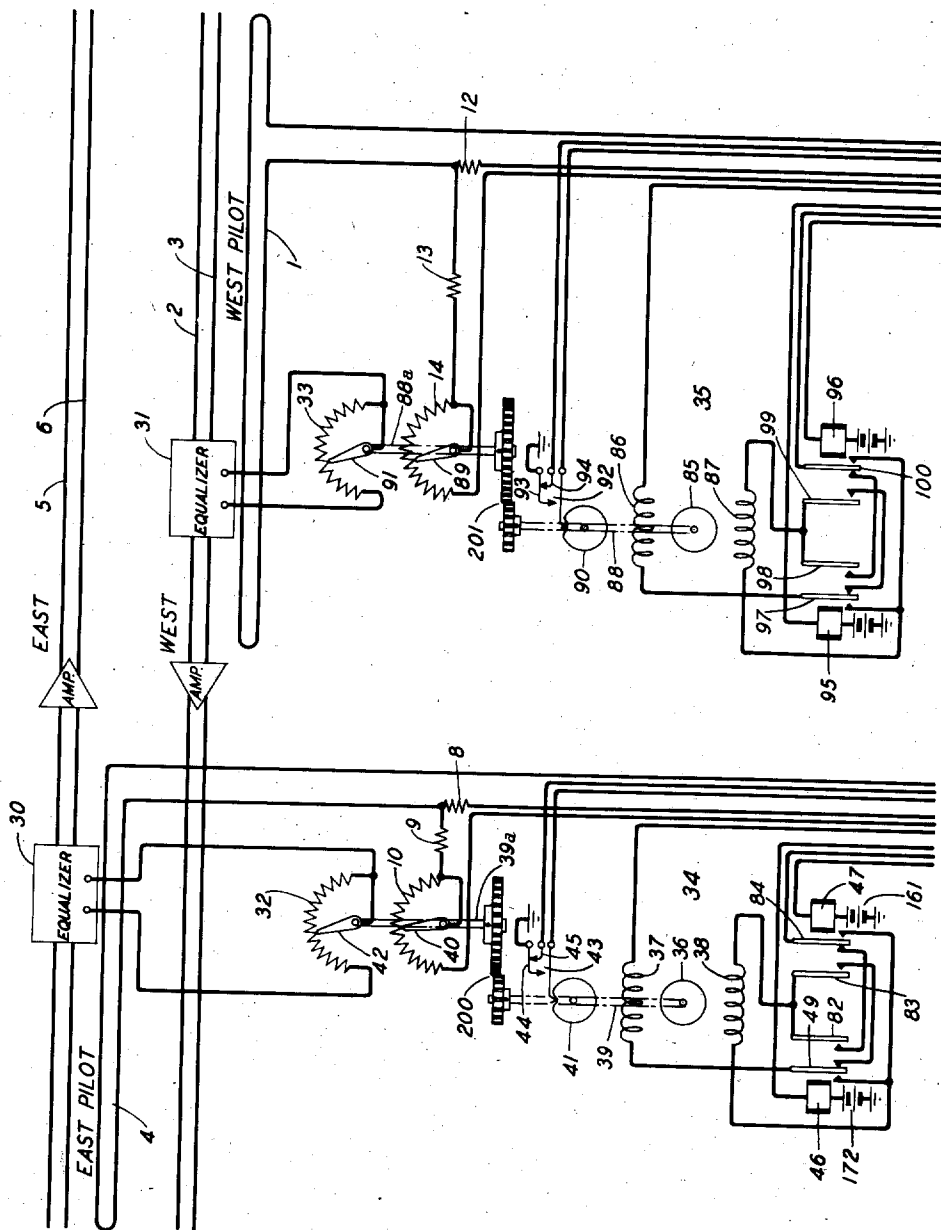
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4 Sheets-Sheet 2

FIG. 4



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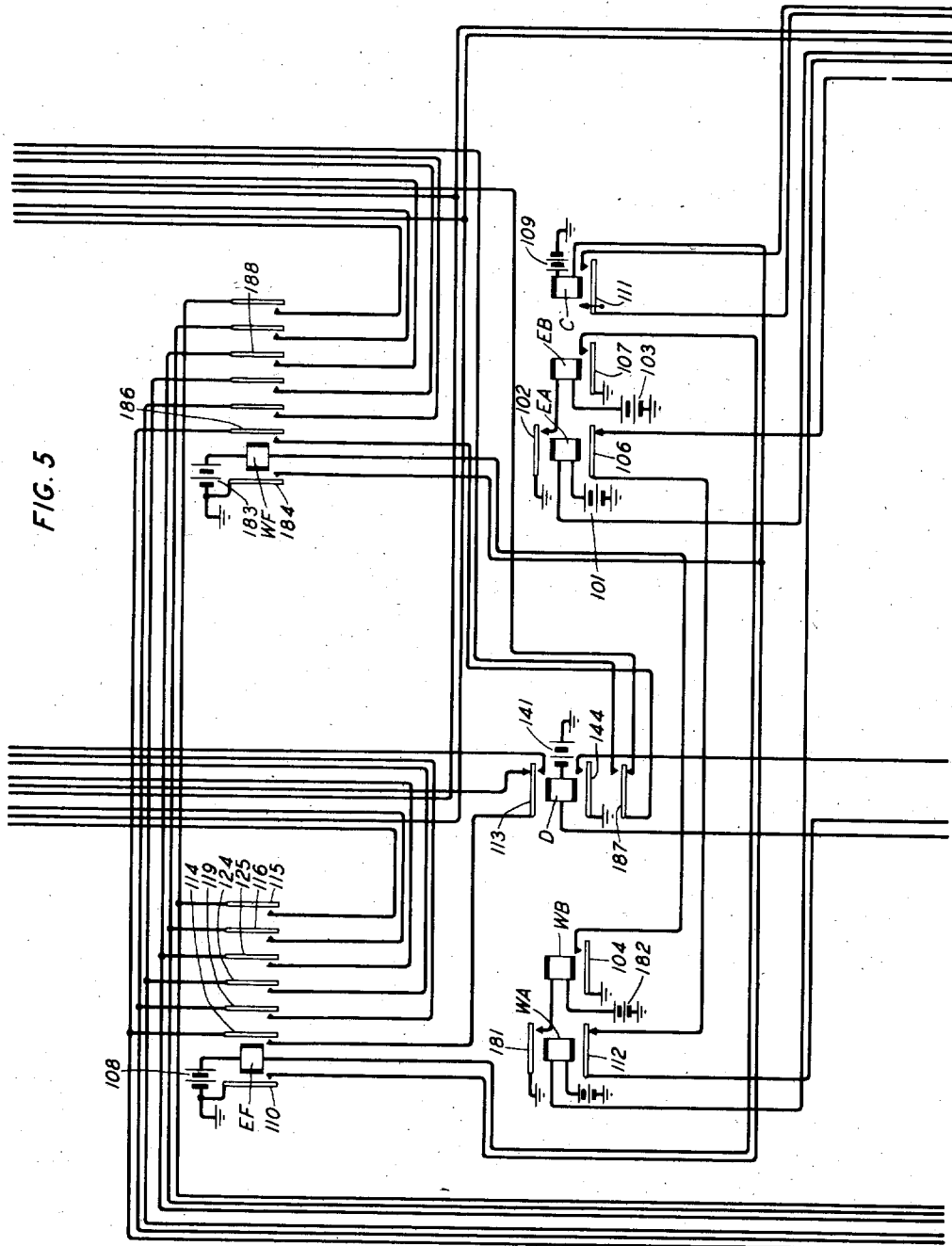
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CONTROL CIRCUIT

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4 Sheets-Sheet 3



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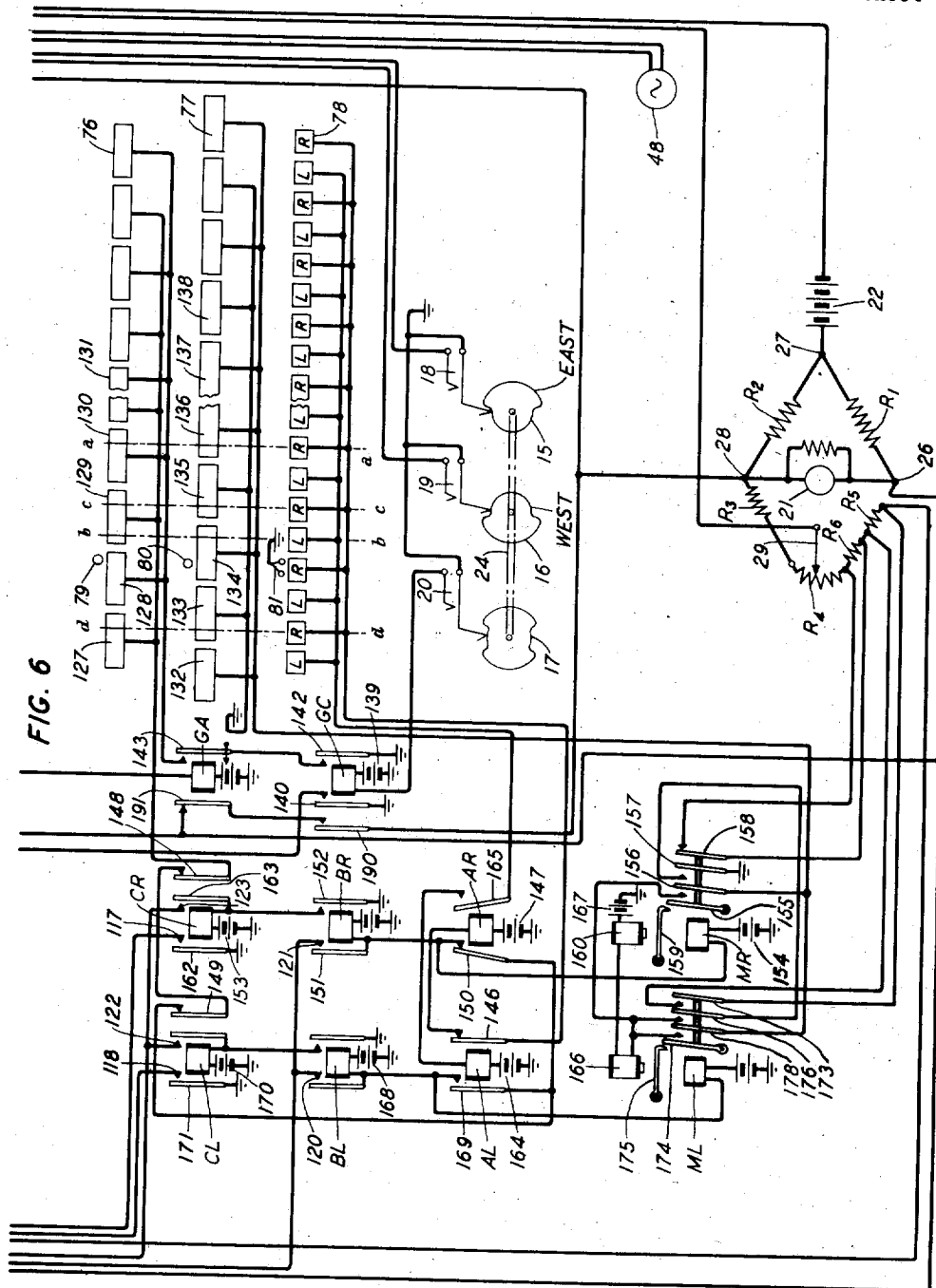
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CONTROL CIRCUIT

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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,030,400

CONTROL CIRCUIT

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Application February 21, 1935, Serial No. 7,573

18 Claims. (Cl. 178-44)

This invention relates to control circuits and particularly to control circuits for adjusting the attenuation on the lines of four-wire signaling systems.

5 One object of the invention is to provide control circuits that shall adjust the attenuation on the lines of a four-wire signaling system in an improved manner.

Another object of the invention is to provide
10 a four-wire signaling system having an east line and a west line with control circuits that shall adjust the attenuation of the east line according to resistance variations in a pilot line associated with the east line and that shall adjust the at-
15 tenuation of the west line according to resistance variations in a pilot line associated with the west line.

Another object of the invention is to provide
20 a four-wire signaling system having an east line and a west line with control circuits having three connected impedance arms and east and west pilot lines that shall adjust the attenuation of the east line under control of a bridge formed with the impedance arms and the east pilot line
25 and that shall adjust the attenuation of the west line under control of a bridge formed with the impedance arms and the west pilot line.

A further object of the invention is to provide
30 a four-wire signaling system having an east line and a west line with control circuits having three connected impedance arms, east and west pilot lines, and galvanometer mechanism that shall adjust the attenuation of the east line under control of the galvanometer mechanism when gov-
35 erned by a bridge formed with the impedance arms and the east pilot line and that shall adjust the attenuation of the west line under control of the galvanometer mechanism when governed by a bridge formed with the impedance arms and
40 the west pilot line.

The attenuation of a signal transmission line varies according to temperature and weather conditions. It is necessary to compensate for these changes in attenuation to obtain good
45 transmission characteristics. It is customary to vary the attenuation of the signal transmission line at repeater and terminal stations.

In a four-wire signaling system as, for exam-
50 ple, a carrier telephone system, a pilot line extending in one direction is used to control the attenuation of one line of the four-wire system extending in the same direction and a pilot line extending in the opposite direction is used to control the attenuation of the other line of the four-
55 wire system extending in the opposite direction. It is inexpedient, by reason of the increased cost, to provide separate control circuits for the lines in each direction.

According to the present invention, a pilot line
60 which is associated with the east line is sub-

jected to the same resistance variations as the east line. A second pilot line which is associated with the west line is subjected to the same resistance variations as the west line. At a repeater or terminal station is provided an east dummy
5 line having approximately the resistance of the east pilot line and a west dummy line having approximately the resistance of the west pilot line. Three connected impedance arms are provided for forming bridge circuits with the pilot lines
10 and the dummy lines to control the attenuation in the east line and in the west line. Cam members which continuously operate control apparatus serve to connect the pilot lines and the dummy lines in a predetermined sequence to the
15 three connected impedance arms for forming the bridge circuits.

A galvanometer is connected across two opposite vertices of the three impedance arms. This galvanometer is operated by the bridge circuits
20 formed between the impedance arms and the pilot and dummy lines to control galvanometer mechanism of the type disclosed in the application of H. I. Romnes, Serial No. 716,934 filed
25 March 23, 1934. The galvanometer control mechanism when operated by a bridge formed with the impedance arms and the east pilot line, serves to control a motor for governing the attenuation in the east line. The galvanometer mechanism
30 when operated by a bridge circuit formed with the impedance arms and the west pilot line serves to govern a motor for controlling the attenuation in the west line. A continuously operating motor which is connected to the galvanometer
35 mechanism for operating it in accordance with the operation of the galvanometer also continuously operates the three cam members. The three continuously operating cam members, as
40 above mentioned, control apparatus for connecting the two pilot lines and the two dummy lines to the three impedance arms to form bridge circuits.

The two pilot lines which are respectively associated with the east and the west lines, have
45 resistance variations approximately the same as the resistance variations in the east and the west lines. The two dummy lines which are respectively associated with the east and the west pilot lines are adjusted periodically to have ap-
50 proximately the same resistance as the pilot lines. The east dummy line includes a variable resistance element which is adjusted when the east pilot line is connected to the three impedance
55 arms to have a resistance value approximately the same as the east pilot line. The west dummy line is provided with an adjustable resistance element which is adjusted when the west pilot line is connected to the three impedance arms
60 so that the west dummy line will have a resist-

ance value approximately the same as the west pilot line.

A dummy line is connected to the three impedance arms before the connection of a pilot line to the three impedance arms in order to approximately balance the bridge circuit to the resistance value of the pilot line which existed when the three impedance arms were last connected to the pilot line. If the east dummy line is connected to the three impedance arms, a bridge circuit is formed for operating the galvanometer according to the resistance value of the east dummy line. The operation of the galvanometer controls the galvanometer mechanism to balance the bridge circuit. At this time, however, no control is effected of the motor which governs the attenuation of the east line. In the system employed to describe the invention, the east dummy line is connected to the three impedance arms before the connection of the east pilot line to the impedance arms for approximately ten minutes. At the end of ten minutes the cam members operate to disconnect the east dummy line from the three impedance arms and to connect the east pilot line to the three impedance arms. The east dummy line during its connection to the three impedance arms forms a bridge circuit and effects balancing of the bridge circuit approximately according to the resistance of the east pilot line which existed when the three impedance arms were last connected to the east pilot line. Accordingly, when the east pilot line is again connected to the three impedance arms, the bridge circuit formed thereby requires balancing by means of the galvanometer and the galvanometer control mechanism only according to the change in resistance of the east pilot line.

The change in the resistance value of the east pilot line from the value it last had when an adjustment was made of the attenuation of the east line, effects operation of the galvanometer and the galvanometer control mechanism. The galvanometer control mechanism not only rebalances the bridge circuit but controls the motor for operating an equalizer in the east line to adjust the east line attenuation. The motor which operates the equalizer in the east line also controls a resistance in the east dummy line to adjust the resistance value of the east dummy line to approximately the resistance value of the east pilot line. The galvanometer control mechanism at this time also operates a switching mechanism of the type disclosed in the above mentioned application of H. I. Romnes, Serial No. 716,934. The galvanometer control mechanism may, if so desired, govern the attenuation of the line by means of the type disclosed in the Romnes application. The east pilot line is connected to the three impedance arms for forming a bridge circuit to control the attenuation in the east line for approximately thirty-five minutes. The cam members then operate to disconnect the east pilot line from the three impedance arms and to connect the east dummy line to the three impedance arms. The bridge circuit formed by the east dummy line at this time performs no useful function as to the operation of the galvanometer and the galvanometer control mechanism. When the east dummy line has been connected to the impedance arms for approximately five minutes, the cam members disconnect the east dummy line from the impedance arms.

A period of ten minutes now elapses when neither the east or west pilot line nor the east

or west dummy line is connected to the three impedance arms. After the ten minute period has elapsed, the cam members again operate to connect the west dummy line to the impedance arms. The pilot lines and dummy lines are disconnected from the impedance arms for ten minutes to effect the operation of gang relays by the cam members at different times. The west dummy line forms a bridge circuit with the impedance arms to operate the galvanometer and control the galvanometer control mechanism. The galvanometer control mechanism at this time balances the bridge formed with the west dummy line but effects no control over the motor which governs the attenuation of the west line. The bridge formed with the west dummy line operates the galvanometer and the galvanometer control mechanism to balance the bridge circuit to approximately the resistance value of the west pilot line which existed when the three impedance arms were last connected to the west pilot line. When the galvanometer and the galvanometer control mechanism have been controlled by the west dummy line for approximately ten minutes, the cam members operate for disconnecting the west dummy line from the three impedance arms and for connecting the west pilot line to the three impedance arms.

The bridge circuit formed by the three impedance arms with the west pilot line serves to effect operation of the galvanometer and the galvanometer control mechanism for not only rebalancing the bridge circuit but also for controlling the motor which controls an attenuation equalizer in the west line. The motor controlled by the galvanometer control mechanism not only operates the attenuation equalizer in the west line but also controls a resistance element in the west dummy line to adjust the resistance value of the west dummy line to approximately the resistance value of the west pilot line. When the west pilot line has controlled the galvanometer and the galvanometer control mechanism for approximately thirty-five minutes, the cam members operate to disconnect the west pilot line from the three impedance arms and to connect the west dummy line to the three impedance arms.

The bridge circuit formed by the three impedance arms with the west dummy line at this time performs no useful function as to the adjustment of the west line attenuation by the galvanometer and the galvanometer control mechanism. When the west dummy line has been connected to the three impedance arms for approximately five minutes, the cam members operate to disconnect the west dummy line from the three impedance arms. A period of ten minutes now elapses when neither east or west pilot line nor east or west dummy line is connected to the three impedance arms. After the ten minute period has elapsed, the cam members again operate to connect the east dummy line to the impedance arms.

The above cycle of operations is again repeated. This cycle of operations, it will be noted, lasts for two hours. The time of one cycle may be decreased if necessary to effect more frequent adjustments of line attenuation. The proportion of time for the operations described above may be changed to suit particular conditions.

In the accompanying drawings:

Fig. 1 is a diagrammatic view of a galvanometer and galvanometer control mechanism employed in controlling circuits constructed in accordance with the invention;

Fig. 2 is a diagrammatic view of the pilot lines,

dummy lines and impedance arms which control the operation of the galvanometer and galvanometer control mechanism shown in Fig. 1 of the drawings:

Fig. 3 is a diagrammatic view illustrating the timed operation of the cam members shown in Fig. 1 of the drawings; and

Figs. 4, 5, and 6 taken together disclose control circuits constructed in accordance with the invention.

Referring to Fig. 2 of the drawings, a pilot line 1 which will be designated as the west pilot line, is shown associated with the west line comprising conductors 2 and 3. The pilot line 1 is subjected to the same attenuation varying conditions as conductors 2 and 3 of the west line. A pilot line 4 which will be designated as the east pilot line, is shown associated with the east line comprising conductors 5 and 6. The east pilot line 4 is subjected to the same attenuation varying conditions as conductors 5 and 6 of the east line. A dummy line 7, comprising resistance elements 8, 9 and 10, is located at the control station which may be a repeater or terminal station. The dummy line 7 which will be designated as the east dummy line has approximately the same resistance value as the resistance value of the east pilot line 4. The resistance element 10 in the east dummy line 7 is adjustable in order to correct the dummy line for changes in the resistance of the east pilot line 4. The manner in which the resistance 10 is adjusted to maintain the resistance of the dummy line 7 substantially the same as the resistance of the east pilot line 4 will be hereinafter described. A dummy line 11 which will be designated as the west dummy line comprises resistance elements 12, 13, and 14. The dummy line 11 is located at the repeater or terminal station and has approximately the same resistance value as the resistance value of the west pilot line 1. The resistance 14 of the west dummy line 11 is adjustable in order to maintain the west dummy line at substantially the same resistance value as the resistance value of the west pilot line 1. The manner in which resistance 14 is adjusted will be described hereinafter.

Three impedance arms comprising resistance elements R_1 , R_2 and R_3 are provided at the control station for forming bridge circuits with the pilot lines 1 and 4 and the dummy lines 7 and 11. An adjustable resistance element R_4 is connected to the three impedance arms R_1 , R_2 and R_3 for balancing the bridge circuits formed when the impedance arms are connected to the pilot and dummy lines. As shown in Fig. 2 of the drawings, the connected impedance arms R_1 , R_2 and R_3 are provided with two terminals a and b which are connected in a predetermined order to the terminals of the pilot lines 1 and 4 and to the terminals of the dummy lines 7 and 11. The connection of the terminals a and b to the terminals of the pilot and dummy lines is under the control of three cam members 15, 16, and 17 shown in Fig. 1 of the drawings. Cam member 15 which will be designated as the east cam member controls a switch 18. Cam member 16 which will be designated as the west cam member controls a switch 19. Cam member 17 which will be designated as the ground cam member controls a switch 20. The manner in which the cam members 15, 16, and 17 operate to connect the pilot and dummy lines to the terminals a and b of the three impedance arms will be described in detail when reference is made to Figs. 4, 5, and 6 of the drawings.

When the terminals a and b of the three impedance arms R_1 , R_2 , and R_3 are connected to the west dummy line 11, a bridge circuit is formed with the dummy line 11 as the fourth arm of the bridge circuit. A galvanometer 21 is connected across two opposite vertices of the bridge so formed and a battery 22 is connected across the other two vertices of the bridge. The galvanometer 21 is then operated in accordance with the resistance value of the west dummy line 11. As will be described hereinafter, the galvanometer 21 when controlled by the bridge circuit formed by the impedance arms connected to the west dummy line 11 governs galvanometer control mechanism 23 shown in Fig. 1 of the drawings for controlling the adjustable resistance R_4 to balance the bridge circuit. After the west dummy line 11 has been connected to the terminals a and b of the three impedance arms R_1 , R_2 , and R_3 for approximately ten minutes, cam members 15, 16, and 17 operate to disconnect the west dummy line 11 from the terminals a and b and to connect the terminals of the west pilot line 1 to the terminals a and b of the three impedance arms R_1 , R_2 , and R_3 .

The bridge circuit formed by the three impedance arms R_1 , R_2 , and R_3 and the west pilot line 1 controls the galvanometer 21 for operating galvanometer control mechanism 23. Galvanometer control mechanism 23 when under the control of the bridge formed with the west pilot line 1, serves to balance the bridge circuit, to operate control mechanism for adjusting the attenuation of the west line comprising conductors 2 and 3, and to adjust the resistance 14 in the west dummy line 11 to maintain the west dummy line at substantially the same resistance value as the west pilot line. The west pilot line is maintained connected to the terminals a and b of the three impedance arms for approximately thirty-five minutes. Then the impedance arms are again connected to the terminals of the west dummy line 11. The west dummy line 11 effects no useful function at this time as to the adjustment of the west line attenuation by the galvanometer 21 and the galvanometer control mechanism 23 but serves to permit the transfer of the control from the west line to the east line. The west dummy line 11 is connected to the impedance arms for approximately five minutes, after which the cam members 15, 16, and 17 again operate. The impedance arms are then disconnected from the west dummy line 11 and for approximately ten minutes remain disconnected from both the east and west pilot lines and dummy lines. After the ten minute period has elapsed, the cam members 15, 16, and 17 again operate and this time the east dummy line 7 is connected to the impedance arms R_1 , R_2 and R_3 for forming a bridge circuit.

The galvanometer control mechanism 23 is controlled by the bridge formed with the impedance arms and the east dummy line 7 to balance the bridge circuit prior to the forming of a bridge circuit with the east pilot line 4. After the east dummy line 7 has been connected to the impedance arms for approximately ten minutes, the terminals of the east pilot line 4 are connected to the terminals a and b of the impedance arms. The bridge circuit formed by the impedance arms and the east pilot line 4 operate the galvanometer 21 and the galvanometer control mechanism 23 for controlling the attenuation of the east line comprising conductors 5 and 6, for balancing the bridge circuit and for adjusting resistance 10 in the east dummy line 7 to maintain the resistance

value of this dummy line substantially the same as the resistance value of the east pilot line 4. The galvanometer 21 is controlled by the bridge formed with the east pilot line 4 for approximately thirty-five minutes. At the end of that period a bridge circuit is again formed between the east dummy line 7 and the impedance arms. The bridge circuit formed at this time performs no useful function as to the adjustment of the east line attenuation by the galvanometer 21 and the galvanometer control mechanism 23. The east dummy line 7 is connected to the impedance arms for approximately five minutes, after which the east dummy line is disconnected. A period of ten minutes now elapses when the terminals *a* and *b* of the impedance arms are not connected to dummy lines 7 or 11 or pilot lines 4 or 1. A more detailed description of the timed relation between the control of the galvanometer 21 by the pilot lines 4 and 1 and dummy lines 7 and 11 will be given when reference is made to Fig. 3 of the drawings.

Referring to Fig. 1 of the drawings, the galvanometer control mechanism 23 will be described in detail. The galvanometer control mechanism 23 governed by the galvanometer 21 comprises a U-shaped rocker arm 50 which is pivotally mounted at points 51. A pointer member 52 of the galvanometer 21 is free to swing directly above a U-shaped supporting member 53 which is attached to the rocker arm 50. The member 53 is shaped to allow the pointer 52 of galvanometer 21 to deflect only a limited amount for the purpose described hereinafter. An arm 54 secured to the rocker arm 50 engages a cam member 55 on a constantly rotating shaft 56. The shaft 56 is preferably connected to a motor 57 by suitable gearing 58. The gearing 58 also connects the motor 57 to a rotating paper roll 59. The motor 57 further is connected to a shaft 24 by means of gearing 25. The shaft 24 carries the cam members 15, 16, and 17.

The constant rotation of the cam member 55 serves to raise the rocker arm 50 at predetermined intervals; preferably, the rocker arm 50 is operated approximately every thirty seconds. A flexible arm 60 engages a second constantly rotating cam member 61 on the shaft 56. A cross arm 62 is pivotally mounted on the resilient arm 60 and carries a pair of shoes 63 which are adapted to frictionally engage a disc 64. The shoes 63 engage the disc 64 for part of each revolution of the shaft 56. The disc 64 by means of a flexible connecting member 65 serves to control the movement of the recording pin 66. The cross arm 62 terminates in a pair of projecting lugs 67 which are located in a position such that a pair of rotating cam members 68 on the constantly rotating shaft 56 will normally not engage them. A plate 69 is fixed to the cross arm 62 and carries a pair of pins 70. Pivotaly mounted arms 71 are held in engagement with the pins 70 by any suitable spring means not shown. The arms 71 are provided with projections 72 positioned above the pointer 52 of the galvanometer 21.

When the galvanometer needle or pointer 52 is deflected in one direction or the other, it will pass under one of the projections 72 attached to the arms 71 and upon the rising of the rocker arm 50 under control of the cam member 55 on the constantly rotating shaft 56, one of the arms 71 will be given a movement of rotation to rotate the cross arm 62 on its pivotal support. The rotative movement of the cross arm 62 places one of the projections 67 in the path of movement of one of

the cam members 68. The cam member 68, upon engaging the projections 67 on the cross arm 62, moves the cross arm back to its original position. Just before the cam member 68 engages the projections 67 on the cross arm 62, the cam member 61 will act to allow the shoes 63 on the cross arm 62 to frictionally engage the disc 64 and as the cross arm 62 is given a movement of rotation, it will give a like movement of rotation to the disc 64 for controlling the recording needle or pointer 66.

The disc 64 is mounted on a shaft 74 which also carries a disc 75 supporting the slide wire resistance R_4 and three commutator rings 76, 77, and 78. The three commutator rings 76, 77, and 78 are respectively shown connected to stationary brush members 79, 80, and 81. The commutator rings 76, 77, and 78 operate in the manner to be set forth when reference is made to Figs. 4, 5, and 6 of the drawings for controlling the attenuation of the east and west lines. The commutator rings also serve to prevent hunting action in the manner disclosed in the above-mentioned application of H. I. Romnes, Serial No. 716,934. A description of this means will be briefly given when reference is made to Figs. 4, 5, and 6 of the drawings.

Referring to Figs. 4, 5, and 6 of the drawings, a description will be given of the mechanism and circuits for controlling the attenuation of the east and west lines by cam members 15, 16, and 17 and commutator rings 76, 77, and 78. With commutator rings 76, 77, and 78 in the position with respect to brushes 79, 80, and 81 as viewed in Fig. 6 of the drawings, all relays are normally operative or released as shown in Figs. 4, 5, and 6 of the drawings. In Fig. 4 of the drawings, an attenuation equalizer 30 is shown in the east line comprising conductors 5 and 6 and an attenuation equalizer 31 is shown in the west line comprising conductors 2 and 3. The equalizer 30 is controlled by an adjustable resistance element 32 and the equalizer 31 is controlled by an adjustable resistance element 33. The two resistance elements 32 and 33 are respectively controlled according to the operation of two motors 34 and 35.

The motor 34 which is preferably an induction motor comprises a squirrel cage rotor 36 and windings 37 and 38. The rotor 36 is mounted on a shaft 39 which carries a cam member 41. The shaft 39 is connected to a shaft 39a by reduction gears 200. The shaft 39a carries an arm 40 for adjusting the east dummy line resistance 10 and a switch arm 42 for adjusting the resistance 32 which controls equalizer 30. The cam member 41 operates a switch arm 43 for engaging a switch arm 44 and for disengaging the contact member 45 from the switch arm 44. The cam member 41 makes a complete revolution for a small movement of arms 40 and 42. Two relays 46 and 47 are provided for connecting the windings 37 and 38 to a source of alternating current 48, shown in Fig. 6, to control the direction of rotation of the motor 34. Relay 46 is provided with two switch members 49 and 82 and relay 47 is provided with two switch members 83 and 84.

The motor 35 comprises a rotor 85, preferably of the squirrel cage type, and two windings 86 and 87. The rotor 85 is mounted on a shaft 88 which carries a cam member 90. The shaft 88 is connected to a shaft 88a by reduction gears 201. The shaft 88a carries a switch arm 89 for adjusting the west dummy line resistance 14, and a switch arm 91 for adjusting the resistance 33 to control the equalizer 31. The cam member 90

operates a switch member 92 for engaging a switch member 93 and for disconnecting switch member 93 from the contact member 94. The windings 86 and 87 of the motor 35 are connected to the source of alternating current 48 by means of two relays 95 and 96. Relay 95 is provided with two switch arms 97 and 98 and relay 96 is provided with two switch arms 99 and 100. Although the two equalizers 30 and 31 are shown controlled by two induction motors 34 and 35, it is to be understood that other types of motors may be employed if so desired.

Assume that the cam member 15 on the constantly rotating shaft 24 has just closed switch 18 for controlling the attenuation on the east line comprising conductors 5 and 6. The cam members 15, 16 and 17 on the constantly rotating shaft 24 cooperate with relays to be described later for transferring the control of the galvanometer control mechanism from one line of the transmission system to another line of the transmission system. The cam shaft 24 makes one rotation every two hours. Each rotation of cam members 15 and 16 on shaft 24 closes the switches 18 and 19 for approximately fifty minutes each, at different times, and cam member 17 closes the switch 20 for about thirty-five minutes during each of the fifty minute periods when switches 18 and 19 are closed.

Upon closure of switch 18 by the cam member 15, a circuit is completed for operating a relay EA. The circuit for operating the relay EA may be traced from a grounded battery 101, through coil of relay EA, switch 18 and ground return to battery 101. The operation of relay EA completes a circuit for operating relay EB. The circuit for operating relay EB may be traced from ground, through a switch member 102 of relay EA, coil of relay EB and battery 103 to ground. The operation of switch member 106 of relay EA opens a circuit which normally short-circuits the galvanometer 21. This circuit may be traced from vertex 28 of the bridge, switch member 106 of relay EA and switch member 112 of relay WA to the vertex 26 of the bridge. The bridge may be formed with either of the two pilot lines or either of the two dummy lines. The operation of switch member 107 of relay EB completes a circuit from battery 108 for operating a gang relay EF. The circuit for operating gang relay EF may be traced from ground, through battery 108, coil of relay EF and switch member 107 of the relay EB to ground.

Upon the operation of gang relay EF a circuit is completed for energizing a slow to operate relay C. The circuit for operating relay C may be traced from ground through battery 109, coil of relay C, switch member 110 of relay EF and ground return to battery 109. Relay C, which is slow to operate, connects bridge battery 22 to vertex 29 of the bridge circuit formed at that time. The circuit completed by battery 22 to the vertex 29 extends from one terminal of battery 22 through a switch member 111 of relay C to the bridge vertex 29.

The operation of the switch member 114 of relay EF connects the vertex 26 of the bridge circuit to switch member 112 of the relay D. When relay D is not operated, the member 113 of relay D is connected to the dummy line 7 and when relay D is operated, the member 113 of relay D is connected to the pilot line 4. The operation of switch member 115 of relay EF connects one terminal of the coil of relay 47 to contact member 117 of the relay CR. The opera-

tion of switch member 116 of relay EF connects one terminal of the coil of relay 46 to contact member 118 of the relay CL. Relays CL and CR control the direction of operation of the motor 34 as will be described hereinafter. Switch member 119 of relay EF connects contact members 120 and 121 of relays BL and BR to the contact member 45 which is normally connected to grounded switch arm 44. The switch arm 44 is controlled by the centering cam member 41. The operation of switch member 124 of relay EF connects contact members 122 and 123 of relays CL and CR to switch member 43 which is controlled by the centering cam member 41. A switch member 125 operated by the relay EF serves to connect one terminal of the east pilot line 4 and one terminal of the east dummy line 7 to the bridge circuit.

The operation of the slow to operate relay C connects battery 22 to the bridge circuit and effects operation of the galvanometer 21 according to the resistance of the dummy line 7. The bridge circuit formed with the dummy line 7 as one arm thereof, may be traced from the vertex 26 of the bridge through switch member 114 of relay EF, switch member 113 of relay D, variable resistance 10 of the dummy line 7, resistance elements 9 and 8, switch member 125 of relay EF, resistances R₅, switch arm 158, slide wire resistance R₄ and the three impedance arms comprising resistance elements R₃, R₂, and R₁ to the bridge vertex 26. The galvanometer 21 controls the galvanometer control mechanism 23, as above set forth, to balance the bridge circuit according to the resistance of the dummy line 7. The bridge is balanced by controlling the slide wire resistance R₄ as before set forth. No operation of the motor 34 or the east equalizer 30 can take place at this time because neither relay CL nor relay CR is operated. Galvanometer 21 is controlled by the dummy line 7 for approximately ten minutes.

After balancing the bridge circuit under the control of the east dummy line 7, the cam member 17 operates the switch 20. The switch 20 completes a circuit from a battery 139 for operating the relay GC. The relay GC operates the switch member 140 for completing a circuit from a battery 141 to operate relay D. The relay GC operates a switch member 142 for connecting ground to the switch member 143 of relay GA. The relay GC operates a switch member 190 for completing a circuit which short-circuits the galvanometer 21 during the time relay D operates. The circuit for short-circuiting galvanometer 21 extends from bridge vertex 26, switch member 191 of relay GA, switch member 190 of relay GC to bridge vertex 28. The operation of the relay D also operates switch member 187 which performs no useful function at this time. The operation of the relay D transfers the bridge control from the east dummy line 7 to the east pilot line 4. Galvanometer 21 is short-circuited during this transfer to prevent false operation. The relay D operates a switch member 144 for completing a circuit to operate the slow to operate relay G. Relay GA, on operating, opens the short-circuit on galvanometer 21. The relay GA serves to connect ground to alternate commutator segments on the commutator ring 76. Ground connection to the alternate segments of commutator ring 76 is withheld until after the relay D is operated in order to prevent any part of the control circuits which are employed to start the motor 34, to function until the bridge circuit is completed. The bridge circuit formed with the east pilot line 4 as an arm thereof may be traced from the vertex 26

of the bridge through the switch member 114 of the relay EF, switch member 113 of the relay D, east pilot line 4, resistance 8, switch member 125 of the relay EF, resistances R_5 , resistance R_4 , resistance R_3 , resistance R_2 , and the resistance R_1 to the vertex 26.

The operation of the motor 34 to govern the equalizer 30 under control of the commutator rings 76, 77, and 78 will now be described. The switches 18 and 20 are respectively operated by the cam members 15 and 17, and the relays EA, EB, C, D, EF, GC and GA are operated.

We will assume that for a particular resistance of pilot line 4 the position of commutator rings 76, 77, and 78 with respect to brushes 79, 80, and 81 should be as viewed in Fig. 6 of the drawings. Resistance 8 is adjusted so that the galvanometer mechanism 23 will balance the bridge to this position. The resistance 9 in east dummy line 7 is adjusted so that the sum of resistance 10 corresponding to the position of the commutator rings as viewed in Fig. 6 of the drawings and resistance 9 is exactly equal to the resistance of the east pilot line 4 for the same position of the commutator rings. Assuming that the resistance of the east pilot line 4 is increasing, which corresponds to a rise in the temperature of the east line comprising conductors 5 and 6, the galvanometer control mechanism 23 operates to effect rotative movement of the commutator rings 76, 77 and 78. To assist in describing the operation of the system, it will be assumed that the rings 76, 77 and 78 which engage the brushes 79, 80, and 81 are given a movement towards the left as viewed in Fig. 6 of the drawings. With the commutator rings 76, 77 and 78 in the position shown in Fig. 6 of the drawings, a circuit is completed from ground through an R segment of commutator ring 78, switch member 146 of a relay AL, coil of the AR relay and battery 147 to ground. The relay AR is operated and held in operative position. Relays MR and ML are in released position.

The rebalancing movement of the galvanometer control mechanism 23 gradually moves the rings 76, 77, and 78 towards the left, as viewed in Fig. 6 of the drawings, so that the brush 79 occupies a position midway between segments 128 and 129 of commutator ring 76. The brush 81 engages an R and an L segment of the commutator ring 78, but inasmuch as the relay AL can operate only from a back contact of the relay AR, the relay AR remains in operative position. The brush member 79 bridges contact segments 128 and 129 of the ring 76 to complete a circuit for operating the relay BR. The circuit for operating the relay BR extends from ground through the switch member 142 of the relay GC, switch member 143 of the relay GA, commutator segments 128 and 129 of the ring 76, switch member 148 of the relay CR, switch member 149 of relay CL, switch member 150 of the relay AR, coil of the relay BR and battery to ground. A locking circuit for the relay BR is completed from grounded battery, through the coil of the relay BR, switching member 151 of the relay BR, contact 121, switch member 119 of the relay EF, contact member 45, and switch member 44 to ground. The switch member 44 is released from the contact member 45 upon operation of the centering cam 41. The switch member 152 of the relay BR completes a circuit from battery 153 for operating the relay CR. The operation of the switch member 151 of the relay BR completes a circuit from battery 154 for operating the relay MR.

The circuit from the battery 154 for operating the relay MR extends through the contact member 45 and switch member 44 which are controlled by the centering cam member 41. The relay MR is provided with an armature 155 directly connected to three switch members 156, 157 and 158. The armature 155, when operated by the relay, is engaged by a latch member 159 and held in operative position. The latch member 159 is controlled by relay 160 to release the armature 155.

The relay CR, upon operation, completes a circuit from a battery 161 for operating the motor control relay 47. The circuit for operating the relay 47 may be traced from grounded battery 161 through the coil of the relay 47, switch member 115 of the relay EF, contact member 117 of relay CR, and grounded switch member 162 of relay CR to the battery 161. The relay 47, upon operation, completes a circuit for energizing the windings 37 and 38 of the motor 34 to effect operation of the motor in a clockwise direction. The circuit completed by the relay 47 may be traced from one terminal of the source of alternating current 48, through winding 37, switch member 49 of the relay 46, switch member 83 of the relay 47, winding 38, and switch member 84 of the relay 47 to the other terminal of the source of alternating current 48. The switch member 148 of the relay CR breaks the ground circuit from the commutator segments 128 and 129 of the commutator ring 76 but the coils of relays BR and MR remain energized from the locking circuit for relay BR. About two seconds after the induction motor 34 starts operating, the centering cam member 41 separates the contact member 45 from the switch member 44 for opening the holding circuit of the relay BR and effects engagement between the switch arm 44 and the switch arm 43 for completing a locking circuit for the relay CR. The locking circuit for the relay CR may be traced from grounded battery 153, through the coil of the relay CR, switch member 163, contact member 123, switch member 124 of the relay EF, switch arm 43 and switch arm 44 to ground.

The motor 34 by means of reducing gears 200 operates the switch arm 42 for adjusting the resistance 32 to reduce the attenuation of the equalizer 30. The equalizer 30 controls the attenuation of the east line comprising conductors 5 and 6. At the same time, the motor 34 operates a switch arm 40 for varying the resistance 10 in the east dummy line 7. The resistance member 10 is varied at this time to maintain the resistance value of the dummy line 7 approximately the same as the resistance value of the associated pilot line 4. More specifically, the resistance value of the dummy line has been increased by an amount equivalent to the resistance change of the pilot line 4 necessary for one step. This is important, since the commutator rings must always take up a position when rebalancing on the dummy line so that brush 81 will always engage only an R segment on commutator ring 78. Reasons for this operation will be described more fully hereinafter. Upon operation of the relay MR, a resistance R_6 is inserted in circuit with the east pilot line 4 in order to increase the resistance value of the pilot line a small amount. This increased resistance R_6 serves to cause the galvanometer 21 to deflect in the same direction as before. The operation caused by the resistance R_6 serves to prevent hunting action and is disclosed and claimed in the application of H. I. Romnes, Serial No. 716,934.

About thirty seconds after the motor 34 is operated and another rebalancing movement of the galvanometer control mechanism 23 takes place, the rings 76, 77 and 78 are moved about one-sixth of a step towards the left, as viewed in Fig. 6 of the drawings. This movement is caused by the change in resistance of the pilot line 4 effected by the resistance element R_s . At this time, the brush member 81 will be wholly in engagement with an L segment of the commutator ring 78. Accordingly, relay AR will be released and relay AL will be operated. The circuit for operating relay AL may be traced from grounded battery 164, through the coil of relay AL, switch member 165 of the relay AR, commutator segment L of the commutator ring 78 and brush 81 to ground. About forty-five seconds after the motor 34 starts operating, the centering cam 43 has nearly completed one rotation. At this time the centering cam disconnects the switch arm 43 from the switch arm 44 to break the holding circuit for relay CR. Upon release of relay CR, the switch member 162 disengages contact member 117 to release the operating circuit for the motor control relay 47. Upon release of relay 47, the induction motor 34 is stopped.

The commutator rings 76, 77, and 78 continue to move towards the left until the brush member 80 bridges the contact segments 134 and 135 of the commutator ring 77. At that time a circuit is completed for operating the release magnet 160. The release magnet 166 is also operated at this time but performs no useful function inasmuch as relay ML is not in operative position. The circuit for operating relay 160 may be traced from ground, through the commutator segment 135, brush 80, commutator segment 134, switch member 156 of the relay MR, coils of relays 160 and 166 in series and battery 167 to ground. Upon operation of the relay 160, the latch 159 disconnects the arm 155 to release relay MR. The release of relay MR short-circuits the resistance R_s which causes a movement of the rings 76, 77 and 78 towards the right, as viewed in Fig. 6 of the drawings, when the next rebalancing movement of the galvanometer control mechanism 23 takes place. This movement towards the right is the same amount that was previously caused towards the left by the insertion of resistance R_s in the pilot line 4. Upon continued movement of rings 76, 77, and 78 towards the left, as viewed in Fig. 6 of the drawings, the brush 80 bridges the commutator segments 134 and 135 a second time. This time nothing happens inasmuch as relays ML and MR are in released position. Continued movement of rings 76, 77, and 78 towards the left, as viewed in Fig. 6 of the drawings, causes relay AL to release and relay AR to operate and the above cycle of operations is repeated.

A change of resistance in a pilot wire is never absolutely uniform in one direction. The operation of the galvanometer control mechanism under control of the east pilot line 4, as set forth above, may occur in one direction for only a limited time. A change of resistance opposite to the general trend of the resistance in the pilot line would cause the galvanometer control mechanism to operate in an opposite direction. The point of reversal of the galvanometer control mechanism may occur when commutator rings 76, 77, and 78 are at any position between steps. If rings 76, 77, and 78 are moving towards the left, as viewed in Fig. 6 of the drawings, and the

resistance of the east pilot line 4 starts to decrease before relay MR is released, brush member 79 would complete a circuit for operating relay BL. The circuit for operating relay BL may be traced from grounded battery 168, through the coil of relay BL, switch member 169 of relay AL, switch member 149 of relay CL, switch member 148 of relay CR, commutator segment 129, brush 79, commutator segment 128, switch member 143 of relay GA and switch member 142 of relay GC to ground.

The operation of relay BL completes a circuit from battery 170 for operating relay CL. Relay CL completes a circuit for operating the motor relay 46. Relay 46 operates motor 34 in a reverse direction. The circuit for operating relay 46 may be traced from grounded battery 172, through the coil of relay 46, switch member 116 of relay EF, contact member 118, and switch member 171 of relay CL to ground. The circuit for energizing windings 37 and 38 of motor 34 which is completed by the operation of relay 46 may be traced from one terminal of the alternating current source 48 through coil 37, switch member 49 of relay 46, winding 38, switch member 82 of relay 46, and switch member 84 of relay 47 to the other terminal of the alternating current source 48. The motor 34, in operation, moves the switch arm 42 in a reverse direction to so control the equalizer 30 as to increase the attenuation of the east line comprising conductors 5 and 6. At the same time, the switch arm 40 is operated by motor 34 to reduce resistance 10 in the east dummy line 7 by an amount equivalent to the resistance change of the east pilot line 4 necessary for one step.

Relay ML is operated by relay AL at the same time that relay BL is operated. Upon operation of relay ML, switch member 173 short-circuits the resistance R_s in the pilot line 4. At the same time, armature 174 of the relay is engaged by a latch 175 under control of the release magnet 166. The operation of relay ML completes a circuit for operating release magnet 160 to release relay MR. The circuit for operating release magnet 160 may be traced from grounded battery 167 through the coil of release magnet 160, coil of release magnet 166, switch member 176 of relay ML, and switch member 157 of relay MR to ground. Relay ML cannot release at this time even though release magnet 166 is energized momentarily. Upon release of relay MR, resistance R_s is short-circuited in the east pilot line 4. At this time, therefore, the two resistance elements R_s and R_s are short-circuited from the east pilot line 4. The withdrawal of resistances R_s and R_s from the pilot line unbalances the bridge circuit which causes movement of rings 76, 77, and 78 approximately one-third of a step towards the right, as viewed in Fig. 6 of the drawings. As the resistance of the pilot line continues to decrease, the rings 76, 77, and 78 are moved towards the right and when the brush 80 bridges the commutator segments 133 and 134, a circuit is completed for releasing relay ML. The circuit completed by the brush member 80 may be traced from ground on commutator segment 133, brush 80, commutator segment 134, switch member 178 of relay ML, coils of relays 166 and 160, and battery 167 to ground. Relay ML is released to insert resistance R_s in the pilot line circuit and the bridge circuit. The insertion of resistance R_s in the pilot line bridge arm causes the movement of the commutator rings 76, 77, and 78 towards the left, as viewed in Fig. 6 of the drawings, and the

77, and 78 approximately one-sixth of a step towards the left.

If the rings 76, 77, and 78 were moving towards the left, as viewed in Fig. 6 of the drawings, and a reversal in the movement of the galvanometer control mechanism 23 takes place by reason of a decrease in the resistance value of the east pilot line 4 just after relays MR and ML were released, the bridge circuit and the rings would be restored to normal position and the next bridging of the commutator segments by the brush 79 on the commutator ring 76 would operate relay 46 for starting motor 34 in a reverse direction and relay ML would move the rings 76, 77, and 78 about one-sixth of a step towards the right, as viewed in Fig. 6 of the drawings. The motor 34 is always started in the proper direction and at the proper time except on reversals when one of relays MR or ML was not released before the reversal took place. In this case, the motor would be started at a time corresponding to one-sixth of a step from normal. Further description of the operation of commutator rings 76, 77, and 78 under control of galvanometer control mechanism 23 is deemed unnecessary inasmuch as the operation thereof is similar to the operation disclosed in the above application of H. I. Romnes, Serial No. 716,934.

The bridge circuit formed with the east pilot line 4 is maintained for approximately thirty-five minutes, at the end of which time the cam member 17 opens the switch 20. Opening the switch 20 releases relay GC which in turn opens the ground circuit applied to segments on the commutator ring 76. Relay D is also released by the switch member 140 of relay GC. Switch member 144 of relay D breaks the operating circuit for relay GA. The galvanometer control mechanism 23 is now operating in accordance with the bridge circuit formed with the east dummy line 7. The galvanometer is not protected from false operation when a transfer is made of the bridge circuit from the east pilot line 4 to the east dummy line 7. This protection is not required because the ground connection has already been removed from commutator ring 76 which controls the motor operation. The bridge circuit formed with the east dummy line 7 is the same as that described prior to the description of the bridge circuit formed with the east pilot line 4. The galvanometer control mechanism 23 is not operated at this time to perform any useful function.

Approximately five minutes after the bridge is formed with the dummy line 7, cam member 15 opens the switch 18. Upon the opening of switch 18, relay EA is released which restores the short circuit on galvanometer 21. When relay EA releases, the circuit through the coil of relay EB is opened. When relay EB releases, the circuit through the coil of relay EF is opened. When relay EF releases, the dummy line 7 bridge arm is opened at switch members 114 and 125 of relay EF. This condition unbalances the bridge, but since the galvanometer 21 is short-circuited, no harmful effect is possible. When relay EF releases, the circuit for the coil of relay C is opened. When relay C releases, the circuit is opened to the bridge battery 22. When relay EF releases, the circuits through the coils of relays 46 and 47 are opened. Moreover, the circuits to the switch members 43 and 45 are opened. The circuit remains in this condition for approximately ten minutes, with the bridge circuit in-

operative and disconnected from pilot lines 4 and 1 and also dummy lines 7 and 11.

The cam member 16 operates the switch 19 to complete a circuit for operating relay WA. The operation of relay WA removes the normal short circuit from galvanometer 21 by means of a switch member 112. The switch member 181 which is operated by relay WA completes a circuit from battery 182 for operating relay WB. The switch member 104 of relay WB completes a circuit from battery 183 for operating the gang relay WF. Switch member 184 of the gang relay WF completes a circuit from battery 109 for operating the relay C. When relay C operates, switch member 111 closes the circuit for the bridge battery 22.

At this time a bridge circuit is formed with the west dummy line 11 forming one arm thereof. The bridge circuit thus formed may be traced from the vertex 26 of the bridge through switch member 186 of the gang relay WF, switch member 187 of the relay D, adjustable resistance 14 of the west dummy line 11, resistance elements 13 and 12, switch arm 188 of the gang relay WF, and resistance elements R₅, R₄, R₃, R₂, and R₁ to the vertex 26. The bridge circuit thus formed with the west dummy line 11 controls the galvanometer control mechanism 23 to balance the bridge circuit approximately according to the bridge circuit which will be formed with the west pilot line 1. The galvanometer control mechanism 23 is governed approximately ten minutes by the bridge formed with the west dummy line 11. At the end of ten minutes, the cam member 17 closes the switch 20.

The closing of the switch 20 completes a circuit from battery 139 for operating relay GC. The switch member 140 of relay GC completes a circuit from battery 141 for operating relay D. The switch member 190 of relay GC closes a circuit to short-circuit galvanometer 21. Switch member 142 of relay GC supplies ground to switch member 143 of relay GA. The operation of relay D operates switch arm 113 which, at this time, performs no useful function. The operation of switch arm 187 of relay D serves to disconnect the west dummy line 11 from the bridge circuit and to connect the west pilot line 1 to the bridge circuit. The operation of switch arm 144 of relay D completes a circuit for operating relay GA which connects ground from switch arm 143 to the segments of commutator ring 76. The bridge circuit completed with the pilot line 1 upon operation of the switch member 187 may be traced from the vertex 26 of the bridge, switch member 186 of the gang relay WF, switch member 187 of the relay D, west pilot line 1, resistance 12, switch member 188 of the gang relay WF, and resistance elements R₅, R₄, R₃, R₂, and R₁ to the vertex 26.

The galvanometer control mechanism 23 is controlled by the bridge circuit formed with the west pilot line 1 for approximately thirty-five minutes. During this time, the commutator rings 76, 77, and 78 are operated by the galvanometer control mechanism 23 for governing the motor relays 95 and 96 to operate the motor 35. The motor 35 operates in exactly the same manner as the motor 34 for controlling the equalizer 31 in the west line comprising conductors 2 and 3 and for controlling the variable resistance 14 in the west dummy line 11. The centering cam 90 is mounted on the shaft 88 of the motor 35 for the same purpose as the centering cam 41 which is operated by the motor 34. Inasmuch as the

circuits and apparatus for controlling the attenuation in the west line are similar in construction and operation to like parts for controlling the attenuation in the east line, it is deemed unnecessary to again repeat the description of the attenuation control. The resistance elements R_s and R_e are controlled by relays ML and MR to prevent hunting action in the same manner as above disclosed when reference was made to the control of the attenuation in the east line. Resistances 12 and 13 are adjusted in a manner similar to the adjustment of resistances 8 and 9.

At the end of thirty-five minutes, the cam member 17 opens the switch 20 to release relay GC. The release of relay GC opens the circuit for relay D which, by means of switch member 187, disconnects the west pilot line 1 from the bridge circuit and connects the west dummy line 11 to the bridge circuit. At the end of five minutes, the cam member 16 opens the switch 19. The opening of switch 19 releases relay WA which releases switch member 112 to short-circuit the galvanometer 21. The release of switch member 181 of relay WA opens the circuit through the coil of relay WB. The release of switch member 104 of relay WB opens the circuit through the coil of relay WF. The release of switch member 184 of relay WF opens the circuit of the coil of relay C and opens the circuit of bridge battery 22. The release of switch members 186 and 188 of relay WF disconnects the bridge from west dummy line 11. A period of ten minutes now elapses when the bridge is inoperative and disconnected from both east and west pilot lines and dummy lines. After this period, the cam member 15 operates switch 18 and the cycle of operations above described is again repeated.

When cam member 15 operates switch 18 a second time, the bridge circuit is connected to east dummy line 7 for approximately ten minutes. The operation of relays EA, EB, C, D, EF, GC, GA, MR, and ML will occur as previously set forth. Assume that the rebalancing movements of the galvanometer mechanism 23 will move the commutator rings 76, 77, and 78 to the position with respect to brushes 79, 80, and 81, as shown in Fig. 6 of the drawings. Further assume that when the bridge circuit was last connected to east pilot line 4 that the rebalancing movements of the galvanometer mechanism 23 moved the commutator rings 76, 77, and 78 to the same position. Further assume that while the bridge circuit was operating on the west pilot line 1 and west dummy line 11, that the resistance of the east pilot line has increased an amount which will move the commutator rings to the left so that brush 79 engages segments 130 of ring 76, brush 80 engages segment 135 of ring 77 and brush 81 engages an R segment only. This position is indicated by dotted line $a-a$ in Fig. 6. After operating ten minutes on east dummy line 7, the cam member 17 operates switch 20 to transfer the bridge circuit to east pilot line 4. The galvanometer mechanism 23 now operates to move the commutator rings to the left an amount equivalent to two steps. Brush 79 will bridge segments on ring 76 twice during this movement which will cause motor 34 to run the equivalent of two steps.

Referring to Fig. 1 of the drawings, the member 53 attached to rocker arm 50 is shaped to limit the deflection of the galvanometer pointer in either direction. The maximum deflection of the pointer will cause the galvanometer mechanism to move the commutator rings one-third of a

step. Therefore, a sudden unbalance of the bridge circuit of two steps will require six rebalancing movements before a balanced position is reached. Each rebalancing movement requires about thirty seconds so that only one rebalancing movement can occur while motor 34 is running for forty-five seconds. Brush 79 cannot bridge segments on commutator ring 76 a second time while the motor is running because of the limited galvanometer deflection.

The purpose of changing the resistances 10 and 14 of dummy lines 7 and 11 by an amount equivalent to one step so that brush 81 will always come to rest on an R segment of ring 78 will now be described. Assume that the east pilot line 4 and east dummy line 7 are adjusted to have a resistance which will cause the galvanometer mechanism to move the commutator rings 76, 77 and 78 with respect to brushes 79, 80, and 81 to the position shown in Fig. 6 of the drawings. Now assume that the bridge is connected to east pilot line 4 for thirty-five minutes and its resistance has increased, causing the commutator rings 76, 77, and 78 to move to the left so that the brushes 79, 80, and 81 are in the position shown by the line $b-b$ in Fig. 6 of the drawings. In moving to this position, motor 34 has operated to increase resistance 10 of east dummy line 7 by an amount which will later cause the brushes 79, 80, and 81 to be in the position $c-c$ with respect to rings 76, 77, and 78. After thirty-five minutes, cam members 15, 16, and 17 will operate to successively connect the bridge to east dummy line 7, west dummy line 11, west pilot line 1, west dummy line 11 and finally again to east dummy line 7. The galvanometer mechanism will operate to move the commutator rings 76, 77, and 78 so that brushes 79, 80, and 81 will be at position $c-c$ in Fig. 6 of the drawings. In moving to this position, brush 80 may have bridged segments on ring 77 to operate the release magnets 160 and 166 causing the release of relays MR and ML. If relays MR and ML are both released, resistance R_s is in the dummy line bridge arm and resistance R_e is short-circuited, causing brush 81 to be in the center of the R segment of ring 78 shown by line $c-c$ in Fig. 6 of the drawings.

If brush 80 did not bridge segments on ring 77 in moving to the position $c-c$, one of relays MR or ML may be locked up, but not both. Both relays MR and ML cannot remain locked up because a circuit will then extend from grounded battery 167, coil of release magnet 160, coil of release magnet 166, switch member 178 of relay ML, switch member 177 of relay MR to ground, causing the release of both relays MR and ML. If one of relays MR or ML is locked up, brush 81 will not come to rest in the center of the R segment on line $c-c$ as viewed in Fig. 6 of the drawings, but will come to rest one-sixth of a step on one side or the other of line $c-c$. However, brush 81 will still engage only the R segment because the brush 81 is less than one-sixth of a step wide and the R segment is one-half step wide.

The cam member 17 will next operate to connect the bridge circuit to east pilot line 4. We will now assume that the resistance of the east pilot line 4 has decreased since the bridge was last connected to it by an amount which will cause the commutator rings 76, 77, and 78 to move to the right so that brushes 79, 80, and 81 will be in the position $d-d$ shown in Fig. 6 of the drawings. In moving to position $d-d$, brush

80 will bridge segments 134 and 135 of ring 77 and release the MR or ML relay to restore the bridge circuit to normal. Subsequent operation of the circuits and apparatus involving the movement of the commutator rings 76, 77, and 78 so that brushes 79, 80, and 81 will be in position $d-d$ is similar to the operation previously set forth. When the brushes 79, 80, and 81 are in position $d-d$, the resistance of the dummy line 7 equals the resistance of east pilot line 4 for the same position. The circuits and apparatus will always function correctly to control the attenuation of the line circuits when a transfer is made of the bridge circuit from a dummy line to the corresponding pilot line.

Referring to Fig. 3 of the drawings, the time relation in the operation of cam members 15, 16, and 17 is diagrammatically illustrated. The curve A represents the operation of the east cam 15. The curve B represents the operation of the west cam 16. The curve C represents the operation of the ground cam 17. The abscissae of the figure represent minutes and are shown to extend for one-hundred and twenty minutes or two hours. The ordinates of the drawing are employed to designate whether or not a cam is operated to open or close the associated switch contacts. On curve A which represents the operation of the east cam 15, from zero to seventy minutes, the switch 18 is open. From seventy minutes to one-hundred and twenty minutes, the cam 15 operates to close the switch 18.

Referring to curve B of Fig. 3, from zero to ten minutes the switch 19 controlled by the cam 16 is open. From ten minutes to sixty minutes the switch 19 is closed by the cam 16. From sixty minutes to one-hundred and twenty minutes, the switch 19 is open. Referring to curve C of Fig. 3, from zero to twenty minutes the switch 20 is open. From twenty minutes to fifty-five minutes, the switch 20 is closed. From fifty-five minutes to eighty minutes the switch 20 is open. From eighty minutes to one-hundred and fifteen minutes the switch 20 is closed, and from one-hundred and fifteen minutes to one-hundred and twenty minutes, the switch 20 is open. Inasmuch as the control of the galvanometer control mechanism by the various bridge circuits depends on the position of the cam members 15, 16 and 17, it is possible by the diagram shown in Fig. 3 to determine the operation of the circuits. From zero to ten minutes, the galvanometer is short-circuited and the galvanometer mechanism is not being controlled. From ten minutes to twenty minutes, the galvanometer mechanism is controlled by the west dummy line 11. From twenty minutes to fifty-five minutes the galvanometer mechanism is controlled by the west pilot line 1. From fifty-five minutes to sixty minutes the galvanometer mechanism is controlled by the west dummy line 11. From sixty minutes to seventy minutes the galvanometer mechanism is not being controlled. From seventy minutes to eighty minutes the galvanometer mechanism is governed by the east dummy line 7. From eighty minutes to one-hundred and fifteen minutes the galvanometer mechanism is controlled by the east pilot line 4. From one-hundred and fifteen minutes to one-hundred and twenty minutes the galvanometer mechanism is governed by the east dummy line 7.

Modifications in the circuits and in the arrangement and location of parts may be made within the spirit and scope of the invention and

such modifications are intended to be covered by the appended claims.

What is claimed is:

1. In a transmission system having separate east and west lines, two pilot lines respectively associated with the east and west lines and having resistance variations respectively according to the resistance variations of the east and west lines, attenuation equalizer means in the east line and in the west line, and means controlled consecutively by the east pilot line and the west pilot line for controlling the east equalizer means and the west equalizer means to govern the attenuation in the east line according to the resistance of the east pilot line and to govern the attenuation in the west line according to the resistance of the west pilot line.

2. In a transmission system having two separate lines, two pilot lines respectively associated with said two lines and having resistance variations respectively according to the resistance variations of the two lines, control mechanism consecutively operated by said two pilot lines, means governed by said control mechanism when operated by one of said pilot lines for controlling the attenuation in the associated line, and means governed by said control mechanism when operated by the other pilot line for controlling the attenuation in the other line.

3. In a transmission system having separate east and west lines, two pilot lines respectively associated with the east and the west lines and having resistance variations respectively according to the resistance variations of the east and west lines, three connected impedance arms adapted to form a bridge circuit with each of said pilot lines, equalizer means in the east line and in the west line, means for connecting said pilot lines consecutively to said three impedance arms to form bridge circuits, and means for operating the east equalizer means according to the operation of the bridge circuit formed with the east pilot line for controlling the attenuation of the east line and for operating the west equalizer means according to the operation of the bridge circuit formed with the west pilot line for controlling the attenuation of the west line.

4. In a transmission system having separate east and west lines, two pilot lines respectively associated with the east and the west lines and having resistance variations respectively according to the resistance variations of the east and west lines, three connected impedance arms adapted to form a bridge circuit with each of said pilot lines, a galvanometer connected between two opposite vertices of said three impedance arms, means for connecting said pilot lines consecutively to said three impedance arms to form bridge circuits for operating said galvanometer according to the resistance variations of the pilot lines, and means controlled by the galvanometer when governed by the east pilot line for controlling the attenuation of the east line and when governed by the west pilot line for controlling the attenuation of the west line.

5. In a transmission system having separate east and west lines, two pilot lines respectively associated with the east and the west lines and having resistance variations respectively according to the resistance variations of the east and west lines, three connected impedance arms adapted to form a bridge circuit with each of said pilot lines, means for connecting each of said pilot lines to the three impedance arms to form bridge circuits, means controlled by the bridge

circuit formed with the east pilot line for governing the attenuation of the east line according to the variations in resistance of the east pilot line, and means controlled by the bridge circuit formed with the west pilot line for governing the attenuation of the west line according to the variations in resistance of the west pilot line.

6. In a transmission system having separate east and west lines, two pilot lines respectively associated with said two lines and having resistance variations respectively according to the resistance variations of the two lines, equalizer means in the east line and in the west line, control mechanism consecutively operated by said two pilot lines, means governed by said control mechanism when operated by the east pilot line for operating the equalizer means in the east line according to resistance variations in the east pilot line, and means governed by said control mechanism when operated by the west pilot line for operating the equalizer means in the west line according to resistance variations in the west pilot line.

7. In a transmission system having separate east and west lines, a pilot line associated with the east line, a pilot line associated with the west line, three connected impedance arms adapted to form a bridge circuit with each of said pilot lines, a galvanometer connected between two opposite vertices of said three impedance arms, galvanometer control mechanism operated according to the operation of said galvanometer, equalizer means in the east line and in the west line, and means for connecting said pilot lines consecutively to said three impedance arms to form bridge circuits, for operating the east equalizer means by said galvanometer mechanism according to variations of resistance in the east pilot line and for operating the west equalizer means by said galvanometer mechanism according to variations of resistance in the west pilot line.

8. In a transmission system having separate east and west lines, three connected impedance arms and two pilot lines respectively associated with the east and the west lines and having resistance variations respectively according to the resistance variations of the east and west lines, the method which consists in forming a bridge circuit with the impedance arms and the east pilot line, in varying the attenuation of the east line according to the bridge variations by the east pilot line while balancing the bridge circuit, in replacing the east pilot line by the west pilot line in the bridge circuit, and in varying the attenuation of the west line according to the bridge variations by the west pilot line while balancing the bridge circuit.

9. In a transmission system having separate east and west lines, three connected impedance arms, two pilot lines respectively associated with the east and west lines and two dummy lines respectively associated with the east and west pilot lines, the method which consists in forming a bridge circuit with the impedance arms and the east dummy line, in balancing the bridge circuit, in forming a bridge circuit with the impedance arms and the east pilot line, in controlling the attenuation of the east line by the bridge formed with the east pilot line while balancing the bridge and varying the resistance of the east dummy line according to the resistance of the east pilot line, in forming a bridge with the impedance arms and the east dummy line, in forming a bridge with the west dummy line and the impedance arms, in balancing the bridge formed with the west dummy

line, in forming a bridge circuit with the impedance arms and the west pilot line and in controlling the attenuation of the west line by the bridge formed with the west pilot line while balancing the bridge and varying the resistance of the west dummy line according to the resistance of the west pilot line.

10. In a transmission system having separate east and west lines, two pilot lines respectively associated with the east and the west lines and having resistance variations respectively according to the resistance variations of the east and the west lines, a dummy line associated with each of said pilot lines, three connected impedance arms adapted to form a bridge circuit with each of said pilot and dummy lines, means for connecting the pilot and dummy lines to the impedance arms in a predetermined sequence to form bridge circuits, means controlled by the bridge formed with the east pilot line for controlling the attenuation of the east line, means controlled by the bridge formed with the west pilot line for controlling the attenuation of the west line, and means for balancing each bridge circuit formed when the impedance arms are connected to the pilot and dummy lines.

11. In a transmission system having separate east and west lines, two pilot lines respectively associated with the east and the west lines and having resistance variations respectively according to the resistance variations of the east and west lines, a dummy line associated with each of said pilot lines, three connected impedance arms adapted to form a bridge circuit with each of said pilot and dummy lines, means comprising continuously operating cam members for connecting the pilot and dummy lines to the impedance arms in a predetermined sequence to form bridge circuits, the dummy line associated with each pilot line being connected to the impedance arms before and after the connection of the pilot line to the impedance arms, and means for balancing the bridge formed when each of said dummy and pilot lines are connected to the impedance arms.

12. In a four-wire transmission system having separate east and west lines, a pilot line associated with each of said lines, a dummy line associated with each pilot line, three arms of a bridge circuit having a galvanometer connected between two opposite vertices, galvanometer control mechanism operated according to the operation of said galvanometer, equalizer means in the east line and in the west line and means for connecting the pilot lines and the dummy lines in a predetermined sequence to said three arms to form bridge circuits, for varying the resistance of each dummy line according to resistance variations of the associated pilot line, for operating the east equalizer means to control the attenuation of the east line by said galvanometer mechanism according to variations of resistance in the east pilot line and for operating the west equalizer means to control the attenuation of the west line by said galvanometer mechanism according to variations of resistance in the west pilot line.

13. In a transmission system having separate east and west lines, two pilot lines respectively associated with the east and the west lines and having resistance variations respectively according to the resistance variations of the east and west lines, a dummy line associated with each pilot line, three connected impedance arms adapted to form a bridge circuit with each of said pilot and dummy lines, means for connecting each of said pilot and dummy lines to the im-

pedance arms in a predetermined sequence to form bridge circuits, the dummy line associated with each pilot line being connected to the impedance arms before and after the connection of the pilot line to the impedance arms, means for balancing each bridge circuit formed when the impedance arms are connected to the pilot and dummy lines, and means for varying the resistance of the east dummy line according to the resistance of the east pilot line when the east pilot line is connected to the impedance arms and for varying the resistance of the west dummy line according to the resistance variations of the west pilot line when the west pilot line is connected to the impedance arms.

14. In a transmission system having separate east and west lines, two pilot lines respectively associated with the east and west lines and having resistance variations respectively according to the resistance variations of the east and west lines, a dummy line associated with each pilot line, three connected impedance arms adapted to form a bridge circuit with each of said pilot and dummy lines, means for connecting each of said pilot lines to the three impedance arms to form a bridge circuit, for connecting the dummy line associated with the east line to the three impedance arms before and after the connection of the east pilot line to the three impedance arms and for connecting the dummy line associated with the west line to the three impedance arms before and after the connection of the west line to the three impedance arms, a galvanometer connected across opposite vertices of said impedance arms, means controlled by said galvanometer for balancing the bridge when the three impedance arms are connected to one of said pilot and dummy lines, for controlling the attenuation of the east line when the impedance arms are connected to the east pilot line and for controlling the attenuation of the west line when the impedance arms are connected to the west pilot line, and means for varying the resistance in a dummy line according to the resistance of the associated pilot line when the impedance arms are connected to the pilot line.

15. In a transmission system having separate east and west lines, two pilot lines respectively associated with the east and the west lines and having resistance variations respectively according to the resistance variations of the east and west lines, a dummy line associated with each of said pilot lines, three connected impedance arms adapted to form a bridge circuit with each of said pilot and dummy lines, means comprising continuously operating cam members for connecting the pilot and dummy lines to the impedance arms in a predetermined sequence to form bridge circuits, means controlled by the bridge formed with the east pilot line for governing the attenuation of the east line, means controlled by the bridge formed with the west pilot line for governing the attenuation of the west line, and means for balancing each bridge circuit formed when the impedance arms are connected to the pilot and dummy lines.

16. In a transmission system having separate east and west lines, two pilot lines respectively associated with the east and the west lines and having resistance variations respectively according to the resistance variations of the east and west lines, a dummy line associated with each of said pilot lines, three connected impedance arms adapted to form a bridge circuit with each of said pilot and dummy lines, means comprising con-

tinuously operating cam members for connecting the pilot and dummy lines to the impedance arms in a predetermined sequence to form bridge circuits, the dummy line associated with each pilot line being connected to the impedance arms before and after the connection of the pilot line to the impedance arms, means for balancing the bridge formed when each of said dummy and pilot lines are connected to the impedance arms, means controlled by the bridge formed with the east pilot line for governing the attenuation of the east line, means controlled by the bridge formed with the west pilot line for governing the attenuation of the west line, and means for varying the resistance of the east dummy line according to the resistance of the east pilot line when the east pilot line is connected to the impedance arms and for varying the resistance of the west dummy line according to the resistance of the west pilot line when the west pilot line is connected to the impedance arms.

17. In a four-wire transmission system having separate east and west lines, two pilot lines respectively associated with the east and west lines and having resistance variations respectively according to the resistance variations of the east and west lines, equalizer means in the east line and in the west line, three connected impedance arms adapted to form a bridge circuit with each of said pilot lines, one of said impedance arms being adjustable to balance the bridge circuit, means for connecting said pilot lines consecutively to said three impedance arms to form bridge circuits, means for adjusting the adjustable arm of the three impedance arms to balance the bridge to the last resistance value of a pilot line when the impedance arms were connected thereto before connection of the pilot line to the three impedance arms, and means for operating the east equalizer means according to the operation of the bridge circuit formed with the east pilot line to control the attenuation of the east line and for operating the west equalizer means according to the operation of the bridge circuit formed with the west pilot line to control the attenuation of the west line.

18. In a four-wire transmission system having separate east and west lines, three connected impedance arms and two pilot lines respectively associated with the east and the west lines and having resistance variations respectively according to the resistance variations of the east and west lines, the method of successively adjusting the east and west lines according to variations in the east and west pilot lines which consists in forming a bridge circuit with the impedance arms and the east pilot line, in varying the attenuation of the east line according to the bridge variations by the east pilot line while balancing the bridge circuit, in forming a bridge circuit with said impedance arms as three arms thereof for balancing the bridge circuit according to the resistance value of the west pilot line when last connected to the three impedance arms, in forming a bridge circuit with the impedance arms and the west pilot line, in varying the attenuation of the west line according to the bridge variations by the west pilot line while balancing the bridge circuit, and in forming a bridge circuit with said impedance arms as three arms thereof for balancing the bridge circuit according to the resistance value of the east pilot line when last connected to the three impedance arms.

VICTOR E. ROSENE.