Feb. 25, 1936. H. I. ROMNES 2,031,980

GAIN CONTROL CIRCUIT

Filed March 23, 1934 3 Sheets-Sheet 1

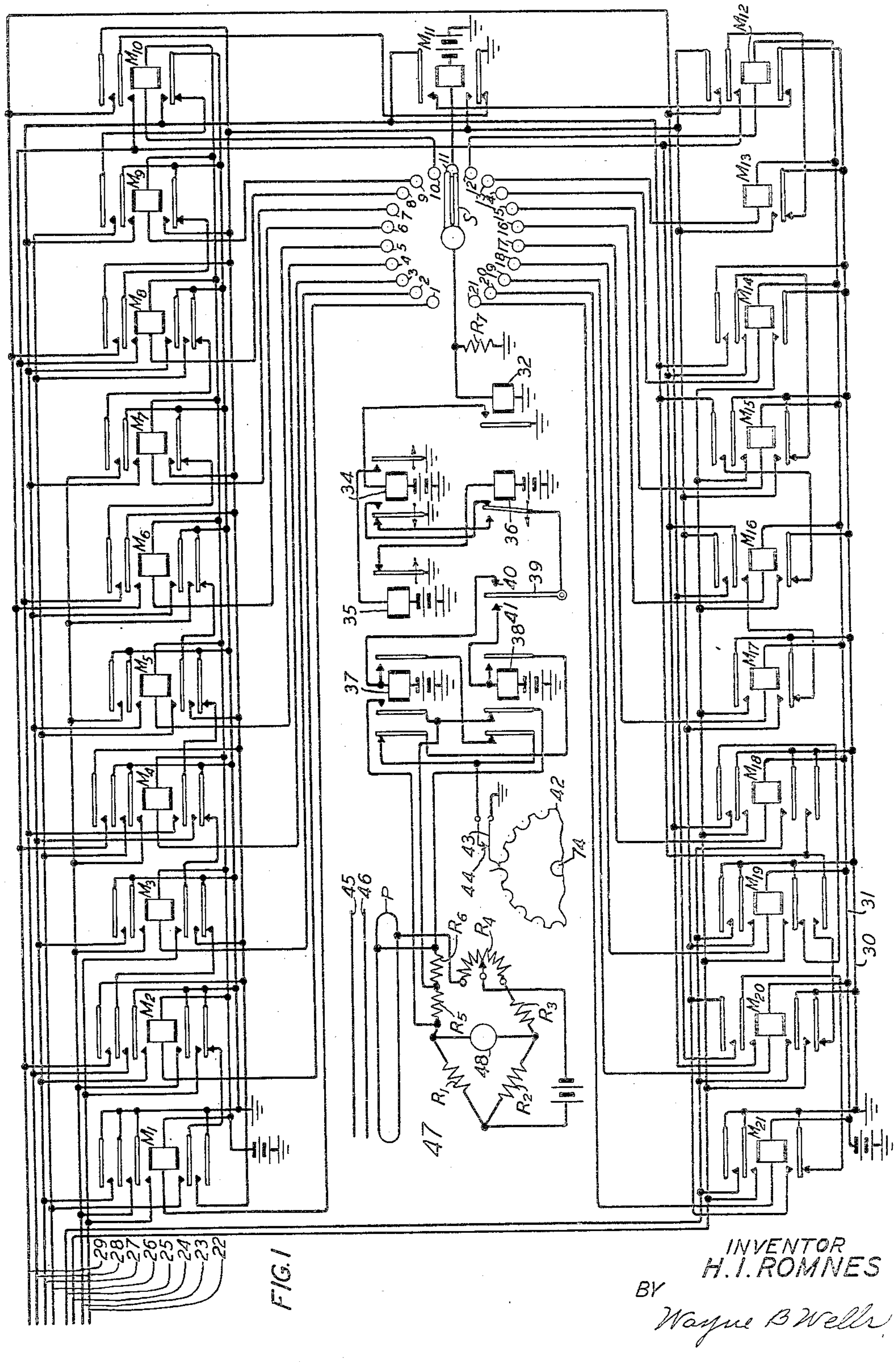

FIG. 1

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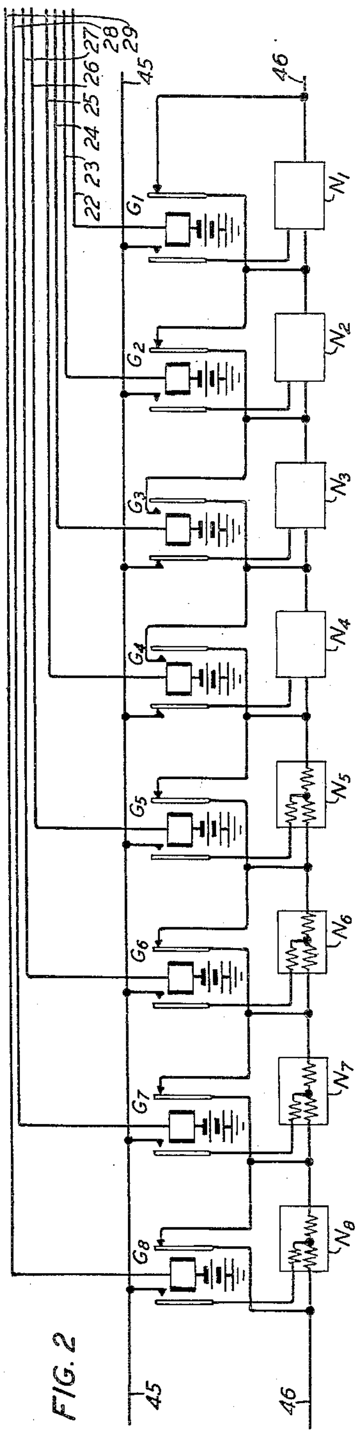

FIG. 2

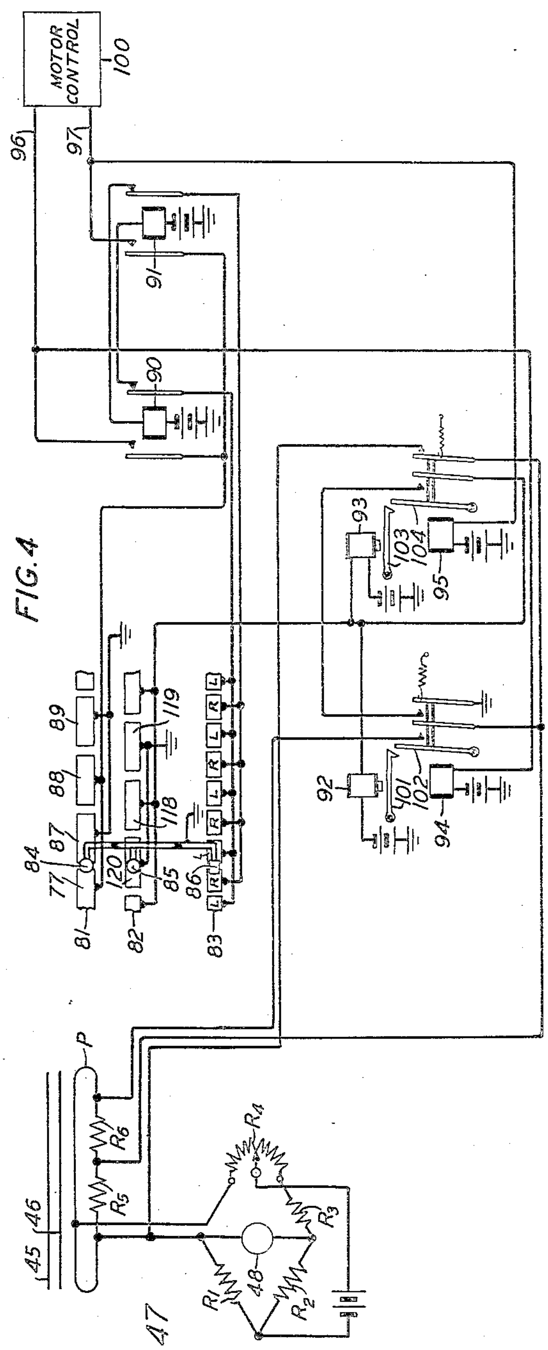

FIG. 4

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FIG. 5

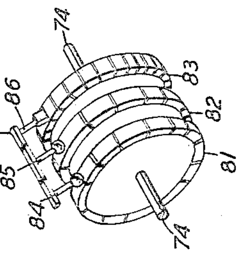
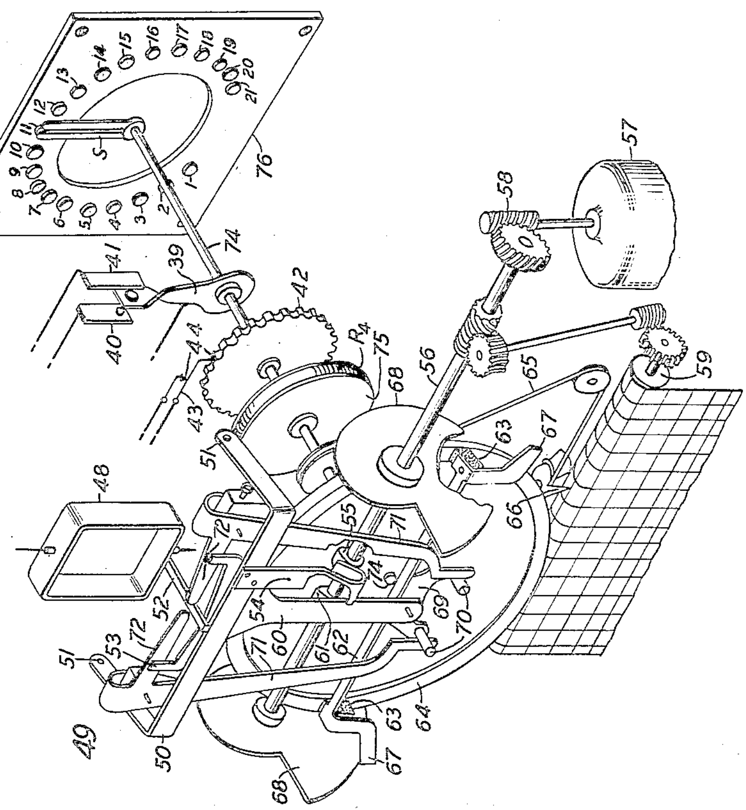


FIG. 3



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Patented Feb. 25, 1936

2,031,980

UNITED STATES PATENT OFFICE

2,031,980

GAIN CONTROL CIRCUIT

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Application March 23, 1934, Serial No. 716,934

19 Claims. (Cl. 178—44)

This invention relates to gain control circuits and particularly to control circuits for controlling the gain at repeater stations on a transmission line.

One object of the invention is to provide gain control circuits having attenuation networks selectively connected to a signal transmission line to maintain the energy level of the signals on the line constant that shall operate in an improved manner without hunting action.

Another object of the invention is to provide gain control circuits at a repeater station on a transmission line having attenuation networks selectively connected to the line according to the resistance variations on a pilot line associated with the transmission line that shall vary the resistance of the pilot line in a manner to prevent hunting action.

A further object of the invention is to provide gain control circuits of the above indicated character that shall so control the resistance on a pilot line as to insure an added effect when connecting an attenuation network to or when withdrawing an attenuation network from the transmission line to prevent hunting action.

The transmission equivalent of a line varies according to the variation of a number of different conditions. One of the main causes of changes in the transmission equivalent is the changes in temperature to which the line is subjected. Regulators are provided at repeater stations and terminal stations to compensate for the changes in attenuation on the line. In one form of regulator, attenuation networks are inserted in and taken out of the transmission line according to the variations in resistance on a pilot line associated with the transmission line. In such a form of regulator, trouble is often encountered by reason of hunting action taking place at the time of inserting a network in or taking a network out of the line. The regulator may be very sensitive so that at the time of changing the attenuation networks one of the networks may be continuously inserted in and withdrawn from the transmission line for a period of time. Such hunting action interferes with the transmission of the signals over the line.

In gain control circuits constructed in accordance with the present invention the pilot line which controls the attenuation networks in the transmission line is provided with two resistance elements which may be selectively connected in the pilot line. Normally one of the resistance elements is included in the pilot line and the other resistance element is excluded from the pilot line. When the regulator circuits operate to insert an attenuation network in the transmission line the resistance element normally included in the pilot line is disconnected from the pilot line to give an added effect to the regulator circuits in inserting the attenuation network in the transmission line. When the regulator circuits operate to withdraw an attenuation network from the transmission line, the resistance element normally disconnected from the pilot line is inserted in the pilot line to give an added effect to the regulator circuits in withdrawing the attenuation network from the transmission line. The resistance elements associated with pilot line are returned to normal position when the regulator is operated a predetermined amount away from a critical network changing point or when the regulator reverses its operation a predetermined amount.

In one gain control arrangement constructed in accordance with the invention, eight attenuation networks are selectively connected to a transmission line by a chain of relays to control the gain at a repeater station and maintain the energy level of the signals on the line substantially constant. A pilot line which may be one pair of wires in a cable is associated with a transmission line which may be another pair of wires in the cable. The pilot line which is subjected to the same attenuation varying conditions as the transmission line forms one arm of a Wheatstone bridge circuit. A galvanometer which is connected between two opposite vertices of the Wheatstone bridge circuit is operated in accordance with the variations in resistance upon the pilot line. The galvanometer operates a galvanometer mechanism carrying a dial switch which governs the operation of the chains of relays controlling the attenuation networks, a slide wire resistance for balancing the Wheatstone bridge circuit and a cam member for restoring the pilot line to normal condition and a direction selector for determining the direction of resistance variations from the pilot line to prevent hunting action.

The dial switch which is operated according to the operation of the galvanometer and in a direction according to the direction of operation of the galvanometer controls the chains of relays to insert or withdraw attenuation networks in or from the transmission line. The attenuation networks are so controlled as to govern the gain at the repeater station and maintain the energy level on the transmission line substantially constant.

Two resistance elements are associated with the pilot line to vary the pilot line resistance in such a manner as to prevent hunting action by the regulator circuits. Normally one of the resistance elements is included in the pilot line and the other resistance element is disconnected from the pilot line. Two pilot relays are provided for controlling the operation of two resistance elements. The direction selector which is operated by the galvanometer mechanism according to the operation of the galvanometer selects the pilot relay which is to be operated at the time an attenuation network is inserted in the transmission line or is withdrawn from the transmission line.

The dial switch when in a position to insert an attenuation network in a transmission line or when in a position to withdraw an attenuation network from the transmission line completes a circuit controlled by the direction selector for operating one of the pilot relays. If the dial switch is in position to insert an attenuation network in the transmission line a pilot relay is operated to withdraw the resistance element from the pilot line which is normally in the pilot line. The withdrawal of the resistance element from the pilot line gives an added effect or operation to the galvanometer and the galvanometer mechanism so as to move the pilot switch away from its critical point and insure against hunting action. If the resistance on the pilot line continues to decrease and the attenuation on the transmission line continues to decrease for a predetermined period, the cam member which is operated by the galvanometer mechanism releases the operated pilot relay which is held in locked position. The cam member releases the operated pilot relay prior to the adding of another attenuation network to the transmission line.

If the resistance on the pilot line increases and the attenuation on the transmission line increases prior to the operation of the cam member for releasing the locked pilot relay, then the direction selector reverses its position to permit the operation of the released pilot relay by the dial switch when an attenuation network is being withdrawn from the transmission line. The operation of the released pilot relay opens the circuit of the operated pilot relay to insert both the resistance elements in the pilot line. The pilot line now has one resistance element included therein more than normal. Such resistance element serves to give an added movement or operation to the galvanometer mechanism to move the dial switch away from its critical position. The resistance element normally withdrawn from the pilot line and now included in the pilot line is withdrawn from the pilot line by the operation of the cam member if the galvanometer continues its present movement or by the operation of the other pilot relay if the movement of the galvanometer reverses.

The galvanometer mechanism controlled by the galvanometer continuously operates the slide wire resistance to balance the Wheatstone bridge circuit. The operation in this regard is similar to the balancing of the Wheatstone bridge circuit in the J. A. Coy and H. I. Romnes application Serial No. 569,360, filed October 13, 1931.

In another modification of the disclosed invention means are provided for controlling the gain control circuits shown in the Coy-Romnes application Serial No. 569,360 to prevent hunting action. In the modified circuits the pilot relays which control two resistance elements associated with the pilot line, are governed by three segmented ring switches operated by the galvanometer mechanism. One of the segmented ring switches serves to select the pilot relay to be operated and to determine whether an attenuation network is to be added to the transmission line or to be withdrawn from the transmission line. Another of the segmented ring switches operated by the galvanometer mechanism completes a circuit for operating the selected pilot relay to change the pilot wire resistance and also completes a circuit for operating the gain control circuits shown in the Coy-Romnes application, above referred to. The third segmented ring switch serves to release the operated pilot relay.

In the accompanying drawings Fig. 1 is a diagrammatic view of control circuits in a gain control arrangement constructed in accordance with the invention;

Fig. 2 is a diagrammatic view showing the relays and an attenuation network which are operated by the circuits shown in Fig. 1 of the drawings;

Fig. 3 is a diagrammatic view of the galvanometer control mechanism employed in the circuit shown in Figs. 1 and 2 of the drawings;

Fig. 4 is a diagrammatic view showing a modification of the gain control circuits shown in Figs. 1 and 2 of the drawings;

Fig. 5 is a diagrammatic view of the commutator rings employed in the gain control circuits shown in Fig. 4 of the drawings.

Referring to Figs. 1, 2, and 3 of the drawings a gain control arrangement is shown for controlling the attenuation on a transmission line comprising conductors **45** and **46**. The attenuation on the transmission line is controlled by governing attenuation networks N—1 to N—8, inclusive. The networks N—1 to N—8, inclusive, are directly controlled by relays G—1 to G—8, inclusive. The networks N—1 to N—4, inclusive, each have an attenuation of four decibels. The networks N—5 and N—6 each have an attenuation of two decibels. The network N—7 has an attenuation of one decibel and the network N—8 has an attenuation of one-half a decibel. The networks N—1 to N—8, inclusive, are selectively inserted in the line conductors **45** and **46** to vary the line attenuation from zero to twenty decibels. It is to be understood that if so desired the attenuation networks may have different values of attenuation. The attenuation networks N—1, N—2, N—5, N—6, N—7, and N—8 are inserted in the transmission line when the relays G—1, G—2, G—5, G—6, G—7, and G—8 are in operative position and the attenuation networks N—3 and N—4 are inserted in the transmission line when the relays G—3 and G—4 are in released position. When one of the relays G—1, G—2, G—5, G—6, G—7, and G—8 is in its unoperated position, the armature to the right of the operating coil short-circuits the element of the associated attenuation network which is in series with the line while the armature to the left of the operating coil opens the shunt connection of the associated network. The armatures of the relays G—3 and G—4 are connected to operate in an opposite manner to the armatures of the relays G—1, G—2, G—5, G—6, G—7, and G—8.

The pilot line P shown in Fig. 1 of the drawings is positioned adjacent to the transmission line conductors **45** and **46** in order to be subjected to the same temperature varying conditions as the conductors of the transmission line. The pilot line P forms part of one arm of a Wheatstone bridge circuit **47** comprising resistance elements R—1, R—2, R—3, R—4, R—5, and R—6. The resistance elements R—5 and R—6 are controlled in a manner to be hereinafter set forth to insure against hunting action when an attenuation network is inserted in the transmission line or is excluded from the transmission line. A galvanometer 48 is connected across to opposite vertices of the bridge circuit 47 to be operated according to the unbalance of the bridge which is caused by variations in the resistance of the pilot line P. The galvanometer is also controlled according to the operation of the resistance elements R—5 and R—6.

The galvanometer 48 controls the galvanometer mechanism 49 shown in Fig. 3 of the drawings for governing the relays M—1 to M—21, inclusive, shown in Fig. 1 of the drawings and the relays G—1 to G—8, inclusive, shown in Fig. 2 of the drawings. The relays G—1 to G—8, inclusive, selectively control the attenuation networks N—1 to N—8, inclusive.

The galvanometer mechanism 49 controlled by the galvanometer 48 comprises a U-shaped rocker arm 50 which is pivotally mounted at points 51. A pointer member 52 of the galvanometer 48 rides on a U-shaped supporting member 53 which is attached to the rocker arm 50. 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 constant rotation of the cam member 55 serves to raise the rocker arm 50 at predetermined intervals. Preferably, the rocker arm is operated approximately every eight 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 disc 64 by means of a flexible connecting member 65 serves to control the movement of a recording pen 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 upon 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. Pivotally mounted arms 71 are held in engagement with 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 48. 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 rotating 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 projection 67 on the cross arm 62 moves the cross arm back to its original position. At this time 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 rocker arm 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, a cam member 42, a direction selector arm 39 and an arm S of the dial switch 76. The disc 75, the cam member 42 and the arm S of the dial switch 76 are fixedly mounted on the shaft 74 and rotated therewith in accordance with the movements of the galvanometer 48. The direction selector arm 39 is adapted to engage one of two contact members 40 and 41 according to the direction of rotation of the shaft 74. The arm 39 is not fixedly connected to the shaft 74 and follows the rotation of the shaft 74 until engagement is made with one of the contact members 40 and 41. The arm 39 engaging one of the contact members 40 and 41 indicates whether the resistance in the pilot line P is increasing or decreasing.

The contact arm S when rotated by the shaft 74 engages contact members 1 to 21, inclusive, of the dial switch 76. The arm S engaging the contact members 1 to 21, inclusive, completes circuits for operating the relays M—1 to M—21, inclusive. The relays M—1 to M—21, inclusive, control the relays G—1 to G—8, inclusive, which in turn control the attenuation networks N—1 to N—8, inclusive.

The cam member 42 is formed in accordance with the number of contact members on the dial switch 76. The depressions on the cam member 42 correspond to the mid-points of the steps on the dial switch 76. When the switch arm S of the dial switch is in mid-position between two steps and in engagement with two contact members, the switch arm 43 which is controlled by the cam member 42 falls in one of the depressions upon the cam member to disengage the contact member 44. The cam member 42 and the contact arm 43 serve to restore the pilot wire resistance to normal before a new step is made by the switch arm S.

When there is a change in the attenuation on the transmission line caused, for example, by change in temperature, a like change is caused in the resistance of the pilot line P. A change in the resistance of the pilot line P unbalances the Wheatstone bridge circuit to effect operation of the galvanometer 48. The galvanometer mechanism 49 is operated according to the operation of the galvanometer 48. The galvanometer mechanism 49, as before set forth, controls the disc 75 and slide wire resistance element R—4 to rebalance the Wheatstone bridge circuit. The galvanometer mechanism 49 operates the switch arm S over the contact members 1 to 21, inclusive, for completing circuits through the grounded resistance element R—7 to operate one or two of the relays M—1 to M—21, inclusive. The operation of one or two of the relays M—1 to M—21, inclusive, applies ground to a combination of conductors 22 to 29, inclusive, to operate a corresponding combination of relays G—1 to G—8, inclusive.

When the switch arm S engages the contact member 11 as shown in Fig. 1 of the drawings a circuit is completed from ground through resistance R—7, switch arm S, contact member 11, winding of relay M—11 and battery to ground. The relay M—11 is operated to complete a circuit from ground through conductor 30, lower armature of relay M—12, upper armature of relay M—11, conductor 27, winding of relay G—6, shown in Fig. 2 of the drawings, and battery to ground. The operation of the relay G—6 inserts the two decibel networks N—6 in the line. The attenuation network N—6 together with the networks N—3 and N—4 which are normally in the line give a total attenuation of ten decibels.

Assuming an increase in the temperature to which the transmission line and the pilot line P are subjected, the alternating current in the transmission line decreases and the resistance of the pilot line P shown in Fig. 1, of the drawings increases. The increase in the resistance of the pilot line P unbalances the Wheatstone bridge circuit to operate the galvanometer 48. The galvanometer 48 operating through the galvanometer mechanism 49 moves the switch arm S to a position where it engages the contact members 11 and 12. The relay M—11 is held in operative position by the circuit above traced and the relay M—12 is operated by a circuit completed when the switch arm S engages the contact member 12. The circuit for operating the relay M—12 may be traced from ground through resistance R—7, switch arm S, contact member 12, winding of the relay M—12, conductor 31 and battery to ground. The operation of the relay M—12 releases the relay G—6 because the energizing circuit for the relay G—6 includes the lower armature of the relay M—12. A circuit is completed for operating the relay G—8 shown in Fig. 2 of the drawings which may be traced from ground through the lower armature of relay M—11, upper armature of relay M—12, conductor 29, winding of relay G—8, shown in Fig. 2 of the drawings and battery to ground. At the same time the relay G—7 is operated by a circuit which may be traced from ground, through the conductor 30, lower armature of the relay M—13, second upper armature of the relay M—12, conductor 28, winding of the relay G—7 and battery to ground. The relays G—7 and G—8 operate the attenuation networks N—7 and N—8 to insert one and one-half decibels attenuation in the line. At this time the attenuation networks N—3, N—4, N—7, and N—8 are included in the line and the total attenuation is nine and one-half decibels.

In a similar manner other combinations of the relays M—1 to M—21, inclusive, and G—1 to G—8, inclusive, are operated by other positions of the switch arm S on the contact members of the dial switch 76. Inasmuch as the invention is not particularly related to the operation of the relays for controlling the attenuation networks a detailed description of each position of the switch arm S is deemed unnecessary. The following table indicates the relays operated and the attenuation networks inserted in the transmission line for various positions of the switch arm S:

Arms makes contact with contact members	Fig. 1 relays operated	Fig. 2 relays operated	Attenuation introduced in transmission line
			Decibel
1	M1	G1, G2, G5, G6	20
1 and 2	M1 and M2	G1, G2, G6, G7, G8	19½
2	M2	G1, G2, G6, G7	19
2 and 3	M2 and M3	G1, G2, G6, G8	18½
3	M3	G1, G2, G6	18
3 and 4	M3 and M4	G2, G5, G6, G7, G8	17½
4	M4	G2, G5, G6, G7	17
4 and 5	M4 and M5	G2, G5, G6, G8	16½
5	M5	G2, G5, G6	16
5 and 6	M5 and M6	G2, G6, G7, G8	15½
6	M6	G2, G6, G7	15
6 and 7	M6 and M7	G2, G6, G8	14½
7	M7	G2, G6	14
7 and 8	M7 and M8	G5, G6, G7, G8	13½
8	M8	G5, G6, G7	13
8 and 9	M8 and M9	G5, G6, G8	12½
9	M9	G5, G6	12
9 and 10	M9 and M10	G6, G7, G8	11½
10	M10	G6, G7	11
10 and 11	M10 and M11	G6, G8	10½
11	M11	G6	10
11 and 12	M11 and M12	G7, G8	9½
12	M12	G7	9
12 and 13	M12 and M13	G8	8½
13	M13	None	8
13 and 14	M13 and M14	G3, G6, G7, G8	7½
14	M14	G3, G6, G7	7
14 and 15	M14 and M15	G3, G6, G8	6½
15	M15	G3, G6	6
15 and 16	M15 and M16	G3, G7, G8	5½
16	M16	G3, G7	5
16 and 17	M16 and M17	G3, G8	4½
17	M17	G3	4
17 and 18	M17 and M18	G3, G4, G6, G7, G8	3½
18	M18	G3, G4, G6, G7	3
18 and 19	M18 and M19	G3, G4, G6, G8	2½
19	M19	G3, G4, G6,	2
19 and 20	M19 and M20	G3, G4, G7, G8	1½
20	M20	G3, G4, G7	1
20 and 21	M20 and M21	G3, G4, G8	½
21	M21	G3, G4	0

When the switch arm S engages or disengages the contact members 1 to 21, inclusive, under control of the galvanometer mechanism 49, trouble may be caused by hunting action which is liable to occur at this time. If the bridge circuit is balanced just at the edge of a gain step, the gain of the repeaters may be alternately increased and decreased if the resistance of the pilot line varies. In accordance with the present invention the gain control mechanism is moved quickly over the edge of a step to insure against hunting action. This function is effected by giving the gain control mechanism an added movement at the edge of a gain step. The added movement is accomplished by controlling the resistance elements R—5 and R—6 of the Wheatstone bridge circuit shown in Fig. 1 of the drawings. The resistance elements R—5 and R—6 are controlled by the relays 32, 34, 35, 36, 37, and 38. The relays 34, 35, and 36 are slow releasing and the relay 32 is a marginal relay. When the Wheatstone bridge circuit 47 is balanced under normal conditions, the resistance element R—5 is included in the pilot line P and the resistance element R—6 is short-circuited. If the resistance of the pilot line P is increasing the resistance element R—6 is added to the bridge circuit to give an added movement to the galvanometer 48. If the resistance of the pilot line is decreasing the resistance element R—5 is excluded from the bridge circuit to give an added movement of the galvanometer 48.

In Fig. 1 of the drawings a circuit arrangement is shown to secure an added effect at the time one of the attenuation networks N—1 to N—8, inclusive, is inserted in or removed from the transmission line. In the table above given, it will be noted that as the switch arm S moves over the contact members 1 to 21, inclusive, it alternately makes contact with one contact member and two contact members resulting in the alternate operation of one relay and two relays of the relays M—1 to M—21, inclusive. Therefore, each time an attenuation network is inserted in or removed from the transmission line by operation of the relays M—1 to M—21, inclusive, there is a change of current flow through the switch arm S and the resistance R—7. The relay 32 which is a sensitive marginal relay is connected across the resistance element R—7 in order to be operated in accordance with the current flow through the resistance R—7. The relay 32 will operate on the voltage across resistance R—7 when the current necessary to operate two of the relays M—1 to M—21, inclusive, flows through the resistance R—7, but will not operate on the voltage across the resistance element R—7 when the current flowing through the resistance is only that required to operate one relay.

The direction selector made up of the contact arm 39 and contact members 40 and 41 is used to determine in which direction the switch arm S is moving and therefore to select the resistance element R—5 or R—6 to be controlled. As shown in Fig. 3 of the drawings, contact members 40 and 41 are fixedly mounted and the contact arm 39 is frictionally mounted on the shaft 74. There is enough friction between the contact arm 39 and the shaft 74 to effect movement of the arm 39 with the shaft as long as the arm is not restrained. The arm 39 slips on the shaft 74 when engagement is effected with one of the contact members 40 and 41. When the switch arm S is moving in a direction from the contact member 1 towards the contact member 21 which corresponds to increasing resistance in the pilot line P and decreasing alternating current in the transmission line, the contact arm 39 engages the contact member 41. When the switch arm is moving in a direction from contact member 21 towards the contact member 1 which corresponds to decreasing resistance in the pilot line P, the contact arm 39 engages the contact member 40.

The relay 37 serves when operated to exclude the resistance element R—5 from the Wheatstone bridge circuit 47 and the relay 38 when operated serves to insert the resistance element R—6 in the bridge circuit. When one of the relays 37 and 38 is operated a locking circuit controlled by the cam member 42 is completed through the contact members 43 and 44. The cam member 42 permits the contact member 44 to disengage the contact member 43 in order to release a locked relay 37 or 38 which has been operated and locked to produce the added effect at the time the attenuation networks N—1 to N—8, inclusive, are inserted in or removed from the transmission line. As shown in Fig. 3 of the drawings, the cam member 42 is mounted on the shaft 74. The cam member 42 is arranged so that engagement between the contact members 41 and 42 is effected at the time switch arm S makes or breaks contact with switch contact member 1 to 21, inclusive, but opens temporarily between the times contacts are made or broken by the switch arm S.

Assume that the switch arm S engages the contact member 11 and is moving in a direction toward contact member 21. Since only relay M—11 is now operated, the current flow through the resistance element R—7 will be too small to provide the voltage necessary to operate the marginal relay 32. In this position of the switch arm S, the relays 32, 34, 35, 37, and 38 are released. The relay 36 is operated by a circuit extending from ground through the armature of relay 35, winding of relay 36 and battery to ground. The contact arm 39 at this time engages the contact member 41 and resistance R—5 is included in the pilot line P. Resistance member R—6 is short-circuited by the inner left armature of relay 38. The resistance elements R—5 and R—6 are of a value equal to the resistance change in the pilot line P which would cause the switch arm S to be moved about one tenth of the distance between the centers of adjacent switch contact members.

If the resistance of the pilot line P increases gradually so that the switch arm S moves to just engage the contact member 12 while remaining in engagement with the contact member 11, the relay M—12 is operated. Operation of the relay 12 increases the current flow through the resistance element R—7 sufficiently to operate the marginal relay 32. The relay 34 is then operated by a circuit extending from ground through the armature of the relay 32, winding of the relay 34 and battery to ground. Operation of the relay 34 completes a circuit for operating relay 35. The operating circuit for the relay 35 extends from ground, through the right armature of relay 34, winding of relay 35 and battery to ground. The operation of relay 35 opens the operating circuit for the slow-releasing relay 36. The operation of relay 34 completes a circuit for operating relay 38. The circuit for operating the relay 38 extends from ground through the left make contact of relay 34, make contact of relay 36 which is slow to release and therefore still in its operated position, arm 39 and contact member 41 of the direction selector, winding of relay 38 and battery to ground. The relay 38 is held in operative position by a circuit extending from ground through contact members 43 and 44, left outer contact of relay 37, right contact of relay 38, winding of relay 38 and battery to ground. The relay 38 opens the short circuit around resistance member R—6. The resistance member R—6 increases the resistance in series with the pilot line P sufficiently to cause the switch arm S to be moved a slight amount in the direction towards contact member 21. The switch arm S is thus moved away from the critical point at the edge of a switch member.

The resistance of the pilot line P may now continue to increase or it may begin to decrease. Assume, first that the resistance of the pilot line P continues to increase and, therefore, the switch arm S continues to move towards the contact member 21. When the switch arm S has moved about one-half the distance between the point where engagement is made with the contact member 12 and the point where engagement is broken with the contact member 11, cam member 42 allows the contact member 43 to break engagement with the contact member 44. The separation of the contact members 43 and 44 opens the locking circuit for the relay 38 which then releases. The resistance member R—6 is short-circuited by the left inner contact of relay 38 in released position. The short circuiting of the resistance element R—6 reduces the resistance in series with the pilot line P. Switch arm S then moves towards switch member 1 a slight amount due to the rebalancing action of the regulator, but this movement has no effect at this time. As the resistance of the pilot line continues to increase the switch arm S finally breaks engagement with the contact member 11 while remaining in engagement with the contact member 12. Since the current flowing through the switch arm S is then only that required to operate one relay, the marginal relay 32 releases and opens the operating circuit for the relay 34. The relay 34 in released position opens the operating circuit for the relay 35. The relay 35 as above set forth is designed to release slowly. The relay 34 in released position operates the relay 38 by a circuit extending from ground through the left break contact of relay 34, break contact of the relay 36, contact arm 39 and contact member 41 of the direction selector, winding of the relay 38 and battery to ground. When the relay 35 releases after a short delay relay 36 is operated. The circuit for operating relay 36 extends from ground through the contact of relay 35, winding of relay 36 and battery to ground. The relay 38 operates to complete a holding circuit for itself and to insert resistance R—6 in the pilot line P as has been previously described. If the resistance of the pilot line P continues to increase the operation already described is repeated each time engagement is made or broken between the switch arm S and the switch contact members 1 to 21, inclusive.

Consider the apparatus to be in the position where engagement has just been made between the switch arm S and the contact member 12 while the arm S continues in engagement with the contact member 11. At this time relays 32, 34, 35, and 38 are operated and the relays 36 and 37 are released. The resistance element R—6 has been inserted in the pilot line P and as a result the switch arm S has been moved toward switch member 21 a slight amount. Assume that a resistance of the pilot line P begins to decrease when the contact arm S moves a small amount towards the contact member 1. Switch arm 39 of the direction selector disengages the contact member 41 and makes engagement with the contact member 40. The switch arm S continues to move towards the contact member 1 until it finally breaks engagement with the contact member 12 while remaining in engagement with the contact member 11. The current flowing through the switch arm S is now only that required to operate one relay and the marginal relay 32 is, therefore, released to open the operating circuit for the relay 34. The right armature of the relay 34 in released position opens the operating circuit for the relay 35. The relay 35 as above set forth is designed to release slowly. The release of the relay 34 also operates relay 37 by a circuit which extends from ground through the left armature of relay 34 in released position, break contact of relay 36, contact arm 39 and contact member 40 of the direction selector, winding of the relay 36 and battery to ground. When the relay 37 operates the holding circuit for the relay 38 is opened at the outer left contact of relay 37. The relay 37 is held in operated position by a circuit extending from ground through the contact arm 43, contact member 44, left outer contact member of relay 38, the right armature of relay 37, winding of relay 37 and battery to ground. The release of relay 38 short-circuits the resistance member R—6 by means of the left inner contact member thereof. The operation of relay 37 short-circuits the resistance member R—5 by means of the left inner contact member thereof. The resistance in series with pilot line P is therefore decreased by an amount equal to the sum of the values of the resistance members R—5 and R—6. The operation of the galvanometer mechanism 49 causes the switch arm S to move towards the contact member 1 and away from the critical point at the edge of a switch member.

If the resistance of the pilot line continues to decrease the relay 37 will first be released by the action of the cam member 42 as previously described. The switch arm S then makes contact with contact member 10. At this time the relays 32, 34, 35, and 37 will operate and the relay 36 will release. The resistance element R—5 will be excluded from the pilot line P to effect movement of the switch arm S towards the contact member 1 and away from the critical point at the edge of a switch contact member. The relays continue to operate in the manner above described.

If the resistance of the pilot line P begins to increase before relay 36 has been released by operation of the cam member 42, the next contact made or broken between the switch arm S and a switch contact member results in the operation of relay 38 by means of relays 32, 34, 35, and 36 as previously described. The operation of relay 38 opens the locking circuit for relay 37 at its left outer contact. Relay 37 then releases and cuts in resistance member R—5 by means of the opening of its inner contact member. The resistance element R—6 is inserted in the pilot line P by the opening of the left inner contact member of relay 38 when the relay operates. The including of the resistance elements R—5 and R—6 in the pilot line causes the switch arm S to be moved away from the critical point at the edge of a contact member.

In the above manner the gain control circuit shown in Figs. 1, 2, and 3 of the drawings operates to vary the attenuation on a transmission line while preventing any hunting action. The resistance elements R—5 and R—6 are varied to change the resistance of the pilot line P so as to insure against hunting action.

Refering to Figs. 4 and 5 of the drawings, a modification of the systems disclosed in Figs. 1 and 2 is illustrated which is controlled by the galvanometer and the galvanometer mechanism used in controlling the system shown in Figs. 1 and 2. Like parts in the modification to those shown in the system of Figs. 1 and 2 will be designated by similar reference characters.

The shaft 74 of the galvanometer mechanism 49 which controls the system shown in Fig. 5 of the drawings carries three commutator rings 81, 82, and 83 in place of the cam member 42, the direction arm 39 and the switch arm S, as shown in Fig. 3 of the drawings. Means for preventing hunting action in the gain control circuits, which are operated by means of motors, are shown in Fig. 4 of the drawings. The gain control circuits, which are operated by means of motors, are disclosed in the J. A. Coy et al. application Serial No. 569,360, filed October 17, 1931. The modification shown in Figs. 4 and 5 of the drawings has the added advantage that it controls a motor operated system without lag so that changes in the gain control circuits follow accurately changes in the resistance of the pilot line.

Referring to Fig. 4 of the drawings, a pilot line P is positioned so as to be subject to the same temperature conditions as the transmission line comprising the conductors 45 and 46. The pilot line P forms one arm of a Wheatstone bridge circuit 47 which comprises resistance elements R—1, R—2, R—3, R—5, and R—6 and slide wire potentiometer R—4.

The galvanometer 48 is connected across two opposite vertices of the bridge circuit. When the resistance of the pilot line P changes due to a change in temperature, the Wheatstone bridge circuit becomes unbalanced and therefore the galvanometer 48 is operated. The galvanometer mechanism 49 shown in Fig. 3 of the drawings is operated by the galvanometer 48 to move the contact member of the slide wire R—4 until the bridge 47 becomes balanced. The three segmented rings or commutator rings 81, 82, and 83 which are mounted on the shaft 74 with the slide wire R—5 engage stationary contact members 84, 85, and 86, respectively. The contact members 84, 85, and 86 are insulated from each other and the contact member 86 is grounded. The contact member 84 is a cylinder or ball so as to bridge two segments of the commutator ring 81 at definite positions when the commutator rings are rotating in either direction. The contact member 85 is preferably a cylinder or ball although it is not essential that it be so constructed. The contact member 86 is broader than the contact members 84 and 85 and bridges two segments of the commutator ring 83 for a considerable movement of the commutator rings.

The commutator rings are mounted with the segments in the relative positions shown in Fig. 4 of the drawings and the three contact members 84, 85, and 86 mounted in the positions relative to each other as shown in Fig. 4 of the drawings. Two relays 90 and 91 are controlled by the commutator rings to place selectively a ground on the conductors 96 and 97 which are connected to the motor control mechanism 100. The motor control mechanism 100 is disclosed and claimed in the application of J. A. Coy et al. Serial No. 569,-360, filed October 17, 1931. The conductors 96 and 97 in the system shown in Fig. 4 of the drawings correspond to the conductors 35 and 36 shown in Fig. 2 of the J. A. Coy et al. application Serial No. 596,360. Two relays 94 and 95, which are shown in Fig. 4 of the drawings, are mechanically locked in operative position when once operated and can only be released by operation of the release magnets 92 and 93. When the relay 94 is operated a latch member 101 engages a bar 102 and holds the relay in operative position. The bar 102 is released when the latch 101 is operated by the release magnet 92. The relay 95 is provided with a bar 104 which engages a latch 103 for holding the relay 95 in operative position. The latch 103 is operated by the release magnet 93 to release the bar 104.

Assume that the resistance of the pilot line P is such that the galvanometer mechanism is balanced with the contact member 84 engaging the contact segment 87 and the contact member 86 engaging a corresponding R segment of the commutator ring 83. In this position of the apparatus the relay 90 is operated by a circuit extending from ground through the contact member 86, commutator segment R, right contact of the relay 91, winding of the relay 90 and battery to ground. Assume now that the resistance of the pilot line is decreasing which corresponds to movement of the commutator rings towards the left as viewed in Fig. 4 of the drawings. When the contact member 84 bridges commutator segments 87 and 88 ground is applied to the conductor 96 of the motor control mechanism through the left contact of the relay 90. The placing of ground connection on the conductor 96 starts the motor control mechanism shown in the J. A. Coy et al. application Serial No. 569,360 to add attenuation networks corresponding to one step to all the associated transmission lines. The relay 94 which is operated by the ground connection on the conductor 96 locks up mechanically under control of the release magnet 92. The operation of the relay 94 short-circuits the resistance R—6 by means of its left armature. The resistance value of the resistance member R—6 is such that when it is taken out of the pilot line the galvanometer mechanism assumes a new balance with the commutator rings 81, 82 and 83 moved to the left, as viewed in Fig. 4 of the drawings, one-fourth of the distance between the centers of two contact segments on the commutator ring 81. In moving to the new position the contact member 86 breaks engagement with the commutator segment R and opens the operating circuit for the relay 90. The release of the relay 90 allows the relay 91 to operate over a circuit extending from ground through the contact member 86, a commutator segment L, right contact of the relay 90, winding of relay 91 and battery to ground. The operation of the relay 91 at this time prepares a circuit for a later operation.

Assume now that the temperature affecting the pilot line P continues to decrease and therefore the commutator rings continue to move towards the left as viewed in Fig. 4 of the drawings. When the contact member 85 bridges commutator segments 118 and 119 a circuit from ground through commutator segment 119, contact member 85, commutator segment 118, winding of the release magnet 92 and battery to ground energizes the release magnet 92 to release the relay 94. The release magnet 93 is also energized but performs no useful function at this time. The release of the relay 94 removes the short circuit around the resistance member R—6. The galvanometer mechanism then assumes a new balance with the commutator rings moved one-fourth of a step to the right as viewed in Fig. 4 of the drawings. A step is considered the distance between the centers of adjacent commutator segments on the ring 81. As the resistance of pilot line P continues to decrease and the segments continue to be moved towards the left as viewed in Fig. 4 of the drawings, the contact member 86 finally breaks engagement with the segment L which allows the relay 91 to release. The release of the relay 91 operates the relay 90 by a circuit extending from ground through the contact member 86, commutator segment R, right contact of relay 90, winding of relay 90 and battery to ground. The operation of relay 90 prepares a circuit for a later operation. As the commutator segments continue to move towards the left as viewed in Fig. 4 of the drawings, the contact member 84 finally bridges commutator segments 88 and 89 to start the motor control mechanism and operate the relay 94 to perform the functions already described.

Considering the apparatus in its former position and assuming that the resistance of the pilot wire P begins to increase and that the commutator segments begin moving towards the right as viewed in Fig. 4 of the drawings, the contact member 84 is on commutator segment 88, the contact 85 is on the commutator segment 118 and the contact member 86 is on the commutator segment L. The relay 91 and the relay 94 are operated and the resistance member R—6 is short-circuited. As the commutator segments move towards the right as viewed in Fig. 4 of the drawings, contact member 84 finally bridges commutator segments 87 and 88 applying a ground connection to the conductor 97 through the commutator segment 87, the contact member 84, commutator segment 88 and the left contact of relay 91. The ground connection placed on the conductor 97 starts the motor control mechanism to subtract an attenuation network corresponding to one step from all associated transmission lines. The relay 95 which is operated by a circuit extending from ground on the conductor 97 locks up mechanically under control of the release magnet 93. The operation of the relay 95 removes the short circuit around the resistance member R—5 by means of its right contact member. The release magnet 92 is energized by a circuit extending from ground on the outer left contact of relay **94**, through the inner left contact of relay **95**, winding of release magnet **92** and battery to ground for releasing the relay **94**. The release of relay **94** removes the short circuit around the resistance member R—**6** and both resistance members R—**5** and R—**6** are cut into the pilot line circuit. The bridge rebalances and moves the segments towards the right as viewed in Fig. 4 of the drawings a distance of one-half step. In moving to the new position the contact member **86** breaks engagement with the segment L allowing the relay **91** to release. The relay **90** is then operated by a circuit extending from ground through the contact member **86**, commutator segment R, right contact of the relay **90**, winding of the relay **91** and battery to ground. As the commutator segments continue moving towards the right as viewed in Fig. 4 of the drawings due to increasing pilot line resistance the contact member **85** bridges commutator segments **118** and **120**. The ground circuit from segment **120** extending through contact **85**, commutator segment **118**, winding of the release magnet **93** and battery to ground causes the release magnet **83** to be energized for releasing the relay **95**. The release of the relay **95** restores the short circuit around the resistance member R—**5** which due to the rebalancing action of the bridge moves the commutator segments one-quarter step towards the left as view in Fig. 4 of the drawings. At this time contact **86** is on a commutator segment R and the relay **90** is operated.

Assume that the pilot line resistance continues to increase and that the commutator segments move towards the right as viewed in Fig. 4 of the drawings. When the contact member **86** breaks engagement with the commutator segment R, relay **90** releases allowing the relay **91** to operate by a circuit extending from ground through the contact member **86**, commutator segment L, right contact of relay **90**, winding of relay **91** and battery to ground. When the contact member **84** bridges commutator segments **87** and **77** ground is applied to the conductor **97** from commutator segment **87** through the contact member **84**, commutator segment **77** and left contact of the relay **91**. The ground connection on conductor **97** starts the motor control mechanism to subtract attenuation corresponding to one step from all associated transmission lines. The ground circuit on the conductor **97** also operates relay **95** which locks up under control of the release magnet **93**. The operation of the relay **95** inserts resistance member R—**6** in the pilot line P which causes the galvanometer mechanism to rebalance and move the commutator segments one-quarter step towards the right as viewed in Fig. 4 of the drawings. As the galvanometer mechanism continues to move the commutator segments the operations described above are repeated.

Modifications in the systems 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 in the appended claims.

What is claimed is:

1. In control circuits for a station on a signal transmission line, a plurality of attenuation networks for controlling the attenuation on said line, control means comprising a galvanometer for selectively inserting and withdrawing said networks in and from the line to maintain the energy level on the line substantially constant, and means for giving said galvanometer an added movement in the direction of the last movement thereof at the time of inserting a network in and withdrawing a network from the line to prevent hunting action.

2. In control circuits for a signal station on a transmission line, a plurality of attenuation networks for controlling the attenuation on said line, a pilot line subjected to the same attenuation varying conditions as the transmission line, an adjustable resistance connected to said pilot line, control means comprising a galvanometer for selectively inserting and withdrawing said networks in and from the line according to the resistance variations of said pilot line to maintain the energy level on the transmission line substantially constant, means controlled by said galvanometer for operating said adjustable resistance according to the changes effected in the line attenuation, and means for giving said galvanometer an added movement in the direction of the last movement thereof at the time of inserting a network in and withdrawing a network from the line to prevent hunting action.

3. In control circuits for a signal station on a transmission line, a plurality of attenuation networks for controlling the attenuation on said line, a pilot line subjected to the same attenuation varying conditions as the transmission line, an adjustable impedance element connected to said pilot line, means comprising a galvanometer for varying the number of attenuation networks in the transmission line by fixed steps according to the resistance variations of said pilot line, means controlled by said galvanometer for operating said adjustable impedance element according to the changes in the line impedance, and means controlled by said galvanometer for effecting a quick variation in the resistance of said pilot line when changing the attenuation on the transmission line by said networks to prevent hunting action.

4. In gain control circuits for a repeater station on a transmission line, a plurality of attenuation networks for controlling the gain on said line, a pilot line subjected to the same attenuation varying conditions as the transmission line, means comprising a galvanometer for varying the number of attenuation networks in the transmission line by fixed steps according to the resistance variations of said pilot line, an auxiliary resistance element normally included in the pilot line, and means controlled by said galvanometer for excluding said auxiliary resistance element from the pilot line when an attenuation network is being added to the transmission line to prevent hunting action and for inserting said auxiliary resistance element in the pilot line prior to the next change of the attenuation networks in the transmission line.

5. In gain control circuits for a repeater station on a transmission line, a plurality of attenuation networks for controlling the gain on said line, a pilot line subjected to the same attenuation varying conditions as the transmission line, means comprising a galvanometer for varying the number of attenuation networks in the transmission line by fixed steps according to the resistance variations of said pilot line, an auxiliary resistance element, and means for inserting said auxiliary resistance element in the pilot line when an attenuation network is being withdrawn from the transmission line to prevent hunting action and for withdrawing said auxiliary resistance from the pilot line prior to the next change of the networks in the transmission line.

6. In gain control circuits for a repeater station on a transmission line, a Wheatstone bridge

circuit having one arm thereof in the form of a pilot line associated with the transmission line, a galvanometer connected to two opposite vertices of said bridge circuit, a resistance element controlled by said galvanometer for balancing the bridge circuit, means comprising attenuation networks controlled by said galvanometer for governing the gain on the transmission line by fixed steps, and means controlled by said galvanometer for excluding an auxiliary resistance element from the pilot line when an attenuation network is being added to the transmission line and for inserting said auxiliary resistance element in the pilot line prior to the next change of the attenuation networks in the transmission line.

7. In control circuits for a station on a signal transmission line, a Wheatstone bridge circuit having one arm thereof in the form of a pilot line associated with said line, a galvanometer connected between two opposite vertices of said bridge circuit, an impedance element for balancing said bridge circuit, control means governed by said galvanometer for operating said impedance element to balance said bridge circuit, means controlled by said galvanometer for controlling the attenuation of said line by fixed impedance steps, and means controlled by said galvanometer for insuring a faster than normal change from one to another impedance step when controlling the attenuation to prevent hunting action.

8. In gain control circuits for a repeater station on a transmission line, a Wheatstone bridge circuit having one arm thereof in the form of a pilot line associated with said transmission line, a galvanometer connected between two opposite vertices of said bridge circuit, a resistance element controlled by said galvanometer for balancing said bridge circuit, means comprising attenuation networks controlled by said galvanometer for governing the gain on the transmission line by fixed steps and means controlled by said galvanometer for varying the resistance of said pilot line when changing the attenuation on the transmission line by said networks to insure a quick change in the attenuation networks in the transmission line and to prevent hunting action.

9. In gain control circuits for a repeater station on a transmission line, a Wheatstone bridge circuit having one arm thereof in the form of a pilot line associated with said transmission line, a galvanometer connected between two opposite vertices of said bridge circuit, a resistance element controlled by said galvanometer for balancing said bridge circuit, means comprising attenuation networks controlled by said galvanometer for governing the gain on the transmission line by fixed steps and means controlled by said galvanometer for increasing the resistance in the pilot line when an attenuation network is being excluded from the transmission line and for decreasing the resistance in the pilot line when an attenuation network is being added to the transmission line.

10. In gain control circuits for a repeater station on a transmission line, a Wheatstone bridge circuit having one arm thereof in the form of a pilot line associated with said transmission line, a galvanometer connected between two opposite vertices of said bridge circuit, a resistance element controlled by said galvanometer for balancing said bridge circuit, means comprising attenuation networks controlled by said galvanometer for governing the gain on the transmission line by fixed steps, and means controlled by said galvanometer for inserting an auxiliary resistance element in said pilot line when an attenuation network is being excluded from the transmission line and for removing said auxiliary resistance element from the pilot line prior to the next change of the attenuation networks in the transmission line.

11. In control circuits for a signal station on a transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, a galvanometer, means for operating said galvanometer according to the resistance variations of said pilot line, segmented ring switches, and means for operating said segmented ring switches according to the operation of said galvanometer to control the attenuation of said transmission line and maintain the energy on the transmission line constant and to vary the resistance of said pilot line to prevent hunting action.

12. In control circuits for a signal station on a transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, segmented ring switches, and means for operating said switches according to the resistance variations of said pilot line to control the attenuation of said transmission line and to vary the resistance of said pilot line.

13. In gain control circuits for a repeater station on a transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, means for varying the resistance of said pilot line, a galvanometer means for operating said galvanometer according to the resistance variations of said pilot line, three segmented ring switches operated by said galvanometer, means for varying the attenuation of said transmission line, means controlled by one of said switches for controlling the direction of attenuation variations on the transmission line and the direction of resistance variation on the pilot line, means controlled by a second one of said switches for operating said attenuation varying means and for operating said resistance varying means, and means controlled by a third one of said switches for returning the resistance varying means to normal condition.

14. In gain control circuits for a repeater station on a transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, a galvanometer, means for operating said galvanometer according to the resistance variations of said pilot line, means for varying the resistance of said pilot line, means comprising a segmented ring switch operated by said galvanometer and two directional relays for determining the direction of attenuation variation on said transmission line and the direction of resistance variation on said pilot line, and means comprising a second segmented ring switch operated by said galvanometer for controlling the attenuation on said transmission line to maintain the energy level on the transmission line constant and for controlling said resistance varying means to prevent hunting action.

15. In gain control circuits for a repeater station on a transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, two resistance elements associated with said pilot line, one of said resistance elements being normally included in and the other resistance element being normally excluded from the pilot line, pilot relays for controlling said resistance elements, a galvanome-

ter, means for operating said galvanometer according to the resistance variations of said pilot line, means for varying the attenuation of said transmission line, three segmented ring switches operated by said galvanometer, directional relays for controlling the direction of attenuation variation in the transmission line and for selecting the pilot relay operation to control the direction of resistance variation in the pilot line, means controlled by one of said switches for selectively operating said directional relays, means controlled by a second one of said switches for operating said attenuation varying means and for operating one of said pilot relays, and means controlled by the third segmented ring switch for releasing the operated pilot relay.

16. In control circuits for a station on a signal transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, means comprising a dial switch operated according to the variations in resistance on the pilot line for varying the attenuation on the transmission line, a direction selector operated according to the direction of operation of the dial switch for determining the direction of resistance variation on the pilot line, means operated by the dial switch and controlled by the direction selector for varying the resistance on the pilot line to prevent hunting action.

17. In gain control circuits for a repeater station on a transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, a dial switch operated according to the resistance variations of the pilot line and in a direction according to the direction of the resistance variations on the pilot line for varying the attenuation on the transmission line by fixed steps, a pilot relay for excluding a resistance element from the pilot line when operated, a second pilot relay for inserting a resistance element in the pilot line when operated, a direction selector operated according to the direction of variation of the resistance on the pilot line and means operated by said dial switch when the attenuation on the transmission line is varied for operating one of said pilot relays according to the operation of the directional selector to vary the resistance on the pilot line and prevent hunting action.

18. In gain control circuits for a repeater station on a transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, a galvanometer, means for operating said galvanometer according to the resistance variations of said pilot line, a dial switch operated according to operation of said galvanometer for varying the attenuation on the transmission line, pilot relays for controlling resistance in said pilot line, a direction selector operated according to the direction of movement of said galvanometer, and means controlled by said dial switch for operating the pilot relays according to the operation of the direction selector to vary the resistance of the pilot line and to prevent hunting action.

19. In gain control circuits for a repeater station on a transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, a dial switch operated according to the variations in resistance on the pilot line for varying the attenuation on the transmission line by fixed steps, two pilot relays for controlling a resistance element normally in and a resistance element normally out of said pilot line, a direction selector operated according to the direction of variation of the resistance in the pilot line, means operated by the dial switch for operating and locking one of said pilot switches according to the operation of said direction selector to control said resistance elements and prevent hunting action when the attenuation on the transmission line is varied by the dial switch, and means comprising a cam member operated according to the variations of resistance on the pilot line for releasing the operated pilot relay.

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