

Jan. 5, 1937.

V. E. ROSENE

2,066,539

CONTROL CIRCUIT

Filed Jan. 30, 1935

2 Sheets-Sheet 1

FIG. 1

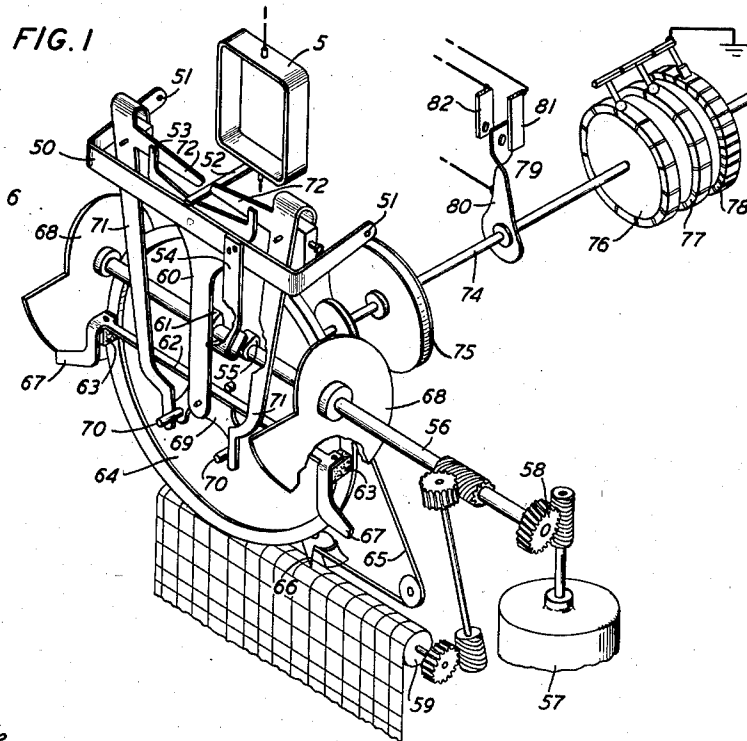
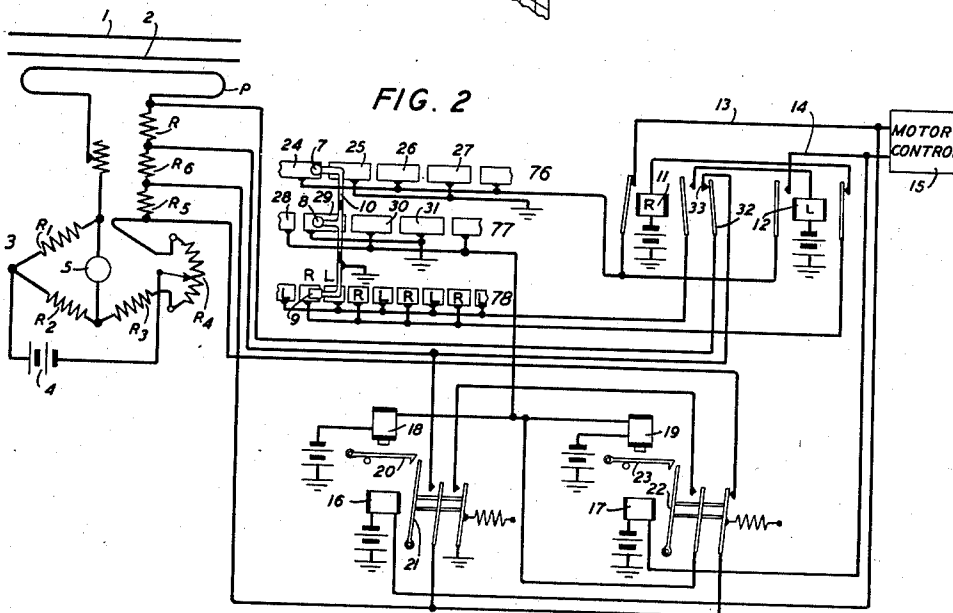


FIG. 2



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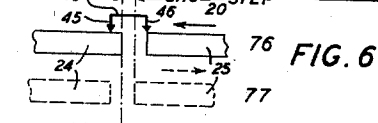
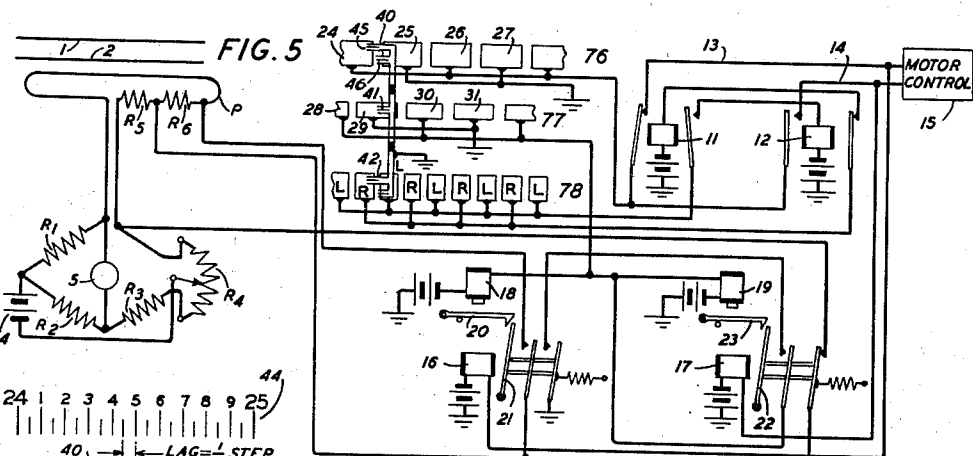
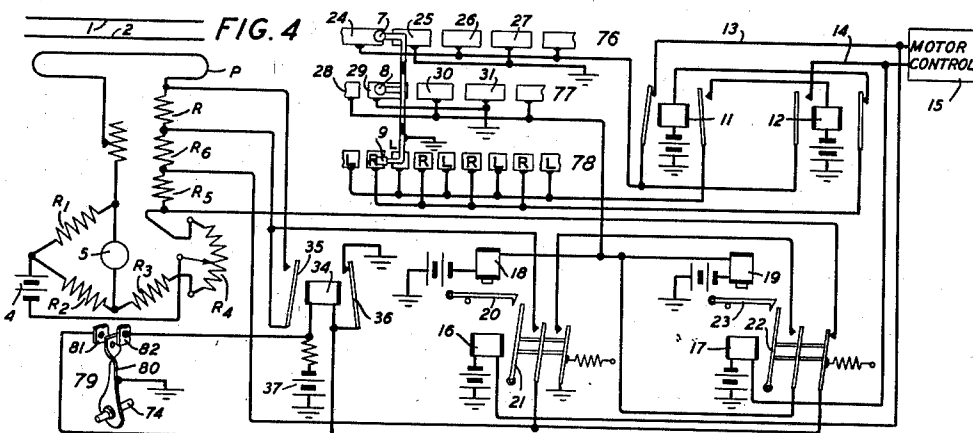
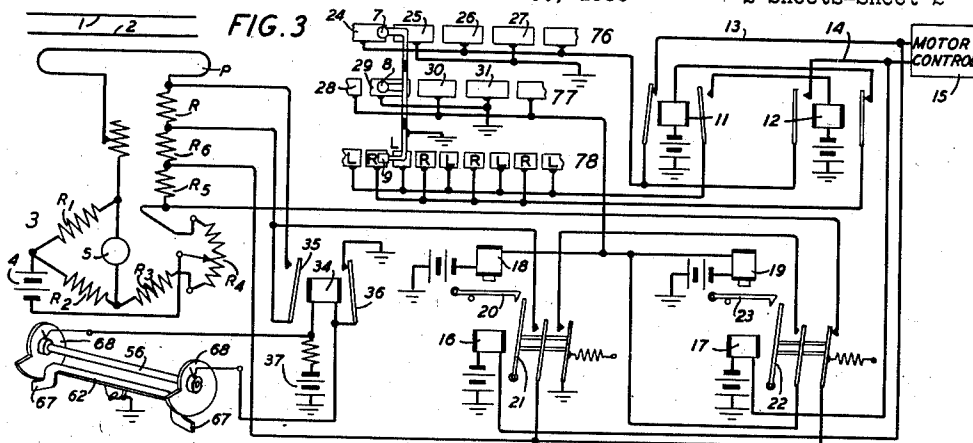
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2 Sheets-Sheet 2



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2,066,539

CONTROL CIRCUIT

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Application January 30, 1935, Serial No. 4,014

14 Claims. (Cl. 178—44)

This invention relates to control circuits and particularly to control circuits for adjusting the attenuation on telephone lines.

One object of the invention is to provide control circuits for adjusting the attenuation on a signal transmission line that shall compensate for the lag encountered when the direction of the attenuation control is reversed.

Another object of the invention is to provide a signal transmission line with attenuation control circuits that shall vary the attenuation on the transmission line according to the resistance variations of a pilot line and that shall compensate for the lag encountered when a reversal is made in the direction of the attenuation control.

Another object of the invention is to provide a signal transmission line with attenuation control circuits that shall vary the attenuation on the transmission line according to the resistance variations of a pilot line and that shall control the resistance of the pilot line to compensate for the lag encountered when a reversal is made in the direction of the attenuation control.

A further object of the invention is to provide a signal transmission line with attenuation control circuits that shall vary the attenuation on the transmission line according to the resistance variations of a pilot line, that shall insure against hunting action by controlling the resistance of the pilot line and that shall control the resistance of the pilot line to compensate for the lag encountered when a reversal is made in the direction of the attenuation control.

The transmission equivalent of a line varies according to the variations of a number of different conditions. One of the main causes of changes in the transmission equivalent is the change 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 of a pilot line associated with the transmission line. In this type of regulator, trouble is often encountered by the lag produced when the direction of the attenuation control is reversed. Regulators of the type under consideration wherein attenuation networks are selectively inserted in and withdrawn from the line are disclosed in the patent to J. A. Coy et al., No. 2,017,654, October 15, 1935 and in the application of H. I. Romnes,

Serial No. 716,934 filed March 23, 1934 now Patent No. 2,031,980 issued Feb. 25, 1936.

In attenuation control circuits constructed in accordance with the present invention, means are provided for so controlling the resistance of the pilot line as to compensate for the lag encountered when the direction of the attenuation control is reversed. The means to compensate for the lag encountered when the direction of attenuation control is reversed may be combined with the means for preventing hunting action disclosed in the application of H. I. Romnes, Serial No. 716,934.

In the attenuation control circuits employed to describe the invention, a pilot line is associated with the transmission lines in a manner to be subjected to the same attenuation varying conditions as the transmission lines. The pilot line forms one arm of a bridge circuit which controls a galvanometer. The other three arms of the bridge circuit preferably comprise fixed resistance elements and a resistance element for balancing the bridge so that the galvanometer is operated in accordance with the variations in resistance of the pilot line. The galvanometer operates galvanometer control mechanism of the type disclosed in the application of H. I. Romnes, Serial No. 716,934.

The galvanometer control mechanism not only balances the bridge circuit after each operation of the galvanometer but also operates three commutator or contact rings. The contact rings not only control attenuation pads in the transmission line but also control the resistance of the pilot line to prevent hunting action at the time an attenuation pad is inserted in the transmission line or an attenuation pad is withdrawn from the transmission line. Two relays are selectively controlled by the contact rings according to the direction of attenuation control. One of the relays is operated when an attenuation pad is being added to the line, and the other relay is operated when an attenuation pad is being withdrawn from the line. One of the relays is provided with an additional armature or switch arm for controlling a resistance in the pilot line to compensate for the lag encountered when the direction of the attenuation control is reversed. The galvanometer control mechanism is provided with a number of moving parts which produce lag. This lag interferes with the adjustment of the line attenuation when a reversal is made in the direction of the attenuation control. In the preferred control circuit, the lag above referred to is compensated for by controlling the resistance of a pilot line. This

control of the resistance of the pilot line to compensate for the lag cooperates with the resistance control of the pilot line to insure against hunting action when an attenuation pad is being inserted in or withdrawn from the transmission line.

In the accompanying drawings:

Fig. 1 is a diagrammatic view of the galvanometer control mechanism employed in the attenuation control circuits;

Fig. 2 is a diagrammatic view of attenuation control circuits constructed in accordance with the invention;

Fig. 3 is a diagrammatic view of a modification of the invention wherein cam members on the galvanometer control mechanism are employed to operate the lag compensating means;

Fig. 4 is a diagrammatic view of another modification of the invention wherein a directional switch associated with the galvanometer control mechanism is employed to operate the lag compensating means; and

Figs. 5 and 6 are diagrammatic views of another arrangement to compensate for the lag encountered in the attenuation control circuits.

Referring to Fig. 2 of the drawings, a pilot line P is shown associated with a transmission line comprising conductors 1 and 2. The pilot line P forms one arm of a Wheatstone bridge circuit 3. The other arms of the bridge circuit 3 comprise resistance elements R_1 , R_2 , and R_3 . An adjustable resistance element R_4 which is varied by the galvanometer control mechanism to balance the bridge is connected between the resistance R_3 and a resistance R_5 in the pilot line arm of the bridge. A battery 4 is connected to two opposite vertices of the bridge 3 and a galvanometer 5 is connected across the other two vertices of the bridge circuit. Two resistance elements R_6 and R_7 are provided for controlling the resistance of the pilot line P to insure against hunting action. A resistance R is provided for controlling the resistance of the pilot line P to compensate for the lag encountered when a reversal is effected in the direction of the attenuation control.

Referring to Fig. 1 of the drawings, the galvanometer 5 is shown controlling galvanometer control mechanism 6. The galvanometer control mechanism 6 governed by the galvanometer 5 comprises a U-shaped rocker arm 50 which is pivotally mounted at points 51. A pointer member 52 of the galvanometer 5 is free to swing directly above 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 50 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 shoes 63 engage the disc 64 for part of each revolution of shaft 56. 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 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. Pivotally 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 point 52 of the galvanometer 5.

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 projection 67 on the cross arm 62 moves the cross arm back to its original position. Just before the cam member 68 engages the projection 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 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. A directional switch 79 may also be mounted on the shaft 74. The directional switch comprises an arm 80 which is adapted to engage one of two contact members 81 and 82 according to the direction of rotation of the shaft 74. The arm 80 is frictionally connected to the shaft 74 and follows the rotation of the shaft 74 until engagement is made with one of the contact members 81 and 82. The arm 80 engaging one of the contact members 81 and 82 indicates whether the resistance in the pilot line P is increasing or decreasing.

Referring to Fig. 2 of the drawings, the commutator rings 76, 77, and 78 which are mounted on the shaft 74 of the galvanometer control mechanism 6 are shown in engagement with brush members 7, 8, and 9 mounted on a switch arm 10. The brushes 7, 8, and 9 are insulated from each other and the brush 9 is grounded. The brush 7 is a cylinder or ball so as to bridge two segments of the commutator ring 76 at definite positions when the commutator rings are rotating in either direction. The brush 8 is preferably a cylinder or ball although it is not essential that it be so constructed. The brush 9 is broader than the brushes 7 and 8 and bridges two segments of the commutator ring 78 for a considerable movement of the commutator rings.

The commutator rings 76, 77, and 78 are mounted with the segments in the relative positions shown in Fig. 2 of the drawings. The three brushes 7, 8, and 9 are mounted in the positions relative to each other as shown in Fig. 2 of the drawings. Two relays 11 and 12 are controlled by the commutator rings to place selectively a ground on conductors 13 and 14 which are connected to the motor control mechanism 15. The motor control mechanism 15 is disclosed and claimed in the patent to J. A. Coy et al., No. 2,017,654, October 15, 1935. The conductors 13 and 14 in the system shown in Fig. 2 of the drawings correspond to the conductors 35 and 36

shown in Fig. 2 of the J. A. Coy et al. Patent No. 2,017,654. Two relays 16 and 17 which are shown in Fig. 2 of the drawings are mechanically locked in operative position when once operated and can only be released by operation of the release magnets 18 and 19. When the relay 16 is operated, a latch member 20 engages a bar 21 and holds the relay in operative position. The bar 21 is released when the latch 20 is operated by the release magnet 18. The relay 17 is provided with a bar 22 which engages a latch 23 for holding the relay 17 in operative position. The latch 23 is operated by the release magnet 19 to release the bar 22.

Assume that the resistance of the pilot line P is such that the galvanometer 5 is balanced with the brush member 7 engaging the contact segment 24 of the commutator ring 76 and the brush member 9 engaging a corresponding R segment of the commutator ring 78. In this position of the apparatus the relay 11 is operated by a circuit extending from ground through the brush 9, commutator segment R, right contact arm of the relay 12, winding of the relay 11 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. 2 of the drawings. When the brush member 7 bridges contact segments 24 and 25 of the commutator ring 76, ground is applied to the conductor 13 of the motor control mechanism through the left contact arm of the relay 11. The placing of ground connection on the conductor 13 starts the motor control mechanism shown in the J. A. Coy et al. Patent No. 2,017,654 to add attenuation networks corresponding to one step to all the associated transmission lines. The relay 16 which is operated by the ground connection on the conductor 13 locks up mechanically under control of the release magnet 18.

The operation of relay 16 short-circuits the resistance R_0 by means of its left armature. The resistance value of the resistance member R_0 is such that when it is taken out of the pilot line, the galvanometer mechanism assumes a new balance with the commutator rings 76, 77, and 78 moved towards the left, as viewed in Fig. 2 of the drawings, one-fourth of the distance between the centers of two contact segments on the commutator ring 76. In moving to the new position, brush member 9 breaks engagement with the commutator segment R and opens the operating circuit for the relay 11. The release of the relay 11 allows the relay 12 to operate over a circuit extending from ground through the brush member 9, commutator segment L, right contact arm of relay 11, winding of relay 12 and battery to ground. The operation of relay 12 at this time prepares a circuit for a later operation.

Upon release of relay 11, armature 32 of the relay disengages the contact member 33 for inserting the resistance R in the circuit of the pilot line P. The resistance R is inserted in the circuit of the pilot line P at this time to compensate for lag in the galvanometer control mechanism in case there is a reversal in the attenuation control. The resistance value of resistance R is such that the galvanometer mechanism assumes a new balance with the commutator rings 76, 77, and 78 remaining in the position taken when the resistance member R_0 was taken out of the pilot line. The effect of inserting resistance R in the pilot line P was to take up the back lash or lag of the galvanom-

eter control mechanism. If the resistance of the pilot line P continues to decrease, the commutator rings 76, 77, and 78 continue to move to the left and before any further change in the attenuation network takes place the relay 11 will again be operated as described later to short-circuit the resistance R. The galvanometer mechanism assumes a new balance again without changing the position of the commutator rings 76, 77, and 78, but with the back lash or lag of the galvanometer mechanism taken up in the opposite direction.

Assume now that the temperature affecting the pilot line P continues to decrease and therefore the commutator rings 76, 77, and 78 continued to move towards the left, as viewed in Fig. 2 of the drawings. When the brush member 8 bridges commutator segments 29 and 30 of the commutator ring 77, a circuit from ground through the commutator segment 29, brush member 8, commutator segment 30, winding of the release magnet 18, and battery to ground, energizes the release magnet 18 to release the relay 16. Release magnet 19 is also energized but performs no useful function at this time. The release of relay 16 removes the short-circuit around the resistance member R_0 . The galvanometer mechanism 6 then assumes a new balance with the commutator rings moved one-fourth of a step to the right, as viewed in Fig. 2 of the drawings. A step is considered the distance between the centers of adjacent commutator segments on the ring 76.

As the resistance of the pilot line P continues to decrease and the segments continue to be moved towards the left, as viewed in Fig. 2 of the drawings, the brush member 9 finally breaks engagement with the segment L and allows relay 12 to release. The release of relay 12 operates relay 11 by a circuit extending from ground through the brush member 9, commutator segment R, right arm of relay 12, winding of relay 11, and battery to ground. The operation of relay 11 prepares a circuit for later operation. As the commutator segments continue to move towards the left, as viewed in Fig. 2 of the drawings, the brush member 7 finally bridges commutator segments 25 and 26 to start the motor control mechanism 15 and operate relay 16 to perform the functions already described. When relay 11 is operated by the circuit completed by brush member 9 and the commutator segment R, it will be noted that resistance R is taken out of the pilot line P prior to the adjustment of the line attenuation when there has been no reversal in the direction of the attenuation control.

Consider the apparatus in its former position and assume that the resistance of the pilot line P begins to increase and that the commutator segments begin moving towards the right, as viewed in Fig. 2 of the drawings. The brush member 7 is on contact segment 25, brush member 8 is on contact segment 29 and brush member 9 is on contact segment L. Under such conditions, relay 12 is operated by a circuit extending from ground, through brush member 9, commutator segment L, right armature of relay 11, winding of relay 12 and battery to ground. When brush member 7 bridges contact segments 24 and 25, a ground connection is applied to conductor 14. The ground circuit for conductor 14 may be traced from ground through commutator segment 25, brush member 7, commutator segment 24 and left armature of relay 12 to the

conductor 14. This ground connection placed on conductor 14 starts the motor control mechanism 15 to subtract an attenuation network corresponding to one step from all associated transmission lines. Relay 17 which is operated by a circuit extending from ground on conductor 14 locks up mechanically under control of release magnet 19. The operation of relay 17 removes the short circuit around resistance member R_s by means of its right contact arm. Release magnet 18 would be operated at this time if relay 16 were in operative position by a circuit extending from ground on the outer right contact arm of relay 16, through the inner left contact arm of relay 17, winding of release magnet 18 and battery to ground for releasing relay 16. At this time, it is apparent that both the hunting control resistance members R_s and R_r are cut into the pilot line P.

The bridge rebalances and moves the commutator rings 76, 77, and 78 towards the right, as viewed in Fig. 2 of the drawings, a distance of one-fourth of a step. In moving to the new position brush member 9 breaks engagement with segment L allowing relay 12 to release. Relay 11 is then operated by a circuit extending from ground through the brush member 9, commutator segment R, right contact arm of relay 12, winding of relay 11 and battery to ground. As the commutator rings 76, 77, and 78 continue moving towards the right, as viewed in Fig. 2 of the drawings, due to increasing pilot line resistance the brush member 8 bridges commutator segments 28 and 29. The ground connection from commutator segment 29 extends through brush member 8, commutator segment 28, winding of release magnet 19 and battery to ground. The operation of the release magnet 19 effects the release of relay 17. The release of relay 17 restores the short circuit around the resistance member R_s which, due to the rebalancing action of the bridge, moves the commutator segments one-fourth step towards the left, as viewed in Fig. 2 of the drawings. At this time the brush member 9 is on commutator segment R and relay 11 is operated.

Resistance R is in circuit with the pilot line P when the relay 12 is operated and relay 11 is released. Thus, it is apparent when a reversal is made in the operation of the attenuation control of the transmission line by reason of the resistance of the pilot line P increasing instead of decreasing, that the resistance R is inserted in the pilot line P to compensate for the lag of the galvanometer control mechanism. If the resistance in the pilot line is increasing and a reversal is made in the attenuation control mechanism, then the resistance R is short-circuited from the pilot line P. Although the resistance R is shown as being controlled solely by relay 11, it is apparent that the control of said resistance may be effected by relay 12 if so desired in which case resistance R would be short-circuited by contacts on relay 12 when this relay is in the released position.

As soon as the pilot line resistance continues to increase and the commutator rings 76, 77, and 78 continue to move towards the right, as viewed in Fig. 2 of the drawings, the brush member 9 breaks engagement with the commutator segment R, relay 11 releases and relay 12 is operated. The circuit for operating relay 12 extends from ground, through the brush member 9, commutator segment L, right armature of re-

lay 11, winding of relay 12 and battery to ground. When brush member 7 bridges the next two adjacent commutator segments of commutator ring 76, ground is again applied to the conductor 14 for operating the motor control mechanism 15 to subtract attenuation pads from the line corresponding to one step. The ground circuit on conductor 14 operates relay 17 as above set forth. The above cycle of operations continues according to the resistance variations in the pilot line. At the same time, resistance R is inserted in or taken out of the pilot line according to whether or not a reversal has been effected in the direction of operation of the attenuation control mechanism.

Figs. 3, 4, and 5 of the drawings disclose modifications of the control circuits shown in Fig. 2 of the drawings. The anti-hunting means and the attenuation control mechanism shown in Figs. 3, 4, and 5 is the same as the anti-hunting means and the attenuation control mechanism shown in Fig. 2 of the drawings. Accordingly a detailed description of such apparatus will not be given again when reference is made to Figs. 3, 4, and 5. Moreover, like parts in Figs. 3, 4, and 5 to those shown in Fig. 2 of the drawings, have been indicated by similar reference characters.

Referring to Fig. 3 of the drawings, resistance R which compensates for the lag encountered when a reversal is made in the direction of the attenuation control is controlled by the galvanometer control mechanism 6 shown in Fig. 1 of the drawings. A relay 34 provided with two armatures 35 and 36 is selectively operated according to the movement of the cross arm 62 which carries the lugs 67. Cams 68 are metallic and insulated from shaft 56 and each other. Contact to rotating cams 68 is effected by brushes riding on slip rings. Cross arms 62 and lugs 67 are metallic and are so adjusted that when the right lug 67 makes contact with the right cam 68, the left lug cannot make contact with left lug 68 and vice versa. If relay 34 is in operative position, as shown in Fig. 3 of the drawings, resistance R is included in series with pilot line P. If relay 34 is released, armature 35 thereof short-circuits resistance R.

If the resistance of pilot line P is decreasing, cross arm 62 is given a clockwise movement of rotation as viewed in Fig. 3 of the drawings so that the left lug 67 engages the left cam 68. When the left lug 67 engages the left cam 68, a circuit is completed for short-circuiting the winding of relay 34 so as to insure the release of relay 34. If the resistance of the pilot line P is increasing and the galvanometer control mechanism 6 is operated to withdraw an attenuation pad from the transmission line, cross arm 62 is given a movement of rotation in a counter-clockwise direction so that the right lug 67 engages the right cam 68. When the cross arm 62 is rotated in a counter-clockwise direction the left lug 67 is moved away from the left cam 68. The engagement of the right lug 67 with the right cam 68, completes a circuit from battery 37 for operating relay 34. The operation of armature 35 of relay 34 removes the short circuit across resistance R. The operation of armature 36 completes a holding circuit from battery 37 for relay 34.

In the above manner resistance R is controlled by relay 34 to compensate for the lag of the galvanometer control mechanism 6 when a reversal is made in the direction of control. If

the galvanometer control mechanism has been operated by increasing resistance in the pilot line and the pilot line starts to decrease, then resistance R is short-circuited from the pilot line. A reverse operation takes place and the short circuit across resistance R is removed if the galvanometer control mechanism has been controlled by decreasing pilot line resistance when the resistance of the pilot line starts to increase.

Referring to Fig. 4 of the drawings, a modification of the invention is illustrated wherein relay 34 which controls resistance R is controlled by a directional switch 79. The arm 80 of the directional switch 79 is mounted on the shaft 74 of the galvanometer control mechanism 6. The arm 80 is frictionally connected to the shaft 74 and follows the rotation of the shaft until engagement is made with one of the contact members 81 or 82. If the resistance of the pilot line is decreasing then shaft 74 is rotating in a direction to move arm 80 into engagement with contact member 82 to establish a short circuit around relay 34 and insure the release of relay 34. When relay 34 is released, the armature 35 short-circuits resistance R as above set forth when reference was made to Fig. 3 of the drawings. If the resistance of pilot line P is increasing, then galvanometer control mechanism 6 is operated to rotate shaft 74 so that contact arm 80 engages contact member 81. When arm 80 engages contact member 81, a circuit is completed from battery 37 for operating relay 34. Upon operation of relay 34, armature 35 opens the short circuit around the resistance R and armature 36 completes a holding circuit for relay 34. The holding circuit for relay 34 is maintained until arm 80 is removed into engagement with contact member 82 to short-circuit relay 34. The operation of relay 34 is the same as above set forth when reference was made to the modification shown in Fig. 3 of the drawings.

Referring to Figs. 5 and 6 of the drawings, a modification of the invention is disclosed wherein the lag of the galvanometer control mechanism 6 is compensated by mechanical means. The three commutator rings 76, 77, and 78 shown in Fig. 5 of the drawings, are provided with brush members 40, 41, and 42. The brush member 40 which engages the commutator ring 76 essentially consists of two brushes 45 and 46 set closely together with the spacing between them determining the amount of the reduction in the lag. The brush member 42 is also in the form of a double brush but the spacing of the parts of the brush member 42 is not important except that the width of the brush must be greater than the width of the two brushes 45 and 46.

In describing the operation of the lag compensating means disclosed in Fig. 5 of the drawings, particular attention is called to Fig. 6 which discloses an enlarged portion of the commutator ring 76. Adjacent to the commutator ring 76 is shown a scale 44 which divides each step of the mechanism into ten parts. Assume that the resistance of the pilot line P is decreasing and that the commutator rings 76, 77, and 78 are given a movement towards the left, as viewed in Fig. 5 of the drawings. When the center of the gap between segments 24 and 25 shown in Fig. 6 of the drawings reaches position 24.5, brush members 45 and 46 (equivalent to brush member 40 in Fig. 5) bridges the commutator segments 24 and 25. At this time a circuit is completed from ground through commutator

segment 25, brush 40, commutator segment 24, and armature of relay 11 to conductor 13 which is connected to the attenuation control mechanism 15. The attenuation control mechanism 15 is operated to change the attenuation pads in the line by one step and then to stop automatically. Ground on conductor 13 also operates relay 16 which locks up and short-circuits resistance R_s. Commutator rings 76, 77, and 78 are moved towards the left, as viewed in Fig. 5 of the drawings by one-fourth step which causes brush 42 to rest on an L segment of the commutator 78. When brush 42 disengages commutator segment R of the commutator ring 78, the circuit operating relay 11 is opened and relay 11 releases. When relay 11 releases, relay 12 operates. A further decrease of pilot line resistance causes commutator rings 76, 77, and 78 to move to the left until brush member 41 bridges contact segments 29 and 30 which operates the release magnet 18. Relay 16 releases and inserts resistance R_s in the pilot line circuit. The galvanometer mechanism rebalances and moves the commutator rings 76, 77, and 78, one-fourth step to the right, as viewed in Fig. 5 of the drawings.

If the resistance trend of the pilot line should change and start increasing, commutator rings 76, 77, and 78 would move towards the right, as viewed in Fig. 5 of the drawings. For any value of pilot line resistance, the commutator segments should arrive at the same position when moving towards the right as viewed in Fig. 5 of the drawings as when the segments were moved to the left previously. This is accomplished, as shown in Figs. 5 and 6, by separating the portions 45 and 46 of brush 40 a distance equal to the lag plus the separation between segments on commutator 76. The separation between all segments on commutator 76 is uniform. In Fig. 6, the lag compensation is shown equal to one-twentieth of a step. When a reversal of pilot line resistance takes place so as to cause the commutator rings 76, 77, and 78 to move towards the right, the lag in the galvanometer control mechanism prevents the commutator rings 76, 77, and 78 to move immediately after the reversal takes place. After the lag in the galvanometer control mechanism is taken up the segments 24 and 25 of commutator ring 76 moves towards the right as viewed in Fig. 6 of the drawings and shown in broken lines. When the center of the gap between segments 24 and 25 reaches position 24.45, the brush 40 bridges these segments. The contact between segments 24 and 25 is therefore accomplished one-twentieth step before reaching position 24.5 which compensates for the lag of the galvanometer control mechanism.

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 combination, a pilot line subjected to resistance varying conditions, galvanometer mechanism, means for operating said mechanism according to the variations in resistance of said line, control means operated by said mechanism for governing the resistance of said line, and electrical means for compensating for the effect on said control means by the lag in the operation of said mechanism upon reversal in the operation thereof.

2. In combination, a bridge circuit, a pilot line subjected to resistance varying conditions and forming an arm of said bridge circuit, galvanometer mechanism, means for operating said mechanism according to the variations in resistance of said line and unbalance of said bridge, means operated by said mechanism for rebalancing the bridge circuit, and electrical means for compensating for the effect on the means operated by said mechanism of the lag in the operation of said mechanism upon reversal in the operation thereof.

3. In a gain control circuit for a transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, control means comprising a galvanometer mechanism operated in a forward and in a reverse direction according to the resistance variations of the pilot line to control the transmission line attenuation, and electrical means for compensating for the effect on said control means of the lag in the operation of said galvanometer mechanism upon reversal in the operation thereof.

4. In a gain control circuit for a transmission line, a bridge circuit, a pilot line subjected to the same attenuation varying conditions as the transmission line and forming an arm of said bridge circuit, galvanometer mechanism, means for operating said mechanism in a forward and in a reverse direction according to the variations in resistance of said pilot line and unbalance of said bridge, means operated by said mechanism for rebalancing the bridge circuit and for controlling the transmission line attenuation, and electrical means for compensating for the effect on the means operated by said mechanism of the lag in the operation of said mechanism upon reversal in the operation thereof.

5. In combination, a bridge circuit, a pilot line subjected to resistance varying conditions and forming an arm of said bridge circuit, galvanometer mechanism, means for operating said mechanism according to the variations in resistance of said line and unbalance of said bridge, means operated by said mechanism for rebalancing the bridge circuit, and means for varying the resistance of said pilot line upon reversal in the operation of said mechanism to compensate for the lag in the operation of the mechanism.

6. In a gain control circuit for a transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, control means comprising a galvanometer mechanism operated in a forward and in a reverse direction according to the resistance variations of the pilot line to control the transmission line attenuation, and means for varying the resistance of the pilot line to compensate for lag in the operation of said galvanometer mechanism upon reversal in the operation thereof.

7. In combination, a bridge circuit, a pilot line subjected to resistance varying conditions and forming an arm of said bridge circuit, galvanometer mechanism, means for operating said mechanism according to the variations in resistance of said line and unbalance of said bridge, means operated by said mechanism for rebalancing the bridge circuit, and means for inserting resistance in said pilot line upon reversal in the operation of said mechanism when operating in one direction and for withdrawing resistance from said pilot line upon reversal in the operation of said mechanism when operating in an opposite

direction to compensate for lag in the operation of the mechanism.

8. In a gain control circuit for a transmission line, a bridge circuit, a pilot line subjected to the same attenuation varying conditions as the transmission line and forming an arm of said bridge circuit, galvanometer mechanism, means for operating said mechanism in a forward and in a reverse direction according to the variations in resistance of said pilot line and unbalance of said bridge, means operated by said mechanism for rebalancing the bridge circuit and for controlling the transmission line attenuation, and means for varying the resistance of said pilot line upon reversal in the operation of said mechanism to compensate for the lag in the operation of the mechanism.

9. In combination, a transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, galvanometer mechanism, means for operating said mechanism in a forward and in a reverse direction according to the variations in resistance of said pilot line, two relays selectively operated by said mechanism for controlling the transmission line attenuation, and means comprising a resistance element controlled by one of said relays for varying the pilot line resistance upon reversal of said mechanism to compensate for the lag in the operation of the mechanism.

10. In combination, a transmission line, a bridge circuit, a pilot line subjected to the same attenuation varying conditions as the transmission line and forming an arm of said bridge circuit, galvanometer mechanism, means for operating said mechanism in a forward and in a reverse direction according to the variations in resistance of said pilot line and unbalance of said bridge, means operated by said mechanism for rebalancing said bridge circuit, two relays selectively operated by said mechanism for controlling the transmission line attenuation, and means comprising a resistance element controlled by one of said relays for varying the pilot line resistance upon reversal of said mechanism to compensate for the lag in the operation of the mechanism.

11. In a gain control circuit for a transmission line, a bridge circuit, a pilot line subjected to the same attenuation varying conditions as the transmission line and forming an arm of said bridge circuit, galvanometer mechanism, means for operating said mechanism in a forward and in a reverse direction according to the variations in resistance of said pilot line and unbalance of said bridge, means operated by said mechanism for rebalancing said bridge circuit, two relays selectively operated by said mechanism for controlling the transmission line attenuation, a resistance element, and means operated by one of said relays for inserting said resistance element in the pilot line upon reversal in the operation of said mechanism when operating in one direction and for withdrawing said resistance from the pilot line upon reversal in the operation of said mechanism when operating in an opposite direction to compensate for lag in the operation of the mechanism.

12. In combination, a transmission line, a pilot line subjected to the same attenuation varying conditions as the transmission line, galvanometer mechanism, means for operating said mechanism in a forward and in a reverse direction according to the variations in resistance of said pilot line to control the transmission line at-

tenuation, and means comprising a switch operated by said mechanism for varying the pilot line resistance upon reversal of said mechanism to compensate for the lag in the operation of the mechanism.

13. In combination, a transmission line, a bridge circuit, a pilot line subjected to the same attenuation varying conditions as the transmission line and forming an arm of said bridge circuit, galvanometer mechanism, means for operating said mechanism in a forward and in a reverse direction according to the variations in resistance of said pilot line and unbalance of said bridge, means operated by said mechanism for rebalancing said bridge circuit and for controlling the transmission line attenuation, and means comprising a switch operated by said mechanism for varying the pilot line resistance upon reversal of said mechanism to compensate for the lag in the operation of the mechanism.

14. In combination, a transmission line, a bridge circuit, a pilot line subjected to the same attenuation varying conditions as the transmission line and forming an arm of said bridge circuit, galvanometer mechanism, means for operating said mechanism in a forward and in a reverse direction according to the variations in resistance of said pilot line and unbalance of the bridge, means operated by said mechanism for rebalancing said bridge circuit and for controlling the transmission line attenuation, a resistance element, and means comprising a switch operated by said mechanism for holding said resistance element in the pilot line when the mechanism is operated in one direction and for holding said resistance element out of the pilot line when the mechanism is operated in a reverse direction to compensate for the lag in the operation of the mechanism.

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