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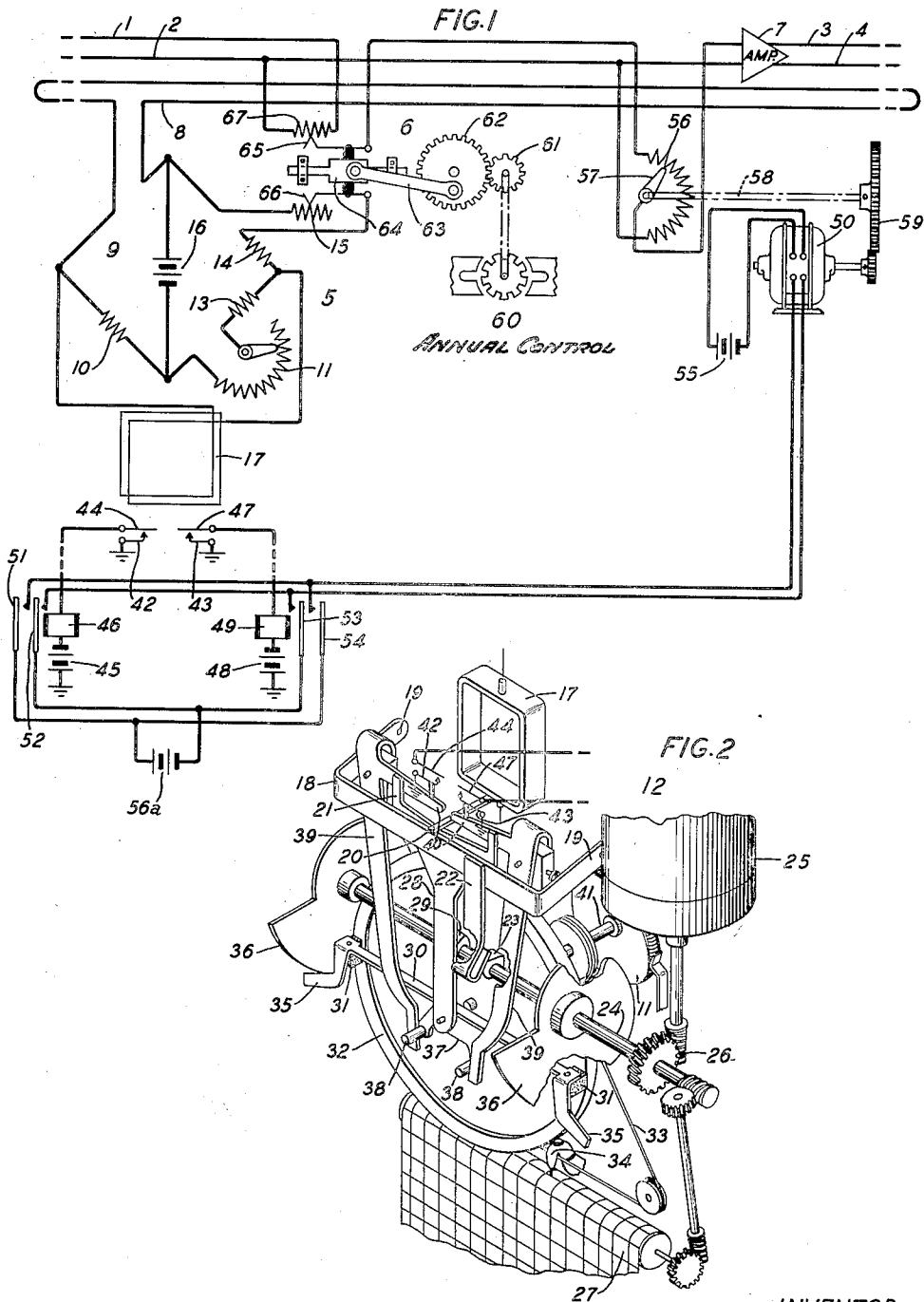
I. G. WILSON

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GAIN CONTROL CIRCUITS

Filed March 19, 1936

2 Sheets-Sheet 1



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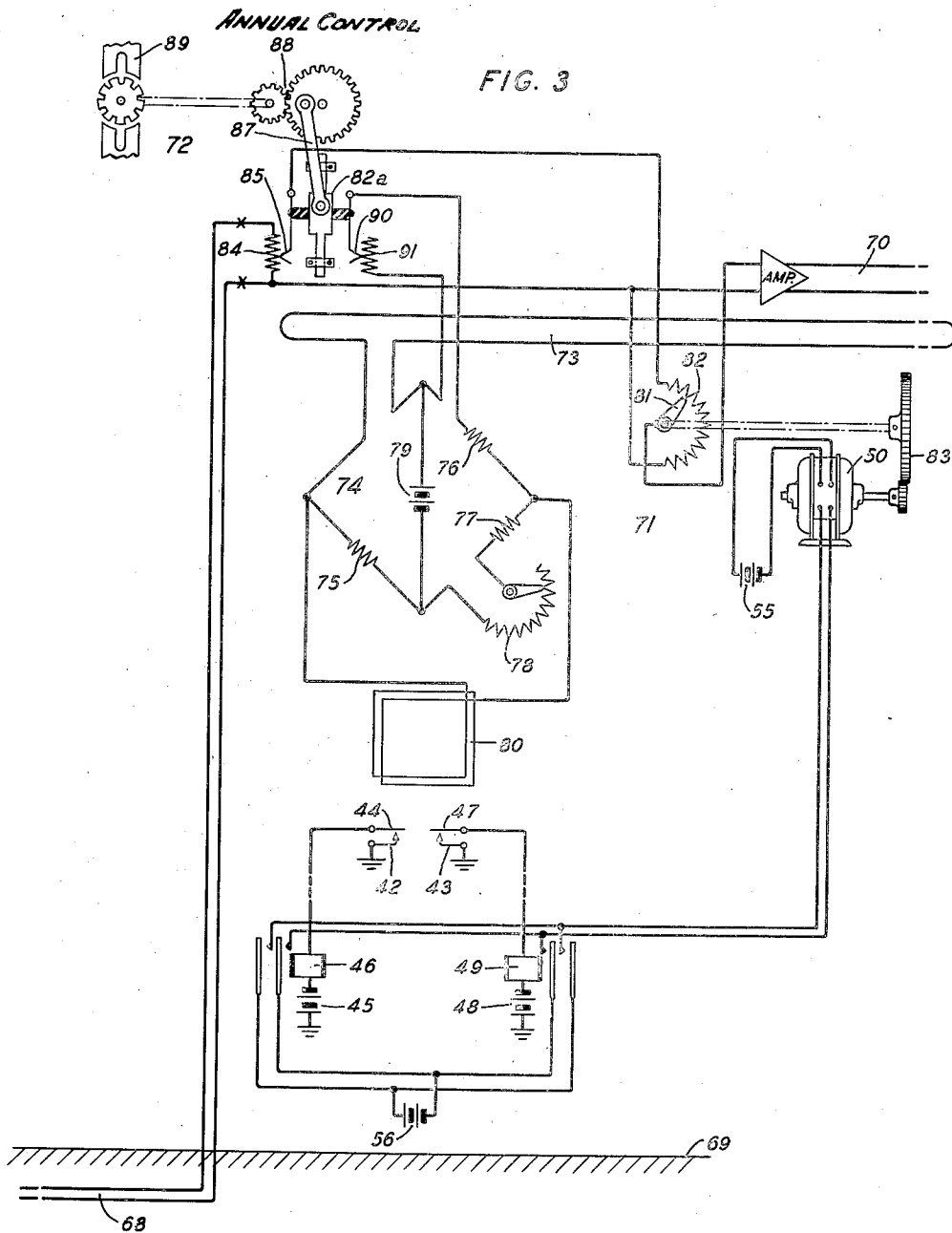
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## UNITED STATES PATENT OFFICE

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## GAIN CONTROL CIRCUITS

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12 Claims. (Cl. 178—44)

This invention relates to control circuits for signal transmission lines and particularly to circuits for controlling the attenuation on signal transmission lines.

5 One object of the invention is to provide a transmission line with control circuits that shall vary the line attenuation not only in accordance with a fixed cycle extending over a relatively long period of time but also in accordance with line  
10 attenuation changes extending over relatively short periods of time.

Another object of the invention is to provide a transmission line with control circuits that shall vary the line attenuation in accordance with the  
15 resistance variations of a pilot line associated with the transmission line and that shall vary the transmission line attenuation in accordance with a fixed cycle varying according to annual temperature changes.

20 A further object of the invention is to provide a transmission line having a pilot line associated therewith which forms one arm of a bridge circuit that shall have the attenuation thereof controlled in accordance with the variations of the  
25 pilot line resistance and that shall vary the attenuation of the transmission line and the resistance of one bridge arm varied in accordance with a fixed cycle.

30 The attenuation of a signal transmission line varies in accordance with different weather conditions. The greatest change in the attenuation of a cable is caused by changes in temperature. The temperature of a transmission line and particularly an aerial line is the function of a number of variables. The temperature of a line is  
35 subjected to an annual temperature change, a daily temperature change, and fortuitous temperature changes which depend to a large extent upon local conditions.

40 It is customary to provide gain control apparatus for controlling the variations in attenuation on a transmission line. The changes in attenuation caused by total temperature changes may be so large as to place severe requirements upon the range of the apparatus employed to correct for the change in attenuation on a line  
45 caused by temperature changes.

In accordance with the present invention it is proposed to have one gain control apparatus correct for the changes in line attenuation caused by  
50 annual temperature changes and to have a second gain control apparatus correct for the changes in line attenuation caused by daily and other temperature changes. It is possible by employing  
55 two gain control apparatuses for respectively tak-

ing care of annual, daily and fortuitous temperature changes to reduce greatly the range of operation of each apparatus.

In some cases a transmission line may have one section located underground and another section located above ground. The section of the line which is located underground will have temperature changes chiefly caused by annual temperature changes. The daily temperature changes will have a very reduced effect upon the section of the line located underground. The section of the line located above ground will have temperature changes caused not only by the annual temperature changes but also by the daily temperature changes without reduction.

A transmission line having a section located underground and a section located above ground may have one gain control apparatus provided to correct for line attenuation changes caused by the annual temperature changes on the line sections located underground and above ground and may have another gain control apparatus provided to correct for line attenuation changes caused by the daily temperature changes on the line section located above ground.

In one circuit employed to describe the invention a pilot wire regulator serves to correct the attenuation of the signal transmission line for daily temperature variations. The annual variations in attenuation are corrected by means of a constantly operating mechanism which follows a fixed cycle. In the pilot wire regulator a pilot line which is subjected to the same temperature variations as the signal transmission line forms one arm of a bridge circuit. A galvanometer which is connected to opposite vertices of the bridge circuit controls a galvanometer mechanism. The galvanometer mechanism operates a motor in a forward and in a reverse direction for controlling the attenuation of the transmission line according to the resistance variations of the pilot line. The galvanometer mechanism also serves to control a resistance element to balance the bridge circuit. In the illustrated circuits the motor controls a potentiometer connected to the signal line.

The annual variations in attenuation on the transmission line are corrected by means of a mechanism controlled by a constantly rotating motor. The constantly operating motor continually adjusts a potentiometer on the transmission line in accordance with the average temperature variations. In the illustrated mechanism the constantly rotating motor is connected to a reciprocating cross-head by means of gearing. The

reciprocating cross-head not only adjusts a potentiometer connected to the transmission line, but also adjusts a resistance in one arm of the bridge circuit. In the circuits as above described it is apparent the correction of the line attenuation variations caused by annual temperature changes serves to lighten the work of the pilot line regulator which takes care of daily attenuation variations. The range of operation of the pilot line regulator may be greatly reduced.

In some cases the transmission line may be partly located underground and partly located above ground. The underground section of the transmission line will have its attenuation varied according to the annual temperature variations but will not be greatly affected by daily temperature changes. The section of the transmission line located above ground will be affected by both the annual temperature changes and the daily temperature changes. It is proposed to provide a regulator following a fixed cycle for correcting for the attenuation variations caused by annual temperature changes in the sections of the line located underground and above ground. The section located above ground is corrected for daily temperature changes by means of a pilot wire regulator.

In the accompanying drawings:

Fig. 1 is a diagrammatic view of a transmission line having control circuits constructed in accordance with the invention;

Fig. 2 is a diagrammatic view of the galvanometer mechanism controlled by the galvanometer shown in Fig. 1; and

Fig. 3 is a diagrammatic view of a modification of the control circuits shown in Fig. 1 of the drawings.

Referring to Fig. 1 of the drawings, a transmission line having input conductors 1 and 2 and output conductors 3 and 4 is shown controlled by a pilot wire regulator 5 and a regulator 6 following a fixed cycle. An amplifier 7 is shown connected to the transmission line beyond the regulators 5 and 6.

The pilot wire regulator 5 comprises a pilot line 8 which is subjected to the same attenuation varying conditions as the signal transmission line. The pilot line 8 forms one arm of a Wheatstone bridge circuit 9. The other arms of the bridge circuit 9 comprise a resistance 10, an adjustable resistance 11 which is controlled by galvanometer mechanism 12 shown in Fig. 2 of the drawings for balancing the bridge circuit, resistance elements 13 and 14 and an adjustable resistance 15 which is controlled by the regulator 6. A battery 16 is connected across two opposite vertices of the bridge circuit and a galvanometer 17 is connected across the other two vertices of the bridge circuit. The galvanometer 17 controls the galvanometer mechanism 12 shown in Fig. 2 of the drawings.

The galvanometer mechanism 12 comprises a U-shaped rocker arm 18 which is pivotally mounted at points 19. A pointer member 20 operated by the galvanometer 17 rides on a U-shaped supporting member 21 which is attached to the rocker arm 18. The U-shaped supporting member 21 limits the movements of the galvanometer pointer member 20. An arm 22 secured to the rocker arm 18 engages a cam member 23 on a constantly rotating shaft 24. The shaft 24 is preferably connected to a motor 25 by a suitable gearing 26. The gearing 26 also connects the motor 25 to a recording paper roll 27. The constant rotation of the cam member

23 serves to raise the rocker arm 18 at predetermined intervals. The rocker arm 18 is operated approximately every eight seconds. A flexible arm 28 engages a second constantly rotating cam member 29 on the shaft 24. A cross-arm 30 is pivotally mounted on the resilient arm 28 and carries a pair of shoes 31 which are adapted to frictionally engage a disc 32. The disc 32 by means of a flexible connecting member 33 serves to control the movement of a recording pen 34. The cross-arm 30 terminates in a pair of projecting lugs 35 which are located in a position adjacent to the paths of rotation of two rotating cam members 36. The cam members 36 are mounted on the constantly rotating shaft 24. A plate 37 is fixed to the cross-arm 30 and carries a pair of pins 38.

Pivotally mounted arms 39 are held in engagement with the pins 38 by any suitable spring means, not shown. The arms 39 are provided with projections 40 positioned about the pointer 20 of the galvanometer 17. When the galvanometer pointer 20 is deflected in one direction or the other it will pass under one of the projections 40 attached to an arm 39 and upon the raising of the rocker arm 18 under control of the cam member 23 on the constantly rotating shaft 24 one of the arms 39 will be given a movement of rotation to rotate the cross-arm 30 on its pivotal support. The rotative movement of the cross-arm 30 places one of the projections 35 in a path of movement of one of the cam members 36. The cam member 36 upon engaging with the projection 35 on the cross-arm 30 moves the cross-arm back to its original position. At this time the cam member 29 will act to allow the shoes 31 on the cross-arm 30 to engage the disc 32 fractionally and as the rocker arm is given a movement of rotation it will give a like movement of rotation to the disc 32 for controlling the recording pen 34. The disc 32 is mounted on a shaft 41 which carries the slide wire resistance 11 forming a part of the bridge circuit 9. The rotation of the shaft 41 and the adjustment of the slide wire resistance 11 serve to rebalance the bridge circuit 9.

The projections 40 on the arms 39 not only control the rotation of the disc 32 for balancing the bridge and recording but also control two switch members 42 and 43. The switch member 42 upon operation engages a contact member 44 for completing a circuit from a battery 45 to operate a relay 46 shown in Fig. 1 of the drawings. The switch member 43 upon operation engages a contact member 47 for completing a circuit from a battery 48 to operate a relay 49. The relays 46 and 49 serve to operate a motor 50 in a forward and in a reverse direction. Relay 46 is provided with switch members 51 and 52 and the relay 49 is provided with switch members 53 and 54. The motor 50 is excited by a battery 55 and is supplied with power by a battery 56. The relays 46 and 49 serve to reverse the connections of the battery 56 to the motor 50.

A potentiometer 56 which is connected to the signal transmission line is controlled by a contact arm 57 mounted on a shaft 58. The potentiometer 56 is tapered and non-linear in order to effect the correct variations in decibels. The shaft 58 is connected to the motor 50 by gearing 59 so that the arm 57 of the galvanometer is given a movement of rotation according to the operation of the galvanometer mechanism 12 which in turn is controlled by the bridge circuit 9 according to the resistance variations in the pilot line 8. The pilot

line regulator above described serves to compensate for the attenuation variations caused by daily temperature changes.

The regulator 6 which corrects for attenuation variations caused by annual temperature changes comprises a motor 60 which is preferably a small synchronous motor of the type employed in operating clocks. The motor 60 is connected by pinion 61 and a gear wheel 62 to a connecting rod 63 attached to a cross-head 64. The cross-head 64 which is slidably mounted on a suitable support carries two contact members 65 and 66. The contact member 65 engages a potentiometer 67 in the signal transmission line and the contact member 66 engages the resistance element 15 in the bridge circuit 9. The gear between the motor 60 and cross-head 64 is such that the cross-head makes one complete reciprocation or goes through one cycle each year. By such means the potentiometer 67 will be adjusted in accordance with the average annual temperature changes. The adjustment of the resistance 15 by the contact member 66 serves to adjust the bridge circuit according to the changes in the line attenuation effected by the potentiometer 67. The resistance 15 serves to effect linear resistance changes in the arm of the bridge circuit whereas the potentiometer 65 is tapered to effect the correct variations in decibels on the line.

Referring to Fig. 3 of the drawings a signal transmission line is shown having a section comprising conductors 68 located below ground indicated by the line 69 and a portion comprising conductors 70 located above ground. The conductors 68 located below ground will vary in attenuation according to the annual temperature changes but will vary little in attenuation according to the daily temperature changes. The section of the line located above ground comprising conductors 70 will be changed in attenuation not only by the annual temperature changes but also by the daily temperature changes.

A pilot wire regulator 71 is provided for varying the line attenuation according to the daily temperature changes on the open wire section of the line and a regulator 72 is provided for adjusting the transmission line attenuation according to the variations in attenuation caused on the underground section and the aerial section of the line by annual temperature changes. The pilot wire regulator 71 comprises a pilot line 73 located adjacent to the section of a transmission line located above ground. The pilot line 73 forms one arm of a bridge circuit 74. The bridge circuit 74 comprises resistance arms 75, 76, and 77, a balancing resistance 78 and a resistance 91. A battery 79 is connected across two opposite vertices of the bridge 74 and a galvanometer 80 is connected across the other two vertices of the bridge. The galvanometer 80 shown in Fig. 3 of the drawings operates a galvanometer mechanism similar to the galvanometer mechanism shown in Fig. 2 and operated by the galvanometer 17. The circuits controlled by the galvanometer mechanism in the modification shown in Fig. 3 are the same as the circuits shown in Fig. 1 of the drawings. Accordingly, a detail showing of the galvanometer mechanism is omitted from Fig. 3 and similar parts have been indicated by like reference characters.

The motor 50 shown in Fig. 3 of the drawings operates the arm 81 of a potentiometer 82 by means of a suitable gearing 83. The potentiometer 82 is tapered to effect steps in decibels and is connected to the conductors 70 of the above-

ground section in the transmission line. The pilot wire regulator 71 operates in a manner similar to the pilot drive regulator shown in Fig. 1 of the drawings.

The regulator 72 shown in Fig. 3 of the drawings comprises a potentiometer 84 controlled by a contact member 85 mounted on a cross-head 86 and a resistance 91 connected in one arm of the bridge 74 and controlled by the contact member 90. The resistance 91 is linear. The cross-head 86 is connected by a connecting rod 87 and suitable gearing 88 to a constantly rotating motor 89. The motor through the gearing 88 serves to effect annual reciprocations of the cross-head 86 to adjust the potentiometer 84 in accordance with an annual cycle. The regulator 72 taking care of the attenuation variations in the underground section of the transmission line serves to relieve the pilot wire regulator and permits the pilot wire regulator to operate with a smaller range.

Modifications in the circuits and in the arrangement and locations 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. Control circuits for a transmission line comprising a pilot line subjected to the same temperature changes as the transmission line, a bridge circuit having one arm thereof formed by said pilot line, means for constantly varying the transmission line attenuation and the resistance of a bridge arm according to normal annual temperature changes, and means controlled by said bridge circuit for governing the transmission line attenuation and for balancing the bridge circuit.

2. Control circuits for a transmission line comprising a pilot line subjected to the same temperature changes as the transmission line, a bridge circuit having one arm formed by said pilot line, means for constantly varying the transmission line attenuation and the resistance of a bridge arm according to a fixed cycle, and means controlled by said bridge circuit for governing the transmission line attenuation and for balancing the bridge circuit.

3. Control circuits for a transmission line subjected to changes in attenuation by reason of temperature changes comprising a pilot line subjected to the same resistance changes as the transmission line, a bridge circuit having one arm thereof formed by said pilot line, means for constantly and automatically changing the line attenuation and the resistance of one bridge arm in accordance with normal annual temperature changes, a galvanometer connected across two opposite vertices of said bridge circuit, and means controlled by said galvanometer for controlling the transmission line attenuation and for balancing the bridge circuit.

4. Control circuits for a transmission line subjected to changes in attenuation comprising a pilot line subjected to the same resistance changes as the transmission line, a bridge circuit having one arm thereof formed by said pilot line, means controlled by said bridge circuit for governing the line attenuation according to variations in the resistance of the pilot line and for balancing the bridge circuit, a continuously operating motor, and means operated by said motor for varying the line attenuation and the resistance of an arm of said bridge circuit according to a fixed cycle.

5. Control circuits for a signal transmission line subjected to changes in attenuation comprising a

pilot line subjected to the same resistance changes as the transmission line, control means governed by said pilot line for varying the transmission line attenuation according to variations in the pilot line resistance, and means for varying the transmission line attenuation and for changing the setting of said control means in a cycle varying according to normal annual temperature changes.

6. Control circuits for a transmission line subjected to changes in attenuation comprising a pilot line subjected to the same resistance changes as the transmission line, a bridge circuit having one arm thereof formed by said pilot line, a galvanometer connected across two opposite vertices of said bridge circuit, galvanometer mechanism controlled by said galvanometer for balancing said bridge circuit, means controlled by said galvanometer mechanism for varying the attenuation of said line according to resistance variations of the pilot line, and means for automatically varying the line attenuation and the resistance of an arm of said bridge circuit according to a fixed cycle.

7. Control circuits for a transmission line subjected to changes in attenuation comprising a pilot line subjected to the same resistance changes as the transmission line, a bridge circuit having one arm thereof formed by said pilot line, a galvanometer connected across two opposite vertices of said bridge circuit, galvanometer mechanism controlled by said galvanometer for balancing said bridge circuit, means controlled by said galvanometer mechanism for varying the attenuation of said line according to resistance variations of the pilot line, a continuously operating motor, and means operated by said motor for varying the line attenuation and the resistance of an arm of said bridge circuit according to a fixed cycle.

8. Control circuits for a transmission line subjected to changes in attenuation comprising a pilot line associated with said transmission line, a bridge circuit having one arm thereof formed by said pilot line, means for constantly and automatically changing the attenuation of said line according to a fixed cycle, and means controlled by said bridge for varying the attenuation of said line and for balancing said bridge.

9. Control circuits for a transmission line subjected to changes in attenuation comprising a pilot line associated with said transmission line, a bridge circuit having one arm formed by said pilot line, a galvanometer connected across two

opposite vertices of said bridge circuit, means controlled by said galvanometer for varying the attenuation of said line according to the resistance variations of said pilot line and for balancing said bridge circuit, and means for automatically varying the attenuation of said line according to a fixed cycle.

10. Control circuits for a transmission line subjected to changes in attenuation comprising a pilot line associated with said transmission line, a bridge circuit having one arm thereof formed by said pilot line, a galvanometer connected across two opposite vertices of said bridge circuit, galvanometer mechanism controlled by said galvanometer for balancing said bridge circuit, means comprising a motor operated in a forward and a reverse direction by said galvanometer mechanism for varying the attenuation of said line according to the resistance variations of said pilot line, and means for automatically varying the attenuation of said line according to a fixed cycle.

11. Control circuits for a transmission line having sections thereof subjected to different temperature conditions comprising a pilot line subjected to the same resistance changes as a portion of said line, a bridge circuit having one arm thereof formed by said pilot line, a galvanometer connected across two opposite vertices of said bridge circuit, means controlled by said galvanometer for governing the line attenuation and for balancing the bridge circuit, and means for varying one arm of said bridge according to a fixed cycle and for constantly and automatically varying the attenuation of the line according to a fixed cycle.

12. Control circuit for a transmission line having a section thereof underground and a section thereof above ground comprising a pilot line subjected to the same resistance changes as the portion of said line above ground, a bridge circuit having one arm thereof formed by said pilot line, means controlled by said bridge circuit for governing the line attenuation and for balancing the bridge circuit, and means for varying an arm of said bridge according to a fixed cycle and for constantly and automatically varying the attenuation of the line according to a fixed cycle to compensate for annual temperature variations of the line located below ground and above ground.

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