Nov. 8, 1938. J. T. DIXON 2,135,566

GAIN CONTROL CIRCUIT

Filed Sept. 2, 1937 2 Sheets-Sheet 1

FIG. 1

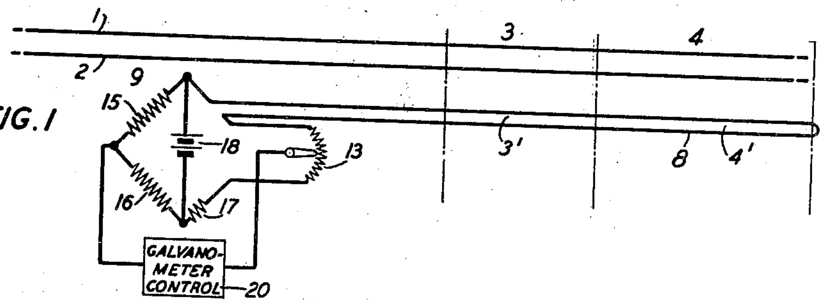


FIG. 2

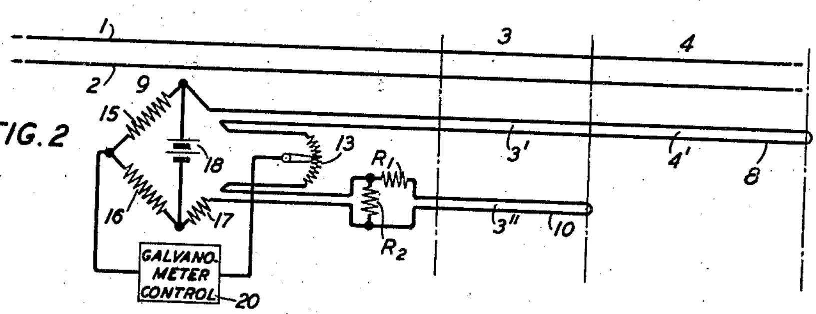


FIG. 3

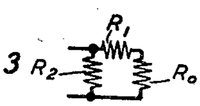
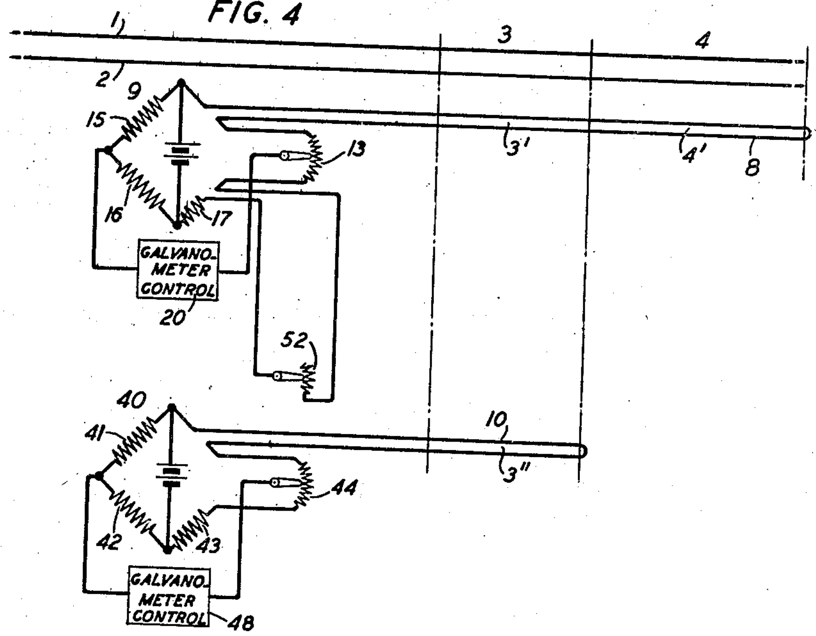


FIG. 4



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2 Sheets-Sheet 2

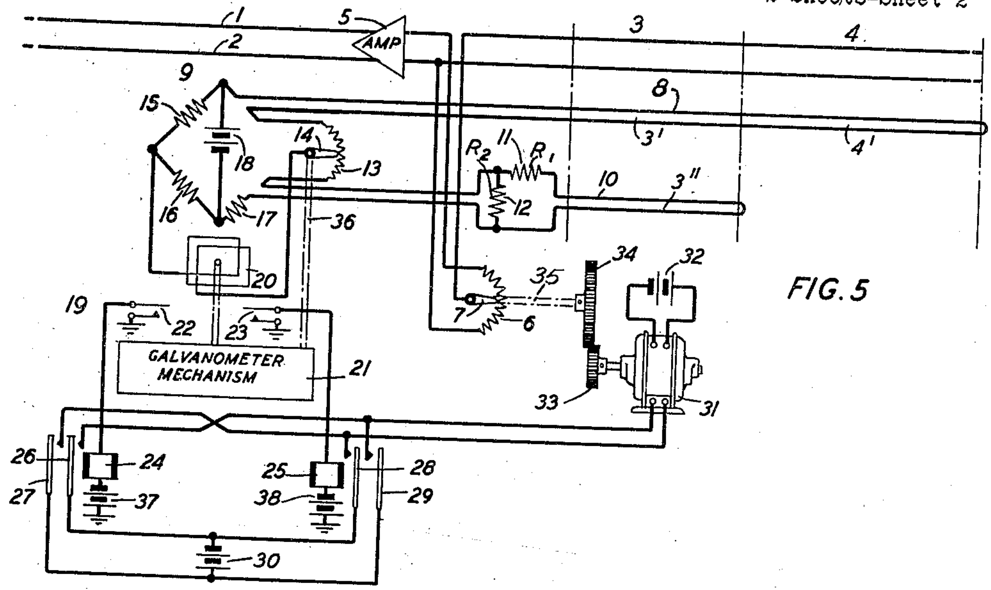

FIG. 5

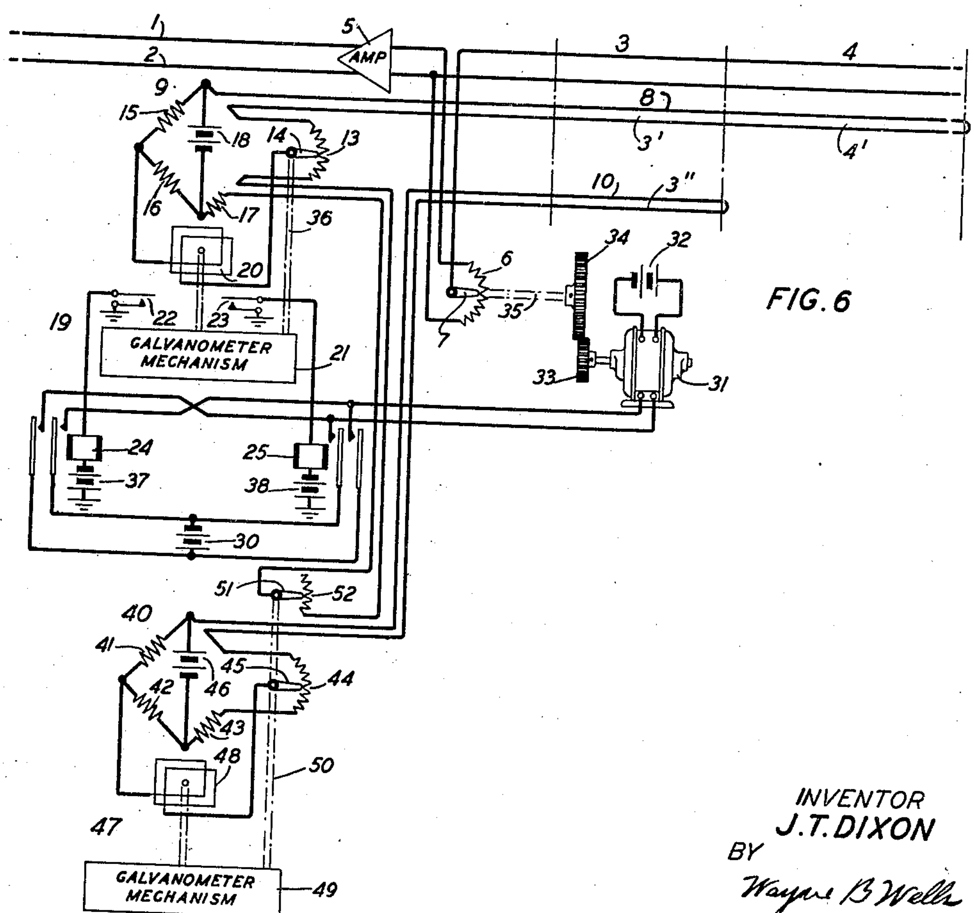

FIG. 6

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UNITED STATES PATENT OFFICE

2,135,566

GAIN CONTROL CIRCUIT

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Application September 2, 1937, Serial No. 162,137

10 Claims. (Cl. 178—44)

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

One object of the invention is to provide a pilot wire gain control circuit for a transmission line having sections varying differently with temperature changes that shall automatically compensate for the different changes in attenuation in the transmission line sections to maintain the line attenuation constant.

Another object of the invention is to provide pilot wire gain control circuits for a transmission line having sections with different attenuation-temperature coefficients that shall control the transmission line attenuation while compensating for the difference in the attenuation-temperature coefficients of the transmission line sections in an improved manner to maintain the transmission line attenuation constant.

A further object of the invention is to provide pilot wire gain control circuits for a transmission line having sections with different attenuation-temperature coefficients that shall adjust the transmission line attenuation according to the resistance changes of a pilot wire circuit associated with all the line sections and according to resistance changes of a pilot wire circuit associated with one line section, while compensating the attenuation controlling operation according to the difference between the attenuation-temperature coefficients of the line sections.

The variations in attenuation in many types of conductors for transmitting signals are generally caused by changes in temperature. Furthermore, the changes in the attenuation in the conductors vary directly with the changes in temperature. A pair of wires in a cable is an example of the signal conductors under consideration. In a long cable line a portion of the cable may be located above ground and a portion thereof may be located below ground. The different sections of the pair of wires in the cable will not have uniform characteristics because the attenuation changes in the different sections of a pair of wires with temperature changes will be different. Because of the different changes in attenuation with temperature changes in the different sections of a pair of conductors of a cable difficulty is encountered in maintaining the attenuation of the pair of conductors constant.

The term attenuation-temperature coefficient which is employed in explaining the invention may be defined as the decibel attenuation change per mile of a transmission line per degree Fahrenheit temperature change. The term attenuation-resistance coefficient of a conductor system may be defined as the decibel attenuation change per ohm change in resistance. Inasmuch as the temperature and the resistance of a conductor are definitely related, a definite relation exists between the attenuation-temperature and attenuation-resistance coefficients for a line section of given length. Because of the above relation it has been customary in the past to use the resistance changes in a direct-current pilot wire circuit for controlling a gain adjustment circuit to effect compensation in a transmission line attenuation in proportion to the resistance changes in the pilot wire circuit.

A single pilot wire control circuit operates very satisfactorily for controlling the attenuation of a transmission line if the transmission line is not made up of sections having different attenuation-temperature coefficients. If the sections of a transmission line do not have the same attenuation-temperature coefficients errors in compensating for changes in attenuation because of temperature changes will take place. The errors in compensation may in some case become serious in magnitude. In the above-mentioned example of a cable having a section underground and a section above ground that change attenuation with temperature changes at different rates, some compensation must be effected for the difference between the attenuation-temperature coefficients of the different line sections.

The invention provides means in a pilot wire gain control circuit for a transmission line having sections with different attenuation-temperature coefficients to compensate for the difference between the attenuation-temperature coefficients of the different sections and maintain the transmission line attenuation constant. In a gain control circuit constructed in accordance with one form of the invention, a pilot wire circuit which is associated with two different sections of a transmission line is included in one arm of a bridge circuit. The bridge circuit may operate galvanometer control mechanism of the type disclosed in the patent to Ira G. Wilson, No. 2,086,105, July 6, 1937, or in the patent to J. A. Coy et al. 2,017,654, dated October 15, 1935, to control the attenuation of the transmission line. The different sections of the transmission line with the different sections of the pilot wire circuit will have different attenuation-resistance coefficients.

The bridge and the galvanometer control mechanism may be set to control the transmission line attenuation according to the resistance variations of the pilot wire circuit associated with all sections of the transmission line and the attenuation-resistance coefficient of one line section. Although the transmission line attenuation changes and the pilot wire resistance changes are caused by the same temperature changes, the transmission line attenuation will not be held constant because the attenuation controlling apparatus is only set according to the attenuation-resistance coefficient of one line section. An error will occur in the adjustment of the line attenuation according to the difference between the attenuation-resistance coefficient of the sections and the resistance of the associated pilot wire section.

One way to correct the above-mentioned error in the adjustment of the transmission line attenuation is to provide a second pilot wire circuit associated with only one section of the transmission line. Resistance elements are connected in series and across the second pilot wire circuit which is included in an arm of the bridge circuit to the bridge arm including the first-mentioned pilot wire circuit. The second pilot wire circuit with the resistance elements serve to adjust the bridge and compensate for the difference between the two attenuation-resistance coefficients.

In the accompanying drawings:

Fig. 1 is a diagrammatic view of a transmission line having sections thereof changing attenuation at different rates with temperature changes;

Fig. 2 is a diagrammatic view of a control circuit for maintaining the attenuation constant on the transmission line shown in Fig. 1;

Fig. 3 is a diagrammatic view of a modification of the control circuits shown in Fig. 2;

Fig. 4 is a diagrammatic view illustrating apparatus for governing the control circuit shown in Fig. 2;

Fig. 5 is a diagrammatic view illustrating apparatus for governing the control circuit shown in Fig. 3;

Fig. 6 is a diagrammatic view illustrating apparatus for governing the control circuit shown in Fig. 4.

Referring to Fig. 1 of the drawings, a transmission line comprising conductors **1** and **2** may be a pair of wires in a cable. The transmission line is assumed to be divided into sections **3** and **4** which are subjected to different attenuation varying conditions. One of the line sections may be located below ground and the other section may be located above ground. A pilot wire circuit **8** which forms one arm of a bridge circuit **9** has two sections **3'** and **4'** respectively associated with the line sections **3** and **4**, and subjected to the same temperature varying conditions. The bridge circuit **9** serves to control the attenuation of the transmission line comprising conductors **1** and **2** as will be described later. The bridge has three arms formed by resistance elements **15**, **16** and **17** and an adjustable resistance **13**.

The resistance element **13** is adjusted to rebalance the bridge after operation thereof by reason of changing of the resistance in the pilot line **8**. A source of potential **18** is connected across two vertices of the bridge. A galvanometer **20** serves to control the rebalancing of the bridge and to control the attenuation of the transmission line.

A pilot wire gain control circuit of the type shown in Fig. 1 of the drawings will effect an error in adjusting the transmission line attenuation which may be determined. Let a_1 be the attenuation-resistance coefficient of section **4** in the cable and a_2 be the attenuation-resistance coefficient of section **3** in the cable. Let the change in resistance from a reference condition, due to temperature changes be ΔR_1 in section **4** and ΔR_2 in section **3**. According to the definitions above set forth the changes in attenuation of the two sections **3** and **4** in series will be

$$a_1\Delta R_1+a_2\Delta R_2.$$

The apparatus controlled by the bridge **9** and the galvanometer **20** may be adjusted to compensate the line attenuation at any desired rate per ohm change in the resistance of the pilot circuit **8**. Let the compensation be introduced at the rate of a_3 decibels per ohm change in the pilot wire circuit **8**. The magnitude of the gain correction which will be introduced by the gain control circuit will then be given by the expression $a_3(\Delta R_1+\Delta R_2)$. Subtracting the change in attenuation of the cable from the gain correction gives the expression

$$(a_3-a_1)\Delta R_1+(a_3-a_2)\Delta R_2$$

as the error in the compensation. It is apparent from the form of this expression that an error arises because the quantities a_1 and a_2 are different and therefore cannot be made simultaneously equal to the quantity a_3. Some simplification results without loss of generality if a_2 is assumed to be greater than a_1 and if a_3 is made equal to a_2. The error in compensation then becomes

$$(a_2-a_1)\Delta R_1. \quad (1)$$

According to the invention the operation of the gain control circuit is controlled to prevent the above error. This is done by an arrangement which automatically causes the control mechanism to correct for a resistance change of $\Delta R_1+\Delta R_2-x$ instead of $\Delta R_1+\Delta R_2$. The quantity x is determined so as to give zero error. The value of the quantity x, which is designated herein as the "resistance correction", is readily evaluated as follows:

The attenuation change of the cable is

$$a_1\Delta R_1+a_2\Delta R_2.$$

The magnitude of the gain correction is

$$a_2(\Delta R_1+\Delta R_2-x).$$

For zero error it is necessary that

$$a_1\Delta R_1+a_2\Delta R_2=a_2(\Delta R_1+\Delta R_2-x)$$

or (2)

$$x=\frac{(a_2-a_1)}{a_2}\Delta R_2$$

One method for automatically introducing a resistance correction of the desired value in the control circuits, in accordance with this invention, is shown by Fig. 2 of the drawings. In Fig. 2 of the drawings like parts to those shown in Fig. 1 have been indicated by similar reference characters. A second pilot wire circuit **10** is placed in a second arm of the bridge **9** adjacent to the arm containing the first pilot wire circuit **8**. The second pilot wire circuit **10** extends only the length of cable section **3**. Associated with the pilot wire circuit **10** are two resistances R_1 and R_2, R_1 being in series and R_2 in shunt with respect to the resistance of the pilot wire circuit. The value of the resistances R_1 and R_2 are so proportioned to the resistance R_0 of the pilot wire circuit **10** that a change in resistance of ΔR_0 in the pilot wire circuit appears as a change of only

$$\frac{a_2-a_1}{a_2}$$

ΔR_0 to the bridge **9**. The pilot wire circuit **10** and its associated resistances, being in an adjacent arm of the bridge, effectively subtract from the total resistance change $\Delta R_1+\Delta R_2$ of pilot circuit **8** and therefore introduced the desired correction as expressed by Equation (2) above.

If the resistance-temperature coefficient a_2 were taken as less than a_1, then the desired correction could be obtained by connecting the combination of resistances R_1, R_2, and pilot wire **10** in series with pilot wire circuit **8**, in the same arm of the bridge.

The proportioning of the resistances R_1 and R_2 with respect to the resistance R_0 of pilot wire circuit **10** will be made clear with reference to the equivalent circuit shown in Fig. 3 of the drawings.

The equivalent resistance of this embodiment is

$$\frac{(R_1+R_0)R_2}{R_1+R_0+R_2} \qquad (3)$$

and the equivalent resistance of the combination when R_0 is changed to $R_0+\Delta R_0$ is

$$\frac{(R_1+R_0+\Delta R_0)R_2}{R_1+R_0+\Delta R_0+R_2} \qquad (4)$$

It is readily shown by subtraction of Equation (3) from Equation (4) that the change in resistance of the combination is

$$\Delta R_0 \cdot \frac{R_2^2}{(R_1+R_0+R_2)^2} \cdot \frac{1}{1+\frac{\Delta R_0}{R_1+R_0+R_2}} \qquad (5)$$

The quantity

$$\frac{1}{1+\frac{\Delta R_0}{R_1+R_0+R_2}}$$

will not differ greatly from unity since the ratio

$$\frac{\Delta R_0}{R_0}$$

is of the order of .12 for aerial conductors.

The resistance R_1 serves to improve this approach to unity and is chosen as high as is consistent with practical considerations involving the operation of the bridge with its control mechanism. Approximately the quantity

$$\frac{1}{1+\frac{\Delta R_0}{R_1+R_0+R_2}}$$

may be taken to be unity and the resistance change of the combination of Fig. 3 becomes equal to

$$\frac{R_2^2}{(R_1+R_0+R_2)^2}=\frac{a_2-a_1}{a_2} \qquad (7)$$

The quantities a_1, a_2 and R_0 are determined by measurment on the cables, the quantity R_1 is chosen as stated in the immediately preceding paragraph, and the quantity R_2 is chosen to fulfill Equation (6).

A second method for making the desired resistance correction in accordance with Equation (2) will be explained with reference to Fig. 4 of the drawings. In Fig. 4 of the drawings like parts to those shown in Fig. 2 of the drawings will be indicated by similar reference characters. In Fig. 4 the gain control mechanism is controlled by the unbalance of the bridge **9**. An auxiliary bridge **40** has a pilot wire circuit **10** in one arm and this pilot wire circuit extends only throughout the length of cable section **3**. The auxiliary bridge has associated with it a galvanometer **48** which controls the galvanometer mechanism shown in Fig. 6 to maintain the bridge in balance by operating the resistance **44**. The resistance **52** in the bridge **9** is also controlled by the bridge **40**. In Fig. 4, the resistance **52** is shown connected in an arm adjacent to that containing pilot wire circuit **8** but it is to be understood that connection in any one of the arms is contemplated as required. The resistance of the element **52** is so chosen that a resistance change of ΔR_2 in pilot wire circuit **10** will cause a resistance of

$$\frac{a_2-a_1}{a_2}\Delta R_2$$

to be introduced in bridge **9**, thereby satisfying the condition for zero error as stated by Equation (2). The resistance elements **44** and **52** are controlled simultaneously by means controlled by the galvanometer **48**.

The preceding exposition has referred to a line section made up of only two cable sections of different type with only two pilot wires used to obtain improved compensation for changes in line attenuation. It is to be understood that the means herein described are not restricted to this particular condition but are applicable to more than two line sections. In such cases, a plurality of pilot wire circuits are required and these may be associated with resistance networks and a single bridge as has been described with reference to Fig. 1 or they may be associated with a plurality of bridges as has been described with reference to Fig. 4.

Referring to Fig. 5 of the drawings apparatus is shown for controlling the attenuation in the line comprising conductors **1** and **2** according to the operation of the bridge shown in Fig. 2 of the drawings. Like parts in Fig. 5 of the drawings to those shown in Fig. 2 of the drawings are indicated by similar reference characters.

The transmission line comprising conductors **1** and **2** may be a pair of wires in a cable. The transmission line may be divided into sections **3** and **4**, which are subjected to different attenuation varying conditions. For example, one of the sections may be located below ground and the other section may be located above ground. An amplifier **5** of any suitable type may be provided for controlling the net attenuation of the transmission line. A potentiometer **6** having a control arm **7** may be connected to the conductors **1** and **2** ahead of the amplifier **5** for controlling the gain of the amplifier. The pilot wire circuit **8** which is associated with sections **3** and **4** of the transmission line is included in one arm of the bridge circuit **9**. The second pilot wire circuit **10**, which is associated only with section **3** of the transmission line, is shown in another arm of the bridge **9** adjacent to the bridge arm including the pilot line **8**. The pilot wire circuit **10** is provided with a series resistance R_1 and a resistance R_2 connected across it for compensating for the difference in attenuation varying conditions of the different line sections, as will be set forth hereinafter.

The adjustable resistance **13** in the bridge circuit **9** is under control of an arm **14** for rebalancing the bridge. The galvanometer control mechanism comprises the galvanometer **20** which governs the operation of galvanometer mechanism **21** according to the unbalance of the bridge circuit **9**. The galvanometer mechanism **21** may be of the type disclosed in the above-mentioned patent to I. G. Wilson, No. 2,086,105 or in the patent to J. A. Coy et al., 2,017,654. The galvanometer mechanism **21** selectively operates two switches **22** and **23**, which respectively control two relays **24** and **25**. The relay **24** is provided with two switch members **26** and **27** and the relay **25** is provided with two switch members **28** and **29**.

The switch members under control of the relays 24 and 25 connect a source 30 to a motor 31 for operating it in a forward or a reverse direction. The motor 31 as shown in the drawings is excited by means of a battery 32. A pinion 33 mounted on the armature shaft of the motor 31 meshes with a gear wheel 34 on a shaft 35. The shaft 35 controls the potentiometer arm 7 for governing the operation of the potentiometer 6.

The sections 3 and 4 of the transmission line will have different attenuation-temperature coefficients. The term, attenuation-temperature coefficient, as before set forth may be considered as the decibels attenuation change per mile per degree Fahrenheit temperature change. Furthermore, the attenuation-resistance coefficients for the line sections 3 and 4 will not be the same. The term, attenuation-resistance coefficient, as before set forth may be considered as the decibels attenuation change in the transmission line per ohm resistance change in the pilot line. A change in the temperature will cause a change in attenuation of the transmission line and at the same time will cause a change in the resistance of the pilot wire circuit 8. The pilot wire circuit 8 unbalances the bridge 9 and thus controls the galvanometer control mechanism 21 to govern the potentiometer 6 and accordingly the net attenuation of the transmission line. The resistance variation of the pilot wire circuit is not proportional to the attenuation variation of the transmission line, because of the difference between the attenuation-resistance coefficients of the two line sections. The bridge 9 and the galvanometer control mechanism 19 when controlled solely by the pilot wire circuit 8 can only be operated in accordance with the attenuation-resistance coefficient of one line section. If the bridge 9 and the galvanometer control mechanism 19 are operated solely according to the resistance of the pilot wire circuit 8 and the attenuation-resistance coefficient of the line section 4, then an error in the net attenuation of the transmission line will be effected.

The second pilot line 10 will effect a correction equal to

$$\frac{a_2-a_1}{a_2}\Delta R_1$$

where a_1 and a_2 are, respectively, the attenuation-resistance coefficients of the line sections 3 and 4, and ΔR_1 is the resistance variation of the pilot wire circuit 10 associated with the line section 3.

The bridge circuit 9, when unbalanced by a variation of resistance of the pilot wire circuit, operates the galvanometer 20. The galvanometer 20 in turn operates the galvanometer mechanism 21 to close either the switch 22 or the switch 23, according to whether there is an increase or a decrease in the resistance of the pilot wire. The galvanometer mechanism 21 also operates a shaft 36 for controlling the arm 14 associated with the resistance 13 to rebalance the bridge circuit. The switch 22, if operated, completes a circuit from battery 37 for operating the relay 24. The switch 23, if operated, completes a circuit from battery 38 for operating the relay 25. The relays 24 and 25 operate the motor 31 in a forward or in a reverse direction to control the potentiometer 6 and accordingly the attenuation on the transmission line.

Referring to Fig. 6 of the drawings, apparatus is shown to compensate for the difference between the attenuation-resistance coefficients of the different line sections in a different manner. Like parts in the circuit shown in Fig. 6 to those shown in Fig. 4 will be indicated by similar reference characters. The second pilot wire circuit 10 shown in Fig. 6 of the drawings is not provided with the adjusting resistance elements R_1 and R_2 and is not connected directly to the bridge 9 as in the circuit shown in Fig. 5 of the drawings. The pilot wire circuit 10 is included in an arm of the auxiliary bridge circuit 40. The bridge 40 comprises resistance arms 41, 42, 43 and a resistance 44 under control of a switch arm 45. A battery 46 is connected across two opposite vertices of the bridge 40. Galvanometer control mechanism 47 which is similar to the galvanometer control mechanism 19 referred to in Fig. 5 of the drawings is controlled by the bridge 40. The galvanometer control mechanism 47 comprises a galvanometer 48 which operates galvanometer mechanism 49. The galvanometer mechanism 49 operates a shaft 50, which not only controls the switch arm 45 for adjusting the resistance 44 to rebalance the bridge 40 after each operation thereof, but also operates an arm 51 which controls a resistance 52. The resistance 52 is included in an arm of bridge 9. The resistance 52 is shown connected in an arm adjacent to the arm including pilot wire 8 but resistance 52 may also be connected in the same arm as pilot wire circuit 8. The resistance 52 controlled by the galvanometer control mechanism 47 serves to compensate the operation of the bridge 9 according to the resistance of the pilot wire circuit 8 associated with the line section 3 and according to the difference between the attenuation-resistance coefficients of the two line sections 3 and 4. The proper compensation depends on the proper selection of the resistance value of resistance 52 as before set forth. The bridge 9 and the galvanometer control mechanism 19 operate in the same manner as that described with respect to the circuit shown in Fig. 1 for controlling the potentiometer 6 to maintain the line attenuation constant.

Modifications in the circuits and in the arrangement 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. A transmission line divided into sections having different attenuation-resistance coefficients, a pilot wire circuit associated with all of said line sections, control means adjusted according to the attenuation-resistance coefficient of one line section and according to the resistance variations of the pilot wire circuit to compensate for attenuation changes of the transmission line, a second pilot wire circuit associated with only one line section and means for adjusting said control means according to the resistance variations of the second pilot wire with reduced control effect so as to correct for an error effected in compensating for the change in the transmission line attenuation in accordance with the attenuation-resistance coefficient of only one line section.

2. A transmission line divided into sections having different attenuation-resistance coefficients, a pilot wire circuit associated with all of said line sections, control means adjusted according to the attenuation-resistance coefficient of one line section and according to the resistance variations of the pilot wire circuit to compensate for attenuation changes of the transmission line, means comprising a second pilot wire circuit as-

sociated with only one line section for adjusting said control means and resistance elements in said second pilot wire for reducing the control effected by the second pilot wire so as to correct for an error effected in compensating for the change in transmission line attenuation by the first-mentioned pilot wire in accordance with the attenuation-resistance coefficient of only one line section.

3. A transmission line divided into sections having different attenuation-resistance coefficients, a pilot wire circuit associated with all of said line sections, a bridge operated according to the attenuation-resistance coefficient of one line section and according to the resistance variations of the pilot wire circuit to compensate for attenuation changes of the transmission line, a second pilot wire circuit associated with one line section and connected to an arm of said bridge and means for reducing the control of the bridge by the second pilot wire circuit to compensate for the error effected in adjusting the transmission line attenuation according to the attenuation-resistance coefficient of only one line section.

4. A transmission line divided into two sections having different attenuation-resistance coefficients, a pilot wire circuit associated with both of said line sections, a bridge having said pilot wire circuit included in one arm thereof, a second pilot wire circuit associated with one line section and included in an arm in said bridge adjacent to the arm including said first mentioned pilot wire circuit, means for reducing the effect of said second pilot wire circuit to adjust said bridge according to the difference between the attenuation-resistance coefficients of the two line sections, and means controlled by said bridge for maintaining the attenuation of the transmission line constant.

5. A transmission line divided into sections having different attenuation-temperature coefficients, a pilot wire circuit associated with all of said line sections, a bridge circuit having said pilot wire circuit included in one arm thereof, means operated by said bridge according to the attenuation-resistance coefficient of one line section or governing the transmission line attenuation according to the resistance variations of the pilot wire circuit, and means for controlling an arm of said bridge adjacent to the arm including said pilot wire according to the resistance variations in one line section and the difference between the attenuation temperature coefficients to correct for the error effected in adjusting the transmission line attenuation in accordance with the attenuation-resistance coefficient of only one line section.

6. A transmission line divided into two sections having different attenuation-resistance coefficients, a pilot wire circuit associated with both of said line sections, a bridge having said pilot wire circuit included in one arm thereof, means operated by said bridge for adjusting the transmission line attenuation according to the resistance variations of the pilot wire circuit and the attenuation-resistance coefficient of one line section, a second pilot wire circuit associated with only one line section and included in an arm of said bridge, and impedance elements inserted in said second pilot wire circuit for reducing the control by the second pilot wire circuit to adjust said bridge according to the difference between the attenuation-resistance coefficients of the two line sections.

7. A transmission line divided into two sections having different attenuation-resistance coefficients, a pilot wire circuit associated with both of said line sections, a bridge having said pilot wire circuit included in one arm thereof, a second pilot wire circuit included in an arm of said bridge adjacent to the arm including said first mentioned pilot line and associated with only one line section, said second pilot wire circuit having resistance elements connected in series and in shunt for adjusting said bridge according to the difference between the attenuation-resistance coefficients of the two line sections, and means controlled by said bridge for maintaining the attenuation of the transmission line constant.

8. A transmission line divided into sections having different attenuation-resistance coefficients, a pilot wire circuit associated with all of said line sections, a bridge circuit having said pilot wire circuit included in one arm thereof, means controlled by said bridge for governing the transmission line attenuation according to the resistance variations of the pilot wire circuit and according to the attenuation-resistance coefficient of one section of said transmission line, a second pilot line associated with one section of said transmission line and included in an arm of said bridge, and impedance means included in said second pilot wire circuit for correcting the bridge balance to compensate for the error effected in adjusting the transmission line attenuation according to the attenuation-resistance coefficient of only one line section.

9. A transmission line divided into two sections having different attenuation-resistance coefficients, a pilot wire circuit associated with both of said line sections, a bridge having said pilot wire circuit included in one arm thereof, means operated by said bridge for adjusting the transmission line attenuation according to the resistance variations of the pilot wire circuit and according to the attenuation-resistance coefficient of one line section, a second bridge circuit, a second pilot wire circuit associated with only one line section and included in an arm of said second bridge circuit, and means operated by said second bridge for adjusting said first mentioned bridge according to the difference between the attenuation-resistance coefficients of the two line sections to maintain the attenuation of the transmission line constant.

10. A transmission line divided into two sections having different attenuation-resistance coefficients, a pilot line circuit associated with both of said line sections, a bridge having said pilot wire circuit included in one arm thereof, means operated by said bridge for adjusting the transmission line attenuation according to the resistance variations of the pilot line and according to the attenuation-resistance coefficient of one line section, a second bridge circuit, a second pilot wire associated with only one line section and included in an arm of said second bridge, and means operated by said second bridge for adjusting an arm of said first mentioned bridge to compensate for the error effected in adjusting the transmission line attenuation according to the attenuation-resistance coefficient of only one line section.

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