

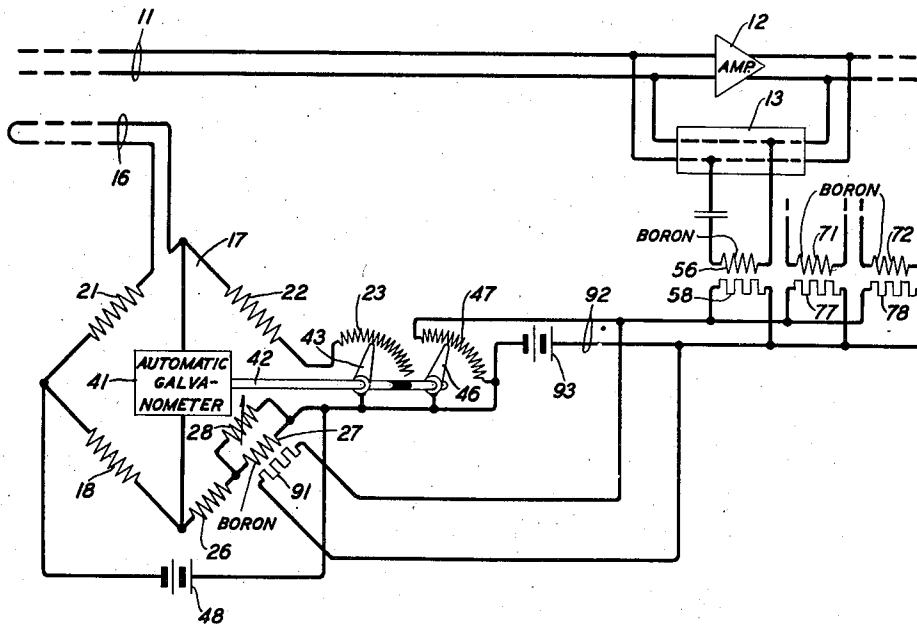
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TRANSMISSION REGULATION

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TRANSMISSION REGULATION

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This invention relates to control circuits for adjusting the gain on signal transmission lines and particularly to a circuit for automatically adjusting the gain at repeater stations associated with transmission lines.

It is well known that in certain types of transmission lines, such as long telephone lines, changes in attenuation of the line occur from time to time due to temperature changes. These temperature changes may be due to climatic conditions, or in certain cases, to the heating effect of the signaling currents. In order to compensate for the effect of such attenuation changes it is usual to provide means for adjusting the gain of the various repeaters provided on the line automatically.

An object of the invention is to adjust the gain of a repeater associated with a transmission line automatically in such a manner as to compensate for changes in attenuation of the line due to temperature changes.

A more specific object of the invention is to adjust the gain of a repeater automatically in such a manner as to compensate for changes in the ambient temperature at the repeater station.

In accordance with one embodiment of the invention, repeater gain is controlled by use of thermo-sensitive elements, i. e., elements the resistance of which changes as their temperature changes. The temperature of these elements is controlled in accordance with change of line attenuation.

In accordance with a feature of the invention the temperature of the thermo-sensitive elements is automatically varied to compensate for the effects thereon of changes in the ambient temperature.

The use of thermo-sensitive elements in gain control circuits has been proposed heretofore, such arrangements being described for example in Patent 2,098,968 issued November 16, 1937 to C. O. Mallinckrodt, "Transmission regulation", and Patent 2,116,600 issued May 10, 1938 to J. R. Fisher and C. O. Mallinckrodt, "Electrical transmission control". In accordance with the prior arrangements it has been the usual practice to enclose the thermo-sensitive elements in a heating chamber whereby radiation from the elements could be controlled within certain limits. In accordance with the arrangement invented by applicant, however, no heat chambers are utilized, the elements being exposed directly to the atmosphere. This practice results in important advantages from an economic standpoint and

renders the elements more accessible and more easily mounted. Means are provided for automatically maintaining the temperature of the elements at a constant value regardless of the rate of radiation; the rate of radiation will vary of course in accordance with variations in the ambient temperature at the repeater station.

A full understanding of the arrangement contemplated by the invention as well as appreciation of the various valuable features thereof may be gained from consideration of the following detailed description in connection with the annexed drawing in which the single figure is a schematic diagram of a circuit embodying the gain regulating arrangement contemplated by the invention.

Referring now to the drawing, line 11 which is shown is assumed to be one of a number of similar lines grouped together and preferably enclosed by a lead sheath, forming a cable of standard construction. Each line is provided at intervals with a repeater, repeater 12 being shown associated with line 11. In the case of lines transmitting voice currents the repeaters may be spaced at intervals of about fifty miles while in the case of lines transmitting high frequency carrier waves the repeaters may be grouped much closer together, for example, at intervals of about ten miles. Repeater 12 is preferably of the stabilized feedback type having a feedback path 13 extending from its output back to its input for feeding back waves in a manner effective to reduce the gain of the repeater thereby increasing its stability and improving its linearity. For a full disclosure of the arrangement and operation of amplifiers of the feedback type reference may be made to Patent 2,102,671 issued December 21, 1937 to H. S. Black, "Wave translation system."

While applicant's invention is being disclosed in connection with an amplifier of the feedback type, it will be understood that other types of amplifiers may be used, suitable provisions being included for changing the gain thereof under control of the regulating apparatus to be described subsequently.

Line 16 is enclosed within the same sheath as line 11 and the other lines comprising the cable. Line 16 extends the length of one repeater section, is looped at the far end, and forms what is commonly known as the pilot wire. Line 16, which is provided for purposes of regulation is subject, of course, to the same variations in temperature as the other lines, such as line 11, of the cable.

The regulating mechanism, which includes bridge 17, is controlled largely by line 16. Bridge 17 comprises four resistance arms, one arm comprising fixed resistance 18, a second arm comprising fixed resistance 21 in series with the resistance of line 16, which varies in accordance with temperature changes, a third arm comprising fixed resistance 22 in series with resistance 23 which is varied by operation of the bridge galvanometer, and the fourth arm comprising fixed resistance 26 in series with variable resistance 27, variable resistance 28 being connected in parallel to resistance 27. Variable resistance 27 is a thermo-sensitive element having a negative temperature coefficient of resistance, for example a boron element.

Automatic galvanometer 41 which is associated with bridge 17, may be, for example, of the type disclosed in Ulrich Patent 1,647,383 issued November 1, 1927. The galvanometer assembly includes a source of mechanical power for rotating shaft 42 through an angle proportional to the angle of deflection of the galvanometer resulting from an unbalanced condition of the bridge. Contact arms 43 and 46 are carried by shaft 42 and determine respectively by their positions the portions of resistances 23 and 47 which are effectively connected in the circuit.

Battery 48 provides the necessary current for bridge 17.

Thermo-sensitive resistance 56, which should be of the same material as element 27, is provided with heater 58, the two being mounted in close association or, if preferable, being actually combined in a unitary structure. Similarly, thermo-sensitive resistances 71 and 72, likewise of the same material as element 27, are provided with respective heaters 77 and 78. Resistance 56 is connected to control the gain of repeater 12 while resistances 71 and 72 may be similarly connected to control other repeaters not shown.

Heaters 58, 77 and 78 which are associated respectively with thermo-sensitive elements 56, 71 and 72 as well as heater 91 which is associated with thermo-sensitive resistance 27 of bridge 17 are energized over a common heater line 92. Battery 93 supplies current to line 92 under control of variable resistance 47. In practice the heater current is so regulated that the temperature of the thermo-sensitive elements is maintained at a point substantially higher than the ambient temperature of the repeater station.

In order to further described the invention, let us assume that the temperature of the cable increases thereby increasing the transmission loss in line 11 and the other lines included in the cable. There will be, of course, a corresponding increase in the temperature of pilot line 16, the resulting increase of resistance thereof unbalancing bridge 17. Movement of automatic galvanometer 41, resulting from the unbalanced condition of the bridge rotates shaft 42 and contact arms 43 and 46 carried thereby, through an angle proportional to the unbalance of the bridge. Readjustment of resistance 23 by movement of contact arm 43 is effective to rebalance the bridge while readjustment of resistance 47 by movement of contact arm 46 is effective to cause an increase of the current flow in heater line 92 thereby resulting in an increase of the temperature of heaters 58, 77, 78 and 91.

In view of the negative temperature coefficient of resistance of element 56 (preferably boron) the resistance thereof will be decreased by the rise in temperature of heater 58, thereby causing the

element to shunt a greater portion of the current in the feedback circuit of amplifier 12. This reduces the amount of feedback and since the feedback is a gain reducing feedback this results in raising the amplification of repeater 12 thereby compensating for the increase in the transmission loss in line 11.

Elements 71 and 72 act in a similar manner to increase the gain of the amplifiers with which they are associated.

While the decrease in resistance of element 27, resulting from the rise in temperature of heater 91, unbalances bridge 17 slightly, resulting movement of galvanometer 41 brings the bridge back into a stable condition.

Let us assume now that there is no further change in the temperature of the cable for the present but that there is a change in the ambient temperature of the repeater station, for example, a considerable decrease of temperature. This will result, of course, in a more or less rapid radiation of heat from element 56 to the cool air surrounding it thereby tending to increase its resistance. Such an increase if persistent would, of course, be undesirable as it would cause a decrease in the gain of amplifier 12. However, in accordance with applicant's invention this undesirable change is prevented due to the fact that provisions are made for bringing about an unbalanced condition of bridge 17 and readjustment of the heater current to compensate for the ambient temperature variation.

It will be evident that the temperature of element 27 will decrease at a rate corresponding to that at which the temperature of element 56 decreases, thereby resulting in an increase of the resistance of element 27 corresponding to the increase of resistance of element 56. The change in resistance of element 27, however, unbalances bridge 17, thereby causing movement of automatic galvanometer 41. The resulting readjustment of resistance 23 brings the bridge back into balanced condition while the readjustment of resistance 47 causes an increase of current flow in heater line 92 sufficient to increase the temperature of elements 56 and 27 a sufficient amount to compensate for the change in ambient temperature. The temperature of element 56 is maintained at a constant value, therefore, notwithstanding the decrease in the ambient temperature of the repeater station.

The resistance of elements 71 and 72 is, of course, maintained at a constant value also in view of the fact that the associated heaters are energized over the same path as heater 58.

It will be understood that the arrangement functions in a similar manner to compensate for increases in the ambient temperature, the bridge being unbalanced in such a case to bring about a decrease of the heater current. The fact that an element is included in an arm of the bridge which is of similar material to the compensating elements included in the feedback path of the amplifier and which is heated from the same circuit and subject to the same ambient temperature, results in an arrangement which maintains the temperature of the gain-compensating elements constant regardless of changes in ambient temperature.

While the use of boron elements as the temperature-responsive resistances has been described, it will be understood that other substances having like characteristics may be used instead of the boron. By way of example, silver sulphide elements may be substituted for the boron ele-

ments. In such event, however, it may be found desirable to utilize an alternating current source in the bridge instead of the direct current source described (battery 48) in order to prevent deterioration of the silver sulphide due to the effects of direct current.

While a certain specific embodiment of the invention has been selected for detailed description the invention is not, of course, limited in its application to the embodiment described. For example, the regulating arrangement described may be utilized in connection with networks rather than repeaters and may be controlled by means other than a pilot wire regulated bridge. In short, the embodiments described should be taken as illustrative and not as restrictive.

What is claimed is:

1. In a regulating system for transmission lines including repeaters, a Wheatstone bridge, means for controlling the balance of said bridge in accordance with line attenuation, a thermo-sensitive element included in a resistance arm of said bridge, a heater for said thermo-sensitive element, a second thermo-sensitive element adapted to control the gain of a repeater, a heater for said second thermo-sensitive element, said elements being directly exposed to the free atmosphere, a single source of heating current for both of said heaters, and means controlled by an unbalanced condition of said bridge for controlling the supply of current from said source to said heaters.

2. In a regulating system for transmission lines including repeaters, a Wheatstone bridge, a circuit for controlling the balance of said bridge in accordance with line attenuation, a thermo-sensitive element included in a resistance arm of said bridge, a heater for said element, a second thermo-sensitive element adapted to control the gain of a repeater, a heater for said second element, both of said elements being directly exposed to the free atmosphere, a source of heating current, a heating circuit common to said source and to said heaters, and means controlled by an unbalanced condition of said bridge for controlling the current in said heating circuit.

3. In a regulating system for transmission lines including repeaters, a Wheatstone bridge, a circuit for controlling the balance of said bridge in accordance with line attenuation, a thermo-sensitive element included in one of the resistance arms of said bridge, a heater for said element, a second thermo-sensitive element adapted to control the gain of a repeater, a heater for said second element, said thermo-sensitive elements being so located with respect to each other that they are incapable of being heated by radiation from a common heater element, a single source of heating current for said heaters, and means controlled by an unbalanced condition of said bridge for controlling the supply of heating current from said source to said heaters.

4. In a regulating system for transmission lines including repeaters, a repeater station, a Wheatstone bridge, means included in one resistance arm of said bridge for controlling the balance of said bridge in accordance with line temperature, means included in another resistance arm of said bridge for controlling the balance thereof in accordance with the ambient temperature of the repeater station, a heater for said last-mentioned means, a thermo-sensitive element at the repeater station adapted to control the gain of a repeater, said thermo-sensitive element being directly exposed to the atmosphere, a heater for said thermo-sensitive element, a source of heating current, and means controlled by an unbalanced condition of said bridge for controlling the supply of current from said source to said heaters.

5. In a regulating system for transmission lines, a repeater station, repeaters at said station, a Wheatstone bridge, a circuit for controlling the balance of said bridge in accordance with line attenuation, a thermo-sensitive resistor in one resistance arm of said bridge, a heater for said resistor, a second thermo-sensitive resistor adapted to control the gain of a repeater, a heater for said second resistor, said resistors being located at separate points in said station, a source of heating current, means for supplying current from said source to said heaters, and means controlled by changes in ambient temperature at said repeater station for controlling the magnitude of the heating current supplied to said heaters from said source.

6. In a regulating system for transmission lines including repeaters, said system comprising a pilot conductor and a Wheatstone bridge controlled thereby, a thermo-sensitive element adapted to control the gain of a repeater, a second thermo-sensitive element, said second thermo-sensitive element being connected to said bridge and effective to unbalance said bridge upon a change in ambient temperature, both of said thermo-sensitive elements being directly exposed to the free atmosphere, a heater for each of said elements, a source of heating current, and means controlled by an unbalanced condition of said bridge for controlling the supply of current from said source to said heaters.

7. In a transmission regulating system, a thermo-sensitive transmission regulating element, means including a local source of heating current for controlling the temperature of said element, means for compensating for the effect on said element of variations in atmospheric temperature, said last-mentioned means comprising a second thermo-sensitive element effective to modify the operation of said first-mentioned means, both of said thermo-sensitive elements being exposed directly to the free atmosphere.

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