

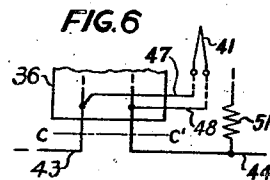
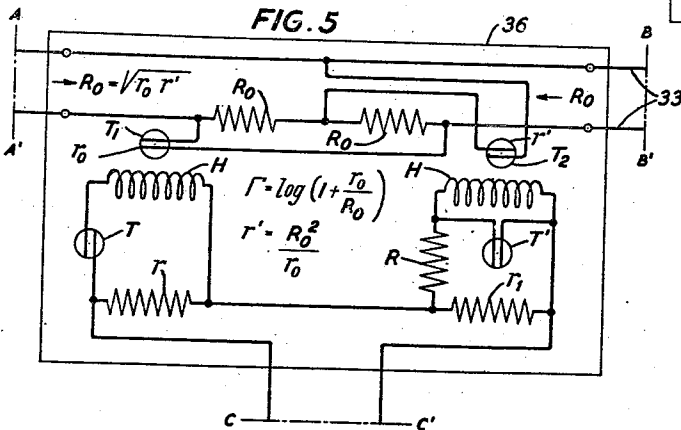
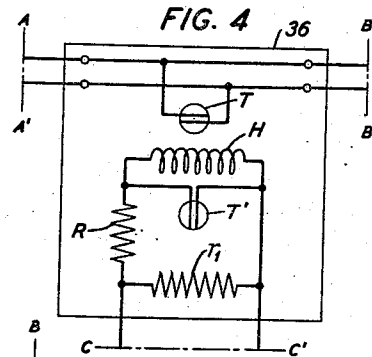
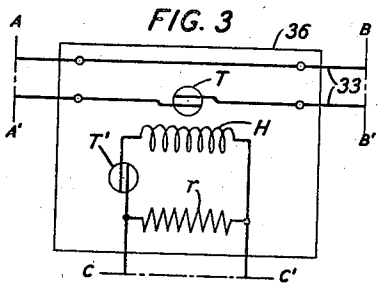
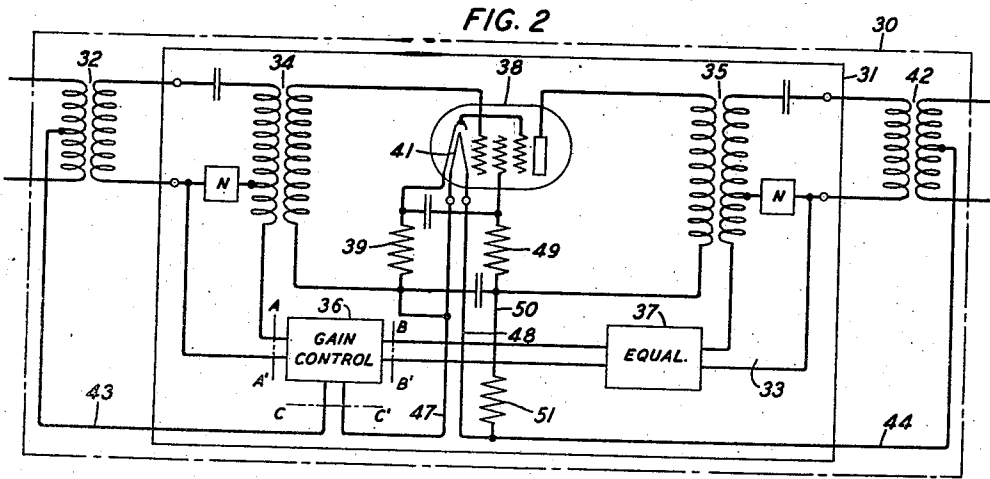
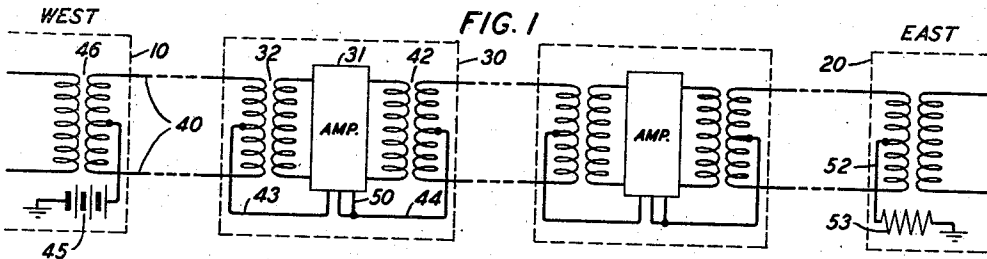
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ELECTRIC WAVE CIRCUIT

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ELECTRIC WAVE CIRCUIT

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3 Claims. (Cl. 178-44)

This invention relates to electric wave transmission systems and, more particularly, to circuit arrangements for regulating the gain of amplifying or repeating devices in a transmission line so as to compensate for the effect of temperature variation on the attenuation characteristic of the system.

An object of the invention is to simplify the circuit and means required in a transmission line to regulate or control the transmission level by compensating for variation in the attenuation of the line caused by variation in temperature thereof.

The invention may be applied to a transmission line connecting geographically separated terminal points or regions and adapted to be buried in the ground, one or more unattended amplifier or repeater stations being located in the line intermediate the terminals thereof. Each amplifier may be of the type embodying a gain-reducing negative feedback connection to increase the stability of, and decrease distortion and noise in the output of the amplifier. One or more temperature-dependent resistance elements or thermistors, having, for example, a negative temperature coefficient of resistance, are provided in the feedback connection or β -path of the amplifier. One resistance element may be connected in the series path and another resistance element may be connected in the shunt path of the feedback connection, and each is caused to vary in resistance in response to changes in the attenuation of the transmission line.

Space current and electrode potentials for the electronic devices or vacuum tubes of the amplifier are supplied over the transmission line from one end thereof, and the heater elements for the thermistors are arranged in the power supply path so as to alter in heating effect with variation in a parameter of the power supply, specifically, the power supply current, which variation results from change in the line resistance with change in temperature. Change in the resistance of the thermistor in the feedback connection varies the loss in the β -path of the amplifier, and, consequently, causes alteration of the amplifier gain in accordance with well-known principles. When a thermistor is included in each of the series and shunt paths of the feedback connection, they are proportioned to constitute a constant resistance network, whereby their presence introduces a minimum impedance change in the feedback or β -path of the amplifier.

A more complete understanding of the invention will be obtained from the detailed descrip-

tion that follows, taken in conjunction with the appended drawing, wherein:

Fig. 1 illustrates a transmission system in which the invention may be incorporated;

Fig. 2 shows in detail the circuit arrangement for an unattended amplifier or repeater station inserted in the line of the system of Fig. 1, the thermistor gain control circuit being located between the lines A-A', B-B' and C-C';

Figs. 3 and 4 show a thermistor connected in the series and the shunt path, respectively, of the feedback connection of the amplifier of Fig. 2, and associated heater elements for the thermistors;

Fig. 5 shows a two-thermistor gain control network for inclusion in the β -path of the amplifier of Fig. 2, proportioned to provide a constant resistance network as the series and shunt thermistors are varied in resistance; and

Fig. 6 illustrates how the heater filament of the amplifier may be included in the thermistor heating circuit.

With reference to the drawing, Fig. 1 shows a transmission system for transmitting communication currents or signals, for example from west to east, between a pair of geographically separated terminal points or stations 10, 20 which may be attended amplifier or repeater stations. Such currents or signals might be of low or high frequency, and specifically might comprise a wave of high or carrier frequency modulated by a low frequency electric wave or signal. The transmission path could be adapted to transmit a single carrier wave, or a plurality of carrier waves distributed over a band of frequencies, for example, twelve channel carrier operation utilizing a 12 to 60 kilocycles per second frequency band. One or more unattended amplifier or repeater stations 30, two of which are shown, are inserted in the transmission path or line 40 at spaced intervals for amplification of the currents or signals being transmitted. The path 40 may be an open-wire telephone pair, or may be included in a cable buried in the earth.

Each unattended station 30 may have the configuration shown in Fig. 2. It comprises an amplifier or repeater 31 whose input and output terminals are connected to the line 40 through repeating coils or transformers 32, 42. The amplifier shown is a single stage feedback amplifier incorporating stabilized negative feedback as disclosed in H. S. Black Patent 2,102,671 of December 21, 1937, the amplifying or mu-path of the amplifier being connected to the feedback or β -path or connection 33 through hybrid coils 34,

35, including the networks N, as taught in the aforementioned Black patent and in H. S. Black Patent 2,209,955 of August 6, 1940. The feedback path includes gain control means 36, described in detail with reference to Figs. 3, 4 and 5, and an equalizer network 37. The vacuum tube or device 38 may be a pentode having a cathode of the indirectly heated type. A cathode resistor 39 provides bias for the input control grid. The heating current for the heater 41 of the tube is obtained over the transmission line from the attended station 10 through the connections 43, 44 coupling the mid-points of the line windings of repeating coils 32, 42.

Figs. 1 and 2 show how anode and screen potential and cathode heater or filament heating current may be supplied to the unattended repeater station from an attended station. The power supply may comprise the battery 45 located at station 10, having its positive terminal connected to the mid-point of the line winding of repeater coil or transformer 46 and its negative terminal connected to ground. As already noted, the mid-points of the line windings of the coil 32, 42 are interconnected by connections 43, 44, connection to the cathode heater 41 being made through conductors 47, 48 and to the screen grid and anode through resistors 49, 51 and conductor 50. The power loop is completed through connection 52 and suitable resistance 53. Power supply for the amplifier or repeater (not shown) at attended station 10, which could be the same as that at the station 30, may be obtained from battery 45 or from a separate source of power. Although not shown, it is obvious that station 20 could be the source of power supply for unattended stations farther to the east along the transmission path or line.

The attenuation of the transmission line will vary with the temperature of the line, being greater for high temperatures than for low. The effect on attenuation of signals of the variation in the resistance of the line can be compensated for by appropriate increase or decrease in the gain of the repeater or amplifier at the repeater station.

Thermistors, that is, devices, substances or elements that vary in impedance, or, specifically, resistance, with variation in their temperature and with either a positive or a negative temperature coefficient of resistance, have been proposed heretofore for use in electrically operated gain control circuits in transmission systems. Such devices or elements are capable, at least in specific instances for example, silver sulphide; boron; uranium oxide; a mixture of nickel, manganese and cobalt oxides; or a mixture of nickel, manganese and copper oxides, of a large change in resistance with temperature, which makes them attractive for use in circuits in which it is desired to compensate for attenuation variation caused by change of temperature.

Fig. 3 shows a circuit configuration for the gain control circuit 36 in which a single temperature-dependent resistance or thermistor T is connected in the series path of the feedback connection 33. The heater winding H for the thermistor T is connected in series with a second thermistor T', this series connection being in parallel with the resistor r. This resistor is connected in series with the connections 43, 44, and is traversed, therefore, by the amplifier energizing current furnished from the power supply at station 10.

Fig. 4 shows another circuit configuration for the gain control circuit 36 in which a single

thermistor T is connected in shunt with the feedback connection 33, the heater winding H and the associated thermistor T' being connected in parallel. This parallel arrangement is in series with a resistance R of a material having a zero or small and linear temperature coefficient of resistance, the series arrangement being in shunt with the resistance r_1 connected in the power supply loop path around the repeater.

Fig. 5 shows still another configuration for the gain control circuit 36. In this, thermistors T₁ and T₂ are connected in the series and shunt paths, respectively, of the feedback connection 33 to constitute with the resistances R₀ a constant resistance network of the bridged-T type. A heater circuit of the type shown in Fig. 3 is associated with the thermistor T₁, and a heater circuit of the type shown in Fig. 4 is associated with the thermistor T₂.

A more complete understanding of the circuit arrangement described hereinabove will be obtained from the discussion which follows. The use of temperature-dependent resistances or thermistors in transmission circuits to compensate for temperature effects is already known and involves a number of advantages. Among these are that temperature dependent resistances may be made sensitive to very small variations in a control current, particularly when they are used in circuits designed to take advantage of a negative resistance characteristic with respect to slowly varying currents. Because of the time required for heating and cooling the thermistor, the latter is relatively sluggish with respect to high frequency or rapid alternating current variations and, accordingly, non-linear distortion is not introduced in alternating current circuits, the resistance of the thermistor in such circuit being substantially constant and approximately equal to its direct current resistance. In addition to these advantages, the use of a heater winding or coil to control the thermistor temperature provides a convenient means for separating the control circuit for the thermistor from the high frequency circuit to be controlled.

The application of a thermistor to a transmission circuit for control or regulating purposes involves at least two problems, (1) that of supplying a suitable control current to the thermistor or to a heater winding or coil for the thermistor, and (2) that of introducing the thermistor into the high frequency circuit in such a way as to provide the control desired. In the transmission system of Fig. 1, the temperature-dependent resistance element is located in the feedback circuit of the amplifier at the unattended station, and the temperature of the thermistor is under the control of the current sent over the transmission line from the attended station 10 to supply power to the heater filament of the amplifying devices.

The use of the line power supply as a control channel for the thermistor has a number of advantages. When the power is supplied over the transmission line, the line itself can be used as a pilot wire or pilot channel, thus obviating the necessity of using an extra pair of wires for temperature control purposes. Since the power sent over the line to supply the amplifiers is appreciable, the sensitive thermistor regulation can be introduced without absorbing any substantial part of the total power available. In addition, the use of the transmission line itself as a part of the transmission regulation circuit enables the gain control thermistor circuit

effectively to measure the resistance of a complete line section between amplifiers. This gives a more accurate transmission control than, for example, an arrangement which would provide for a measurement of the temperature of the earth only at one particular point. This arrangement also permits of remote manual control of the amplifier gain at the unattended repeater station. This is readily accomplished by variation in the power supply current at the attended station 10.

If it is assumed that the source 45 provides a constant voltage through the power supply loop, variations in the resistance of the line caused by temperature changes in the line will cause variations in the current supplied from the power supply, which variations may be utilized to vary the temperature and, therefore, the resistance of the thermistor gain control circuit at the unattended station. The power supply current changes will be relatively small and, consequently, not large enough to affect adversely the operation of the amplifying device at the unattended station, but will be sufficient to produce the desired changes in thermistor resistance.

The arrangements of Figs. 3 and 4 constitute simple embodiments of the invention. In their principle of operation, however, they are of essentially different kinds. With the arrangement of Fig. 3 an increase in the power supply current (corresponding to a decrease in the temperature of the transmission line) results in a decrease in the resistance of the thermistor T as the potential drop across the resistance r increases, whereas, with Fig. 4, increase in the power supply current causes an increase in the resistance of the thermistor T. This manner of operation results from the fact that when the steady voltage across the resistor r or the resistor r_1 is adjusted to a certain critical bias value, a further increase in voltage thereacross causes a relatively rapid increase in the current flow through the directly heated thermistor T'. In the arrangement of Fig. 3, this results in an increase in the current through the heater winding H, while in the arrangement of Fig. 4, there is a decrease in the current in the heater winding H. Since, in the practical design of feedback amplifiers, the over-all change in gain of the amplifier is substantially equal to the loss or change in loss in the feedback path, to increase the gain to compensate for rising temperature, the thermistor T is connected in series in the beta-path and in shunt of the beta-path, in Figs. 3 and 4, respectively. It will be evident, of course, that in order to obtain particular circuit characteristics any number of ordinary linear resistances and/or reactances, can be associated with the thermistors T and T'.

In the circuit of Fig. 3, the heater winding H could be connected directly across the resistance r , but this would not be as sensitive as the arrangement shown. The directly heated thermistor T' accelerates the current change produced by a voltage change across the resistance r . A convenient way of considering the circuit is to regard it as a very low frequency alternating current amplifier. For slow current variations, the thermistor T' has a negative resistance which should be somewhat less than the positive resistance of the heater winding H. The thermistor T' then provides an insertion gain when connected between the resistor r and the heater winding H. In arrangements of this type tried out experimentally, stable gains of from

20 to 30 decibels were obtained. Because of the relatively small variation in the resistance of the line, this amplification action is of considerable value in producing the necessary variation in the resistance of the thermistor T.

Whereas the thermistor heater circuit in the arrangement of Fig. 3 is essentially a voltage amplifier, that of the arrangement of Fig. 4 is essentially a current amplifier. Some advantage might be derived from connecting the thermistor T' directly into the connection 43 in place of the resistor r_1 but the thermistor T' would have to be of large current carrying capacity. The insertion of the resistance R, however, makes the heater circuit arrangement of Fig. 4 approach a constant current input to the parallel combination of the thermistor T' and the heater H.

Instead of using a resistor r or r_1 as a source of control voltage for the thermistor heating circuit, the potential drop across the heater filament of the amplifying device could be used, as illustrated in Fig. 6. In addition to requiring less voltage to be supplied to the line, such an expedient has the advantage that the heater filament behaves to a certain extent like a ballast lamp in that small current variations therein produce relatively large variations in the voltage drop thereacross. Such "ballast lamp effect" provides an additional increase in the sensitivity of the circuit regulation.

The simple series or shunt arrangements of Figs. 3 and 4 would introduce an impedance change in the beta-path of the amplifier. Under certain conditions this might affect the stability of the amplifier. To avoid this, a constant resistance network of the well-known bridged-T type could be employed and this is shown in Fig. 5. The arrangement of Fig. 5, in effect, combines the arrangements of Figs. 3 and 4. In order to obtain the constant resistance characteristic required, the circuit of Fig. 5 is proportioned so that the product of the resistances of the thermistors T_1 and T_2 for any given input voltage is constant and equal to the square of the desired characteristic resistance of the network.

By the provision of a selecting arrangement of the general nature disclosed in my copending application Serial No. 448,547, filed June 26, 1942, allowed December 3, 1942, entitled Speech transmission system, the gain control arrangement of the present invention may be adapted to use in a system utilizing a plurality of separated amplifiers wherein it is desirable to control the gain of one or more of the amplifiers selected at will.

Although this invention has been disclosed with reference to certain specific embodiments, it will be appreciated that it is not limited thereto but is of a scope evidenced by the appended claims.

What is claimed is:

1. An electric wave circuit comprising an amplifier having a stabilizing negative feedback connection including a series path and a shunt path, and a temperature-dependent variable impedance in each of said paths, and means individual to each impedance for indirectly heating the impedance, one of said means including a heater winding in series with a temperature-dependent resistance to be directly heated by current flow therethrough, and the other means including a heater winding and a temperature-dependent resistance to be directly heated by current flow therethrough and connected in parallel with the second-mentioned heater winding.

2. An electric wave circuit comprising an amplifier having a stabilizing negative feedback connection including a series path and a shunt path, said amplifier including an electronic device having a cathode and an anode, a source of cathode heating current and anode potential, a temperature-dependent variable impedance individual to each of said paths, and means individual to each impedance for indirectly heating it, each of said means being supplied with current from said source and comprising a network including a heater winding and a temperature-dependent resistance connected in parallel with a resistor.

3. An electric wave circuit comprising a series path and a shunt path and a variable resistance

individual to each of said series and shunt paths, said resistances having high temperature coefficients of resistance, and means individual to each resistance for indirectly heating said resistance, one of said heating means comprising a heater winding in series with a temperature-dependent resistance to be directly heated by current flow therethrough, said series-connection being in parallel with a resistor, and another of said heating means comprising a heater winding in parallel with a temperature-dependent resistance to be directly heated by current flow therethrough, said parallel-connection being in parallel with a second resistor, said resistors being connected in series.

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