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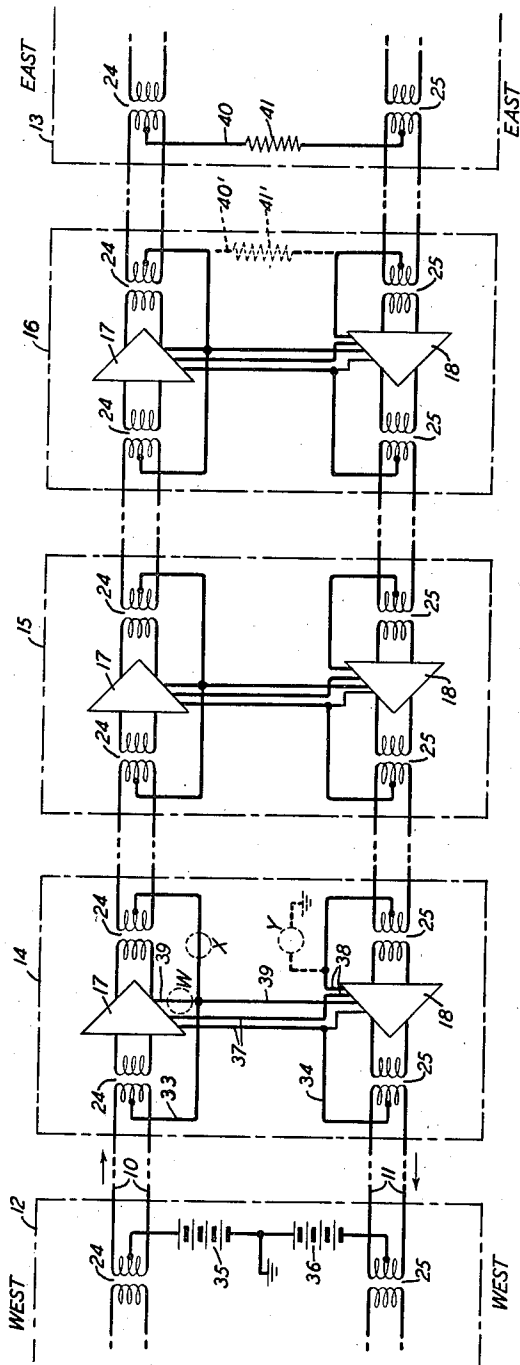
W. M. BISHOP
TRANSMISSION SYSTEM

2,272,735

Filed May 11, 1940

4 Sheets-Sheet 1

FIG. 1



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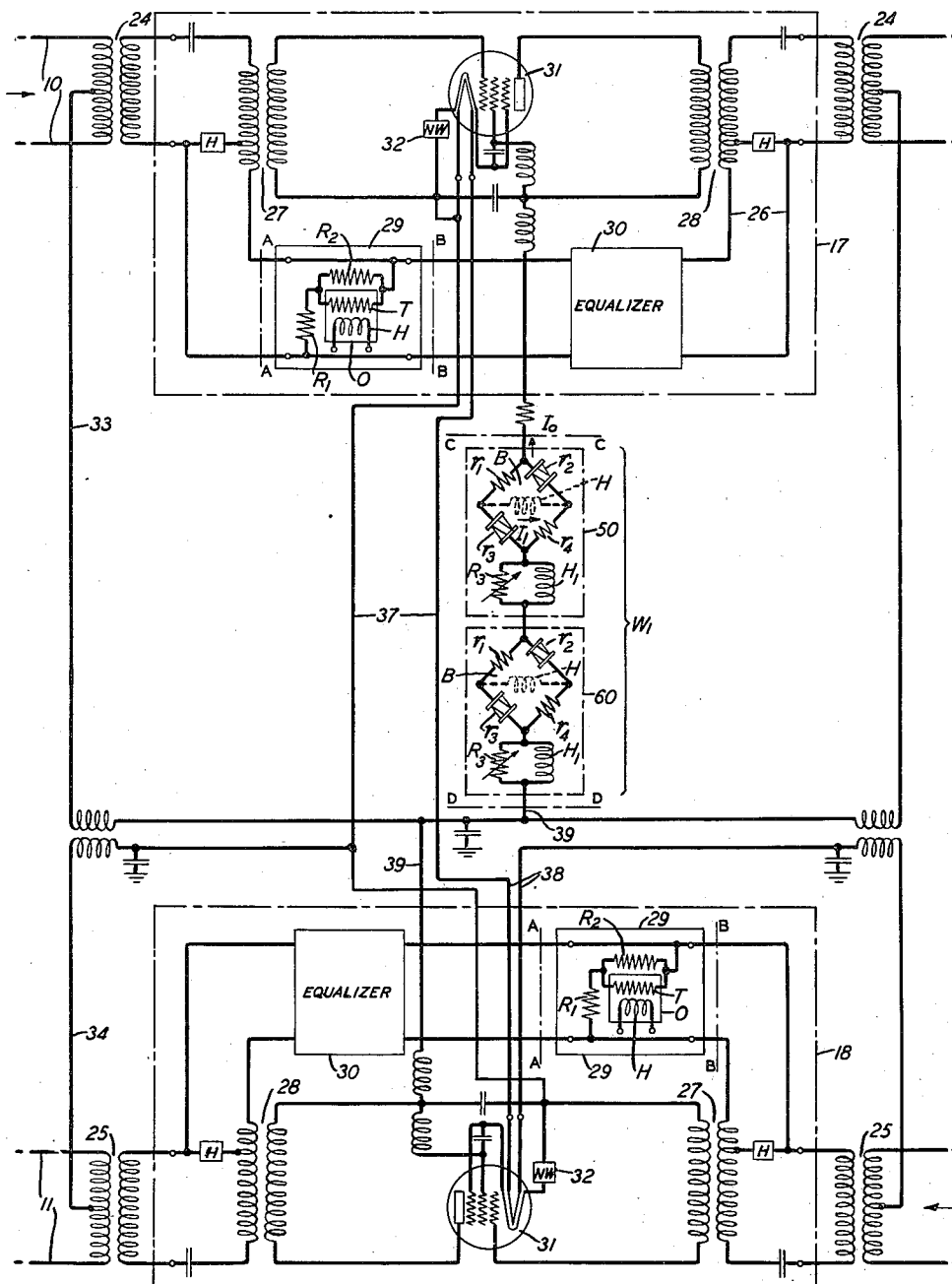
2,272,735

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FIG. 2



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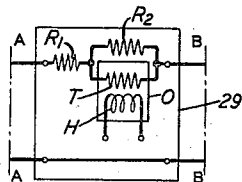


FIG. 2A

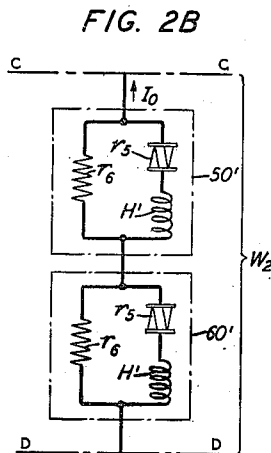


FIG. 2B

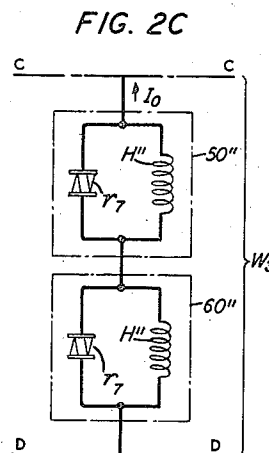


FIG. 2C

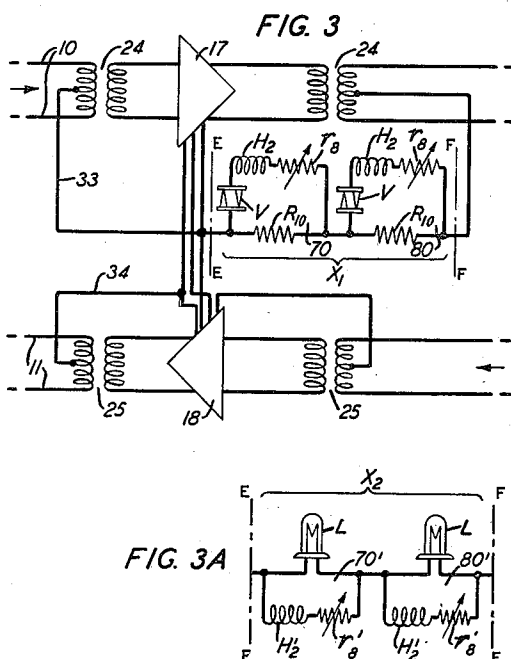
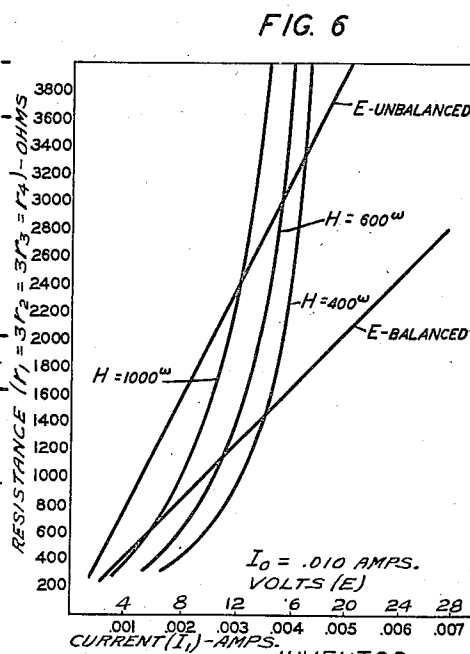


FIG. 3A



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FIG. 4

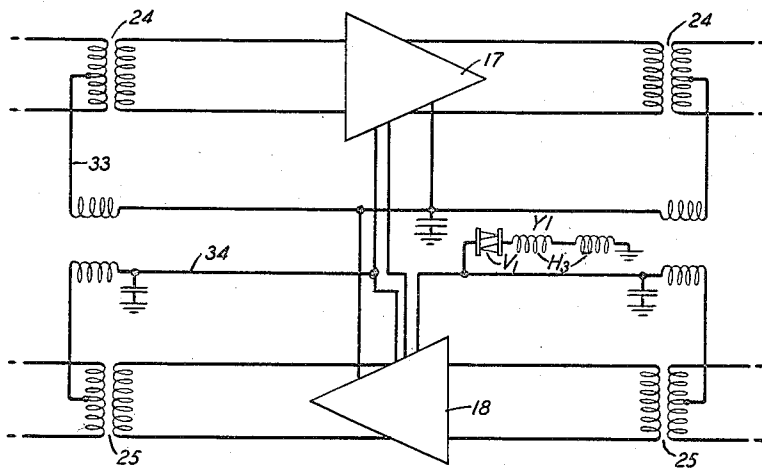
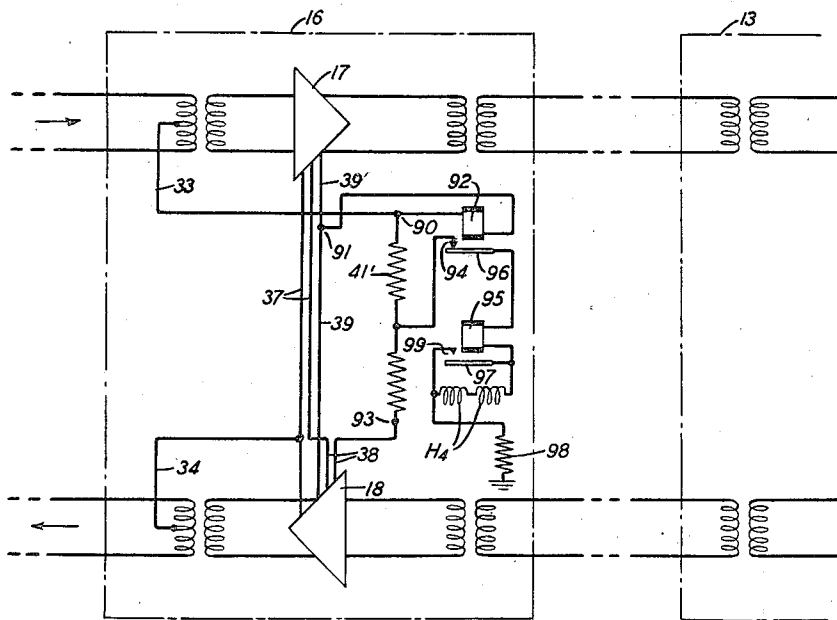


FIG. 5



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2,272,735

TRANSMISSION SYSTEM

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Application May 11, 1940, Serial No. 334,540

15 Claims. (Cl. 179—170)

This invention relates to transmission systems, and, more particularly, to a transmission system including one or more unattended repeater stations between attended stations or between the terminals of the system, and means and a method for controlling transmission levels along the system.

Transmission systems are known in which a plurality of repeater stations are located at geographically separated points along a transmission line between attended repeater stations or between the terminals of the line, and in which the power supply for the repeater stations is located at attended repeater stations only, or at one terminal only of the system. Such a transmission system may include individual transmission lines for transmission in opposite directions respectively, such lines comprising pairs of insulated wires buried in the ground; or, two pairs of conductors in a buried or a suspended lead-covered cable; or, pairs of wires especially insulated for pole line construction; or, a pair of submarine cables. In such systems, variations in the temperature of the lines and their surroundings will cause variations in the transmission levels of the communications currents, for example, a voice frequency modulated carrier wave, being transmitted over the lines.

An object of the invention is to regulate, control or compensate for the effects of temperature variation on the characteristics of the transmission system, such that the transmission level is maintained substantially constant.

In accordance with the invention, a transmission system comprising a pair of transmission paths or lines for transmitting electric wave energy in opposite directions, has a plurality of attended and unattended repeater stations at spaced intervals along the transmission lines. At each attended station, power supply is provided for the repeaters or amplifiers of the latter station and for the repeaters or amplifiers of the unattended stations between such attended station and the next attended station, or the power supply is provided at one terminal only of the system. Transmission level regulation or control means is provided at some of the stations, or, at each station, and/or at the terminals, and comprises resistance elements variable with temperature change and adapted for insertion in a gain control circuit for the repeaters or amplifiers. The means for varying the temperature and, therefore, the resistance of the variable resistance elements, responds to variations in the voltage or the current of the power supply voltage

or current at the particular station, such power supply variations resulting from the variations in the temperature of the lines and their surroundings and, consequently, their impedance. The invention also contemplates that resistance elements or devices variable with voltage thereacross or current therethrough may be used in the transmission level regulation means.

In a more specific aspect this invention contemplates a transmission system comprising a pair of transmission paths constituted by pairs of insulated wires buried in the ground by plowing them therein with attended and non-attended repeater stations along the transmission paths at geographically spaced intervals. One pair of wires is for transmission in one direction, and the other pair for transmission in the opposite direction. Transmission level regulation for temperature changes of the earth and, therefore, of the transmission paths, is provided by introducing heater elements in the power loop, originating at an attended station, that control the temperature and, therefore, the resistance of gain control variable resistance elements in each repeater at the unattended station. The heater element may be controlled by voltage or by current change in the power loop, or by change in the potential of a point in the loop with respect to a fixed potential (e. g., ground), and may be included in a network of positive and negative temperature coefficient of resistance resistances, or of varistor elements, such as copper oxide rectifiers or ballast lamps.

A more complete understanding of this invention will be derived from the detailed description that follows, taken in conjunction with the appended drawings, wherein:

Fig. 1 shows a transmission system in which this invention may be embodied;

Fig. 2 shows the repeaters or amplifiers at a station in the system of Fig. 1, in which transmission level regulation means in accordance with the invention are included;

Fig. 2A shows an alternative arrangement for the gain control means in the β -path of the repeaters of Fig. 2;

Figs. 2B and 2C show alternative arrangements for the networks regulating the resistance of the variable resistance element of the gain control circuits of Figs. 2 and 2A;

Fig. 3 shows a transmission level control circuit means included in the series or current path of the power supply;

Fig. 3A shows an alternative for the level control circuit means of Fig. 3;

Fig. 4 shows level control circuit means at a repeater station, connected between the power supply phantom and ground;

Fig. 5 shows how the level control circuit means may be connected at the last repeater station between ground and a point on the plate voltage drop resistor near the neutral point of the power system; and

Fig. 6 shows characteristic curves for heater elements of different resistances that might be used in the bridge of the network W1 of Fig. 2.

Fig. 1 shows a transmission system extending between geographically separated points or regions comprising a transmission path or line 10 for transmitting electric wave energy in one direction, for example, from west to east, and another transmission path or line 11 for transmitting electric wave energy in the opposite direction, that is, from east to west. Such electric wave energy might be communication or other signal energy superimposed on a wave of carrier frequency, and the transmission path could be adapted for the transmission of a single carrier wave in each direction, or for the transmission of a plurality of carrier wave frequencies distributed over a preassigned frequency band. For example, the system could be one adapted for 12-channel carrier operation utilizing a 12-kilocycle to 60-kilocycle frequency band. The transmission line may comprise pairs of insulated wires buried in the ground; or, two pairs of conductors in a buried or a suspended lead covered cable; or, pairs of wires especially insulated for pole line construction; or, a pair of submarine cables. The specific arrangement considered herein, however, is that of a transmission system comprising pairs of insulated wires buried in the ground, for example, by being plowed thereinto, and having one or more unattended repeater stations intermediate the terminal or attended station and also buried in the ground.

A plurality of attended repeater stations 12, 13, are provided at geographically separated points along the transmission line and a plurality of unattended repeater stations 14, 15, 16 at smaller separations are provided intermediate the attended station. If the transmission system is not a long one, the attended stations could be the terminal stations of the system, and only one unattended station might be required between them. At each repeater station there is an amplifier 17 for amplifying electric wave energy incoming thereto and being transmitted in one direction, for example from west to east, and an amplifier 18 for amplifying electric wave energy incoming thereto and being transmitted in the opposite direction, that is, from east to west.

Fig. 2 shows the circuit arrangement for an unattended repeater station. The amplifiers 17, 18 are substantially identical and specific description of one is equally applicable to the other, like elements bearing corresponding identifying numerals. The input and output terminals of amplifier 17 are coupled to the line 10 through repeating coils 24, and the corresponding terminals of amplifier 18 are coupled to line 11 through repeating coil 25. The amplifier 17 is a single stage feedback amplifier incorporating stabilized negative feedback as disclosed in H. S. Black Patent 2,102,671 issued December 21, 1937, the amplifying or mu-path of the amplifier being connected to the feedback path 26 through hybrid coils 27, 28 including the networks H, as

taught in the aforesaid Black patent, and in the pending H. S. Black application, Serial No. 114,390, filed December 5, 1936, allowed November 10, 1939 now Patent No. 2,209,955, issued August 6, 1940. The feedback path includes gain control means 29 and an equalizer network 30. The amplifying device, or tube, 31 may be a pentode having a cathode of the indirectly heated type. A network 32 may be connected in the cathode lead in accordance with D. D. Robertson Patent 1,994,486, issued March 19, 1935, to minimize any tendency for the amplifier to sing at some frequency outside of the transmission range. The heating current for the heater element of the amplifying devices and anode and screen grid potential are obtained over the transmission line, either from the terminals of the system or from an attended station, through the connections 33 and 34 coupling the mid-points of the line windings of the repeating coils 24, 25 in the lines 10, 11, respectively. The impedances in the connections 33, 34 are of high impedance to signal frequencies.

Figs. 1 and 2 show how anode and screen potential and cathode heater or filament heating current may be supplied to the unattended repeater stations from an attended station. The power supply may comprise the batteries 35, 36, the former having its positive terminal connected to the mid-point of the line winding of the repeating coil 24 at station 12, and its negative terminal, together with the positive terminal of battery 36, connected to ground, the battery 36 having its negative terminal connected to the mid-point of the line winding of repeating coil 25 at station 12. As already noted with reference to Fig. 2, the mid-point of the line windings of the repeating coils in each line are interconnected by connections 33, 34, connection to the cathode heater being made through conductors 37, 38, and to the screen grids and anodes through conductors 39.

The power loop is completed through the connection 40 and suitable impedance 41, for example, a resistor, shown in Fig. 1 as connecting the line windings of coils 24, 25 at attended station 13. Possible unnecessary power loss in the lines 10, 11 between stations 16 and 13 could be obviated by having the power loop be completed through the line windings of the output coils 24, 25 at station 16, as indicated at 40'. Power supply for the repeaters or amplifiers (not shown) at attended station 12, which could be the same as those of repeaters 17, 18 of the unattended stations, may be obtained from the batteries 35, 36 or from a separate source of power. Although not shown, it is obvious that attended station 13 could be the source of power supply for unattended stations farther to the east along the transmission paths or lines.

The characteristics of the transmission lines of the system will vary with variations in the temperature of the lines and of their surroundings. The effect of the variation in the frequency characteristics can be compensated or provided for in the equalizers associated with the feedback circuits of the repeaters. The effect of the variation in the impedance or resistance of the lines on the transmission level of the communications current can be compensated for by appropriate increase or decrease in the gain of the repeaters or amplifiers at the repeater stations.

Thermistors, i. e., devices that vary in impedance, or, specifically, resistance, with variation

in their temperature, and with either a positive or a negative temperature coefficient of resistance, and varistors, i. e., devices that vary in impedance, or, specifically, resistance, with variation in the potential applied thereacross or the current flowing therethrough, the resistance change with temperature, voltage or current being linear or non-linear, have been proposed heretofore for use in electrically operated gain control circuits in transmission systems. These devices or elements are capable, at least in specific instances, for example, silver sulphide, boron, or uranium oxide, of a wide range in resistance, which makes them attractive as elements for circuits in which it is desired or necessary to keep the fixed loss low. The resistance range of a silver sulphide thermistor in a vacuum tube, particularly, can be covered with the expenditure of a very minute amount of power.

The use of such devices involves at least two aspects: a suitable circuit arrangement for the device, i. e., an appropriate place at which to insert it into the transmission path as well as a satisfactory method of connecting the resistance into that path to get the desired effect, and a supply of power to the heater elements for the thermistors, together with a control of such power that gives the desired relation between it and the temperature of the path to be regulated.

The system described with reference to Figs. 1 and 2 is seen to be one of extreme simplicity, in that the repeaters employ a single stage of amplification whose output may be below that necessary to operate known thermistors. This would appear to eliminate direct pilot channel operation, except possibly on a manual basis at a low frequency. In such a system, furthermore, it might not be economical to provide extra line wires for any sort of resistance measuring arrangement, i. e., pilot wire operation, even if such an arrangement involved taking no appreciable extra power from the main power circuit. In order to keep the cost of the system, both as to power consumption and equipment, to a minimum, it might be undesirable to add vacuum tube circuits to the system for gain regulation. It would appear, therefore, that entirely new means for and method of operating thermistor elements are indicated for the system described. The detailed description which follows hereinafter discloses how this need is met by the present invention.

In general, there are two ways in which thermistors may be used at a repeater station to cause a change in the net transmission of a circuit: to introduce a loss in the direct transmission path, or to vary the losses in the β -circuit or path of the repeater or amplifier. Because of the power carrying limitations of thermistors such as silver sulphide, particularly direct current power, the devices should be isolated from the power circuit. Using thermistors in the direct transmission path would appear to require, therefore, the use of an extra repeating coil at the input of the amplifier, or an extra winding on the present one. In either case, it might be necessary to terminate with the characteristic impedance at the point where the thermistor is inserted to prevent undue disturbance to the line impedance, which might introduce more fixed loss than could be tolerated. The introduction of the gain control thermistor into the β -path of the amplifier offers the least difficulty. Since the β -path will, in general, require the introduction of some fixed loss for other reasons,

this fixed loss and the gain control could be combined to reduce any undesirable effect that the gain control resistance might have on the β -circuit propagation.

It is necessary to increase the losses in the β -path in order to increase the gain of the repeater when the transmission line and surrounding temperatures are high, and, in order to take advantage of the greater reduction in thermistor resistance due to an increasing ambient temperature in increasing the β -path losses, it is desirable to shunt the thermistor across this circuit.

The simplified gain control circuit 29 of the amplifier of Fig. 2 comprises a fixed resistance R_1 in series with the thermistor T, and the value of which is large compared to the minimum value of the thermistor resistance. R_2 should be small compared to the maximum thermistor resistance. The effective resistance across the β -path varies, therefore, between R_1 and $R_1 + R_2$. By having these resistances become effective in something less than the full range of the transmission line temperatures, the effect upon the gain control circuit of thermistor variations due to manufacturing variations, aging and ambient temperature changes will be reduced. This gives the gain control a tendency toward two-point working, i. e., high and low. The arrangement 29' of Fig. 2A is an alternative for that of Fig. 2, and shows the resistances R_1 , R_2 and thermistor T connected in series with the β -path. The thermistor T and its associated heater H are enclosed, as is well known in the art, in an appropriate enclosure or oven O.

Power for operating the thermistor T from the system of Fig. 1 powered by direct current supplied over the phantom, may be obtained in a number of ways. For example, there is a minimum potential drop at each repeater constituting power ordinarily wasted in adjusting the plate voltages to their desired values. Or, by supplying additional power to the system, a small potential drop in series with the power loop may be made available at each repeater. Or, a small current drain either across the power loop or from either side thereof to earth may be utilized. In the case of the last repeater in the power loop, the current could be taken off of the plate voltage drop resistor near the neutral point of the power system. How these sources may be utilized will now be described in detail.

In Fig. 2 is shown an arrangement for using the power ordinarily lost in dropping the voltage across the phantom to the desired value for plate potential, or the drop from which plate potential is obtained for the last repeater in the power loop. The necessary network is indicated in Fig. 1 by the dotted-line circle W, and a specific network W_1 is shown in Fig. 2 connected between points C—C and D—D in the connection 29 between the plate of tube 31 of repeater or amplifier 17 and the connection 33. The network comprises two similar sections or portions 50, 60, the sections 50, 60 being associated respectively with the gain control circuits of repeaters 17, 18.

In each section 50, 60, resistances r_1 and r_4 are ordinary resistances, either independent of temperature or with a small positive temperature coefficient such as is observed with iron wire. Resistances r_2 and r_3 are thermistors with negative temperature coefficients of resistances about like that of silver sulphide, but of some

material, such as boron or uranium oxide, suitable for use in direct current circuits. An auxiliary heater H_1 for the thermistor T may be included for adjusting or biasing the thermistor T to preassigned extent or initial condition, variable resistance R_3 being connected in shunt with the heater H_1 . Although the latter is not shown in the oven O , it would be provided therein with the heater H . The thermistor T may be of silver sulphide, which is available with a maximum to minimum resistance ratio of 10^5 and 10^6 , can be made with a minimum resistance of one ohm, and be operated over this range by a total heater dissipation of about 21 milliwatts.

The arrangement shown in Fig. 2 for the network W_1 has the advantage over the alternative networks W_2 and W_3 of Figs. 2B and 2C, of giving a larger current ratio for any one heater, although not necessarily a larger total power ratio. Fig. 2 shows the heater control bridge B in but one heater circuit, that of heater H . A bridge circuit could be added to the second heater circuit, that of heater H_1 , or the circuits of networks W_1 , W_2 , W_3 could be combined to obtain different characteristics and adjustments as well as to enable the employment of the entire thermistor resistance ratio with the available plate current, if the latter should prove desirable.

In Fig. 2B, the sections 50', 60' comprise the gain control thermistor (T) heater H' in series with heater circuit control resistor r_5 similar to resistors r_2 , r_3 , and a parallel resistor r_6 similar to resistors r_1 , r_4 ; and in Fig. 2C, a resistor r_7 similar to that of resistors r_2 , r_3 , r_5 , and the gain control thermistor (T) heater H'' .

If it is assumed that the transmission lines temperature range is between 0° and 21° C. and the resistors r_1 , r_2 , r_3 , r_4 are located so that they will assume approximately the same temperatures as the lines, then it will be possible to get resistance ratios $(r_1=r_4)/(r_2=r_3)$ of about 3:1. Fig. 6 shows the relation between $r_1=3r_2=r_4$ and I_1 for different values of H for the arrangement of Fig. 2. The relation between the resistance r_1 and E for both the balanced and unbalanced condition is also shown. As will be evident from the curves, it is possible to get 10 milliwatts into the heater H when r_1 equals approximately 2700 ohms and H equals 1000 ohms, at a current I_1 of approximately 3.2 milliamperes. This will cause a voltage variation of about 26 volts across two such bridge circuits in series, most of which will appear on the plates of the tubes 31 since the plate circuits are inherently of a constant current nature. This voltage variation will be partly compensated for, however, by the winter-summer fluctuation of voltage in the power loop which will be in the opposite direction if the thermistor T is connected as in Fig. 2. The maximum impedance of the bridge and, therefore, the voltage and the voltage fluctuation, can be reduced by interchanging the values of the variable and the fixed arms of the bridge in Fig. 2, but the action of the thermistor T will be opposite for the same direction of temperature change. At the last repeater in the power loop, where the circuit will be more nearly constant voltage in nature, the current I_1 would be larger than indicated by Fig. 6, and a different heater, or a shunt across the 1000 ohm heater H , would be required. A feature of these thermistor power circuits when used in conjunction with the two-point operation mentioned above,

is the possibility of locating the temperature sensitive elements r_2 , r_3 within the repeater service boxes or within the repeater containers.

Fig. 3 shows a circuit arrangement for taking power for the thermistor T from the power loop at a repeater station, in series with the connection 33. The necessary network is indicated in Fig. 1 by the dotted line circle X , and a specific network $X1$ is shown in Fig. 3 connected between points $E-E$ and $F-F$ in the power loop connection 33. The network $X1$ comprises sections or portions 70, 80, the former being associated with the gain control circuit of repeater 17, and the latter being associated with the gain control circuit of repeater 18. Each of the sections 70, 80 comprises a resistor R_1 in the connection 33, this resistor being shunted by a series circuit comprising a varistor V , a heater or heating coil H_2 for thermistor T , and a variable resistance r_8 . An alternative network $X2$ is shown by Fig. 3A wherein a ballast lamp L is connected in series with the connection 33 and has in shunt to it the thermistor heater H_2 and variable resistance r_8 . The varistor V may be of the copper-oxide type and, in connection with the arrangement of Fig. 3A, could also be included in series with the heater windings thereof. By operating the power loop input on a constant voltage basis, and by connecting the thermistor in series with the β -circuit of the repeater as shown in Fig. 2A, it is possible to make use of the voltage variation in the power loop to operate this type of circuit on a fully automatic basis. By controlling the input voltage, it would be possible also to control the gain manually at the power source. The most sensitive arrangement as regards current variations would be to use a ballast lamp in series with the power loop and a varistor in series with the thermistor heater, the latter two both being in shunt with the ballast lamp. By working the ballast lamp at or near the first bend in its characteristic, a point may be found where a 5 per cent current variation (the current variation expected in a constant voltage powered loop as the temperature varies between 0° C. and 21° C.) which would produce the voltage change necessary to operate the varistor.

Figs. 4 and 5 show how the thermistor temperature regulating source may be obtained by taking off a small current either across the power loop, or from either side thereof to ground.

The latter alternative is shown in Fig. 1 and Fig. 4. Its necessary network is indicated in Fig. 1 by the circle Y in the dotted line connection to ground from connection 34, and a specific network $Y1$ is shown in Fig. 4 as comprising a varistor $V1$ in series with two heaters or heating coils H_3 , H_3 , one for the thermistor of repeater 17 and the other for that of repeater 18. The varistor $V1$ may be of the copper oxide type, and should be connected to the loop at that repeater station where the voltage to ground can be varied 2 to 1 throughout the year, either automatically or manually.

The arrangement of Fig. 5 is adapted to be included at the last unattended repeater station in a single power loop. In Fig. 1 the necessary network would be associated with the repeater station 16 and with the connection 40'. The connection 33 terminates at the end 90 of impedance 41', potential for the anodes of amplifiers 17, 18 being obtained through the common point 91 connected to end 90 through the winding of relay 92. Connection 34 is connected to the other end 93 of impedance 41', an intermediate point

on which is connected to the contact 94 of relay 92. One end of the winding of a second relay 95 is connected to armature 96 of relay 92, and its other end is connected to armature 97 and through the heaters H₄, H₄ and a resistance 93 to ground. The contact 99 of relay 95 is connected to the series-connected heaters H₄ for the gain-control thermistors in the feedback circuits of the amplifiers 17, 18. When the loop is undergoing routine insulation tests and the power is off, relay 92 releases and ground is removed from the loop by the opening of contact between armature 96 and contact 94. Relay 95 places a short around the thermistor heaters H₄ by closure of armature 97 and contact 99, when the current to ground exceeds a preassigned value above which damage might result to the heaters. Resistance 93 reduces the effect of earth potentials which might be superimposed on the phantom unbalance voltages.

Although this invention has been disclosed with reference to certain specific embodiments, it will be understood that they are believed at this time to be the preferred forms, and that the scope of the invention is not limited thereto but by the appended claims in the light of the prior art.

What is claimed is:

1. A transmission system comprising a line for transmitting communication currents in one direction, a line for transmitting communication currents in the reverse direction, a repeater station along said paths comprising electron discharge device repeaters for amplifying said currents, each of said devices comprising a cathode, an input grid and an anode, means for supplying said station with anode potential from one terminal only of said system, and means for regulating the gain of said repeaters with variation in temperature conditions along said lines comprising a feedback path in each repeater and including an element variable in impedance with temperature variation, and temperature controlling means for said variable element including a heater element the current through which varies directly with changes in the anode potential supplied to the repeaters over the line.

2. A transmission system comprising a transmission path for transmitting communication currents in one direction, a second transmission path for transmitting communication currents in the opposite direction, one or more repeater stations intermediate the ends of said transmission lines with separate amplifiers at each station for amplification of the communication currents being transmitted in each direction, a phantom circuit loop including said lines and repeater stations, a source of power supply for said amplifiers and included at one end of said loop, and means for regulating the gain of said amplifiers with variation in temperature conditions along said lines comprising a feedback path in each repeater and including an element variable in impedance with change in its temperature, and temperature controlling means for said variable element including a heater element the current through which varies directly with changes in the current supplied from said power source to the repeaters over said loop.

3. A transmission system comprising a transmission path for transmitting communication currents in one direction, a second transmission path for transmitting communication currents in the opposite direction, one or more repeater

stations intermediate the ends of said transmission lines with separate amplifiers at each station for amplification of the communication currents being transmitted in each direction, a phantom circuit loop including said lines and repeater stations, a source of power supply for said amplifiers and included at one end of said loop, and means for regulating the gain of said amplifiers with variation in temperature conditions along said lines comprising a feedback path in each repeater and including an element variable in impedance with change in its temperature, and temperature controlling means for said variable element including a heater element the current through which varies directly with changes in the potential between a point of fixed potential and a point in said loop at a repeater station.

4. A transmission system comprising a transmission path for transmitting communication currents in one direction, a second transmission path for transmitting communication currents in the opposite direction, a plurality of attended and unattended repeater stations intermediate the ends of said transmission lines with separate amplifiers at each station for amplification of the communication currents being transmitted in each direction, a phantom circuit loop including said lines and repeater stations, a source of power supply for said amplifiers and included at one end of said loop, and means for regulating the gain of said amplifiers with variation in temperature conditions along said lines comprising a feedback path in each repeater and including an element variable in impedance with change in its temperature, and temperature controlling means for said variable element, located at the repeater station at the end of the phantom circuit remote from the power supply and including a heater element the current through which varies directly with changes in the current supplied from said power source to the repeaters over said loop.

5. A transmission system between geographically separated points and buried in the ground, comprising oppositely directed transmission paths and one or more geographically spaced repeaters therein for amplifying the communication currents being transmitted, the power supply for said repeaters being provided over a power loop comprising one of said paths from an attended repeater station to each unattended station intermediate attended stations, and back over the other of said paths through each unattended station to said one attended station; and means at an unattended repeater station for regulating the transmission level of the communications currents, to compensate for changes in the characteristics of the transmission paths with change in their temperature and that of their surroundings, said means comprising temperature-controlled variable impedances in the repeaters at said unattended station, and means connected to said power loop for regulating the temperature of said impedances and responsive only to changes in the electrical condition of said power loop.

6. A transmission system comprising oppositely directed transmission paths and one or more geographically spaced repeaters therein for amplifying the communication currents being transmitted, the power supply for said repeaters being provided over a power loop comprising one of said paths from an attended repeater station to each unattended station intermediate attend-

ed stations and back over the other of said paths through each unattended station to said one attended station; and means at an unattended repeater station for regulating the transmission level of the communication currents, to compensate for changes in the characteristics of the transmission paths with change in their temperature and that of their surroundings, said means comprising temperature-controlled variable impedances in the repeaters at said unattended station, and means regulating the temperature of said impedances and responsive to changes in the resistance of said power loop, in which the means for regulating the temperature of a said repeater impedance comprises a heater element in a network connected between the power loop and the plate electrode of the repeater, said network including a bridge of resistance elements.

7. A transmission system comprising oppositely directed transmission paths and one or more geographically spaced repeaters therein for amplifying the communication currents being transmitted, the power supply for said repeaters being provided over a power loop comprising one of said paths from an attended repeater station to each unattended station intermediate attended stations and back over the other of said paths through each unattended station to said one attended station; and means at an unattended repeater station for regulating the transmission level of the communication currents, to compensate for changes in the characteristics of the transmission paths with change in their temperature and that of their surroundings, said means comprising temperature-controlled variable impedances in the repeaters at said unattended station, and means regulating the temperature of said impedances and responsive to changes in the resistance of said power loop, in which the means for regulating the temperature of the said repeater impedances at a repeater station comprises a heater element in each of a plurality of networks connected between the power loop and a plate of the repeater for amplification in one transmission path, each network including a bridge of resistance elements.

8. A transmission system comprising oppositely directed transmission paths and one or more geographically spaced repeaters therein for amplifying the communication currents being transmitted, the power supply for said repeaters being provided over a power loop comprising one of said paths from an attended repeater station to each unattended station intermediate attended stations and back over the other of said paths through each unattended station to said one attended station; and means at an unattended repeater station for regulating the transmission level of the communication currents, to compensate for changes in the characteristics of the transmission paths with change in their temperature and that of their surroundings, said means comprising temperature-controlled variable impedances in the repeaters at said unattended station, and means regulating the temperature of said impedances and responsive to changes in the resistance of said power loop, in which the means for regulating the temperature of a said repeater impedance comprises a heater element in a network connected between the power loop and a plate electrode of the repeater, said network including a bridge of resistance elements, two opposite arms of which are of the type having a negative temperature coefficient of resistance.

9. A transmission system connecting geographically separated points and buried in the ground, comprising oppositely directed transmission paths and one or more geographically spaced repeaters therein for amplifying the communication currents being transmitted, the power supply for said repeaters being provided over a power loop comprising one of said paths from an attended station to each unattended station intermediate it and the next attended station, and back over the other of said paths through each unattended station to said one attended station; and means at an unattended repeater station for regulating the transmission level of the communication currents, to compensate for changes in the characteristics of the transmission paths with change in their temperature and that of their surroundings, said means comprising temperature-controlled variable impedances in the repeaters at said unattended station, and means regulating the temperature of said impedances and responsive to changes in the resistance of said power loop, said regulating means comprising a pair of series-connected resistors in series with the power loop, each resistor having in shunt thereto a heater for one of said impedances and a variable resistance element, said heater and resistance element being connected in series.

10. A transmission system connecting geographically separated points and buried in the ground, comprising oppositely directed transmission paths and one or more geographically spaced repeaters therein for amplifying the communication currents being transmitted, the power supply for said repeaters being provided over a power loop comprising one of said paths from an attended station to each unattended station intermediate it and the next attended station, and back over the other of said paths through each unattended station to said one attended station; and means at an unattended repeater station for regulating the transmission level of the communication currents, to compensate for changes in the characteristics of the transmission paths with change in their temperature and that of their surroundings, said means comprising temperature-controlled variable impedances in the repeaters at said unattended station, and means regulating the temperature of said impedances and responsive to changes in the resistance of said power loop, said regulating means comprising a pair of series-connected ballast lamps in series with said loop, each of said lamps having connected in shunt therewith a heater element for one of said impedances.

11. A transmission system connecting geographically separated points and buried in the ground, comprising oppositely directed transmission paths and one or more geographically spaced repeaters therein for amplifying the communication currents being transmitted, the power supply for said repeaters being provided over a power loop comprising one of said paths from an attended station to each unattended station intermediate it and the next attended station, and back over the other of said paths through each unattended station to said one attended station; and means at an unattended repeater station for regulating the transmission level of the communication currents, to compensate for changes in the characteristics of the transmission paths with change in their temperature and that of their surroundings, said means comprising temperature-controlled variable im-

pedances in the repeaters at said unattended station, and means regulating the temperature of said impedances and responsive to changes in the resistance of said power loop, said regulating means comprising a pair of series-connected heaters for the impedances of the repeaters at the unattended station, said heaters being connected in series with a variable resistance element and between a point of fixed potential and a point on said loop at said unattended repeater station.

12. A transmission system comprising a transmission line, an amplifier in said line comprising an electron discharge device having a cathode, an input electrode, an anode, and a cathode-heating filament, energizing power for said anode and said filament being supplied over said line, a feedback connection between the output and input of said amplifier, temperature-responsive resistance means in said feedback connection for regulating the feedback in and the gain of said amplifier, and means for altering the temperature of said resistance means in accordance with temperature change in said line, said temperature-altering means being responsive only to a change in an electrical characteristic of the energizing power supplied over said line.

13. A transmission system comprising a transmission path for communication currents, a repeater station in said path, means at one end of said path for supplying power to said repeater station over said path, a communication currents path through said repeater at said repeater station, a power path around said repeater at said repeater station, and gain control means at said station, said means including an impedance device variable in impedance with temperature, and a temperature-varying device connected to said power path and re-

sponsive only to a change in the electrical condition of said power path for varying the temperature of said impedance device with change in the electrical condition of said power path.

14. A transmission system comprising a transmission path, an amplifier in said path, said amplifier comprising an electron discharge device having an anode, a power supply at one end of said path for said amplifier, a power path around said amplifier, the potential for the anode of said device being supplied over said paths, and means to regulate the gain of said amplifier with variations in the line characteristics because of changes in the temperature of the transmission path and its surroundings, said means including a current responsive device connected to said anode and said power path.

15. A transmission system comprising a transmission path, an amplifier in said path for communication currents, said amplifier comprising an electron discharge device having an anode, a cathode, and a cathode-heater filament, a power supply for said amplifier at one end of said path, the potential for said anode and the current for said filament being supplied over said path, a feedback connection for said amplifier between the output and input circuits of said amplifier, a temperature-controlled variable impedance in said feedback connection arranged so that its impedance change alters the amount of feedback, and temperature-varying means for said variable impedance, connected to said path but independent of the output of said amplifier, said means comprising a heater element the current through which varies with change in the electrical condition of the transmission path with respect to the power supplied thereover.

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