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2,259,945

TRANSMISSION CONTROL

Filed Oct. 12, 1940

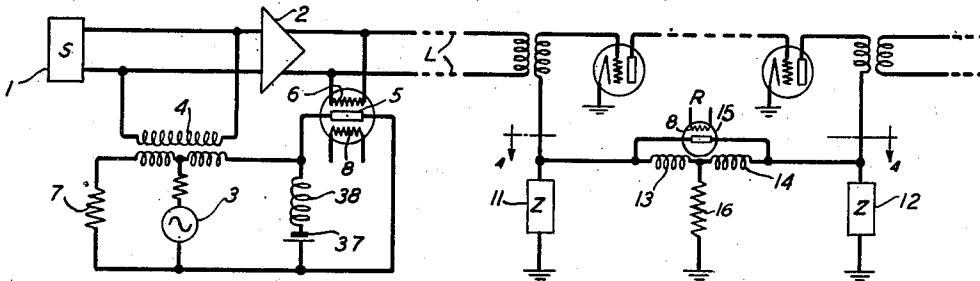


FIG. 1

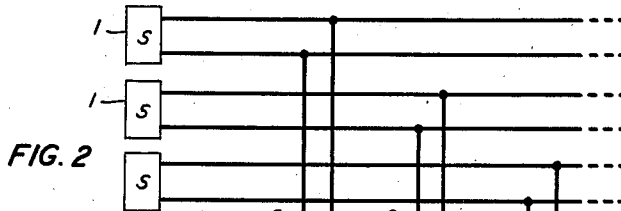


FIG. 2

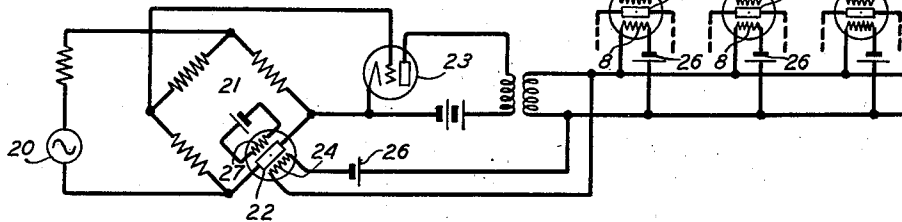


FIG. 3

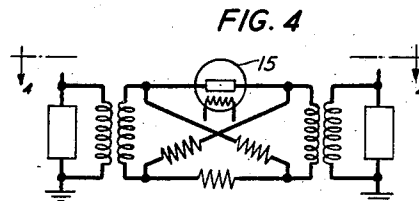
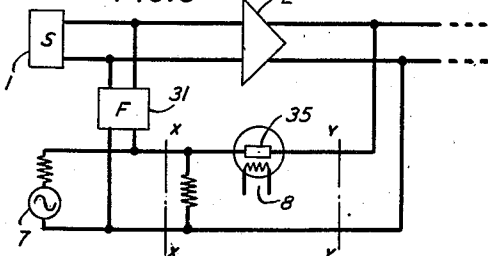


FIG. 4

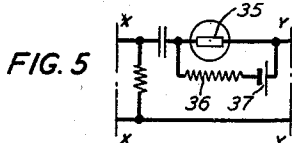


FIG. 5

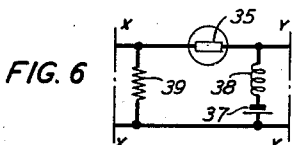


FIG. 6

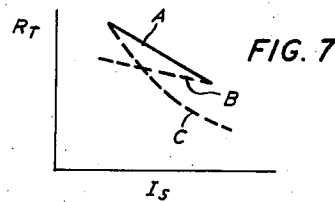


FIG. 7

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TRANSMISSION CONTROL

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6 Claims. (Cl. 178-44)

The present invention relates to electric transmission systems and more particularly to transmission regulating systems comprising thermosensitive control elements of variable impedance.

A principal object of the invention is to improve and simplify regulation of the amplification of repeaters in a wire line or other signal transmission system.

Another object of the invention is to provide an improved circuit comprising a thermosensitive element for the amplitude modulation of a pilot wave in a system in which the gain of the repeaters is controlled by the signals and pilot waves jointly.

A further object of the invention is to increase the differential sensitivity or operating range of a thermosensitive resistance, more especially where the thermosensitive resistance is disposed in gain controlling relation in the beta circuit of a feedback repeater amplifier.

Still another object is to facilitate the matching of the characteristics of a plurality of thermosensitive resistances and to provide a simplified circuit for accurately compensating a plurality of thermosensitive resistances for changes in ambient temperature.

The nature of the present invention and the means by which the foregoing and related objects of the invention are attained will appear from the following description of the illustrative embodiments represented in the accompanying drawing.

Fig. 1 shows a repeated wire line signaling system arranged for adjustment of repeater gain under the joint control of signals and pilot currents transmitted over the line;

Fig. 2 illustrates an arrangement for compensating thermosensitive resistances, such as employed in the system of Fig. 1, for fluctuation of ambient temperature;

Figs. 3 and 4 show modified components of the Fig. 1 system; and

Figs. 5 to 7 relate to the adjustment of the response characteristics of the thermosensitive element.

Referring more particularly now to Fig. 1 there is shown in schematic outline a wire line signal transmission system in accordance with the invention utilizing thermosensitive resistance elements for repeater gain control purposes. Signals from a source 1 at the left are applied through transmitting amplifier 2 of constant gain to transmission line L which has one or more signal repeaters R spaced apart therein. To adjust the gain of the repeaters to compensate for

changes in the attenuation of the transmission line L, single frequency pilot waves from an oscillator or other suitable source 3 are applied to the line for transmission concurrently with the signals. In conformity with the principles disclosed in United States patent to J. H. Bollman No. 2,231,558 and in United States patent to J. G. Kreer No. 2,231,538, both issued February 11, 1941, the pilot waves from source 3 are so varied in initial intensity that the total power content of the signal and pilot waves as applied to the line is maintained constant, and at each repeater station the repeater gain is adjusted under the control of signal and pilot waves combined to maintain the combined power of the two substantially constant at the output of the repeater, whereby the transmission equivalent of the system is maintained constant despite changes in the attenuation of the transmission line. To effect the desired initial variation of pilot current intensity, the pilot source 3 is connected to the signaling system through a bridge circuit that is variably unbalanced under the control of an element 5 having a high temperature coefficient of resistance. Elements of this character will be referred to hereinafter as thermistors.

The bridge circuit includes a hybrid coil 4 and a pair of balancing arms comprising thermistor 5 and fixed resistor 7. Pilot current source 3 is connected to the input terminals of the bridge and the output terminals of the hybrid coil 4 are connected across the signaling circuit at the input of transmitting amplifier 2, so that the amount of pilot current transmitted through the hybrid coil to the signaling circuit is a function of the degree of unbalance of the bridge. The unbalanced condition of the bridge is in turn controlled by thermistor 5, which is assumed to have a negative temperature coefficient of resistance and which is enclosed in proximity to a heater element 6 within a thermally insulated chamber. The heater element 6 is connected to receive and convert into heat a fixed proportion of the total wave power output of amplifier 2, thereby regulating the temperature and resistance of thermistor 5 in accordance with the total wave power output of amplifier 2. The elements of the bridge circuit are so proportioned that with no signals delivered from source 1 the bridge is unbalanced enough that the pilot current power appearing at the output of amplifier 2 is of the predetermined required value. When the source 1 contributes to the total output of amplifier 2, the temperature of thermistor 5

tends to be raised and its resistance reduced, and the bridge tends to a balanced condition thereby reducing the pilot current output and tending to maintain the total power output of amplifier 2 at the predetermined constant value. Although the nature of the circuit is such that the total power output is not maintained exactly constant, the high differential sensitivity of the bridge, that is, the responsiveness of the bridge circuit to slight changes in thermistor resistance, permits a substantially perfect approximation to a constant power output condition. Contributing to the same object is a shunt across thermistor 5 comprising battery 37 and inductance 38 which may optionally be provided and which will be further described with reference to Fig. 6.

In view of the fact that a slight change in the temperature and resistance of thermistor 5 gives rise to a greatly magnified change in the amount of pilot current introduced into the signaling circuit, it is especially desirable that thermistor 5 be substantially immune to changes in the temperature of the air or other ambient surrounding the chamber in which it is enclosed. Compensation for ambient temperature changes is effected by means of an auxiliary heater element 8 that is enclosed within the same chamber and that is variably heated by means to be described with reference to Fig. 2.

In an illustrative case in accordance with the pilot modulating circuit described, balancing resistor 7 may be 1,000 ohms and the pilot source 3 may be adjusted so that with no signal input to amplifier 2 the resistance of thermistor 5 is 1,060 ohms, corresponding to a transmission loss through the bridge of 30 decibels. Thermistor 5 is selected or adjusted to have such characteristics that with maximum signal power applied to amplifier 2 its resistance is slightly greater than that of resistor 7, e. g. 1,005 ohms, corresponding to a transmission loss through the bridge circuit of 50 decibels.

The repeater R in Fig. 1 is represented as including a negative feedback amplifier that has a beta circuit unbalanced with respect to ground and terminated at its extremities by impedance elements 11 and 12, respectively. Interposed in the beta circuit is a T-network of which the two series arms comprise closely coupled inductances 13 and 14 shunted by a thermistor 15 having a negative temperature coefficient, and in which the shunt element is a resistor 16. The thermistor is indicated as being directly or self-heated by the beta circuit currents traversing it although a supplementary heater winding 8 is provided as for thermistor 5. The aforementioned T-network constitutes a hybrid bridge circuit which introduces a beta circuit attenuation that is a sensitive function of its proximity to balance as controlled by thermistor 15. Thermistor 15 is heated in proportion to the total output of the amplifier, the latter varying only with the attenuation of the preceding line section. Accordingly, the attenuation of the beta circuit and therefore the gain of the amplifier is a function of the total output of the amplifier, and by proper proportioning of the various circuit elements and of the thermistor characteristics any tendency for the total power output to change can be made to give rise to a compensating change in the gain of the repeater. Again it is important that the gain of the repeater and more particularly the characteristics of thermistor 15 be made independent of the temperature of the ambient surrounding thermistor 15.

In a practical example the balancing resistor 16 may be 250 ohms. Whereas the bridge would be balanced and the beta circuit transmission zero if thermistor 15 had a resistance of 1,000 ohms, the characteristics of the thermistor are so chosen or adjusted that its resistance varies from 980 to 820 ohms, for example, for the range of line attenuation encountered in practice. The effectiveness of the combination is indicated by the fact that a change in amplifier output which causes a sixteen per cent change in thermistor resistance may occasion a 20-decibel change in beta circuit transmission as contrasted with the 1-decibel change that might be obtained in the absence of the hybrid bridge circuit. The circuit positions of thermistor 15 and resistor 16 may be interchanged, if desired, provided corresponding changes be made in the circuit proportions.

Fig. 2 shows in detail a preferred embodiment of the ambient temperature compensating circuits to be associated in accordance with the present invention with the auxiliary thermistor heaters in the Fig. 1 system. It may be assumed that there are a plurality of systems of the kind shown in Fig. 1 that terminate at the same central office and that their respective pilot supply circuits and more especially their respective thermistors 5 are disposed together so that they are all subject to the same variations in room temperature. The several thermistors 5 are illustrated in Fig. 2 in schematic fashion as being associated with their respective transmission systems as suggested by the connections from the several heaters 6. Each thermistor is provided with its supplementary heater 8 as indicated also in Fig. 1. Despite the heat insulating chambers around the several thermistors 5 heat is continually lost to the surrounding air and the rate of heat loss and therefore the temperature within the chamber varies with the room temperature. Accordingly, it is a purpose of the auxiliary circuits provided to supply to each of the thermistor chambers a variable amount of heat power so correlated with the variable heat losses therefrom that the temperature within the chamber is independent of the room temperature. The compensating circuit to be described represents an improvement over the ambient temperature compensator disclosed in I. G. Wilson Patent 2,151,821, issued March 28, 1939.

Referring to Fig. 2 the supplementary heating current is derived from an alternating current source 20, of 60 cycles for example, which is connected to the input terminals of a bridge circuit 21. The output terminals of the bridge are connected to the auxiliary heaters 8 through an amplifier tube 23, the importance of which will appear shortly. One arm of the bridge comprises a thermistor 22 which is enclosed within a heat insulating chamber and provided with an auxiliary heater 24. The other arms of the bridge are fixed resistors of substantially equal value. The thermistor 22 and its enclosing chamber are preferably substantially identical with the several thermistors to be controlled and in any event are so proportioned as to have substantially the same electrothermal characteristics as the others. It is furthermore to be exposed to the same variations in ambient temperature. Heater 24 is connected to the output of amplifier 23 so that it dissipates within the chamber the same amount of heat power as do the respective heaters 8 associated with thermistors 5. It is evident then that in any event all of the thermistors receive the same amount of supplementary heating.

Thermistor 22, in accordance with a feature

of the present invention, is not to be heated by the bridge current traversing it but is to be substantially responsive only to variations in room temperature and variations in the current traversing heater 24. Accordingly, the operating voltage of source 20 is so chosen with reference to the operating resistance range of thermistor 22 that the i^2R loss in the latter has negligible effect on its temperature and resistance. The differential sensitivity of the bridge is nevertheless preserved and the effective resistance range of thermistor 22 is magnified in high degree. To translate the effective resistance variation of thermistor 5 into proportional variations of power sufficient for the power requirements of the thermistor heater 8, the amplifier 23 is interposed in the output circuit of the bridge.

At the highest room temperature for which the compensating system is designed, or at some higher temperature, heater 24 and thermistor 22 may be so proportioned that bridge 21 is in balance and no supplementary heating is provided by source 20. As the room temperature decreases from the maximum value, thereby tending to increase the amount of heat dissipated by all of the thermistors, the resistance of thermistor 22 changes in such sense as to increasingly unbalance the bridge thereby admitting more heat power to all of the supplemental heaters 8 and 24. In view of the sensitivity of the bridge to changes in thermistor 22 the operating temperature range of the latter may be made so narrow that its temperature is almost constant. The reflexive control circuit connected to heater 24 is adapted to supply heat power in such quantity as to counteract in large measure the comparatively large changes in thermistor temperature that would otherwise accompany a change in ambient temperature.

It may be understood then that Fig. 2 comprises a bridge circuit that is variably unbalanced to produce a magnified change in power transmitted through the bridge under the control of a thermistor that is exposed to changes in ambient temperature but that is maintained at substantially constant temperature by supplementary heating that in turn is controlled by the bridge unbalance and by the thermistor itself. It will be understood further that inasmuch as the bridge thermistor is maintained at substantially constant temperature, the auxiliary heating power supplied to it is just sufficient to compensate for ambient temperature variations and that inasmuch as the controlled thermistors have the same electrothermal characteristics and receive the same amount of auxiliary heating power they too are accurately compensated for ambient temperature variations.

As a further refinement that is especially applicable in the case assumed where the thermistors 5 are all maintained at the same, constant elevated temperature, master thermistor 22 is, or may be, provided with a second heater 27 that is supplied with heating current from a battery or other constant current source in such amount that the temperature of thermistor 27 is maintained not only substantially constant but also equal to the constant temperature of the controlled thermistors 5. Thus it is further assured that the variations in heat loss with changes in ambient temperature will be precisely the same for both master and controlled thermistors and the supplementary heating regulated precisely to compensate for such variations.

Fig. 3 illustrates a modification of the circuit

that is shown at the transmitting end of the Fig. 1 system for supplying a pilot wave of desired varying amplitude. In this case the pilot currents from source 7 are applied to the input of amplifier 2 through a narrow band-pass filter 31 which is included also in a gain reducing or negative feedback path around amplifier 2. A substantially fixed fractional portion of the total power output of amplifier 2 is applied to a self-heating thermistor 35 that is disposed in series in the feedback path and the resistance of which therefore is controlled by the total power output of the amplifier. The attenuation of the feedback path as determined by thermistor 35 controls the gain of the amplifier but only at the pilot frequency inasmuch as transmission through the feedback path at other frequencies is blocked by the filter 31. When the signals from source 1 are of maximum power thermistor 35 is controlled thereby to maintain the gain of amplifier 2 at a low value at the pilot frequency so that the pilot current power appearing at the output of amplifier 2 is negligible. Any reduction of the signal power tends to increase the resistance of thermistor 35, thereby tending to increase the attenuation of the feedback path at the pilot frequency and to increase the gain of amplifier 2 only at the pilot frequency. The circuit may be so proportioned that as the signal power varies at the input of the amplifier the gain of the amplifier at the pilot frequency is varied in such sense and degree that the total power output of the amplifier 2 is maintained substantially constant and the gain of the amplifier at signal frequencies is constant.

In accordance with a modification of the repeater circuit shown in Fig. 1 the T-network in the beta circuit thereof may be replaced by a transformer coupled resistance bridge of which one series arm is a thermistor 15, as indicated in Fig. 4.

In accordance with an important feature of the present invention the proportioning and adjustment of circuits comprising thermistors and the effective matching of thermistors having characteristics that are not quite identical, are facilitated by the provision of auxiliary current or voltage sources in a manner to be described. It should be appreciated that thermistors may be almost microscopic in size and that it is accordingly difficult to duplicate precisely any given electrothermal characteristics. One significant characteristic, designated as the R_0 of the thermistor, is the thermistor resistance at a predetermined reference temperature, e. g., seventy degrees F. Another important parameter is the slope of the thermistor resistance versus current intensity characteristic.

As illustrated in Fig. 2 the R_0 of each of the thermistors 5 is controlled by means of a battery 26 or other current source connected in the respective supply circuits of heaters 8. The voltages of the several sources 26 are adjusted by any suitable means so that with no current supplied from other sources and with the ambient at the standard reference temperature the respective resistances of the several thermistors 5 are precisely alike. The thermistors may be said then to be thermally biased to a standard R_0 value.

Provision may be made for independently adjusting the slope of the resistance versus current characteristics of a self-heating thermistor or of the resistance versus heating power characteristic of an indirectly heated thermistor by sub-

jecting the thermosensitive element to the direct action of an electric biasing source that contributes variably to the heat power dissipated by and within it. Figs. 5 and 6, which may be understood as optionally replacing a correspondingly identified portion of the Fig. 3 circuit, illustrate the application of an electric bias for decreasing and increasing, respectively, the slope characteristic of a thermistor having a negative temperature coefficient of resistance.

In Fig. 5 the thermistor 35 is shunted by the series combination of a high resistance 36 and battery 37 so that it is traversed by substantially constant biasing current from the battery as well as by variable control currents. The intensity of the biasing current that flows through the thermistor and therefore also the power from the biasing source that is dissipated in the thermistor depends on the resistance of the latter, which in turn depends on the intensity of the signal or other control currents. That the combination operates to decrease the slope of the resistance (R_t) versus current (I_s) characteristic may be more readily understood by considering the extreme case where resistance 35 is so large that the biasing current is substantially constant and independent of the thermistor resistance and contrasting it with the case where no bias is provided. Bearing in mind that the temperature and resistance of the thermistor are functions of the i^2R losses occurring in it, it is evident that when the control current is small or zero the thermistor resistance in the extreme case is much lower, because of biasing power losses present, than it would be if there were no bias, while if the control current is so large that the biasing current is small or negligible in comparison the i^2R losses may be approximately the same in the two cases.

In Fig. 6 biasing battery 37 is connected in such relation to the thermistor 35 that an approximately constant biasing voltage is maintained across the latter. Inductance 38 connected in series with battery 38 has low resistance to direct currents but offers high shunt impedance to the control currents. The biasing circuit is completed through resistor 39. In other cases it may be convenient to connect the biasing source directly across the thermistor, interposing in the connection only an element or network of low direct current resistance and of high impedance to the control currents. As contrasted with the case where no biasing source is provided it will be evident that when the control current is small and the thermistor resistance high the biasing voltage may be so small in relation to the high resistance of the thermistor that a negligible amount of biasing current flows to affect the resistance, but that when the control current is large the thermistor resistance may be so low that the biasing source drives a current of high intensity through the thermistor thereby tending to reduce its resistance substantially. The same elements are shown shunted across thermistor 5 in Fig. 1 where they operate to increase the slope of the thermistor resistance versus heating current characteristic and to reduce the maximum power that must be diverted from the signaling circuit to heater 6. Inductance 38 offers low impedance to the biasing current from source 37 but high impedance to the currents of pilot frequency. Hence the effect of the shunt on the bridge balance may be made negligible.

Fig. 7 shows qualitatively in graphical form

the relation between thermistor resistance R_t and control current I_s for the three cases considered, curve A applying to an unbiased thermistor, curve B to one in which the slope has been reduced by constant current bias, and curve C to one in which the slope has been increased by constant voltage bias. It will be understood that intermediate slopes may be obtained by adjustment of the resistance in series with the biasing source and that equal slope characteristics can thereby be obtained for the several thermistors 5 in Fig. 2.

What is claimed is:

1. In combination, a source of signals of normally variable intensity, an amplifier connected to receive the signals from said source, a bridge circuit having input and output terminals, said output terminals being connected to the input of said amplifier, a pilot current generator connected to the input terminals of said bridge, a thermosensitive element connected to control the degree of unbalance of said bridge in accordance with the temperature of said element and means for heating said thermosensitive element in proportion to the total wave power output of said amplifier, said bridge being maintained slightly unbalanced for all intensity values of said signal, and said bridge and thermosensitive element being so proportioned that said thermosensitive element is maintained at a substantially constant temperature.

2. A combination in accordance with claim 1 in which said bridge circuit comprises a hybrid coil, one winding of said hybrid coil being connected to said output terminals of said bridge, and two other windings of said hybrid coil comprising ratio arms of said bridge.

3. In combination, a plurality of systems in accordance with claim 1 in which all of said thermosensitive elements are maintained at substantially the same constant temperature, and means for variably heating all of the said thermosensitive elements to compensate accurately for variations in ambient temperature, said last-mentioned means comprising a master thermosensitive element having the same electrothermal characteristics as the aforesaid thermosensitive elements and subject to the same variations in ambient temperature, means for variably heating all of said thermosensitive elements under the control of said master element in accordance with ambient temperature variations, and means for maintaining said master thermosensitive element at a substantially constant temperature.

4. In combination, a plurality of systems in accordance with claim 1 in which all of said thermosensitive elements are maintained at substantially the same constant temperature, and means for variably heating all of the said thermosensitive elements to compensate accurately for variations in ambient temperature, said last-mentioned means comprising a master thermosensitive element having the same electrothermal characteristics as the aforesaid thermosensitive elements and subject to the same variations in ambient temperature, means for variably heating all of said thermosensitive elements under the control of said master element in accordance with ambient temperature variations, and means maintaining said master thermosensitive element at an elevated temperature equal to the said substantially constant temperature of said first-mentioned thermosensitive elements.

5. In combination, a multiplicity of like, separately housed thermistors subject to the same variations in ambient temperature, each of said thermistors having an individual heater and one of said thermistors constituting a master thermistor, a bridge circuit comprising said master thermistor as a balance controlling element thereof, an alternating current source connected to the input of said bridge, said current source being of such low intensity that said master thermistor is substantially unheated by bridge currents flowing therefrom, a power amplifier connecting the output of said bridge to all of said heaters including the said heater

for said master thermistor, the gain of said amplifier being so adjusted that the variable power output thereof applied to the heater of said master thermistor is sufficient to maintain said master thermistor at a substantially constant temperature despite fluctuations in ambient temperature.

6. A combination in accordance with claim 5 comprising means for thermally biasing said master thermistor to a temperature substantially equal to the operating temperature of the others of said thermistors.

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