Jan. 14, 1930. M. K. ZINN 1,743,260

MEANS AND METHOD FOR MAINTAINING CONSTANT TRANSMISSION EFFICIENCY

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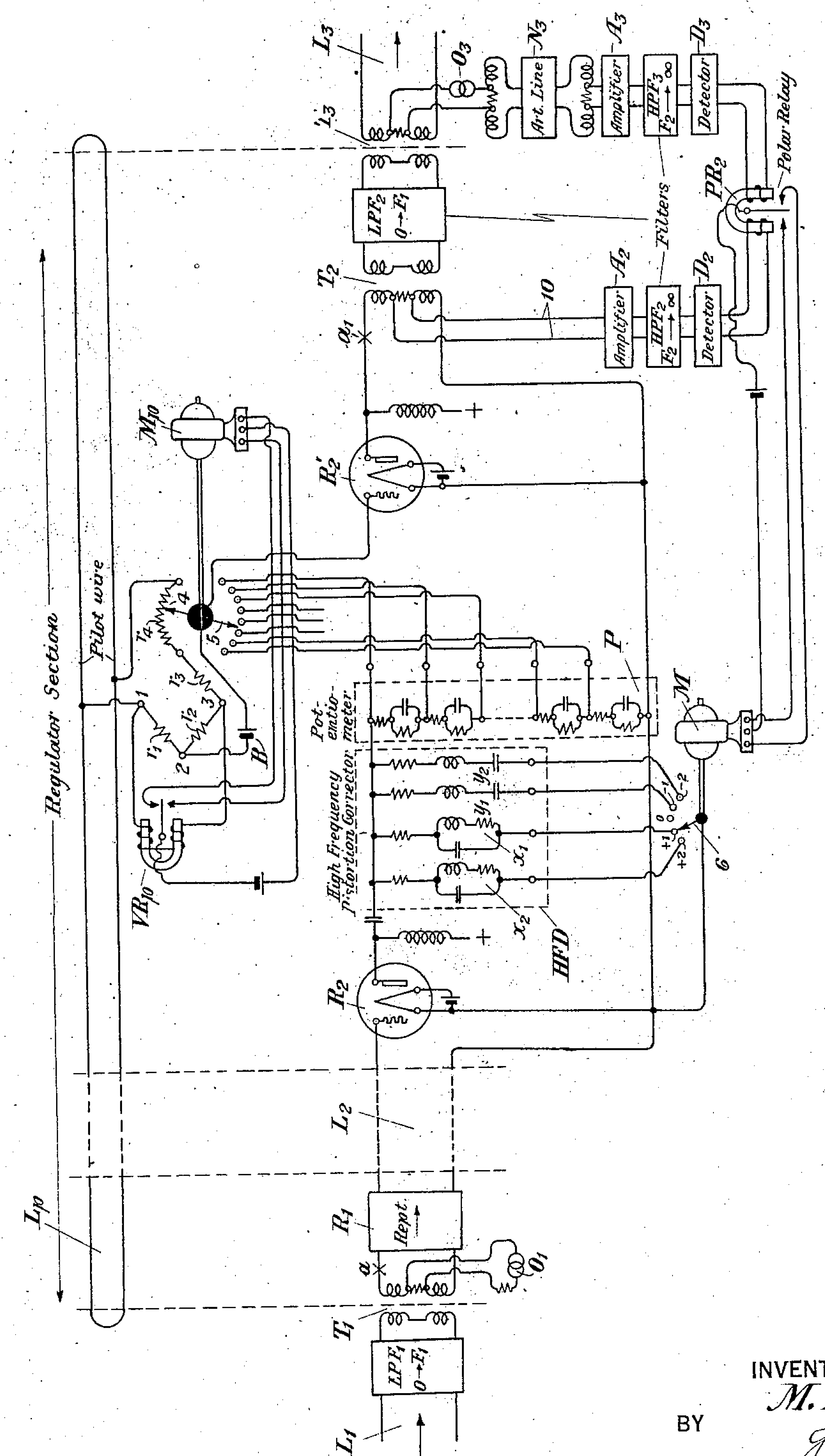

Fig. 1

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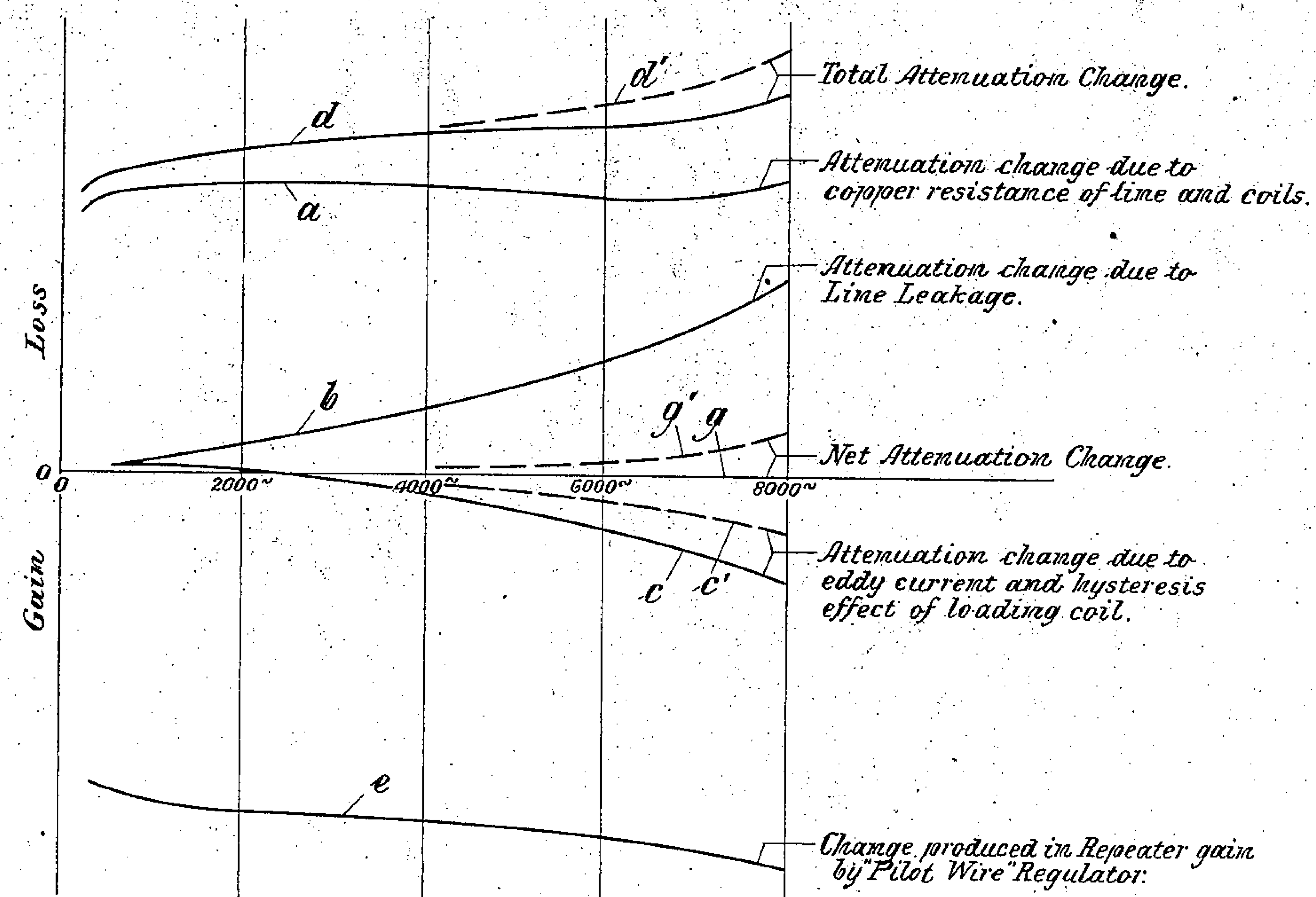

Fig. 2 - Components of change in attenuation of Loaded Line and change in gain of regulating repeater for given increase in temperature.
——— Assumes line and coils at same temperature.
— — — Result when coil temperature lags behind that of line.

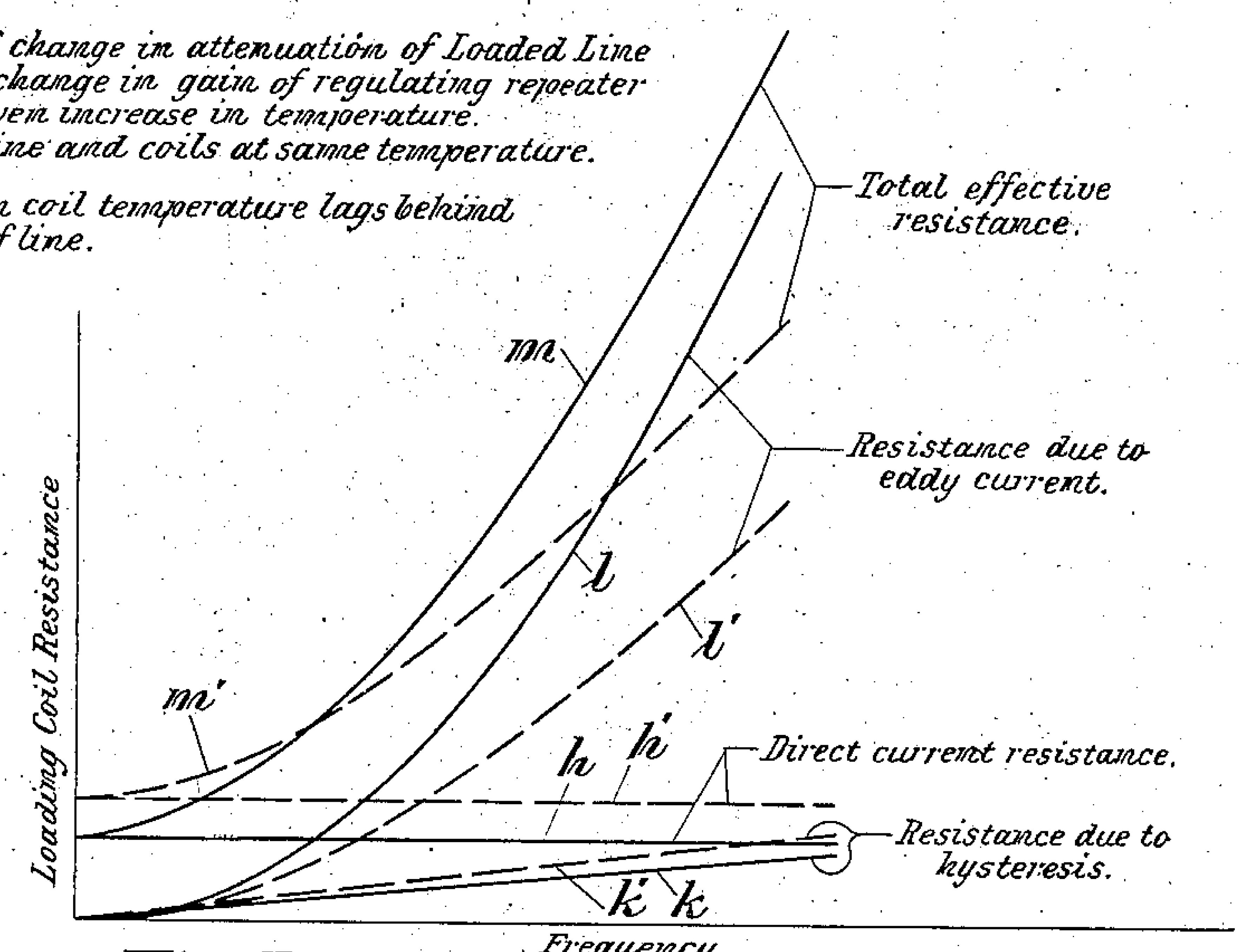

Fig. 3 - Components of the resistance of a loading coil.
——— at a temperature T.
— — — at a temperature T,' higher than T.

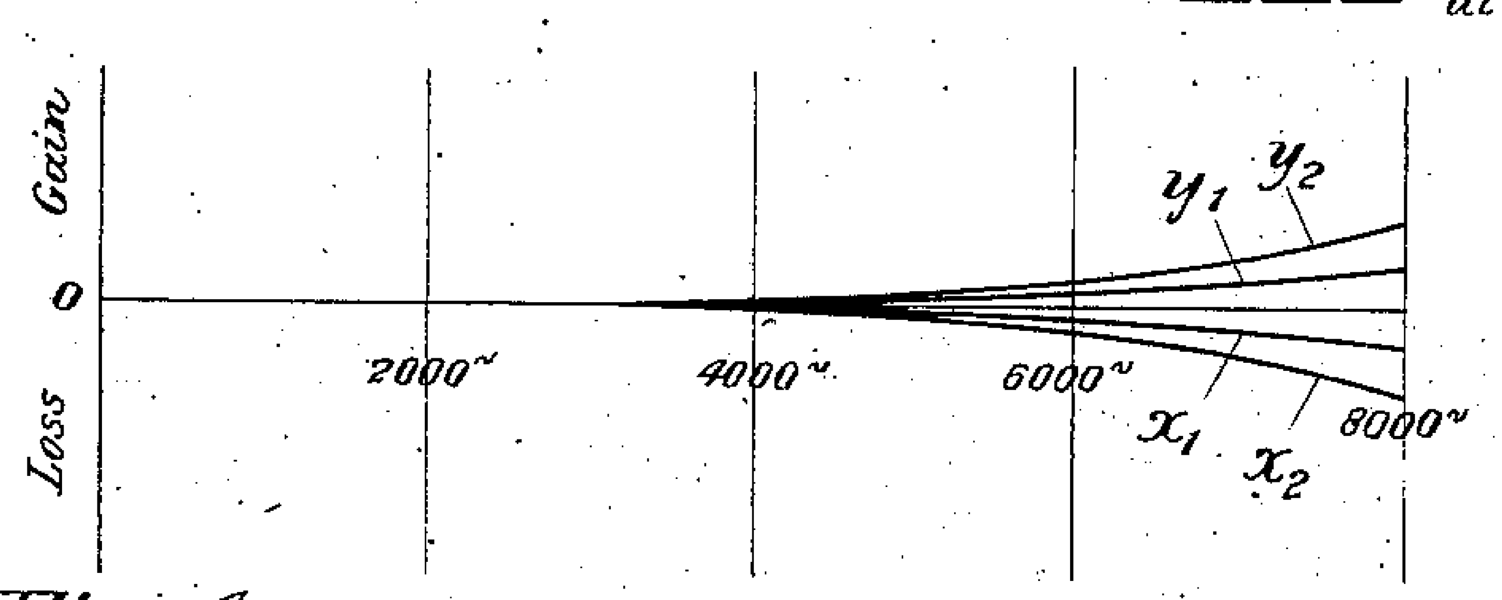

Fig. 4 - Characteristics of Distortion Corrector Network

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UNITED STATES PATENT OFFICE

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MEANS AND METHOD FOR MAINTAINING CONSTANT TRANSMISSION EFFICIENCY

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This invention relates to maintaining constant transmission efficiency at relatively high frequencies on transmission circuits, and is more particularly applicable to high grade program transmission circuits which are loaded to permit of the transmission of a wide band of frequencies.

The development of radio broadcasting has made necessary the transmission of wider ranges of frequencies over certain types of telephone circuits in order that musical programs may be transmitted without distortion. In certain cases it is necessary to load these program circuits in order that a sufficiently wide band of frequencies may be transmitted without undue attenuation. To maintain a uniform transmission loss on circuits of this type, at all frequencies, under different temperature conditions, requires a more elaborate method of transmission regulation than the so-called pilot wire method which is commonly employed for ordinary telephone circuits.

The pilot wire method of regulation involves the provision of a circuit having characteristics similar to the circuits to be controlled and subjected to the same changes in temperature. As the temperature changes, the resistance of the pilot wire changes and automatically controls the adjustments of potentiometers associated with regulating repeaters in the controlled circuits to compensate for the change in transmission efficiency, due to the change in temperature. For a given change in temperature, the change in transmission will be different for different frequencies. The pilot wire regulating system is based upon the principle that if the direct current resistance of the circuit is known, its temperature is known; and once the temperature is known, the transmission loss at all frequencies is known. When this proposition holds true it is possible to design the steps on the potentiometer to give proper increments of gain so that the net loss of the circuit may be maintained at a constant value for all frequencies at any temperature. This is accomplished by making the potentiometer steps not pure resistance (which would introduce a change in the repeater gain which would be constant for all frequencies) but a combination of resistance and reactive elements.

For ordinary telephone transmission, such a method of regulation has been found to be adequate. At higher frequencies, however, this method of regulation is inadequate as it involves the assumption that the form of the transmission-frequency curve at any temperature is always the same. The behavior of the loading coil resistance, however, introduces factors which make the transmission frequency characteristic depend upon the "history" of the cable with respect to temperature. That is to say, the transmission frequency characteristic, particularly at the higher frequencies, may not always be the same at a given temperature, depending upon whether the temperature is rising or falling at the time the given temperature is reached. If the pilot wire circuit is adjusted to give a flat transmission characteristic at a given temperature, it may not be "flat" when that temperature is reached again under a different set of preceding conditions.

The principal factor responsible for these difficulties is the fact that, when the temperature is changing, the temperature of the loading coils tends to lag behind that of the cable by reason of the heat-insulating property of the compound with which the loading coil cases are filled. The result is that the loss at high frequency may increase when the temperature increases and decrease when the temperature decreases, even though the net loss characteristic has been adjusted to be flat on the assumption of the same temperature for both coils and cable.

It is therefore proposed to supplement the pilot wire regulation apparatus by a high frequency pilot channel regulator designed to introduce into the repeater gain characteristic the proper amount of "twist" to compensate for the distortion at high frequency due to the lag in temperature of the loading coils with respect to the cable itself. This pilot channel arrangement involves the transmission of a pilot frequency above the signal range to be transmitted (but below the cut-off of the loading system), and the pilot frequency controls mechanism to provide a continuous automatic means of adjusting the high frequency gain of the regulating repeater in such a way as to maintain a constant value of net loss at the pilot frequency. When the pilot wire regulator operates in response to a change in temperature, and adjusts the potentiometer to restore the transmission frequency characteristic to its normal "flat" condition, any departure of the circuit from this flat condition, due to a lag in the temperature of the loading coils, will result in a change in the normal transmission level of the pilot channel. Consequently the supplementary pilot channel regulating apparatus will be adjusted to introduce suitable networks to bring the pilot frequency back to normal.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawing in which Figure 1 is a circuit arrangement embodying one form of the invention; Fig. 2 is a series of curves illustrating the principles of the invention; Fig. 3 is a series of curves showing the component elements of the resistance of a loading coil; and Fig. 4 shows a series of curves illustrating the character of the adjustments made by the pilot frequency apparatus.

For good program transmission it may be desirable to transmit a range of frequencies extending up to about 8,000 cycles per second. In order that the loaded circuit may properly transmit such a band, the loading system should be so designed as to have a cut-off at about 11,000 cycles. The attenuation loss of such a loaded line, at the more important frequencies in the middle of the transmitted range, is approximately proportional to the total resistance of the line including the resistance of the loading coils. At low frequencies the increment in the loss for a given resistance change is less than that at the middle frequencies, while at high frequencies it is greater.

The change in attenuation for a given temperature change is due to a change in the resistance of the line wires, to a change in the line leakage, and to a change in the resistance of the loading coils. The change in line resistance with temperature is independent of the frequency, and the same holds true for the copper resistance of the loading coils. Referring to Fig. 2, the curve *a* represents the attenuation change at various frequencies due to the copper resistance of the line and loading coils for a given change in temperature. The change in attenuation due to line leakage for a given change in temperature, may be as represented by curve *b* of Fig. 2.

The total change in attenuation for a given temperature also depends upon certain other characteristics of the loading coils other than the copper resistance. If a change in temperature produces a change in the line resistance ΔR, a change in the line leakage ΔG and a change in the loading coil resistance ΔR_c, then the change of attenuation of the loaded line that results from the temperature change may be written approximately

$$\Delta\alpha=\frac{\Delta R}{2Z_o}+\frac{\Delta R_c}{2SZ_o}+\frac{\Delta GZ_o}{2}$$

at frequencies between .3 and .8 of the cut-off frequency. In the foregoing equation, $\Delta\alpha$ is the change in attenuation, Z_o the impedance of the loaded line, and S the spacing of the loading coils.

The change in the loading coil resistance ΔR_c may be divided into three components, the direct current or copper resistance of the coil, a resistance due to hysteresis, and a resistance due to eddy currents. In Fig. 3, the full line curves show how these factors vary with frequency at a given temperature T and the dotted line curves represent the same factors when the temperature is changed to T′, the temperature T′ being higher than T. The direct current or copper resistance is constant at all frequencies and has a value represented by the curve *h* of Fig. 3 at a given temperature T. When the temperature is increased to T′, the direct current resistance will increase to the value represented by the horizontal dotted line curve *h′*.

The part of the resistance of the loading coils that results from hysteresis loss in their cores, increases with temperature, while that part due to eddy current loss decreases as the temperature increases. The resistance component of the loading coil, due to hysteresis at a given temperature, say T, increases with frequency linearly, as indicated by the heavy line curve *k* of Fig. 3. When the temperature is increased to T′, the resistance component due to hysteresis will be as represented by *k′*. From this it will be seen that the percentage change in the resistance component due to hysteresis, for a given change in temperature, is the same at all frequencies.

The resistance component of the loading coil due to the eddy current loss at a given temperature T, increases with the square of the frequency as represented by the curve *e*. When the temperature is increased to T′, the resistance component due to eddy current losses will vary with frequency, as indicated by the curve *e′*. A comparison of the curves *e* and *e′* shows that the resistance component due to eddy currents decreases with an increase in temperature although it increases with frequency.

The total effective resistance of the loading coil at a given temperature T, due to the several factors above enumerated, is represented by the curve *m* of Fig. 3, and the corresponding total resistance at the temperature T′ is represented by the dotted line curve m' of Fig. 3. A study of the curves of Fig. 3 shows that at low frequencies the hysteresis loss is a major part of the loading coil core loss, while at higher frequencies the eddy current loss predominates. The result is that the total effective resistance of the coil increases with frequency, regardless of the temperature, but it increases with temperature only over the lower frequency range while it decreases with an increase in temperature over the higher frequency range, as shown by curves m and m' of Fig. 3.

In considering the changes in attenuation of the loaded line as a whole, it is simpler to treat the attenuation due to the direct current resistance of the loading coil (which is approximately constant with frequency) as a part of the copper resistance of the line as a whole. As has already been stated, the attenuation change, due to the copper resistance of the line and coils for a given change in temperature from, say, T to T′, will be as represented by the curve a of Fig. 2. The corresponding attenuation component due to line leakage will be represented by curve b. The attenuation change due to the hysteresis and eddy current components of the loading coils for a given change in temperature from T to T′, will then be as represented by the curve c of Fig. 2. It will be noted from the curve c that this change in the attenuation constitutes an increase in attenuation for frequencies up to about 2,000 cycles, but for frequencies higher than 2,000 cycles, actually constitutes a decrease in attenuation. This, of course, is to be expected from a consideration of curves m and m' of Fig. 3.

If, now, we combine all of the factors entering into the change in the attenuation due to a given change in temperature, it will be found that the increase in attenuation varies with frequency as represented by the curve d, which is the summation of the values represented by the curves a, b, and c. It will be understood, of course, that the curve d represents the change in attenuation for a given change in temperature and that for different temperature changes there will be a family of curves similar to the curve d, one corresponding to each change in temperature. For each of these curves the attenuation varies with frequency. Obviously, if the shape of the curve corresponding to each given temperature were fixed, it would be possible to keep the attenuation constant at all frequencies, regardless of change in temperature, by means of the pilot wire method. This method depends upon adjusting a potentiometer network in accordance with changes in the resistance of the pilot wire, the theory being that when the resistance is known the temperature is known, and when the temperature is known the curve corresponding to d is known. Therefore, all that is necessary is to include in the circuit some element which will produce a complementary change in attenuation such as is represented by the curve e of Fig. 1, thus bringing the over-all attenuation change to zero, as represented by the curve g.

The pilot wire arrangement for accomplishing this result is illustrated in Fig. 1. In this figure, L_2 is a section of line to be regulated, the said line interconnecting line sections such as L_1 and L_3. A repeater R_1 is interposed between the line sections L_2 and L_1, and regulating repeaters comprising amplifiers R_2 and R'_2 are interposed between the line sections L_2 and L_3. The pilot wire comprises a line section L_p which will be included in the same cable and will be loaded and otherwise constructed in the same manner as the line section L_2. The pilot wire L_p comprises with the resistance r_4 one of the arms of a Wheatstone bridge of which r_1, r_2, and r_3 comprise the other three arms. A voltmeter relay VR_p is bridged across two opposite terminals 1 and 3 of the bridge and a battery B is connected from the terminal 2 to an adjustable terminal 4 which may be shifted to balance the bridge. The voltmeter relay VR_p controls the circuits of a motor M_p which drives a shaft to shift the movable contact 4 along the resistance r_4 of the bridge. Consequently, when the resistance of the pilot wire L_p changes with temperature and the bridge becomes unbalanced, the voltmeter VR_p closes one or the other of its contacts, depending upon the sense in which the bridge is unbalanced, to drive the motor forward or backward, as the case may be, until the bridge is automatically balanced by the adjustment of the contact 4.

The operation of the motor M_p also drives the switch-arm 5 over a series of contacts which are connected to various points on the potentiometer P. As the switch-arm 5 is connected with the grid of the repeater R'_2, the shifting of the switch 5 along the contacts leading to the various points of potentiometer P changes the gain of the repeater accordingly. On the assumption that the resistance of the pilot wire changes with temperature in a similar manner to that of the line section L_2, the result of this action is that the change in attenuation due to the change in resistance of the line section L_2, will be compensated for by the adjustment of the gain of the amplifier R_2. If the potentiometer P consisted of pure resistance, the change in gain of the amplifier would be uniform with frequency, whereas it should vary with frequency in such a manner as to compensate for the variation of the curve d of Fig. 2. This may be accomplished by including reactance elements, such as condensers, in the various sections of the potentiometer P.

With such an arrangement, the compensation for each change in temperature could be taken care of provided that the curves, such as d, would always be the same shape when the circuit arrived at that temperature. For ordinary telephone purposes, where frequencies not exceeding about 3,000 cycles are involved, it has been found that the curve d is nearly enough the same shape under all conditions, so that the regulation obtained by the pilot wire scheme above described is sufficiently accurate for practical purposes. When, however, we are dealing with frequencies as high as 6,000 or 8,000 cycles, the behavior of the loading coil resistance introduces factors which make the variation loss characteristic, represented by the curve d, depend upon the "history" of the cable with respect to temperature. The variation loss at these high frequencies may not always be the same at a given temperature, depending upon whether the temperature is rising or falling at the time the given temperature is reached.

This is due principally to the fact that, as the temperature of the system changes, the temperature of the loading coils tends to lag behind that of the cable conductors by reason of the heat-insulating property of the compound with which the loading coil cases are filled. Consequently, when we have a change in temperature which would produce attenuation changes corresponding to the curves a and b as a result of the change in copper resistance and the change in line leakage, the component of the attenuation change due to the eddy current and hysteresis effect of the loading coil, will not attain the value indicated by the curve c but will attain the lesser value indicated by the curve c', due to the fact that the loading coil has not been heated up to the same point as the line conductors. This tends to produce an increase in the attenuation loss at the higher frequencies, due to an increase in temperature as indicated by the curve d' of Fig. 2. Therefore, when the pilot wire arrangement adjusts the potentiometer to produce a compensating effect in accordance with the curve e, the net attenuation change instead of being zero, as represented by the curve g, becomes that represented by the curve g' of Fig. 2. The curve g' may be higher or lower than indicated at the higher frequencies, depending on the amount that the loading coil temperature lags behind the temperature of the line conductor.

The curves of Fig. 2 are drawn on the assumption that the temperature is increased to a given temperature. If, however, the temperature had been above this final temperature and had decreased to the same temperature, a series of curves similar to that of Fig. 2 but having opposite signs would result, so that in this case the net attenuation change represented by the curve g' would be in the direction of a gain rather than a loss. The result is that with the pilot wire arrangement the net attenuation change instead of being a straight line such as the curve g, may have a "twist" either up or down, depending on whether the temperature is rising or falling, due to the lag in the temperature of the loading coil. This is particularly noticeable at the higher frequencies, and consequently, it is not possible by means of the pilot wire regulator to produce a sufficiently accurate compensation for the change in attenuation due to a change in temperature.

It is therefore proposed to supplement the action of the pilot regulator by high frequency pilot regulation. For this purpose a high frequency pilot current is transmitted over the circuit to be regulated, the pilot frequency being preferably just above the range of frequencies to be used during transmission. If, therefore, after the pilot wire arrangement has operated in response to a change in temperature, the net attenuation change departs from zero, as represented by the curve g' or any similar curve (either gain or loss) the amplitude of the high frequency pilot current will be correspondingly changed and can produce an auxiliary regulation as will now be described.

For this purpose the pilot current from the source O_1 is applied to the line section L_2 through the secondary of the transformer T_1. This current is then transmitted through the repeater R_1 over the line L_2, through first stage of the regulating repeater R_2, over the potentiometer P, through the second stage of the regulating repeater R'_2 to the primary of the transformer T_2. A low pass filter LPF_2 is interposed between the transformer T_2 and the transformer T_3 to prevent the pilot current being transmitted to the line section L_3. The pilot current therefore is transmitted over conductors 10 through the amplifier A_2 and high pass filter HPF_2 to a detector D_2 in whose output circuit is arranged one winding of a polar relay PR_2. A pull will therefore be produced by the winding of the polar relay PR_2 which is proportional to the amplitude of the high frequency pilot current transmitted over the line section L_2.

As the armature of the polar relay PR_2 should be in neutral position for a certain normal amplitude of the pilot current, a current of fixed amplitude is supplied by the generator O_3 through the pad or artificial line N_3 having the desired net loss at the pilot frequency for the circuit between a and a'. This current is then transmitted from an amplifier A_3 similar to the amplifier A_2 through a filter HPF_3 similar to the filter HPF_2 to the detector D_3 which has in its output circuit another winding of the polar relay PR_2. The current supplied by the source O_3 may also be transmitted over the next line section L_3 as the high frequency pilot current for that section by means of the connections shown.

With the arrangement above described, the polar relay PR_2 will operate whenever the attenuation of the circuit between a and a' departs from the normal value at the pilot frequency. If the attenuation increases, the armature of the relay will be shifted in one direction and if it decreases, it will be shifted in the opposite direction. When a change in temperature of the circuit occurs, the normal pilot wire regulator will operate to readjust the potentiometer P. If, after this readjustment, the attenuation of the circuit is normal at the pilot frequency (as it would be if the resultant net attenuation change corresponded to the curve g of Fig. 2), the polar relay PR_2 would not be actuated. If, however, there is a twist up or down in the curve corresponding to g after the pilot wire regulator is operated, the pilot channel apparatus will cause the polar relay PR_2 to shift its armature in one direction or the other, depending upon whether the twist is up or down. The polar relay PR_2 controls a motor M which drives a switch arm 6 over a series of contacts which bridge one or the other of several networks of a high frequency distortion corrector HFD across the circuit between the repeaters R_2 and R'_2.

When the armature of the polar relay PR_2 is in neutral position, the switch arm 6 rests upon its zero contacts and none of the networks of the distortion corrector HFD_2 will be bridged across the circuit. If, however, the amplitude of the pilot frequency departs from the normal as represented by the line g of Fig. 2, after the pilot wire arrangement has been readjusted in response to a change in temperature, the polar relay PR_2 will cause the motor M to shift the arm 6 to one of the contacts serving to bridge the network of the high frequency distortion corrector across the circuit.

The high frequency distortion corrector HFD, as shown, includes two each of two different types of networks, although it will be understood that any particular number of each type may be employed as conditions may require. When the temperature is rising, and the loading coils lag in temperature behind the rest of the circuit, the net attenuation curve of Fig. 2 will have a rising characteristic so that the loss increases with frequency. To offset this the motor M cuts in one of the networks x_1 or x_2, which will have a complementary falling characteristic as indicated by the curves of Fig. 4. If, on the other hand, the temperature is falling, the net attenuation change curve corresponding to g' of Fig. 2, will have a falling characteristic, in which case the motor M acts to cut in one of the networks such as y_1 or y_2 which have a rising characteristic.

The operation of the pilot channel arrangement, including the polar relay PR_2, motor M, and high frequency distortion corrector HFD, is to correct a "twist" up or down in the frequency transmission characteristic of the system which results from any adjustment of the potentiometer P by the pilot wire arrangement. The pilot wire arrangement will of course be common to a number of circuits, so that by providing the shaft of the motor M with a number of switch arms corresponding to 5, the potentiometers of other line sections in the same cable as the line section L_2 may be regulated. In a similar manner the pilot frequency apparatus associated with the line section L_2 may serve for a group of similar lines by arranging the motor M to drive switches corresponding to 6 for such other lines. This will result in making the same adjustments of the high frequency distortion correctors of each of the lines subject to the same conditions.

A line used for broadcasting must handle a wide range in electrical power level, particularly when orchestral music is being transmitted. For such service, a long loaded line may introduce appreciable distortion because the shape of the transmission-loss characteristic is affected by the amount of power sent into the line. This type of distortion is due to hysteresis losses in the loading coils.

The part of the effective resistance of the loading coil attributable to hysteresis increases linearly with the strength of the current flowing in the coil. When strong currents are transmitted over a loaded line, the resistance, and therefore, the attentuations are greater for strong currents than for weak currents. (The eddy current loss does not vary with current strength.) Consequently, a variation in the attenuation of a loaded line results from change in the power level, this variation being of a similar type to that represented by the curve g' of Fig. 2 although at any given instant it may be in a direction to either oppose or aid the distortion due to the lag in temperature of the loading coils.

The pilot frequency arrangement may also serve to correct for the distortion introduced by the change in power level for the obvious reason that the pilot frequency is responsive to any departure of the net attentuation curve g from its normal zero position whether it be caused by variation in the power level or by lag in the temperature of the loading coil. The high frequency pilot arrangement serves to correct the "twist" in the high frequency range regardless of the temperature adjustment of the pilot wire. It will, of course, be necessary, where the networks of the high frequency distortion corrector HFD are designed to take care of the effect in the change of power level as well as lag in the temperature of the loading coils, to provide a separate pilot channel apparatus for each circuit to be corrected. This is for the obvious reason that the changes in the power level are not the same on all of the circuits in the same cable as they may be transmitting different programs.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a system for regulating the transmission over a loaded line in which in response to a given change in temperature the resultant transmission change varies with frequency, the method which consists in observing the change in resistance of a circuit similar to the loaded line to be regulated, adjusting a variable transmission element of the loaded line, to produce a transmission change corresponding to the observed change in resistance, and varying with frequency in a manner complementary to that of the loaded line, on the assumption that the loading coils have undergone the same temperature change as the other elements of the line, transmitting a pilot wave over a circuit having the same electrical characteristics as the loaded line to be regulated, observing the variation of the level of the received pilot wave from the level it should have under the assumed condition after the adjustment indicated by the observed resistance change has been made, and adjusting another adjustable transmission element of the loaded line to compensate for the observed change in level.

2. In a system for regulating the transmission over a loaded line in which in response to a given change in temperature the resultant transmission change varies with frequency, the method which consists in observing the change in resistance of a circuit similar to the loaded line to be regulated, adjusting a variable transmission element of the loaded line, to produce a transmission change corresponding to the observed change in resistance, and varying with frequency in a manner complementary to that of the loaded line, on the assumption that the loading coils have undergone the same temperature change as the other elements of the line, transmitting a pilot wave over a circuit having the same electrical characteristics as the loaded line to be regulated so that the pilot wave will be received at a predetermined normal level when the circuit is properly regulated, observing any departure of the received pilot wave from normal level, and adjusting another adjustable transmission element to compensate for the observed change in level.

3. In a system for regulating transmission, a loaded line in which in response to a given change in temperature the resultant transmission change varies with frequency, a pilot circuit having characteristics similar to those of the loaded line, means to indicate the change in resistance of the pilot circuit resulting from a change in temperature, an adjustable transmission element in said loaded line, means to adjust said transmission element in accordance with the indicated change in resistance to produce a transmission change varying with frequency in a manner complementary to that which would result in the loaded line in response to the change in temperature if all parts of the line including the loading coils had undergone the same temperature change, means to transmit a pilot wave over a circuit similar to said loaded line and subjected to similar transmission adjustments, means to indicate after such transmission adjustment any departure from the normal level of said pilot wave due to a lag in the temperature change of the loading coils of the circuit with respect to other elements of the circuit, a second adjustable transmission element in said loaded line, and means to adjust said second transmission element to compensate for the indicated change of level of said pilot wave.

4. In a system for regulating transmission, a loaded line in which in response to a given change in temperature the resultant transmission change varies with frequency, a pilot circuit having characteristics similar to those of the loaded line, means to indicate the change in resistance of the pilot circuit resulting from a change in temperature, an adjustable transmission element in said loaded line, means to adjust said transmission element in accordance with the indicated change in resistance to produce a transmission change varying with frequency in a manner complementary to that which would result in the loaded line in response to the change in temperature if all parts of the line including the loading coils had undergone the same temperature change, means to transmit a pilot wave over a circuit similar to said loaded line and subjected to similar transmission adjustments, means to indicate any departure from the normal level of said pilot wave, a second adjustable transmission element in said loaded line, and means to adjust said second transmission element to compensate for the indicated change in level.

5. In a system for regulating transmission, a loaded line in which in response to a given change in temperature the resultant transmission change varies with frequency, a pilot circuit having characteristics similar to those of the loaded line, means to indicate the change in resistance of the pilot circuit resulting from a change in temperature, an adjustable transmission element in said loaded line, means controlled by said indicating means for automatically adjusting said transmission element in accordance with the indicated change in resistance to produce a transmission change varying with frequency in a manner complementary to that which would result in the loaded line in response to the

change in temperature if all parts of the line including the loading coils had undergone the same temperature change, means to transmit a pilot wave over a circuit similar to said loaded line and subjected to similar transmission adjustment, means to indicate after such transmission adjustment any departure from the normal level of said pilot wave due to a lag in the temperature change of the loading coils of the circuit with respect to other elements of the circuit, a second adjustable transmission element in said loaded line, and means automatically controlled by said last-mentioned indicating means to automatically adjust said second transmission element to compensate for the indicated change of level of said pilot wave.

6. In a system for regulating transmission, a loaded line in which in response to a given change in temperature the resultant transmission change varies with frequency, a pilot circuit having characteristics similar to those of the loaded line, means to indicate the change in resistance of the pilot circuit resulting from a change in temperature, an adjustable transmission element in said loaded line, means controlled by said indicating means for automatically adjusting said transmission element in accordance with the indicated change in resistance to produce a transmission change varying with frequency in a manner complementary to that which would result in the loaded line in response to the change in temperature if all parts of the line including the loading coils had undergone the same temperature change, means to transmit a pilot wave over a circuit similar to said loaded line and subjected to similar transmission adjustment, means to indicate any departure from the normal level of said pilot wave, a second adjustable transmission element in said loaded line, and means controlled by said last-mentioned indicating means to automatically adjust said second transmission element to compensate for the indicated change in level.

7. In a system for regulating transmission, a loaded line in which in response to a given change in temperature the resultant transmission change varies with frequency, a pilot circuit having characteristics similar to those of the loaded line, means to indicate the change in resistance of the pilot circuit resulting from a change of temperature, an amplifier in said loaded line and an adjustable potentiometer associated with said amplifier, said potentiometer including reactance elements, means to adjust said potentiometer with its reactance elements in accordance with the indicated change in resistance to produce, by the cooperation of said potentiometer and amplifier, a transmission change varying with frequency in a manner complementary to that which would result in the loaded line in response to the change in temperature if all parts of the line including the loading coils had undergone the same temperature change, means to transmit a pilot wave over a circuit similar to said loaded line and subjected to similar transmission adjustments, means to indicate after such transmission adjustment any departure from the normal level of said pilot wave due to a lag in the temperature change of the loading coils of the circuit with respect to the other elements of the circuit, an adjustable transmission element associated with said loaded line and capable of adjustment to produce varying degrees of transmission change with frequency, and means to adjust said transmission element to compensate for the indicated change of level of said pilot wave.

8. In a system for regulating transmission, a loaded line in which in response to a given change in temperature the resultant transmission change varies with frequency, a pilot circuit having characteristics similar to those of the loaded line, means to indicate the change in resistance of the pilot circuit resulting from a change of temperature, an amplifier in said loaded line and an adjustable potentiometer associated with said amplifier, said potentiometer including reactance elements, means to adjust said potentiometer with its reactance elements in accordance with the indicated change in resistance to produce, by the cooperation of said potentiometer and amplifier, a transmission change varying with frequency in a manner complementary to that which would result in the loaded line in response to the change in temperature if all parts of the line including the loading coils had undergone the same temperature change, means to transmit a pilot wave over a circuit similar to said loaded line and subjected to similar transmission adjustments, means to indicate any departure from the normal level of said pilot wave, an adjustable transmission element in said loaded line capable of being adjusted to produce varying degrees of transmission change with frequency, and means to adjust said transmission element to compensate for the indicated change in level.

In testimony whereof, I have signed my name to this specification this 18th day of October 1928.

MANVEL K. ZINN.