

March 29, 1949.

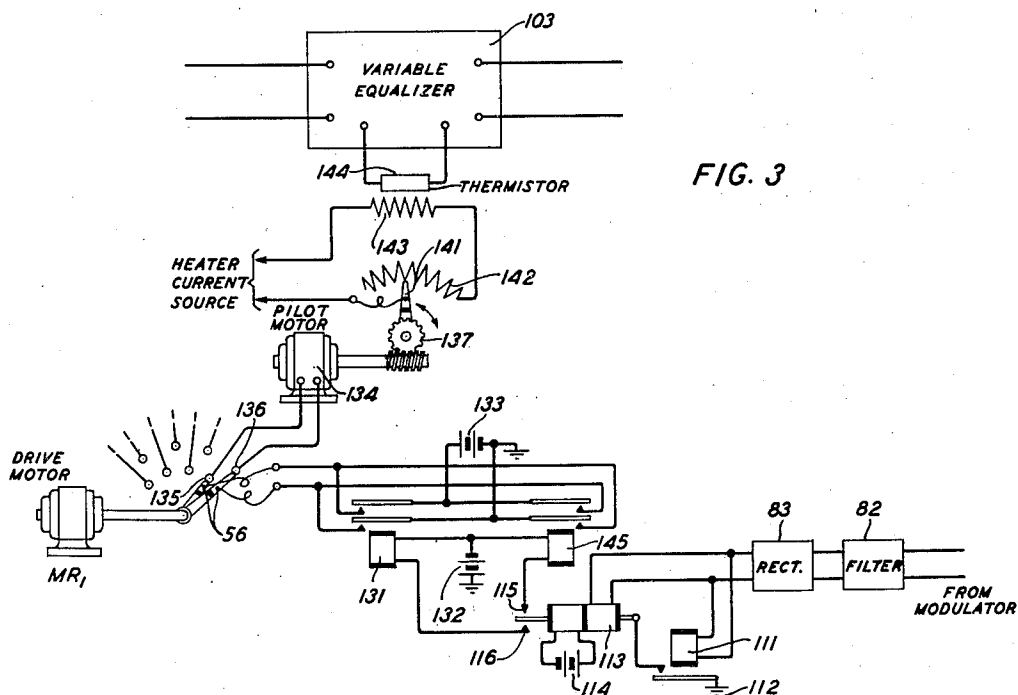
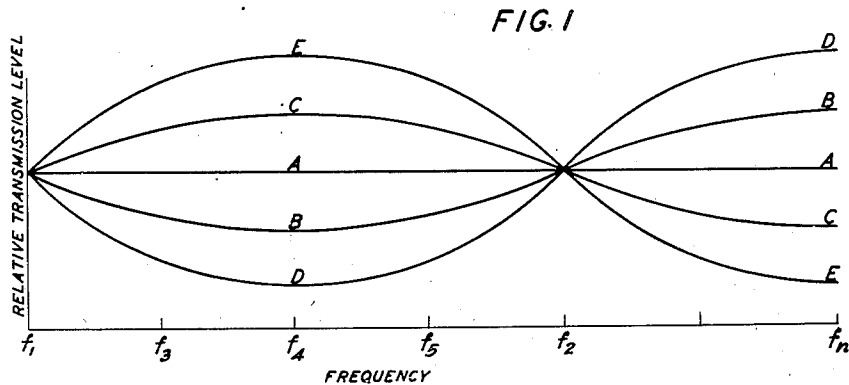
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2,465,531

TRANSMISSION CONTROL SYSTEM

Filed June 8, 1945

2 Sheets-Sheet 1



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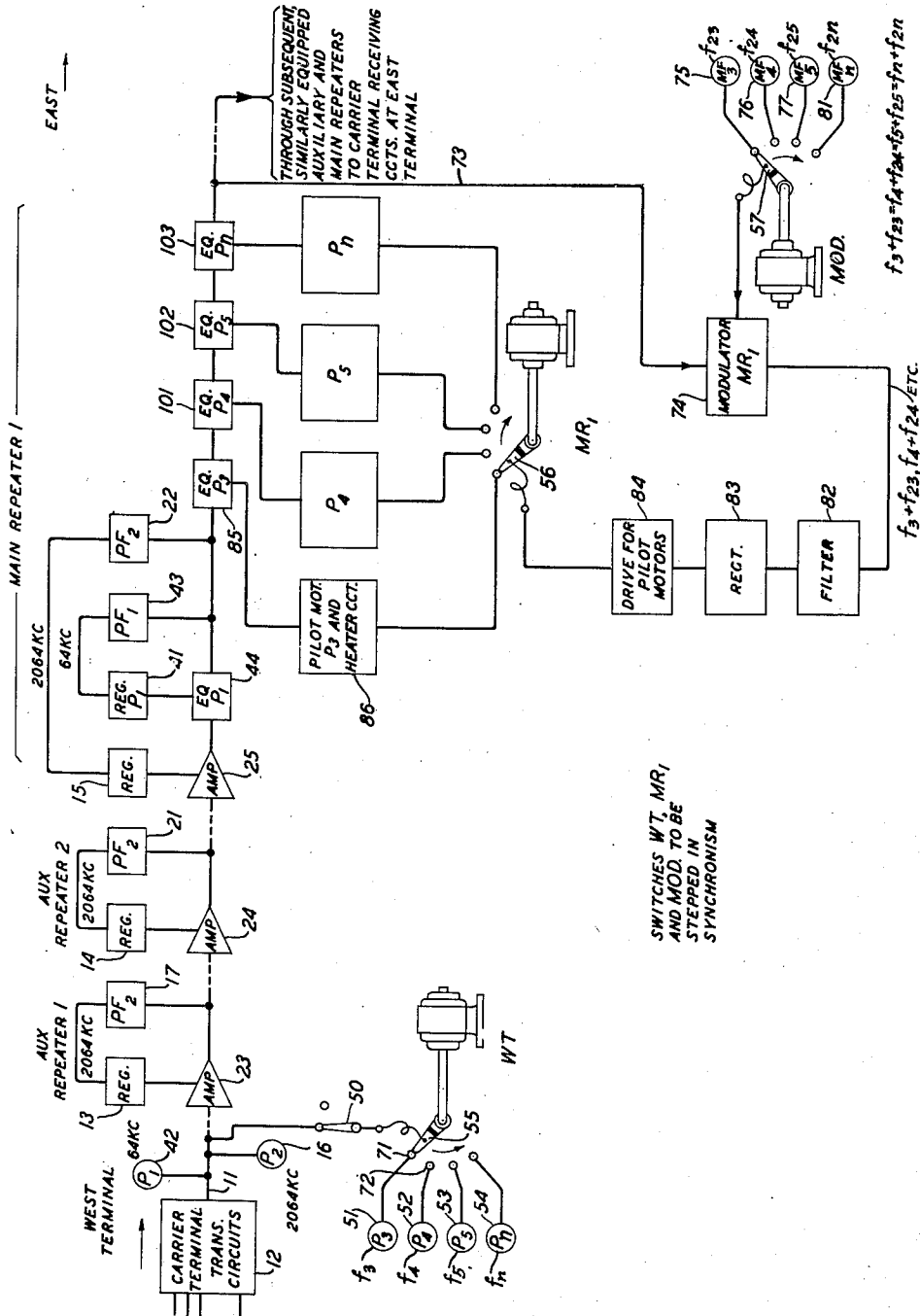
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2 Sheets-Sheet 2

FIG. 2



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TRANSMISSION CONTROL SYSTEM

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3 Claims. (Cl. 178—44)

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This invention relates to electric wave transmission systems and more particularly to the regulation of transmission over such systems.

It is an object of the present invention to improve the quality of transmission over an electric wave transmission system.

Another object of the present invention is to provide automatic transmission regulation of increased effectiveness.

In present-day long transmission systems, it is customary practice to provide means at some, or all, of the separated repeater points of the system for transmission regulation, i. e., for compensating for certain variables in transmission such, for example, as the changing resistance of the line with temperature changes. These regulators may be, to a large extent, automatic in their operation and may operate under control of so-called pilots or pilot frequencies, transmitted over the system. For example, in certain broad band systems, such as the coaxial cable system, at least two pilot frequencies have commonly been used for purposes of regulation. One of these pilots, the one provided for compensating for changes of cable attenuation with temperature changes, has usually been placed fairly high in the frequency band to be covered inasmuch as the change of cable attenuation with temperature variations increases with increasing frequency. Another of the pilot frequencies, the one provided for controlling "flat gain," i. e., for introducing changes of gain that are uniform over the entire frequency range, is usually placed at, or near, the bottom of the frequency range to be covered.

If the compensation resulting from use of the above two pilots were perfect, the characteristic of transmission level versus frequency would be a straight line. However, the regulation introduced by the two pilots is entirely correct only at the frequencies of the pilots themselves and considerable departure can occur between the pilots in a system wherein the transmitted frequency band is wide. Corrections for such departures could be achieved by multiplying the number of pilot channels but this involves complication and expense and may make it difficult to utilize the frequency range as desired. Furthermore the additional pilots may overload the amplifiers and make it necessary to restrict the number of working channels.

A feature of the present invention is a "roving" pilot which is applied intermittently to the line and which successively introduces corrections at several different frequencies.

In accordance with a specific embodiment of

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the invention, the usual two pilot frequencies, i. e., the pilot placed high in the frequency range for correcting for change of cable attenuation with temperature and the pilot placed near the bottom of the frequency range for controlling flat gain, are provided. In addition a relatively large number of different pilot frequencies (i. e., the roving pilots) are applied in turn to the line, these pilot frequencies extending over the range between the usual two pilot frequencies referred to above. At the receiving end of the line, or other point of regulation, the respective frequencies making up the roving pilots are modulated with respective frequencies so selected that the produced frequency is the same regardless of which pilot is being transmitted at the particular moment. The produced frequency is applied to the equalizer elements of the regulator. If desired the roving pilots may be utilized only during periods when the revenue load on the system is normally light for example during the late hours of the night.

Complete understanding of the arrangement contemplated by the present invention may be gained from consideration of the following detailed description and the accompanying drawings in which:

Fig. 1 is a set of curves illustrating possible relative transmission level vs. frequency relationships;

Fig. 2 is a schematic representation of a portion of a wide band transmission system showing the application of the various pilots at one terminal and the manner in which the pilots are utilized at a main repeater station for regulation; and

Fig. 3 is a schematic representation showing in somewhat more detail the arrangement associated with one of the equalizers for varying the heating current applied to a variable element of the equalizer in accordance with variations in the regulating frequency.

Referring now to Fig. 1, it will be assumed that f_1 and f_2 correspond, respectively, to the flat-gain pilot frequency and the pilot frequency provided for correction of cable attenuation change with temperature, i. e., the two pilot frequencies normally applied to a long transmission system. With use of these two pilot frequencies, if compensation were perfect, the characteristic of transmission level versus frequency would be as indicated by straight line A of Fig. 1. Due to residual effects, however, the compensation obtained will be imperfect and may at different times result in transmission level versus frequency

characteristics such as those indicated by curved lines B, C, D and E. It will be noticed that these lines all pass through the same point at the two assumed pilot frequencies f_1 and f_2 but exhibit substantial departures at other frequencies.

In order to correct for these departures it is possible to employ additional pilot frequencies. Considerable improvement might be obtained, for example, with two additional pilots placed at f_4 and f_n . It is apparent, however, that, even though provision of these additional pilots would result in the transmission level versus frequency curves passing through additional common points, f_4 and f_n , there would still be bowed characteristics at frequencies in between. These curves could finally be straightened out by addition of sufficient pilots but as pointed out above it is undesirable to overload the system with pilots. In accordance with the arrangement contemplated by the present invention and now to be described in detail, pilots are introduced successively at points $f_3, f_4, f_5 \dots f_n$, the number (n) being sufficient to bring within limits substantially all bowed portions of the transmission level versus frequency curves. The system is not overloaded with additional pilots, however, in view of the fact that the roving pilots are applied only intermittently and may, if desired, be withheld entirely during periods when the revenue load is high.

Referring now to Fig. 2, there is illustrated schematically the portion of a broad band coaxial system between one terminal (west) and the first main repeater station; there are shown included between the terminal and the main repeater station, two auxiliary repeaters. The main repeater stations, which are normally attended, may be of the order of 50 miles apart (and this may also be the approximate distance between the terminal and the first main repeater) while the auxiliary repeater stations, which are normally unattended, may be of the order of five miles apart. There are usually two amplifiers at each repeater station, one for each direction of transmission. (In Fig. 2 only the west-east amplifier in each case is illustrated.) These amplifiers are for transmission under normal conditions and, in addition, one or more amplifiers may be provided at some or all of the stations for emergency purposes.

The message channels are applied to line 11 at the west terminal in the usual manner over the terminal transmitter circuits 12. The message channels may be divided into a plurality of different groups, different frequency bands being occupied by the different groups. Alternatively part or all of the frequency band may be used for television.

In accordance with the usual practice there is provided at each auxiliary repeater station and at the main station means for compensating for changes of cable attenuation with temperature, regulator 13 being provided at auxiliary repeater No. 1 for this purpose, regulator 14 at auxiliary repeater No. 2 and regulator 15 at main repeater No. 1. These regulators are controlled by pilot frequency P_2 (2064 kilocycles) which is applied to line 11 from source 16. Band-pass filters 17, 21 and 22 (PF_2) are designed to pass a narrow band of frequencies, which includes 2064 kilocycles. Regulators 13, 14 and 15 may be of the type whereby adjustment is secured through use of thermistors in the feedback circuit of the respectively associated amplifiers 23, 24 and 25. The

thermistors are heated from the output of the regulators which, in turn, are controlled by the amplitude of the pilot frequency P_2 . (The provision of a thermistor in the feedback path of an amplifier for gain control purposes has been described in earlier patents, for example, Patent 2,179,915 issued November 14, 1939 to R. R. Blair.)

In addition to the regulator just referred to and also in accordance with the usual practice, there is provided at main repeater No. 1 (as well as at subsequent main repeaters) regulator 41 for controlling flat gain. This regulator operates under control of pilot frequency P_1 (64 kilocycles) which is applied to line 11 at the west terminal from source 42; this frequency is applied to regulator 41 through band-pass filter 43, (PF_1), which is designed to pass a narrow band of frequencies including 64 kilocycles. The controlling output current of regulator 41 is not applied to amplifier 25 (as was the output of regulator 15) but is applied instead to transmission equalizer 44. Equalizer 44 may be of any suitable type adapted to be regulated under control of a pilot current; for example H. W. Bode Patent 2,096,027, issued October 19, 1937, discloses an adjustable attenuation equalizer and brings out in the paragraph starting with line 60, column 1, page 8 of the specification that this type of equalizer may be adjusted in accordance with variations of a pilot current transmitted over the line.

In accordance with the novel features of the present invention, there are provided at the west terminal, in addition to the usual pilot sources 16 and 42, a plurality of additional sources of different pilot frequencies, sources 51, P_3 (f_3); 52, P_4 (f_4); 53, P_5 (f_5); and 54, P_n (f_n) being illustrated. These pilot frequencies are preferably located between the various message channels.

The last-mentioned pilots, i. e., f_3, f_4, f_5 and f_n , are applied to line 11 in a "roving" or intermittent manner through operation of switch 55 (WT) assuming that switch 50 is in closed position. Switch 55 at the west terminal operates in synchronism with switches 56 (MR_1) and 57 (MOD) of main repeater station 1. When the rotating brush of switch 55 engages contact 71, pilot frequency f_3 will be applied to the line; when contact 72 is engaged, pilot frequency f_4 will be applied and so on. The particular one of the group of pilot frequencies that is being applied to line 11 at the moment is transmitted over the line to main repeater station No. 1 where it passes over line 73 to modulator 74.

A group of frequency sources, corresponding in number to the number of roving pilot sources at the west terminal, is provided at main repeater station No. 1. Illustrated are sources 75, MF_3 (f_{23}); 76, MF_4 (f_{24}); 77, MF_5 (f_{25}); and 81, MF_n (f_{2n}) being shown. These sources are applied intermittently to modulator 74, through switch 57, in step with the application of the intermittent pilots, $f_3 \dots f_n$, to line 11 at the west terminal. Thus, as pilot f_3 is applied to line 11 and to modulator 74, modulating frequency f_{23} is simultaneously applied to the modulator through switch 57. In the same way pilot frequency f_4 and modulating frequency f_{24} are simultaneously applied to modulator 74 as are pilot frequency f_5 and modulating frequency f_{25} and pilot frequency f_n and modulating frequency f_{2n} .

The modulating frequencies are so selected that the modulation product produced in the output of modulator 74 by each combining process is always the same, i. e.,

$$f_3 + f_{23} = f_4 + f_{24} = f_5 + f_{25} = f_n + f_{2n}$$

The fact that this frequency is the same at all times regardless of the particular pilot frequency applied to the line is a valuable feature of the arrangement as it reduces materially the amount of equipment that must be provided for the purposes of regulation. A modulation product, for example the upper side frequency resulting from the modulating process which we may refer to as f_m , passes through band-pass filter 82, is rectified by rectifier 83 and applied to the motor drive 84. (These portions of the equipment will be described in greater detail subsequently with reference to Fig. 3.) A similar result could be obtained by choosing different modulating frequencies and using the lower side frequency from the modulator.

Switch 56, as previously stated, operates in synchronism with switches 55 and 57 so that as pilot f_3 is applied to line 11, frequency f_m is applied to the pilot motor and heater circuit associated with equalizer 85; this equipment is represented by box 86 in Fig. 2. Also, as pilot frequency f_4 is applied to the line 11, f_m is applied to the motor circuit associated with equalizer 101. Frequency f_m is applied to the motor circuit associated with equalizer 102 when pilot frequency f_5 is applied to the line and frequency f_m is applied to the pilot motor and heater circuit associated with equalizer 103 when pilot frequency f_n is applied to the line.

The equalizers 85, 101, 102 and 103 are designed to introduce successive corrections in different parts of the transmission band and it is obvious that less than the four illustrated, or more than four, may be provided depending upon the width of the transmission band of the system as well as upon the exactness of the regulation required. These equalizers may be of the general type of variable equalizer disclosed in Fig. 7, page 238 of the article "Variable equalizers" by H. W. Bode, Bell System Technical Journal, April 1933. The variable resistor will be presumed, in the present instance, to be a thermistor. The four equalizers 85, 101, 102 and 103 may be looked upon as comprising a transmission equalizing network with individual control circuits for each respective equalizer. It will be observed that the received pilots themselves pass through the equalizing network before being applied to modulator 74.

It will be apparent that, through provision of the plurality of sources of modulating frequencies at the main repeater station and the novel manner in which they are utilized whereby the regulating current applied to the pilot motors is the same frequency at all times, considerable economy of apparatus results, it being possible to utilize a single set of equipment (filter 82, rectifier 83 and drive 84) common to all of the equalizers. However, in view of the novel way in which this regulating current is applied to each equalizer in step with the application of the pilots to the line at the terminal end, the regulating current applied to the equalizers at any instant corresponds in amplitude to the corresponding pilot frequency as it enters line 73.

There is illustrated in greater detail in Fig. 3 the arrangement of drive 84 of the pilot motors and of the heater circuit associated with equalizer 103. (The pilot motor and heater circuits of all of the equalizers are similar and those of equalizer 103 have been selected for detailed description.) In order to add detail to the showing

of this portion of the circuit it has been disclosed in the normal "two-wire" form rather than in the "single-wire" form that was followed in Fig. 2.

Referring now to Fig. 3, relay 111 is adapted to be operated by rectified current supplied by rectifier 63 whenever a regulating current is supplied over line 73 (Fig. 1) to the modulator. Operation of relay 111 connects ground 112 to the armature of marginal relay 113. The rectified pilot current is applied to the right-hand winding of marginal relay 113 while direct current from battery 114 is applied to the left-hand winding thereof. The relay is so designed and adjusted that under normal conditions, i. e., when the amplitude of the received pilot current is such that no adjustment in the transmission level is required, the "pull" of the opposing windings of relay 113 will be exactly balanced and the armature will rest on the normal position illustrated midway between upper contact 115 and lower contact 116. However, if the amplitude of a received pilot current varies due to a change in the transmission characteristics of the system, relay 113 will then be operated either to lower contact 116 or upper contact 115 depending upon whether there is an increase or a decrease in the amplitude of the received pilot current causing a corresponding variation in the regulating current produced by modulator 74.

Let us assume first that the amplitude of the received pilot is below normal level. In such case the operating current applied to the left-hand winding of relay 113 will be stronger than that applied to the right-hand winding and the armature will be operated to lower contact 116. This operation will complete a path over which relay 131 operates, this path being traced from ground 112, armature of relay 113, winding of relay 131 to battery 132.

Operation of relay 131 connects battery 133 across the operating windings of pilot motor 134 (through the two make contacts of relay 131, the brushes of switch 56 being in engagement with contacts 135 and 136 of the switch). The polarity of the voltage so applied is such that that pilot motor 134 operates in the direction which causes counter-clockwise rotation of gear wheel 137. Rotation of gear wheel 137 in this direction causes corresponding movement of contact arm 141 along resistance 142. This increases the effective resistance in the circuit supplying current to heater 143 of thermistor 144 and correspondingly decreases the heating action of heater 143 on thermistor 144. The resulting change in temperature of thermistor 144 changes the characteristics of equalizer 103 to raise the level of the transmission therethrough.

This action of the equalizer in raising the transmission level results in the desired increase in the level of the communication frequencies and, at the same time, causes a like increase in the amplitude of the pilot itself. When the pilot has reached the desired normal level, relay 113 will assume its normal position with the armature midway between contacts 115 and 116 and the operating circuit of pilot motor 134 will be opened and the motor will stop, leaving arm 141 in its last adjusted position. The heater circuit of thermistor 144 is therefore left in the condition whereby the characteristics of equalizer 103 are held at the point which gives, for the time, the proper transmission level therethrough.

Let us assume now that, for some reason, the amplitude of the pilot current being received is above the normal value. In such case the oper-

ating current applied to the right-hand winding of relay 113 will be stronger than that applied to the left-hand winding and the armature will be operated to engage upper contact 115. This operation completes (by operation of relay 145) a circuit to apply voltage from battery 133 to the operating circuit of pilot motor 134, the polarity in this case being opposite to that applied in the instance just described above. Motor 134 is therefore operated in the opposite direction so as to operate gear wheel 137 in the clockwise direction. This causes corresponding operation of arm 141 whereby the effective resistance in the circuit of heater 143 is decreased. The corresponding increase in temperature of thermistor 144 and resulting adjustment of equalizer 103 is such that the transmission level therethrough is lowered. Here again, after the normal level of the pilot has once more been attained, relay 113 re-assumes normal position and equalizer 103 is left in the last adjusted position.

As pointed out above the respective equalizers 85, 101, 102 and 103, are intended to introduce corrections in respectively different parts of the transmission band and it follows that each of the roving pilots has "assigned" thereto a particular part of the frequency band for checking and correcting when necessary. This of course is the underlying reason for the operation of switch 53 in step with the application of the successive pilots to the line.

In the manner above described proper adjustment is made in the equalizers 85, 101, 102 and 103, as the corresponding roving pilot f_3 , f_4 , f_5 and f_n are applied in turn to line 11, which is necessary to keep the transmission level of the system at the desired normal value. In view of the fact that these several pilots are applied to the line intermittently the system is not unduly loaded with pilots and the available band width is not impaired for transmission purposes. It will be apparent that in a suitable manner, for example by opening switch 50, the intermittent pilots may be entirely withdrawn from the system during desired periods, for example during periods when the revenue load is high.

While the use of only four roving pilots has been illustrated, it will be understood that a considerably larger number may be used in the same general manner. Less than four roving pilots may also be used. It will be understood also that, while the use of the roving pilots in conjunction with two regular pilots has been illustrated, the plan may be applied in the same general manner in conjunction with a different number of regular pilots. The same general advantage results in any instance, that is, a more exact regulation without undue loading of the system with pilot currents.

While specific embodiments of the invention have been selected for detailed description it should be understood that the invention is not limited in its application to such embodiments. The embodiments described should be taken as illustrative of the invention and not as restrictive thereof.

What is claimed is:

1. In a system for automatic regulation of the gain characteristics of a transmission line under the control of pilot frequencies transmitted thereover, a transmission line between geographically separated points, a first source of pilot current of a frequency relatively low in the frequency band transmitted over the line at one of said points, a second source of pilot current

of a frequency relatively high in the frequency band transmitted over the line at said one point, means for continuously applying pilot currents from said first and second sources to said line for transmission to the other of said points, a first transmission regulator and a second transmission regulator at the other of said points, means for applying the first pilot current to said first regulator and for applying the second pilot current to said second regulator, a plurality of sources of other pilot currents at said one point, the frequencies of said other pilot currents differing one from the other and being higher than the frequency of said first pilot current and lower than the frequency of said second pilot current, a transmission equalizing network at said other point, means at said one point for intermittently applying pilot currents from said other sources in predetermined sequence and at predetermined times to said line for transmission thereover to said other point and through said network, and means at said other point for regulating the characteristics of said equalizing network in accordance with the amplitude characteristics of the respective intermittently applied pilot currents after passage through said equalizing network.

2. In a system for automatic regulation of the gain characteristics of a transmission line under the control of pilot frequencies transmitted thereover, a transmission line between geographically separated points, a first source of pilot current of a frequency relatively low in the frequency band transmitted over the line at one of said points, a second source of pilot current of a frequency relatively high in the frequency band transmitted over the line at said one point, means for continuously applying pilot currents from said first and second sources to said line for transmission to the other of said points, a first transmission regulator and a second transmission regulator at the other of said points, means for applying the first pilot current to said first regulator and for applying the second pilot current to said second regulator, a plurality of sources of other pilot currents at said one point, the frequencies of said other pilot currents differing one from the other and being higher than the frequency of said first pilot current and lower than the frequency of said second pilot current, a transmission equalizing network at said other point, a plurality of individual control circuits for said network, the number of said control circuits corresponding to the number of sources of said other pilot frequencies, means at said one point for intermittently applying pilot currents from said other sources in predetermined sequence and at predetermined times to said line for transmission to said other point and through said network and means for intermittently applying to said control circuits, in synchronism with application of said other pilot currents to said line, control currents having the amplitude characteristics of said other pilot currents after passage through said equalizing network.

3. In a system for automatic regulation of the gain characteristics of a transmission line under the control of the pilot frequencies transmitted thereover, a transmission line between geographically separated points, a plurality of sources of different pilot frequencies at one of said points, means for applying the different pilot frequencies to said line in a predetermined sequence and at predetermined times, a trans-

mission equalizing network connected to said line at the other of said points for correcting transmission characteristics, a plurality of individual control circuits for said network, the number of said control circuits being equal to the number of different pilot frequencies, a plurality of sources of different modulating frequencies at said other point, a modulator also at said other point, means for selectively connecting said modulating frequencies to said modulator for combining with the respective pilot frequencies transmitted over said line and through said equalizing network, the value of the modulating frequencies respectively selected being such that the upper side frequency resulting from the modulating process will be of the same value at all times regardless of which of the respective pilot frequencies is being received, means for selectively applying the upper side frequency resulting from the modulating process to said control circuits of said equalizer network,

and means for synchronizing the operation of said pilot frequency applying means, said modulating frequency connecting means and said upper side frequency applying means.

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