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2,326,871

GAIN CONTROL

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2 Sheets-Sheet 1

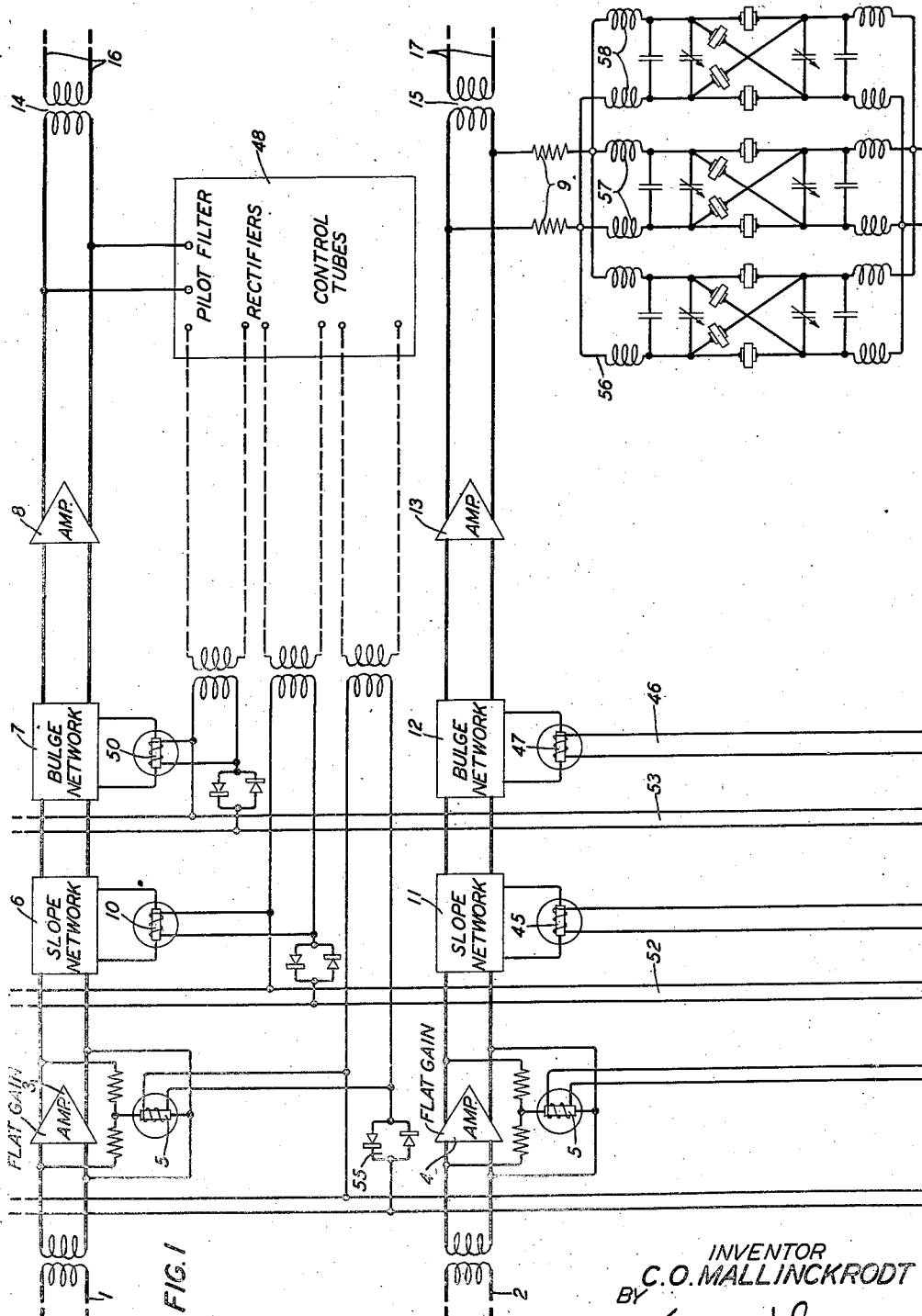


FIG. 1

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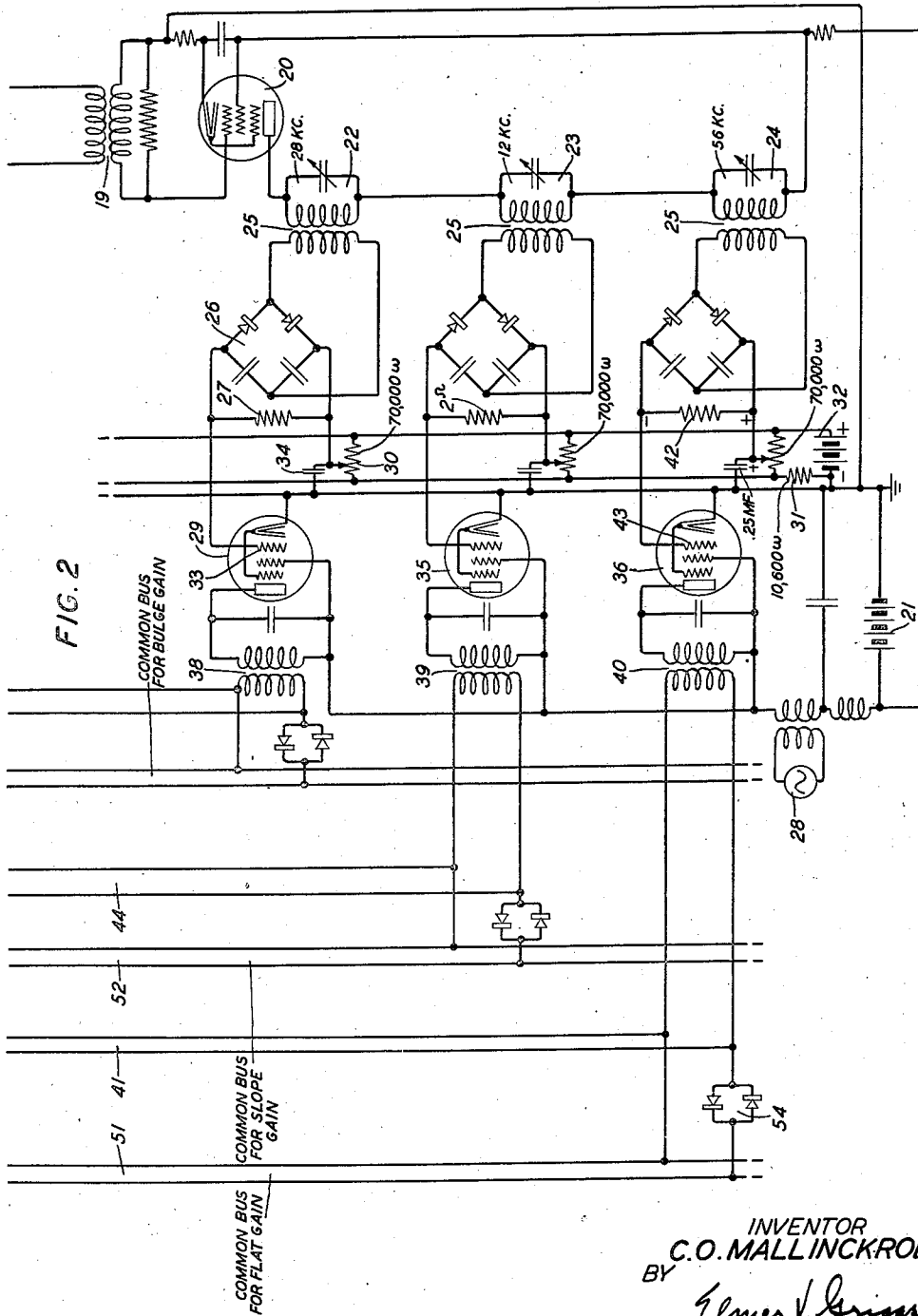
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UNITED STATES PATENT OFFICE

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GAIN CONTROL

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5 Claims. (Cl. 178—44)

This invention relates to pilot channel gain control apparatus such as is used for regulating amplifications effected by repeaters of carrier wave communication systems.

An object of the invention is to limit the gain or amplification which may ensue at a repeater station upon failure of the pilot current which controls the repeater.

Another object of the invention is to limit the gain at a regulated carrier repeater station which may ensue in the event of trouble in the regulator control circuit.

Another object of the invention is to prevent excessive amplifications in carrier systems which may result in two-way singing or in excessive cross-talk between adjacent circuits.

The attenuation experienced by carrier communication circuits in traversing cable conductors of the types commonly used for this purpose is such as to require the use in a long communication circuit of a considerable number of amplifying repeater stations. In the case of carrier communication systems requiring a band of frequencies extending from say 12 kilocycles minimum frequency to 60 kilocycles maximum frequency, the attenuation for 19 gauge quadded cable circuit conductors is such as to necessitate amplification of the currents at intervals of about 16 to 17 miles measured along the cable conductors. In systems of that type which are in wide spread commercial use, the gain introduced in each circuit by the respectively associated amplifier at the repeater station is controlled in accordance with the amplitude of pilot currents transmitted over one or more of the circuits. As the attenuation of the conductors for the message carrying carrier currents increases the pilot current which is preferably of a carrier frequency lying well within the message transmission frequency band experiences a corresponding change in attenuation. The consequently varying pilot current at each repeater station may be utilized to control the gain of the respective repeater amplifiers to restore the level of the pilot currents at the output circuit of the repeaters and by the same token the output level of the message carrier currents.

The change in attenuation that occurs with variations in temperature of long conductors such as those of a quadded toll cable may be divided into two components, one, depending upon frequency and known as "twist" and the other, not depending upon frequency and known as "flat change." The "twist" component may, in turn, be divided into two components, one,

varying linearly with frequency and known as the "slope" component and the other known as the "bulge" component having zero magnitude at the limiting frequencies and a maximum at an intermediate frequency.

Of the change of attenuation of the conductors which occurs at carrier frequencies of such a range as 12 kilocycles to 60 kilocycles with variation in temperature of a long transmission system perhaps 90 per cent is occasioned by the "flat change" component which is independent of frequency. Accordingly, each of the repeater stations located at intervals of approximately 17 miles along the carrier system will be provided with a flat gain amplifier to compensate for this component of attenuation which in a typical system of 19 gauge quadded cable may have a magnitude of about 46.8×10^{-4} decibels per mile per degree Fahrenheit.

The slope component of the same typical system varies linearly from zero at 12 kilocycles to approximately 1.8×10^{-4} decibels per mile per degree Fahrenheit at 60 kilocycles. The bulge component is zero at both 12 kilocycles and 60 kilocycles and has a maximum of about 4.9×10^{-4} decibels per mile per degree in the neighborhood of 26 kilocycles. An adequate compensation for the twist, that is, the slope and bulge components may, therefore, be had by equipping every fifth or sixth repeater station with amplifiers and controls to compensate for the slope and bulge attenuations.

A conductor pair serving for transmission of message carrier waves in one direction may, in addition to the ordinary lower frequency current message service, provide in the range of 12 to 60 kilocycles for twelve speech modulated carrier frequency channels. In addition to these message currents it may transmit three pilot frequency currents, one, to control flat gain, a second, to control the slope gain and a third, to control the bulge gain. In a typical system the frequencies of the pilot frequency currents may be 12 kilocycles for slope gain, 28 kilocycles for the bulge gain and 56 kilocycles for the flat gain. It will, of course, be understood that the magnitudes which have been given of frequency ranges and attenuations are merely illustrative of a typical system to which the invention may be applied.

In accordance with the invention, the feedback of a flat gain amplifier at a regulated repeater station of a long carrier wave transmission system is controlled by a thermistor, the heating current of which is made responsive in amplitude

to the magnitude of a pilot current transmitted over a conducting line of the transmission system with which the amplifier is connected. For slope and bulge gain controls the controlled thermistor is an element of an attenuating network. For each type of gain as, for example, flat change or slope gain, there is provided an auxiliary common bus supplied with heating current from each of the corresponding thermistor heating circuits through varistors which insure that the magnitude of the heating current on the bus follows in a general way that of the heating currents of the corresponding thermistor circuits to such an extent that no large difference of potential may exist, for example, between any one flat gain thermistor heating circuit and the common flat gain bus. Should a pilot current fail or should the regulating apparatus associated with a particular pilot channel become deranged the potential of its associated heating circuit may drift so far from that of the common bus that the respective varistors connecting them will be subjected to a considerable difference of potential. Under these circumstances, the resistances of these particular varistors suddenly drop, permitting potentials of the respective heating circuit and the connected common bus to more nearly equalize thus restricting the heating current of the deranged heating circuit to a magnitude which is a joint function of the pilot currents of the other circuits associated with the common bus. Accordingly, failure of a pilot channel transfers control of the amplifier gain from that pilot channel to a composite of the other pilot channels so that an excessive gain will be prevented and, at the same time, the gain will be controlled in accordance with pilot channel attenuations which may be expected to follow in a general way that experienced by the carrier currents which are to be regulated.

The drawings in which Fig. 1 is to be placed above Fig. 2 illustrates schematically a portion of the one-way circuits of a carrier wave repeater station including the circuits and apparatus which compensates for both flat change and twist attenuation. The circuits shown are designed for transmission in the direction from left to right of speech modulated or other signal modulated carrier currents. Accordingly, for a two-way telephone conversation one of the two-conductor circuits shown may serve for the west to east channel and a similar circuit, not shown, provided in the same or a separate cable may provide the east to west channel. Systems of this general type are disclosed in United States Patent 2,254,205, issued September 2, 1941 to J. H. Bollman for Signal transmission system.

Referring to the drawings, a pair of two-conductor circuits 1 and 2 may typify conductor pairs of a cable employed for carrier wave communication. The circuits 1 and 2, shown as used for west to east channels are connected by suitable transformers to their respective flat gain amplifiers 3 and 4 each of which is of the reverse feedback type with an externally heated thermistor 5 connected in shunt across the feedback circuit to control the gain introduced by the amplifier. It will be understood that at each repeater station each two-conductor pair is provided with its individual flat change amplifier so that in their traverse along the system the carrier wave message currents are amplified approximately every 16 or 17 miles. As illustrated the output of amplifier 3 is connected in tandem sequence to a slope network 6, a bulge network

7 and a twist amplifier 8. The slope network 6 in conjunction with twist amplifier 8 compensates for changes in the slope component of attenuation. The network 6 may be designed in accordance with well-known principles and may, for example, be of the type illustrated at Fig. 27 of United States Patent 2,096,027, issued October 19, 1937 to H. W. Bode. The variable resistor 10 of the network 6 may be a thermistor with an external heating circuit to control the resistance of the thermistor and hence the characteristic of the slope network. Similarly, the bulge network 7 may be of the type illustrated in Fig. 8 of United States Patent 2,153,743, April 11, 1939 to S. Darlington.

Channel 2 resembles channel 1 in every respect and is provided with a corresponding flat gain amplifier 4, slope network 11, bulge network 12 and twist amplifier 13. The output terminals of the twist amplifiers 8 and 13 are respectively connected through transformers 14 and 15 respectively, with the corresponding channel conductors 16 and 17 of the outgoing line section to the east of the repeater station.

As has previously been stated, the compensation at the repeater station for variations in attenuation occasioned by change in line temperatures is effected by pilot currents transmitted over the same conductors that serve to transmit the message modified carrier waves. Accordingly, there are transmitted from a remote terminal station at the west end of the transmission system over each channel such as channels 1 and 2 three different frequency pilot currents, for example, of 12, 28 and 56 kilocycle frequency. The currents are impressed on the channel each with a fixed amplitude so that variations in line attenuation may be measured at a repeater station by the amplitudes of these pilot currents as they arrive at the repeater station. Connected in shunt across the output circuits of the amplifiers 8 and 13 are the input connections of pilot current filters. As illustrated in detail in connection with channel 2, the input connections involve series resistances 9 to which are connected in parallel the input terminals of three narrow band-pass filters 56, 57 and 58 each designed to accept to the substantial exclusion of other frequency currents a particular one of the pilot currents. These filters may be of well-known types. Their output terminals are, likewise, connected in parallel to the input winding of a transformer 19 the output of which is connected to a pentode amplifier 20, space current for which is supplied by a source 21. The output path of the amplifier 20 includes three loop-tuned circuits 22, 23, 24, each tuned to a respective pilot current frequency to select that pilot current and impress it by a transformer 25 upon a voltage doubler rectifier 26 of the type disclosed in United States Patent 2,084,115 issued June 15, 1937 to D. M. Terry. It follows that as the 28 kilocycle pilot current rises and falls in amplitude with changes in attenuation of channel 2, the rectified current supplied to resistor 27 by the rectifier 26 associated with the tuned circuit 22 will likewise vary. A local source 28 of thermistor heating current, for example, of 60 cycles, is connected in the space current path of a heating current control tube 29. The input path of the control tube 29 includes in series the rectifier resistor 27, a variable potentiometer resistor 30 and a fixed resistor 31. A grid bias source 32 is connected to the resistors 30 and 31 with such a polarity as to tend to render posi-

tive the grid 33 of the control tube 29, the resistor 27 serving to apply a counter electromotive force which tends to render the grid negative. The resistance of element 31 may be of the order of 10,600 ohms, that of the entire potentiometer 30 may be 70,000 ohms. Across the constant potential input terminals of the tube 29 is connected an individual by-pass capacitor 34 which may be of .25 millifarad capacity to divert any variable electromotive force in the bias path of tube 29 from the bias paths of the control tubes 35 and 36 which are controlled respectively by the 12 kilocycle and 56 kilocycle pilot currents. The grid bias circuit which opposes steady bias potentials to the amplified rectified electromotive force obtained from the pilot current permits the net grid potential of the control tube to change by a considerable amount with a consequent large change in output. Each control tube is connected by its individual output transformer 38, 39, 40 to the heating circuit of one thermistor associated with each channel. For example, the control tube 36 which is associated with the 56 kilocycle pilot current channel for regulating flat gain is connected by transformer 40 and path 41 to the terminals of the heater of thermistor 5 which controls the flat gain introduced into channel 2 by amplifier 4. As the attenuation on channel 2 rises the 56 kilocycle pilot current selected by circuit 24 falls. Likewise the potential across rectifier resistor 42 falls permitting the impedance control grid 43 of control tube 36 to become more positive thus increasing the heating current supplied by transformer 40 to path 41. The resistance of thermistor 5 accordingly diminishes thus reducing the feedback of amplifier 5 and permitting its gain to rise by an amount which just compensates for the flat gain component of the increased line attenuation. In the same manner, the 12 kilocycle pilot current controls the heating current output of the control tube 35 so that the energy applied over transformer 39 and path 44 to the heating circuit of thermistor 45 regulates the characteristic of the slope network 11 so that in conjunction with twist amplifier 13 compensation is had for change in the slope component of the attenuation of channel 2. Similarly, also, the 28 kilocycle pilot current controls the control tube 29 to supply regulated heating current over path 46 to the heating circuit of thermistor 47 which constitutes an element of the bulge network 12. Consequently, the three pilot currents of channel 2 actuate their respective regulators to insure that the flat gain, the slope gain and the bulge gain are maintained at the magnitudes required to compensate for the attenuation occurring on channel 2.

Channel 1 is similarly provided with pilot filters, rectifiers and control tubes represented by the block 48. It will be appreciated that the flat gain thermistor 5, the slope network thermistor 10 and the bulge network thermistor 50 are each under the control of respective pilot currents exactly as in the case of channel 2, the only difference being that in the instance of channel 1 the pilot currents employed are those transmitted over channel 1 and which have experienced the attenuation characteristic of that particular channel at the moment.

Should the pilot currents of a particular channel fail for any reason such as failure of the pilot amplifier 20, the respectively associated control tubes might impress such large heating currents on the regulating thermistors as to permit excessive gain at the repeater station. This

would be reflected in the level of the carrier currents over the next section and there would be a corresponding compensation at the next traversed repeater. However, that condition is quite undesirable since it may give rise to excessive cross-talk to other channels. In order to preclude such a result the repeater station is provided with a heating circuit bus for each of its three types of regulators. A common flat gain bus 51, a common slope gain bus 52 and a common bulge gain bus 53 are illustrated in the drawings. The bus 51 is energized by varistor connections 54, 55, etc. to each of the flat gain heating paths such as path 41. The varistors 54, for example, comprise a set of oppositely directed non-linear elements having a high resistance characteristic for low impressed electromotive forces and having a relatively low resistance for higher electromotive forces. They are so designed that in the case of varistor 54 there will always be a leak of heating current through the varistors from path 41 to bus 51 so long as path 41 is energized by heating current and there is any difference of potential between the path and the bus. If, however, the current in path 41 should become dangerously large thus giving rise to a high difference of potential across varistors 54 their resistance will drop and, in effect, shunt across the path 41 the low impedance bus 51 which thus tends to divert the excess heating current from thermistor 5 and to reduce the electromotive force applied to the thermistor heater. During such periods of derangement of a particular pilot carrier source or pilot current channel such as that associated with path 41 the thermistor does not become uncontrolled but the control is automatically shifted by the varistor unit to the bus to which the varistor unit connects the path. Moreover, the current in the bus which now serves to regulate the thermistor is neither arbitrarily fixed nor random since it is derived by leak through a large number of varistors at the station. Because of that fact the bus current at a time is a function of the magnitudes of all heating currents at the station which are derived from the same cable section or similar cable sections to regulate the same component of attenuation. That means that as the temperature of the cable rises or falls the heating currents of the operative paths of all the similar thermistors change accordingly and affect the bus in the same manner. From this it is apparent that the bus may serve as an emergency control to vary the gain in the same direction that it would be varied were the respectively associated pilot channel apparatus effective.

It has been remarked that flat attenuation for 19 gauge conductor cable in the carrier frequency ranges presented is sufficiently large to require amplification at intervals of approximately 16 or 17 miles along the cable. However, the flat change constitutes perhaps 90 per cent of the total change in attenuation. It has been found possible therefore to correct for the slope and bulge components at each fourth or fifth repeater, called twist repeaters to differentiate from those at which flat gain only is provided. The twist repeaters which will be spaced at intervals of 80 to 100 miles may, therefore, be constructed to embody for each direction of transmission circuits of the type illustrated in the drawings. The intermediate repeater stations having flat gain repeaters may be simplified by omission of the slope and bulge networks and their respectively

associated pilot control channels together with the twist amplifier.

In addition to the role of the varistors in transferring control of the gain regulation from a disabled pilot channel to the common bus heating circuit, the varistors serve to reduce transient effects by virtue of their property of preventing the gain of any one amplifier from departing too greatly from the average of that station. In other words, any change in conditions which would tend to set up an excessive current in the output of an amplifier will react upon the system disclosed just as if the pilot channel had become deranged. The varistors are so quick-acting as to be able to take care of the changed condition by a decrease in the resistance which they interpose between the common bus circuit and the individual heating circuit. In the same manner, upon disappearance of the abnormal condition, the varistors quickly restore to their normal high resistance state thus effectively isolating the individual regulation circuit from the common bus and so permitting the regulation of each individual channel to be controlled substantially solely by pilot channel currents transmitted over the same conductors.

What is claimed is:

1. A carrier communication system comprising a plurality of message carrier current channels extending between terminals of the system, a plurality of pilot current gain control channels subjected to attenuations varying with temperature in a manner similar to the attenuation variations of the message channels, each of said message channels including a variable gain amplifier, means controlled by one of the pilot currents for regulating the gain of each variable gain amplifier and means responsive to failure of the respective pilot current for placing the variable gain amplifier under the control of pilot current of the same frequency as the currents that failed whereby the gain of the amplifier remains controlled in accordance with variable pilot channel attenuation.

2. In a carrier system, a plurality of message channels each including a variable gain amplifier, a plurality of pilot channels each of which experiences an attenuation varying similarly to that of the message channels with change in temperature, means connecting a corresponding plurality of the variable gain amplifiers in the message channels to regulate the transmission levels of the respective message channels connected therein and means actuated upon the failure of the pilot current of one of the pilot channels to place the amplifiers controlled by that pilot channel under control of pilot channels which are still

operative whereby the gain of the amplifiers continues to be regulated in accordance with varying attenuation experienced by pilot channel current.

3. A communication system comprising a plurality of message channels and at least two pilot current channels extending between the same points as the message channels so as to be subjected to similarly varying attenuation with change in environment, individual amplifiers in each of the message channels, means connecting one of the pilot channels to each of the amplifiers to regulate the transmission level of the message channels in a manner tending to compensate attenuation variations and means responsive to failure of the current of a pilot channel to place its respectively connected amplifier under control of the other pilot channel whereby the transmission level of the message channel in which said amplifier is connected continues to be regulated in accordance with variable attenuation experienced by the channels.

4. A regulating circuit, a pair of relatively long physically adjacent transmission channels for electric currents subjected to similar variations in impedance in consequence of variations in temperature, means directly connecting one of said channels to said regulating circuit to supply thereto currents varying in accordance with the attenuation experienced in the channel and means connecting the other channel to said regulating circuit, said last-mentioned connecting means being normally ineffective but becoming effective upon failure of the varying current of said one channel to cause similarly varying current to be supplied to the regulating circuit by the other channel.

5. A regulating circuit, a pair of relatively long physically adjacent transmission channels for electric currents subjected to similar variations in impedance in consequence of variations in temperature, sources of substantially constant alternating electromotive force connected respectively to said channels, a regulator directly connected to one of said channels to receive thereover from one of said sources control currents which vary with impedance variations of said channel, means comprising varistors connecting the regulator with the other channel to present high impedance during the time that the control currents of the first channel are impressed but operative upon failure of the control current from the first channel to present lower impedance and permit control currents to be impressed from the other channel to replace the control currents that failed.

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