

Nov. 3, 1942.

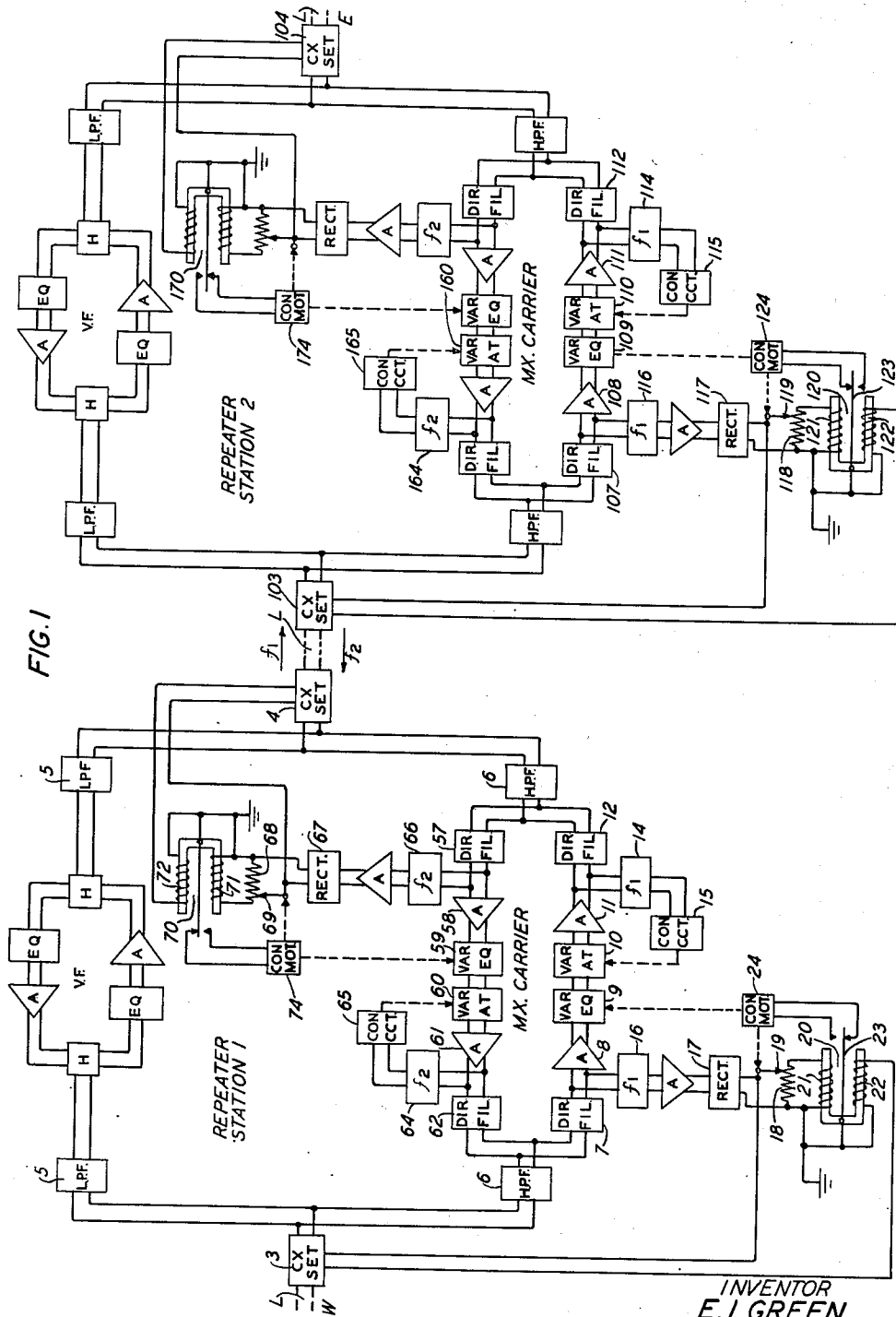
E. I. GREEN

2,300,415

TRANSMISSION CONTROL

Filed April 26, 1941

2 Sheets-Sheet 1



INVENTOR
E. I. GREEN
BY
N. D. Ewing
ATTORNEY

Nov. 3, 1942.

E. I. GREEN

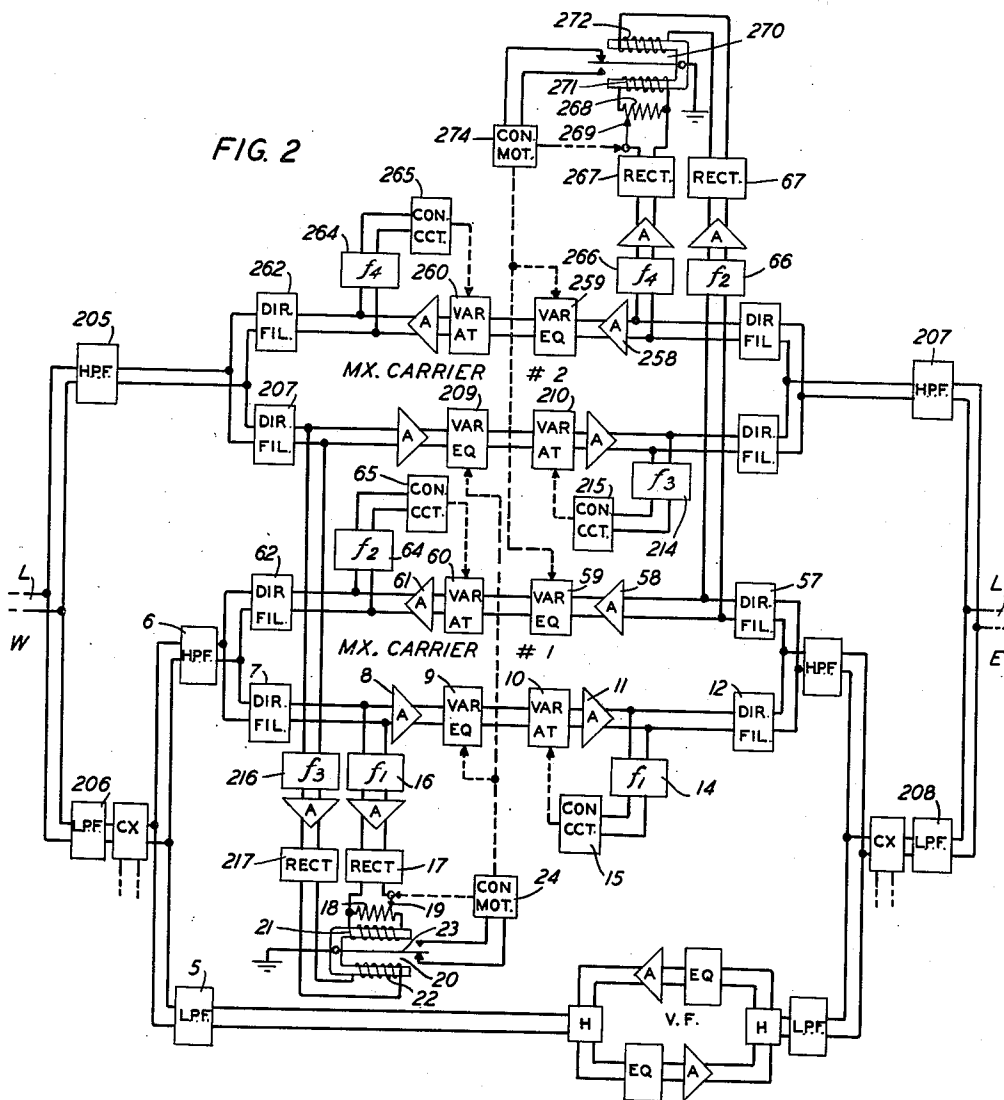
2,300,415

TRANSMISSION CONTROL

Filed April 26, 1941

2 Sheets-Sheet 2

FIG. 2



INVENTOR
E. I. GREEN

BY

N. D. Ewing
ATTORNEY

UNITED STATES PATENT OFFICE

2,300,415

TRANSMISSION CONTROL

Estill I. Green, Short Hills, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application April 26, 1941, Serial No. 390,471

7 Claims. (Cl. 179—15)

This invention relates to transmission systems utilizing a wide band of frequencies and more particularly to regulation of the transmission characteristics of repeaters in such systems to compensate for changes in the transmission properties of the transmission medium.

A principal object of the invention is to improve and simplify the construction and operation of transmission regulating equipment for wide band signaling systems.

Another and more particular object is to provide a simple and economical arrangement for automatically regulating the transmission characteristics of repeaters in a signaling system to compensate automatically for changes in the transmission characteristics of the transmission medium that are non-uniform over the frequency range occupied by signals.

Although the present invention will be described hereinafter largely in terms of its application to the control of repeater gain in a wide band wire line signaling system, it will become apparent that the invention, at least in its broader aspects, is not limited in these respects and that it is susceptible of various other embodiments within the spirit and scope of the appended claims.

It is well known that in long distance wire line signaling systems, the attenuation of the line varies over a wide range with changes in temperature and other effects, and that it is desirable to effect compensating changes in the system to maintain the transmission equivalent thereof substantially constant. One method of automatic compensation proposed heretofore involves the transmission concurrently with the signals of a single frequency pilot wave that experiences the same attenuation as the signals, and automatic regulation of the gain of the signal repeaters in the system under the control of the pilot wave. The compensating gain change thus introduced is a flat gain change, that is, it is the same at all frequencies in the signal frequency range. The line attenuation change, however, is ordinarily not quite the same at all frequencies and in a long distance wide band system it may be desirable to supplement the flat gain regulation with a compensating gain change that is not uniform over the frequency range. To a first approximation the non-uniform gain change required is a change in the slope of the gain-frequency characteristic of the repeater.

For automatic slope control it has been proposed that a predetermined change of slope be introduced in accordance with the change in am-

plitude of a single pilot frequency. This method is not entirely satisfactory since a given change of pilot level may involve a fairly wide range of different slopes. It has also been proposed that two pilot waves of different frequencies be transmitted concurrently with the signals so that at the repeater stations a measure can be had of the difference in line attenuation at the two frequencies. Changes in the relative intensities of the two pilots indicate changes in the slope characteristic of the transmission line and they may be utilized to effect automatically a compensating change in the slope characteristic of the repeaters. This automatic slope regulation requires at least one additional pilot frequency in each direction of transmission.

In accordance with a feature of the present invention automatic slope regulation is provided without the addition of pilots other than those required and used for flat gain regulation.

In accordance with another feature of the present invention, individual pilot channels respectively associated with a plurality of transmission systems superposed on the same transmission line or medium are conjointly utilized to effect non-uniform repeater gain control in one or more of the superposed systems in addition to effecting uniform or flat gain control in their respective systems.

In accordance with still another feature of the invention, pilot currents of different frequencies transmitted in opposite directions through a transmission line or other medium for flat or uniform gain control of individual, oppositely directed systems are utilized jointly to effect non-uniform gain control or, more specifically, slope control of one or more of the superposed systems and for either one or both directions of transmission therein.

The nature of the present invention and its various features, objects and advantages will appear more fully from a consideration of the embodiments illustrated in the accompanying drawings, in which:

Fig. 1 shows the invention as embodied in a multiplex signaling system utilizing two oppositely directed pilots for controlling flat gain in each direction of transmission; and

Fig. 2 shows an embodiment of the invention utilizing like-directed pilots of different frequencies that are used to regulate the flat gain characteristics of two superposed multiplex telephone systems.

Referring more particularly now to Fig. 1, there are shown two successive repeater stations

in a multiplex transmission system embodying the present invention. In general outline, there is provided a two-way voice frequency telephone system and a two-way multiplex carrier telephone system superposed on the same pair of line conductors. In the carrier telephone portion of the system, one group of channels is utilized for multiplex transmission in one direction through the system and another group of channels in a different frequency range is utilized for multiplex transmission in the opposite direction. With each of these two groups of channels there is associated an individual pilot wave transmitted concurrently with the signals for effecting automatic flat gain control in the repeater amplifiers.

The two repeater stations shown are or may be exactly alike and there may be, for example, many other stations of the same kind spaced apart in the transmission line connecting the terminals of the system as well as other repeater stations equipped for only flat gain regulation or for none at all.

As will appear from a consideration of station 1, the voice frequency system is provided with a 22-type repeater that is connected into the transmission line L through low-pass filters 5. In parallel with the voice frequency repeater but effectively isolated therefrom by high-pass filters 6 is a repeater for the superposed carrier system. In the carrier repeater, the W—E amplifier section is isolated by directional filters 7 and 12 at the input and output respectively thereof, these filters passing only the W—E group of carrier telephone channels and its associated flat gain controlling pilot wave. The E—W section is similarly equipped with directional filters 57 and 62.

It may be supposed for specific example that the W—E carrier channels are three in number and occupy the frequency range from 17.7 to 28.4 kilocycles and that the frequency f_1 of the accompanying pilot wave is 24.4 kilocycles. Similarly the E—W group of carrier channels may also be three in number and occupy the frequency range from 6.3 to 15.8 kilocycles, the frequency f_2 of the respectively corresponding pilot wave being 9.4 kilocycles.

Examining the W—E section of the carrier repeater at station 1, the directional input filter 7 thereof is followed by an amplifier 8, a variable equalizer 9, a variable attenuator 10, an amplifier 11 and the directional output filter 12. At the output of amplifier 11, pilot f_1 is partially diverted through a filter 14 and the amplitude variations thereof are utilized in control circuit 15 to so adjust variable attenuator 10 as to maintain the pilot level at the output of amplifier 11 substantially constant. Flat gain regulators appropriate for this portion of the circuit are well known in the art.

The E—W section of the carrier repeater is substantially the same as the W—E section excepting for the frequency range to be accommodated, and elements 57, 58, etc., thereof respectively correspond with elements 7, 8, etc. It will be understood then that pilot f_2 in the E—W section operates on variable attenuator 60 to control the flat gain in the E—W direction and to maintain the output intensity of pilot f_2 substantially constant. The same is true at repeater station 2 where elements 107, 108, etc., are respectively the same as elements 7, 8, etc., and elements respectively the same as elements 57, 58, etc., may be readily identified.

Considering briefly the transmission between the two repeater stations, it will be evident that

the amplitude of pilot f_1 as received at station 2 affords a measure of the line attenuation at frequency f_1 and that changes in the received pilot amplitude indicate directly the extent and direction of changes in line attenuation at frequency f_1 . Likewise the amplitude of pilot f_2 as received at station 1 affords a measure of the line attenuation at its frequency and changes in its amplitude indicate directly the extent and direction of changes in line attenuation at frequency f_2 . As previously described, these changes in pilot amplitudes are utilized at the respective stations at which they are observed to effect a compensating change in the flat gain of the repeater.

In accordance with a principal feature of the present invention, the two pilots f_1 and f_2 , provided for regulating the flat gain in the respective directions of transmission, are utilized without the aid of additional pilots to effect slope control of the several repeater gain characteristics. The specific means provided for this purpose are as follows.

At the input of amplifier 108 in station 2, the pilot f_1 is partially diverted through a filter 116, amplified and applied to a rectifier 117. The unidirectional output current from rectifier 117 is then applied through a motor-controlled voltage divider 118—119 to one winding 121 of a differential relay 120. Likewise, at the input of amplifier 58 in station 1, the pilot f_2 is partially diverted through a filter 66, amplified and applied to a rectifier 67, the output of which is connected through a motor-controlled voltage divider 68—69 to one winding 71 of a differential relay 70. Composite sets 4 and 103 at the terminals of the intervening section of line L provide two ground-return circuits each utilizing one of the line conductors and each appropriate for the transmission of unidirectional currents. One of these ground-return circuits is connected to the output terminals of rectifier 67 and the other end thereof is connected at station 2 to a winding 122 on differential relay 120. Inasmuch as the output of rectifier 67 fluctuates in accordance with the varying intensity of pilot f_2 as received at station 1, the unidirectional current in relay windings 122 varies likewise, for the line attenuation is substantially constant for direct current.

Thus at station 2, the armature 123 of differential relay 120 is subject to the opposing effects of the respective currents in windings 121 and 122, the one effect tending to be proportional to the intensity of the pilot f_1 as received at station 2 and the other tending to be proportional to the intensity of pilot f_2 as received at station 1. Relay armature 123 is connected in the control circuit of motor 124 which in turn controls simultaneously the position of the contactor 119 on voltage dividing resistor 118 and the slope of the attenuation characteristic introduced by variable equalizer 109. If the opposing effects in relay 120 are equal, armature 123 assumes a neutral position. If they are unequal the armature is moved in one direction or the other, depending on which effect is the greater, to cause motor 124 to rotate in such direction that the consequent movement of contactor 119 is in the proper direction to bring the opposing forces to equality.

The difference in intensity of the two pilots, as received at the respective repeater stations after transmission over the intervening section of line L, is correlated with the slope characteristic of

the line attenuation, and changes in the intensity differential afford a direct measure of slope changes in line attenuation. Inasmuch as the position of contactor 119 is uniquely correlated with the intensity differential, it follows that for every position of the contactor there is a definite change in slope characteristic to be introduced by equalizer 109. The latter can be and is so varied concurrently with the movement of contactor 119 as to introduce the required compensating change in repeater slope characteristic.

Whereas automatic slope regulation is thus provided in the W—E path at station 2 to compensate for the varying slope characteristic of the intervening section of transmission line L, station 1 is similarly equipped to provide automatic slope regulation for E—W transmission through the same line section. More particularly the other ground-return circuit afforded by composite sets 4 and 103 is utilized to convey from the output of rectifier 117 to winding 72 on relay 70 a measure of the intensity of pilot *f*1 as received at station 2. This measure is compared at station 1 with the output of rectifier 67 and the intensity differential is utilized to control motor 74 and voltage divider 68—69 and to continuously maintain a balanced condition. Motor 74 simultaneously controls the changes in slope characteristic that variable equalizer 59 introduces in the E—W signaling path at station 1. It will be understood too that differential relay 20 at station 1 and differential relay 170 at station 2 together with their associated control equipment cooperate with similar apparatus at other repeaters to compensate the changing slope characteristics of the adjoining sections of transmission line.

Fig. 2 illustrates schematically one of a succession of identical repeaters embodying the present invention in a form somewhat different from that described with reference to Fig. 1. In this embodiment two separate two-way multiplex carrier telephone systems and a two-way voice frequency telephone system are superposed in multiplex carrier relation on the same transmission line. Carrier system No. 1 may be the same as the carrier system described with reference to Fig. 1 excepting for the means provided for automatic regulation of the slope characteristic of the repeaters. It is so illustrated and corresponding elements are identified by the same reference characters. Carrier system No. 2 may be a twelve-channel system, for specific example, occupying the frequency range from 36 to 140 kilocycles. At the repeater station this second carrier system is isolated by high-pass line filters 205 and 207 for application to a repeater. Low-pass line filters 206 and 208 similarly segregate the other carrier system and the voice frequency system which in turn are separated from each other by low-pass and high-pass filters 5 and 6.

In carrier system No. 1 a pilot wave *f*1 of 24.4 kilocycles, for example, accompanies the signals in the W—E direction of transmission and, as before, is utilized to adjust variable attenuator 10 and thereby effect automatic flat gain regulation. Likewise a pilot wave *f*2 of frequency 9.4 kilocycles accompanies the E—W channels in carrier system No. 1 and is utilized as before to control the flat gain adjustment at variable attenuator 50.

In carrier system No. 2 a pilot wave *f*3 of frequency 59.9 kilocycles, for example, is transmitted concurrently with the signals in the W—E direction of transmission, and a pilot wave *f*4 of frequency 116.1 kilocycles, for example, is similarly

transmitted with the signals in the E—W direction. These two pilots control the flat gain in the respectively corresponding portions of the system No. 2 repeater. Excepting as it is adapted for a different frequency range, this repeater is or may be the same as the repeater for carrier system No. 1, and the two pilots *f*3 and *f*4 are similarly used for regulating the flat gain therein. Thus at the output of the W—E repeater section pilot *f*3 is diverted through filter 214 and applied through control circuit 215 to the flat gain regulator, i. e., variable attenuator 210. Similarly at the output of the E—W repeater section pilot *f*4 is diverted through filter 264 and utilized to effect automatic flat gain regulation by controlling the loss introduced by variable attenuator 260.

Whereas Fig. 2, as hereinbefore described, provides only the minimum number of pilot waves necessary for automatic flat gain regulation in the two superposed carrier systems, automatic slope regulation for both systems and for both directions of transmission is derived in accordance with the invention without the addition of other pilot waves. In general, pilot waves *f*1 and *f*3 are utilized to control motor 24 to effect automatic slope adjustment of variable equalizers 9 and 209 in the W—E paths of the respective carrier systems. Similarly, pilot waves *f*2 and *f*4 jointly control motor 274 to effect automatic slope adjustment of variable equalizers 59 and 259 in the E—W paths.

Considering first the means provided for slope regulation in the W—E direction of transmission, it will be noted that the respective amplitudes of pilot waves *f*1 and *f*3 as received at the repeater station afford an indication of the line equivalent or attenuation at the frequencies of the respective pilots. The difference in attenuation at these two frequencies affords a measure of the slope characteristic of the transmission line and may be utilized to effect a compensating adjustment in the slope characteristic of the repeater.

Thus at the respective inputs of the W—E sections of the two repeaters the two pilot waves *f*1 and *f*3 are picked off by the respective filters 16 and 216, amplified and applied to the respective rectifiers 17 and 217. The output of rectifier 17 is applied through motor controlled voltage divider 18—19 to one winding 21 of differential relay 20. The output of rectifier 217 is applied to winding 22 of the same relay. Any disparity between the forces on the relay armature due to currents in the relay windings 21 and 22 calls for adjustment of the slope characteristic of equalizers 9 and 209. This adjustment is brought about by motor 24 which, in the event of disparity in the opposing forces and consequent movement of relay armature 23, adjusts contactor 19 to reduce the disparity. Simultaneously, it adjusts equalizers 9 and 209 to compensate for the indicated disparity between the slope characteristic of the preceding line section and the slope characteristic of the respective repeaters. Control motor 24 continues to operate until as a result of the movement of contactor 19 the relay armature is restored to a neutral position.

Automatic slope control for the opposite direction of transmission is effected by essentially the same method and means. Pilot waves *f*2 and *f*4 are picked off at the respective input ends of the corresponding sections of the repeater, and after rectification and amplification are applied to the control of differential relay 270, pilot *f*2 being operative in winding 272 thereof and pilot *f*4 being operative through voltage divider 268—

269 in relay winding 271. Relay 270 controls the operation of motor 274 which in turn controls the position of contactor 269 and simultaneously the slope characteristic introduced by the respective variable equalizers 259 and 59.

Whereas in Fig. 2 slope control for a given direction of transmission is effected by means of two pilots, such as f_1 and f_3 , that are transmitted in the same direction, it will be evident that oppositely directed pilots could be used for the same purpose in the manner shown in Fig. 1. That is, f_1 and f_2 could be used in the manner shown in Fig. 1, and f_3 and f_4 could be likewise paired for control of slope in system No. 2. In the same way pilots f_1 and f_4 could be paired for slope control in one system and f_2 and f_3 paired for slope control in the other system.

Whereas the invention has been described with reference to systems in which transmission in both directions takes place over the same line circuit, the invention is not thus limited for it has application also to systems in which, for example, separate transmission lines subject to the same variations in temperature are utilized for the respective directions of transmission.

What is claimed is:

1. A multiplex carrier wave transmission system comprising a transmission line subject to variations in attenuation, means for transmitting two sets of signals in respective frequency ranges in mutually opposite directions through said line, a multiplicity of two-way repeaters spaced apart in said line for amplifying said signals, means for transmitting an individual pilot wave concurrently with each of said sets of signals, means at each of said repeaters for separating the said two sets of signals together with their individual pilot waves, an individual amplifier for each separated set of signals and pilot wave, a flat gain regulator for each of said amplifiers controlled by the respectively corresponding pilot wave and operative to maintain said pilot wave at a substantially constant intensity at the output of the repeater, a slope regulator at one of said repeaters operative on one of said separated sets of signals, means for conveying from another of said repeaters to said one repeater a measure of the amplitude of one of said pilot waves as received at said other repeater after transmission from said one repeater, means at said one repeater for deriving a measure of the amplitude of the other of said pilot waves as received thereat after transmission from said other repeater, and means for automatically controlling said slope regulator in accordance with the disparity of said measures of amplitude.

2. A multiplex carrier wave transmission system comprising a transmission line subject to variations in attenuation, means for transmitting different sets of signals in different frequency ranges over said line from one terminal thereof to the other, means for transmitting concurrently with each of said sets of signals an individual pilot wave of non-signal frequency that is subject to substantially the same variations in attenuation as the said set of signals to which it is individual, means at a point along said line for separating and separately amplifying said different set of signals together with said respectively corresponding pilot waves, a flat gain regulator for each of said separate amplifying means controlled by the respectively corresponding pilot

wave, and a slope regulator operative on one of said sets of separated signals in accordance with the difference in attenuation experienced by said pilot waves in their transmission through said line.

3. In a system for the transmission of signals in opposite directions in respective frequency ranges through a medium subject to variations in a propagation characteristic, the method which comprises transmitting control waves of different frequencies concurrently with the said signals in each direction of signal transmission, maintaining the intensity of both of said control waves substantially constant at widely separated points along said system, comparing the intensities of said control waves as received at said points after transmission through the intervening portion of said system, and automatically compensating said variations in said system in accordance with the relative intensities of said control waves as so compared.

4. In a two-way repeatered transmission system, the method which comprises transmitting pilot currents of different frequencies in opposite directions through a repeater section and controlling a transmission characteristic of a repeater at one end of said section in accordance with relative changes in a parameter of said pilot currents as received at opposite ends of said section.

5. In combination, a transmission line, a pair of terminal stations for said line comprising means for superposing a plurality of separate two-way multiplex signaling systems on said line, a repeater station along said line comprising means for separating the respective sets of signals of the several systems, and means for further separating the oppositely directed signals in each of said separated sets, means for transmitting respective pilot waves in both directions of signal transmission for each of said superposed systems, an individual signal and pilot wave amplifier at said repeater station for each direction of transmission in each of said systems, means for automatically regulating a transmission characteristic of each of said amplifiers under the separate control of the pilot wave individual thereto, and means for automatically regulating another transmission characteristic of at least one of said amplifiers under the joint control of a plurality of said pilot waves.

6. A combination in accordance with claim 5 in which said repeater station comprises means for deriving separate measures of the intensity of like-directed pilot waves as received at said repeater, a slope regulator for each of a plurality of said systems, and means for controlling said slope regulators in accordance with the relative values of the derived measures.

7. In a carrier transmission system, the method which comprises transmitting two pilot waves of different frequencies over a line section, converting one of said pilot waves after transmission through the line section into a wave of different frequency, transmitting said wave of different frequency in the opposite direction through the same line section and utilizing it jointly with the other of said pilot waves to control the amplification of signals transmitted over a band of frequencies.

ESTILL I. GREEN.