Jan. 20, 1925.

1,523,874

J. W. HORTON

AUTOMATIC TRANSMISSION CONTROL SYSTEM

Filed Dec. 31, 1921

2 Sheets-Sheet 1

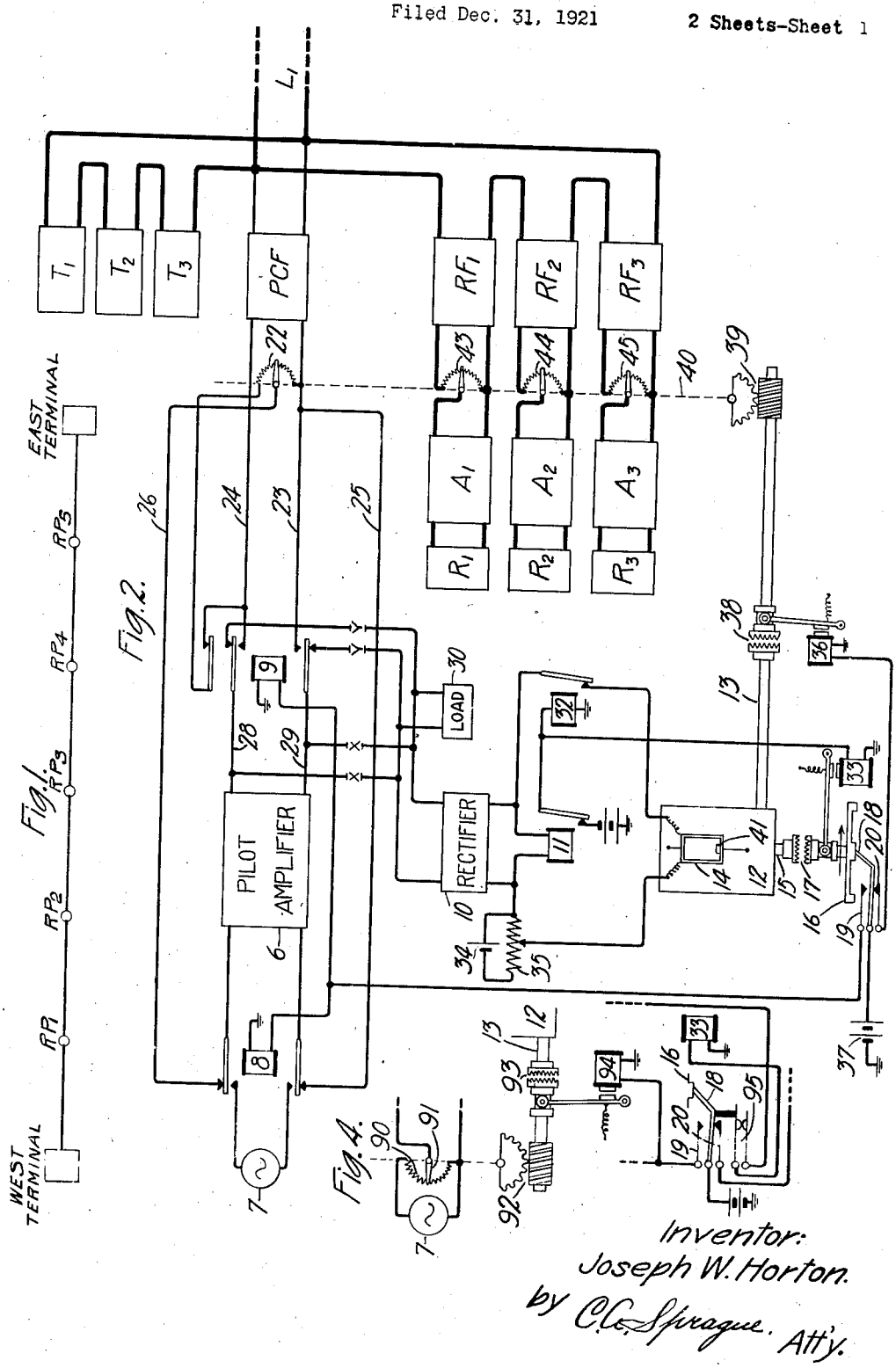


Fig. 2.

Fig. 1.

Fig. 4.

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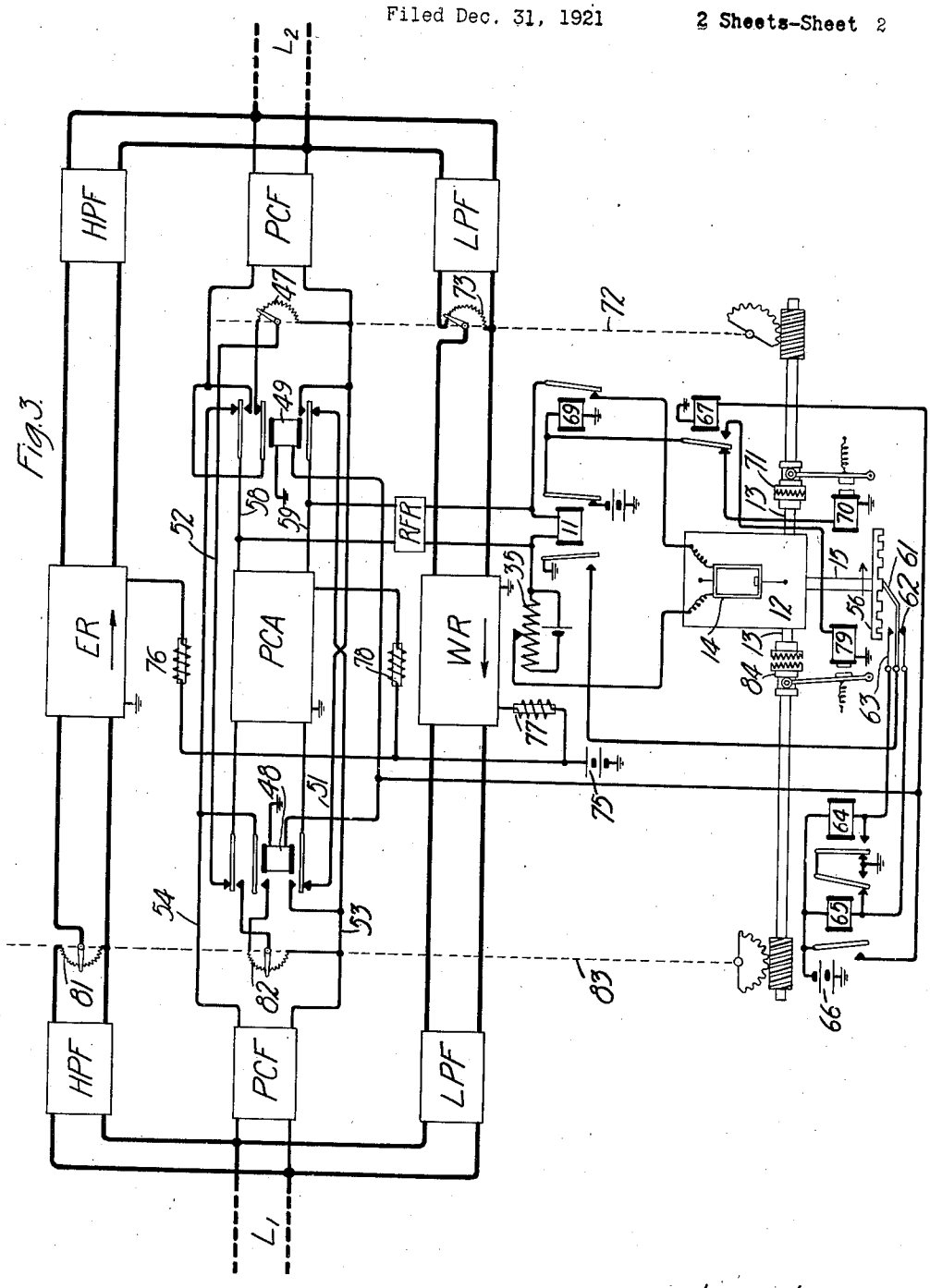
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Fig. 3



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Patented Jan. 20, 1925. 1,523,874

UNITED STATES PATENT OFFICE.

JOSEPH W. HORTON, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

AUTOMATIC TRANSMISSION-CONTROL SYSTEM.

Application filed December 31, 1921. Serial No. 526,382.

To all whom it may concern:

Be it known that I, JOSEPH W. HORTON, a citizen of the United States, residing at East Orange, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in Automatic Transmission-Control Systems, of which the following is a full, clear, concise, and exact description.

The present invention relates to transmission control, and more particularly to the separate and automatic control of a transmission circuit for each direction of transmission thereover.

The invention is applicable to terminal stations and to intermediate stations where circuits are employed the transmission characteristics of which are to be altered, and is especially advantageous in gain-control systems in which the operating characteristics of mid-line repeaters or terminal amplifiers are to be varied to control the transmission properties of the system.

A feature of the invention is the use of common controlling apparatus alternately for the two directions of transmission. This apparatus is arranged to transmit control current first in one and then in the opposite direction and to effect an adjustment or alteration, if such is necessary, of the circuits over which the regular one-way transmissions take place. Since for most if not all practical purposes, continuous adjustment is not necessary but periodical adjustment is sufficient, the invention by using the same apparatus in succession for different transmission adjustments, effects an economy in apparatus over systems heretofore used or proposed.

The invention is particularly applicable in carrier current systems in which currents or waves of distinctive frequencies are employed to transmit signals. As the number of channels is increased it becomes a matter of great importance to economize in the number or range of frequencies used for any one purpose in order that all of the desired channels may be included in the available total frequency-range. It has been suggested, heretofore, to employ one distinctive frequency to effect gain control for one direction of transmission and a different distinctive frequency for control in the opposite direction. These two frequencies occupy a valuable portion of the available range that might otherwise be used for transmitting signals. The present invention by using the same character of current alternately to control for opposite directions of transmission, which in the case of a carrier system would be a current of the same frequency in both directions, effects an economy not only in the amount of necessary apparatus but also in the frequency range utilized for exercising the control.

Briefly and specifically the invention in its preferred form employs at each of two terminal stations co-ordinated transmitters whereby characteristic control current of constant strength or amplitude is sent from each station alternately in timed intervals. At an intermediate station such as a repeating station this control current is selectively transmitted to a one-way amplifier which is arranged to be switched to and fro relative to the line sections to receive the control current from whichever terminal station happens to be sending it out, and to repeat it to a succeeding station. As the direction of transmission of the control current alternates, the amplifier is reversed to receive from the new direction of transmission. Suitable control apparatus is located at each repeating station for effecting an adjustment of the repeaters for the signaling channels. This apparatus preferably includes a balanced circuit the condition of balance of which is determined by the strength of the control current received at the respective repeater station, since the strength of this current may be taken as a measure of the line attenuation. Changes in the line attenuation tends to upset the balance of this circuit and the apparatus is brought into play to alter the setting of the input potentiometers of the repeaters to increase or decrease their gain.

The general nature and objects of the invention having been breifly indicated, a more detailed description of the invention in its preferred form will now be given, from which the various features and objects will be more readily apparent.

In the drawings, Fig. 1 is a schematic representation of a system with a number of intermediate repeating stations, to which the invention is applicable; Fig. 2 illustrates diagrammatically circuit arrangements concerned in the invention and located at a terminal station of a line or system; Fig. 3

shows similar circuit arrangements that would be found at a repeater station; and Fig. 4 shows a modification of the sending arrangements at a terminal station.

In Fig. 1 a system is indicated having east and west terminal stations RP_1, RP_2, RP_3, RP_4, and RP_5. Each repeating station may be assumed to have an east repeater and a west repeater for enabling two-way communication over the system. According to the invention, a control current is arranged to be sent alternately from the east and west terminal stations through the line for controlling the adjustment of these repeaters. On account of the length of the line it is necessary to provide amplifiers at the repeating stations for this control current also. In the present system, a control current of the same frequency is transmitted in each direction and since, in the present system, the separation of the oppositely directed transmissions at the repeater stations is accomplished by filtering, the selective path for the control frequency at each repeating station from two opposite line sections is the same regardless of the direction of transmission of the control current. The control or pilot amplifier used at a repeating station is a one-way amplifier and in accordance with the invention, arrangements are provided for reversing the connections of this repeater to enable it to receive alternately from the direction of the west station and from the direction of the east station.

It is necessary to have the terminal transmitters for this control current and the pilot amplifiers at the several repeating stations coordinated so that when the west station is transmitting, for example, the pilot amplifiers of all of the intermediate repeating stations will be aligned in the direction to receive from the west station and to transmit towards the east station. The transmitters and the pilot amplifiers could conceivably be controlled in a time relation so that when the west station, for example, ceases transmitting, each repeater would reverse its direction. However, in case one or more pilot repeaters should get out of step with the remainder of the control system, the system might be rendered largely or wholly inoperative. Such a contingency is provided against in the present invention by making the operation of the transmitting means at the terminal stations and the reversing means for the pilot repeaters dependent upon received control current. Either transmitter is prevented from transmitting so long as it is receiving the control current and each pilot repeater is arranged to "hunt" when no control current is being transmitted, that is, to connect its receiver alternately to the line sections with which it is associated, and when the control current comes in from either line section to remain in position to receive this current.

Associated with each of these pilot amplifiers is a correcting or controlling mechanism for controlling the adjustment of the signaling repeaters or amplifiers. The control current varies in strength at any receiving point in accordance with variations in the transmission characteristics of the line over which this control current is received and the variations in the strength of the received control current are made use of to alter the gain of the various repeaters to compensate for these variations in the transmission characteristics of the line. Similar correcting means may be used at a terminal station, preferably for adjusting the amplifiers of the incoming channels.

Turning now to Fig. 2, the arrangement at a terminal station such as the west terminal station of Fig. 1 will be described. The main line L_1 corresponding to the line indicated in Fig. 1 is shown provided with transmitting and receiving terminal apparatus. The transmitters T_1, T_2 and T_3 are assumed to be carrier current transmitting channels of usual type and to be equipped with suitable filtering circuits for separating the frequencies comprised in the several transmissions which they control. Three receiving channels are also shown, which may serve as return channels for the three transmitters. They comprise receiving band filters RF_1, RF_2 and RF_3 leading to amplifiers A_1, A_2, A_3 associated with suitable receivers R_1, R_2 and R_3. Transmitter T_1 and receiver R_1 may be associated with a low frequency telephone line or a Morse telegraph line for two-way repeating therebetween, and transmitting channel T_2 and receiving channel R_2 may be similarly associated with another low frequency line, etc. These lines have not been shown, in order to prevent unnecessary complication of the drawing but since their mode of association with the transmitting and receiving channels is well understood, such lines may be assumed to enter the central station shown and to be arranged for cooperation with the multiplex line L_1.

In addition to the signaling channels indicated, a control channel is also associated with the line L_1 employing a frequency different from that of any of the signaling channels and comprising the band pass filter PCF for the pilot channel frequency, the pilot amplifier 6, and the pilot current source 7 together with suitable receiving and controlling circuits to be described presently. The pilot amplifier 6 is arranged to be connected between the source 7 of pilot or control current frequency and the filter PCF when this station is transmitting control current and to be connected between the filter PCF and the receiving and controlling cir-

cuits when this station is receiving control current from the line. Relays 8 and 9 control the reversal of the connections of the amplifier 6 to enable it to amplify outgoing current and incoming current alternately. The received control current passes through the rectifier 10 and operates the relay 11 which exercises a general control over the correcting or adjusting mechanism.

This correcting or adjusting mechanism as has been described comprises means for automatically changing the adjustment of the amplifiers for the signaling frequency in accordance with variations in strength of the received control current and for this purpose employs a kind of potentiometer circuit, the condition of balance or of unbalance of which determines the direction and extent of adjustment of the signal amplifiers. The potentiometer circuit includes a galvanometer 14 for indicating the balanced or unbalanced condition of the circuit and the relation between this galvanometer and the adjusting mechanism is secured through the medium of an automatic controlling apparatus generally indicated at 12. This controlling apparatus 12 by itself forms no part of the present invention and has not been illustrated in detail, since it may comprise any suitable or well known arrangement by which a power shaft, such as 13, is held stationary when the galvanometer 14 is in its zero or mid-position and is automatically rotated in one direction or the other dependent upon the direction of deflection of the galvanometer. Such rotation persists, continuously or by steps, until the galvanometer is again brought to its zero position. One specific system for accomplishing this is shown and described in the U. S. Patent to Brewer, No. 1,356,804, issued October 26, 1920 and for a more complete description of the circuits and mechanism involved, this patent may be referred to.

Certain additions and alterations external to the controlling mechanism 12 and not found in the said Brewer patent have been provided in the present invention, and these will appear as the description proceeds. As stated, the shaft 13 is rotated in one direction or the other by a certain amount under control of the galvanometer 14. The shaft 15, however, shown extending from below the mechanism 12 is a continuously rotating shaft and is governed by a suitable driving motor to have a fairly constant speed of rotation. This shaft 15 is arranged to drive a cam member 16 through the medium of suitable clutch mechanism 17. The cam 16 controls a contact spring 18 to close one or the other of the contacts 19 and 20, the purpose of which will be described later.

The nature and arrangement of the apparatus having been generally indicated, a better understanding of the system will be had from the following detailed description of its operation. The apparatus is shown in condition to receive control current from the line L_1 since the contact 19 is at this instant open, allowing the armatures of the relays 8 and 9 to be closed against their back or resting contacts. A circuit is then closed from the line L_1 through the pilot channel filter PCF and across the terminals of potentiometer resistance 22, the lower terminal of this resistance being connected over conductor 23 to the lower terminal of the filter and the upper terminal of the resistance being connected over the back contact and upper outer armature of relay 9 and conductor 24 to the upper terminal of the filter. Conductor 23 is extended over the conductor 25 and the lower back contact of relay 8 to the lower input terminal of the amplifier which may be assumed to lead to the cathode, it being assumed that the amplifier is of the well-known three-electrode electric discharge type. The adjustable arm of the resistance 22 is connected over conductor 26 and upper back contact of relay 8 with the upper input terminal of the amplifier which, in this case, may be led to the grid. With these connections, the received control current is impressed on the input circuit of amplifier 6. The output conductors 28 and 29 of the amplifier 6 are connected through the inner armatures and back contacts of relay 9 with the rectifier 10. A suitable network circuit acting as a "dummy load" is indicated at 30 to control the load taken by the rectifier 10, and particularly to absorb the load representing that portion of the pilot amplifier output which in the case of the mid-line stations is passed on to the outgoing line. This load circuit 30 is not essential, however, and can be dispensed with. Also the rectifier may have an adjustable input connection, if dsired. The incoming control current amplified at 6 and converted into direct current at 10 actuates the relay 11 which attracts its armature and causes the energization of relays 32 and 33. Relay 32 connects the constant source of potential comprising battery 34 and variable resistance 35 in series with the galvanometer 14, and with the output of the rectifier 10, in parallel with relay 11. Relay 33 in attracting its armature separates the normally engaged members of clutch 17 and causes the cam member 16 to stop rotating. Contact 20 being closed, relay 36 is energized from battery 37, causing engagement of the clutch 38 leading to the worm gear coupling 39.

With a given setting of the resistance 35 and with a normal, constant potential between the output terminals of rectifier 10, the galvanometer 14 may be assumed to receive no current, the battery 34 being of the proper polarity and voltage. This corre-

sponds to the condition of balance in which the pointer 41 of the galvanometer remains in its zero or mid-position and no movement is given to the shaft 13 in either direction. As the strength of the incoming control current varies from the strength corresponding to this condition of balance, the potential between the output terminals of the rectifier 10 no longer equals that across the portion of the resistance 35 included in the galvanometer circuit and the galvanometer 14 receives current causing its pointer 41 to deflect and the shaft 13 to rotate in a certain direction and to a certain extent as governed by the control mechanism 12. Rotation of shaft 13 actuates the gearing 39, since clutch 38 is engaged, and causes the rotation of a shaft indicated at 40 to which are attached the adjusting contact arms of input potentiometer 22 and of a similar input potentiometer in each of the receiving channels, indicated at 43, 44 and 45. Movement of the arm of potentiometer 22 varies the potential impressed on the input circuit of amplifier 6 and hence varies the strength of current finally reaching the rectifier 10. If it be assumed that the deflection of the galvanometer needle 41 was caused by a decrease in the potential between the output terminals of the rectifier 10, the control mechanism is so arranged that the resulting rotation of the shafts 13 and 40 moves the several potentiometer arms in a direction to increase the potential impressed on the amplifiers 6, A_1, A_2 and A_3. Rotation of the shaft 40 continues until the galvanometer needle 41 returns to its equilibrium position corresponding to the condition of balance, which means that the strength of the received control current in the circuit 28, 29 is restored to its normal value. Assuming that the currents employed by the several receiving channels are affected by variations in the transmission characteristics of the line L_1 in the same way that the control current is affected, and that the potentiometers 43, 44 and 45 have the same relations with the respective amplifiers of the receiving channels that potentiometer 22 has with the amplifier 6, then the strength of signaling current received at R_1, R_2, etc. is restored to its normal value and in general is maintained substantially constant notwithstanding fluctuations in the line attenuation.

As long as control current continues to come in and hold the relay 11 energized, the correcting mechanism is kept in condition for operation to adjust the receiving amplifiers in accordance with fluctuations in strength of the control current. When, however, the control current ceases to be received, relay 11 deenergizes causing relays 32 and 33 to be deenergized. Relay 32 opens the circuit of the galvanometer 14. The upwardly tensioned armature of relay 33 causes the clutch 17 to engage and connect cam member 16 with constantly rotating shaft 15 and to be driven in the direction of the arrow. As the spring 18 drops from a high portion to a low portion of the cam surface, contact 20 is opened and contact 19 is closed. The circuit from battery 37 to relay 36 is broken causing the disengagement of the members of clutch 38 and leaving shaft 40 to rest in the position to which it was last moved. Relays 8 and 9 are energized in parallel from battery 37 over contact 19 now closed. Relay 8, in energizing, breaks the circuit previously traced through its back contacts and connects the control current source 7 through its front contacts to the input circuit of amplifier 6. Relay 9 breaks the circuits previously traced through its back contacts and connects the output conductors 28 and 29 of the amplifier 6 directly through the pilot channel filter PCF to the line L_1. Thus, when relays 8 and 9 energize, the receiving circuits are dissociated from the line and the transmitting source 7 is connected to the line, the circuits continuing in the transmitting condition as long as spring 18 is traversing the low portion of the cam 16. When the spring 18 rides up on a high portion of the cam surface, the circuit of relays 8 and 9 is broken at contact 19, and the receiving circuits are again associated with the line through the amplifier 6 at the back contacts of relays 8 and 9 as originally traced, and magnet 36 is energized by the closure of contact 20 to place shafts 13 and 40 into operative engagement. If, with the circuits in this condition, no control current is received from the line, relay 11 remains deenergized permitting relays 32 and 33 to remain deenergized and the cam member 16 continues rotating since clutch 17 is engaged. If no control current is received at any time during the passage of spring 18 over a high portion of the cam surface, the cam member 16 is allowed to continue rotating and the spring 18, dropping into a low portion of the cam, shifts the circuits to the transmitting condition again. In this way, the control current continues to be transmitted in intervals corresponding to the length of the low portion of cam member 16 and it is interrupted from transmission for intervals corresponding to the length of the high portions of the cam so long as no control current is being received.

It is assumed that the distant terminal station is equipped with apparatus similar to that shown in this figure and hence the distant station will also send out control current for intervals which may correspond to the transmitting intervals of the station of Fig. 2. It will be noted that the low portion of the cam member 16 is longer than the high portion. The length of the low

portion determines the interval of transmission of the control current whereas the length of the high sector of the cam determines the period during which the terminal station will wait in condition to receive from the distant station before again starting to transmit in the event of failure to receive the control current. This receiving interval is sufficiently long to enable current starting from the distant terminal to pass in succession through the pilot amplifiers of all the repeating stations after having effected the necessary reversing operation of these amplifiers and to arrive at the receiving terminal station before the spring 18 of the receiving station has passed off from the high sector. The transmitting interval is sufficiently long to control the directing of all of the intermediate pilot amplifiers for reception and retransmission of this pilot current and thereafter to allow a considerable period of time during which the automatic correcting of the mid-line repeaters and terminal amplifiers may be accomplished. The length of the "listening" interval of a terminal station should be somewhat greater than the maximum length of time required to reverse an intermediate repeater multiplied by the number of repeaters in series in the line. The relation between the terminal stations will be such that a terminal station will, in the normal operation of the system, always receive control current from the opposite station each time the spring 18 passes over a high sector of the cam 16. However, it will be seen that if these terminal sending arrangements get out of step for any reason, they will continue to send and "lisen" for definite periods until a condition is reached in which one terminal repeater is "listening" at the same instant that the distant terminal is transmitting and in which, with this relation of the terminal stations existing, all of the intermediate repeaters will have had time to be turned in a direction to transmit this current through the entire system. The cam 16 of the terminal station then in receiving condition will be arrested and thereafter the normal cooperation of the terminal stations will be resumed. The length of the transmitting and receiving sectors of cam 16 may differ in the two stations, if desired, or other variations may be made to prevent the terminal stations from remaining too long in exactly out of step relation, but such expedients will be obvious and will suggest themselves to an attendant or workman of ordinary skill in the art.

Turning now to Fig. 3 a somewhat similar arrangement of circuits will be found with such modifications as are necessary to enable the apparatus to serve as a two-way repeating station. Signaling currents received over the line section L_1 from the transmitters T_1, T_2, etc., of Fig. 2, upon arriving at the repeater station are directed through the high pass filter HPF adjacent the line L_1, the eastward repeater ER, the filter HPF adjacent the line L_2 and into the east line section L_2, it being assumed that the east transmissions employ a group of frequencies higher than those used for transmitting west. Similarly, transmissions received over the line L_2 pass through the low pass filter LPF adjacent that line, the west repeater WR, the low pass filter LPF in the output of this repeater and into the line section L_1. The control frequency channel is connected between the line sections L_1 and L_2 through the control or pilot channel filters PCF and this channel also includes a pilot channel amplifier PCA which, due to its circuit connections, may be employed for alternate transmissions in opposite directions.

Assuming that the control current is being received at the instant under consideration from the line section L_2, this current will pass through the filter PCF at the right in the drawing and will be impressed across the terminals of the potentiometer resistance 47, the upper terminal of this resistance being connected to the upper terminal of the filter through the inner armature and back contact of relay 49, and the lower terminal of the resistance being connected directly to the lower terminal of the filter. The lower terminal of resistance 47 is also connected by way of conductor 51 and lower back contact of relay 48 with the lower input terminal of the amplifier PCA which terminal may be assumed to be connected with the cathode of the three-electrode vacuum discharge tube of this amplifier. The movable terminal of the resistance 47 is connected by way of conductor 52 and the upper back contact and armature of relay 48 with the upper input terminal of the amplifier PCA which terminal may be assumed to lead to the grid of the amplifier. The amplified control currents in the output circuit 58, 59 pass in part to the rectifier RFR and actuate the relay 11, corresponding to relay 11 of Fig. 2, and in part through the outer armatures and back contacts of relay 49, the conductors 53 and 54 and the control channel filter PCF at the left, to the line section L_1 for transmission to the terminal station in Fig. 2.

The control mechanism 12 of this figure including the galvanometer 14 and the resistance 35 may be similar to that described in connection with Fig. 2 except that the shaft 13 is shown extending from both sides of the control mechanism for controlling two adjusting devices and the continuously rotating shaft 15 is not provided with a clutch. The cam member 56 is, therefore, continuously driven by the shaft 15 causing the spring 61 to be shifted continually to

close the alternate contacts 62 and 63. When no current is being received and the relay 11 is consequently deenergized, spring 61 is connected to ground over the left-hand back contact of relay 11, and ground is therefore alternately applied through contacts 62 and 63 to first one and then the other of the two relays 64 and 65, energizing these relays in turn from battery 66. When either relay energizes, it closes a locking circuit for itself independent of contact 62 or 63, relay 65, for example, upon energizing having a locking circuit from battery 66, winding of relay 65, back contact of relay 64 to ground. If relay 64 is now energized it breaks the locking circuit of relay 65 by attracting its armature and when relay 65 deenergizes relay 64 similarly has a locking circuit independent of contact 63 by way of battery 66, winding of relay 64, back contact of relay 65 and ground. It is the function of these two relays to control the reversing relays 48 and 49 which are similar in function to relays 8 and 9 of Fig. 2, and the relay 67, the purpose of which will be indicated presently.

Assuming as was stated, that the control current is being received from line L_2 and is holding relay 11 energized, the ground is removed from spring 61 at the left-hand armature of relay 11 and the continued rotation of cam 56 has no effect upon the relays 64 and 65. It will be seen from the drawing that relays 48 and 49 must be deenergized in order to receive from the line L_2, and this corresponds to the condition in which relay 65 is energized. If current is received from L_2 at the instant when relay 65 is energized by its local control circuit and therefore when spring 61 is closed against contact 62, the relay 11 energizes in response to the incoming line current and prevents the subsequent energization of relay 64 which would normally occur when spring 61 drops into a slot of the cam 56 and closes contact 63. As long as relay 11 remains energized, therefore, it is impossible, assuming relay 65 to be energized, to energize relay 64, and the locking circuit for relay 65 remains closed at the back contact of relay 64. Relays 48 and 49 therefore remain deenergized placing the repeater PCA in position to receive continuously from the line L_2.

When relay 11 energizes in response to received control current, it closes a circuit for relay 69 at its right-hand front contact and armature and at the same point closes a circuit for magnet 70 through the back contact and armature of relay 67, this relay being deenergized due to the opening of the left-hand contact of relay 65. Relay 69 closes the circuit through the galvanometer 14 and the potentiometer resistance 35, while relay 70 causes the clutch 71 to engage thereby coupling the adjusting shaft indicated at 72 with the driving shaft 13. Variations in the strength of the received control current from the line L_2 cause deflections of the galvanometer 14 and consequent movements of the shaft 13 as described in connection with Fig. 2, thereby altering the setting of the input potentiometers 47 and 73 which are fixed to the shaft 72. The potentiometer 47 is thus given varying settings causing the current in the output circuit 58, 59 of the amplifier PCA to tend to increase or to decrease in such a manner as to compensate for the varying transmission characteristics of the line L_2. The result is that the output current of the amplifier PCA remains substantially constant and when an unbalance of the galvanometer is overcome by the adjustment of the potentiometer 47, movement of the shafts 13 and 72 ceases. An empirical relation is assumed to exist between potentiometers 47 and 73 such that the changes in the setting of potentiometer 47 which are necessary to maintain the received pilot or control current substantially constant are accompanied by changes in the potentiometer 73 of such a direction and extent as to maintain the received signaling currents in the output of repeater WR substantially constant.

Since the output current of the pilot current amplifier PCA is employed to indicate the variations in transmission characteristics of the system and since this current is subject to fluctuations in the plate battery supply of the repeater tube, in order to balance out the effects of these battery fluctuations in the different repeaters, the same space current supply is provided for both of the signaling repeaters ER and WR and for the pilot current source 75 of the amplifier PCA, the circuits to these repeaters including the choke impedances 76, 77 and 78 respectively.

As long as relay 11 continues energized in response to current received over the line L_2, the repeater PCA is held in position to repeat the control current from the line L_2 to the line L_1 and the correcting mechanism for actuating the potentiometers 47 and 73 is held in operative condition under control of currents received through the rectifier RFR. When control current from the line L_2 is cut off and relay 11 deenergizes, ground is again connected to spring 61 and the relays 64 and 65 become energized and deenergized, successively. As relay 65 opens and closes its left-hand armature and contact it causes the reversing relays 48 and 49 to release and attract their armatures and also causes relay 67 to shift its armature between the control circuits of magnets 70 and 79. It has been described how when relays 48, 49 and 67 are deenergized, the control currents are repeated west and the west repeater WR is adjusted by means of its potentiometer 73. In a similar manner, when relays 48, 49 and 67 are energized, the control currents are re-

peated from line L_1 to line L_2 and the east repeater is automatically adjusted by means of its variable potentiometer 81. The variable arms of this potentiometer and the potentiometer 82 of the pilot current amplifier for pilot current transmitted east are driven from the shaft indicated at 83, which is operatively associated with the driving shaft 13 through the medium of the clutch 84 when the relays 11 and 67 are energized causing the magnet 79 to bring the members of clutch 84 into engagement. The circuit of magnet 79 extends from battery and right-hand front armature and contact of relay 11, front contact and armature of relay 67, magnet 79 to ground.

If during the alternate energization of relays 64 and 65, control current is received from line L_1 when the pilot amplifier is connected to receive from that line due to the energization of relay 64 and the falling back of relay 65, relay 11 pulls up and holds relays 64, 48, 49 and 67 energized as long as control current is received. With relays 48 and 49 energized, the lower input terminal of the pilot current amplifier PCA is connected over the lower front contact and armature of relay 48 to the lower terminal of potentiometer 82, the upper potentiometer terminal being connected over the upper inner armature and front contact of relay 48 to conductor 54. The movable arm of potentiometer 82 is connected over the upper outer armature and front contact of relay 48 to the upper input terminal of the amplifier. Control currents received from the line L_1 therefore pass through the filter PCF and are impressed on the input of the amplifier PCA. The output conductors 58 and 59 of the amplifier PCA are connected through the outer armatures and front contacts of relay 49 direct to the terminals of the right-hand filter PCF whereby the amplified control currents are repeated into the line section L_2. A portion of the output current passes to the rectifier RFR, actuates the relay 11 and, the relay 69 being energized, sets up a potential in the galvanometer circuit in opposition to the potential derived from resistance 35. Deflections of the galvanometer in response to variations in the received control current cause the shaft 13 to be rotated and these rotational movements are transmitted through the clutch 84, now engaged, to the shaft 83 which changes the setting of the potentiometers 81 and 82. The potentiometer 82 is adjusted to restore the output current in the amplifier PCA to its normal value corresponding to the balanced condition of the galvanometer circuit, when movement of the shaft 83 ceases. Simultaneously, movement of the arm of potentiometer 81 adjusts the east repeater ER to maintain the amplified currents in the output circuit of this repeater substantially constant.

It has been assumed in the foregoing description that the variations in strength of the current received at any point in the system can be taken as indicative of the variations in the transmission characteristics of the circuit over which this current is received. This is true, of course, only on condition that the transmitting source, such as 7 in Fig. 2, maintains a constant current amplitude. Any suitable regulating or adjusting means may be employed for keeping the output current strength constant. For example, the source may be carefully constructed and maintained under constant operating conditions and may be provided with manual regulating devices and a suitable indicating meter to enable an attendant to make adjustments from time to time as required. Or automatic regulators such as are known in the art may be employed.

It is preferred, however, to maintain the current output of the source 7 constant under control of the controlling mechanism 12, and the necessary arrangements for exercising this control are indicated in Fig. 4. When the arrangement in Fig. 4 is used, the rectifier 10 is to be permanently connected to the output of the pilot amplifier 6 and for his purpose the leads will be opened at the points Y, Y, and closed at the points X, X. The load 30 may also be disconnected, this artificial load being in any case not an essential element of the system, as heretofore explained. The source 7 has a resistance 90 connected across its terminals over which the arm 91 is adapted to be moved under control of the coupling 92. The conductors extendings to the right of the resistance 90 and arm 91 are assumed to lead to the armature contacts of the relay 8. The shaft 13 is shown extending to the left from the controlling mechanism 12 and to be provided with a clutch 93 for driving the coupling 92. This clutch is controlled by a magnet 94. The spring 18, actuated by the cam member 16, is provided with an extra pair of contact springs 95 in addition to the contacts 19 and 20 as in Fig. 2. The contacts 95 are placed in series in the energizing circuit of the clutch magnet 33.

The operation of the modified arrangement shown in Fig. 4 will be clear on considering these modifications in connection with the circuit of Fig. 2. When the spring 18 is riding over a high portion of cam surface 16, contacts 20 and 95 are closed and contact 19 is opened. Relays 8 and 9 are in their deenergized or receiving condition and magnet 36 is energized. In case the control current is at this moment being received from the distant station, relay 11 is energized and closes a circuit from battery and its front contact, contact 95, magnet 33 to ground. Magnet 33 releases the clutch 17 and stops cam member 16. Relay 32 also

energizes over the armature of relay 11 closing the galvanometer circuit and since the clutch 38 is now engaged, the apparatus is in condition to exercise control over the potentiometers 42, 43, 44 and 45 as heretofore explained.

When the incoming control current ceases, relay 11 falls back allowing magnet 33 to be deenergized and re-engage clutch 17. Cam 16 starts rotating and when the spring 18 drops into a depression of the cam surface, the energizing circuit of magnet 33 is broken at 95 insuring the continued rotation of the cam 16 until the spring 18 again rides up on a high portion of the cam, when magnet 33 is again placed under control of relay 11. With the spring 18 traversing a low portion of the cam surface, contact 20 is opened and contact 19 is closed causing energization of relays 8 and 9, as previously described, and in addition causing magnet 94 to energize and engage clutch members 93. Relays 8 and 9 connect the source 7 to the line through the medium of the pilot amplifier 6 and the filter PCF. A portion of the output current from the pilot amplifier 6 passes into the rectifier 10 and actuates relay 11 which, in turn, causes the relay 32 to energize and connect the galvanometer circuit to the potentiometer 35. Relay 11, however, has no control at this time over magnet 33 since contacts 95 are opened. Any tendency of the current being impressed on the line to fluctuate causes the control mechanism 12 to exercise control over the shaft 13 and the variable arm 91 through the medium of the driving mechanisms 92 and 93. If the tendency is for the current from amplifier 6 to increase, the resulting correcting movement of arm 91 is in a direction to decrease the voltage impressed on the amplifier and vice versa. In this manner, the output current impressed on the line is maintained substantially constant.

In the foregoing description, no preferred value has been stated for the frequency of the pilot or control channel, since this will depend entirely on the conditions present in any given system. It is desirable to assign one of the higher frequencies of the system for this purpose since the higher frequencies suffer greater attenuation and a high frequency control is therefore more sensitive to changes in attenuation than a low frequency control. However, it may happen that in the interest of economy in frequencies in a given system, a lower frequency can more advantageously be used. In a system of the type shown in the drawings, it has been found convenient to employ for control purposes a frequency in the narrow range included between the directional groups of frequencies, the filter PCF being made sharply selective of this frequency.

While the invention has been described with reference to a specific type of transmission system, it is to be understood that the invention as a whole and its separate features are capable of broader application than has been specifically indicated, and that the invention is not to be limited by the particular disclosure but its scope is defined in the appended claims.

What is claimed is:

1. In a carrier current transmission system, a plurality of one-way transmission channels, amplifying means therefor, another plurality of one-way transmission channels, amplifying means therefor, a control channel common to all of said transmission channels, means to transmit control current through said control channel and means actuated by said control current for effecting an adjustment of each of said amplifying means in alternation.

2. In a transmission system, a transmission circuit, means to transmit control current alternately in each direction over said circuit, means to transmit signaling current in one direction over said circuit, means to transmit other signaling current in the opposite direction over said circuit and means responsive to said control current when it is being transmitted in each of its two directions of transmission to vary the transmission characteristics of the circuit for the particular signaling current being at the time transmitted in the same direction as said control current.

3. In a carrier current system, a plurality of two-way carrier transmission channels, a single non-signaling control channel and means arranged to respond to control current transmitted through said control channel for adjusting certain of said carrier channels and for separately adjusting others of said channels.

4. In a carrier transmission circuit, eastward channels employing carrier frequencies grouped within a given range, westward channels employing frequencies grouped within a different range, a single control channel employing current of a single frequency intermediate said frequency ranges and means arranged to be operated by said control channel for controlling the eastward and the westward channels.

5. In a transmission system, a transmission circuit including an amplifier and a transmission control member, means to transmit a control current of definite character over said circuit, means responsive to current of said character for adjusting said amplifier at times and at other times for controlling said transmission control member.

6. In a transmission system, a transmission circuit including amplifying means and transmission control devices independ-

ent of said means, means to transmit currents of different frequencies over said circuit for exercising distinct controls and means responsive to current of a certain frequency for effecting an adjustment of said amplifying means at certain times and at other times for actuating one of said transmission control devices.

7. In a carrier current system, a plurality of eastward transmitting channels and a plurality of westward transmitting channels, amplifying means for the channels of each direction of transmission, means for transmitting control current of a definite frequency alternately east and west and means acting in response to said control current when it is being transmitted in either direction for effecting an adjustment of the amplifying means for the said plurality of channels transmitting in the same direction.

8. In combination, a vacuum discharge tube having an input and an output circuit, a plurality of transmission circuits each having a device associated therewith, a driven member, means controlled by said driven member for associating said discharge tube input circuit successively with different ones of said transmission circuits and means in the output circuit of said discharge tube for controlling the device of the transmission circuit with which said input circuit is at the time associated.

9. In combination, a plurality of transmission circuits, a vacuum tube amplifier, means for associating said amplifier successively with different ones of said circuits and means actuated by said amplifier for controlling the adjustment of the associated transmission circuit.

10. In combination, a vacuum tube circuit having input and output circuits, a plurality of incoming circuits, means for associating said tube with different incoming circuits in succession and means controlled from the output circuit of said tube for variably adjusting the incoming circuit with which said tube is at the time associated.

11. In a carrier transmission system, a line, means for transmitting in one direction thereover, a plurality of carrier signaling currents of distinctive frequencies and a control current of a distinctive frequency, means for transmitting in the opposite direction thereover, a plurality of carrier signaling currents of distinctive frequencies and a control current of the same frequency as the first-mentioned control current and means arranged to be controlled by control current transmitted in either direction for effecting an adjustment of the system.

12. In a signaling system, two stations, automatically operating means whereby each station alternately transmits current to and receives current from the other, and transmission-controlling means for said system controlled by said current.

13. In a signaling system, two stations, automatically operating means whereby each station alternately transmits current to and receives current from the other, signal amplifying means for said system, and means controlled by said current for modifying the operation of said amplifying means.

14. In a signaling system, two stations, automatically operating devices whereby each station alternately transmits current to and receives current from the other, oppositely directed signal amplifiers for said system, and means controlled by the said current transmitted in either direction for effecting an adjustment of the signal amplifier adapted for transmission in the same direction.

15. In a signaling system, a line, a two-way two-repeater station thereon, a one-way-working device for effecting an adjustment of a repeater, and means operating in response to line current for alternately operatively associating said device with one and with the other of the two repeaters at said station.

16. In a signaling system, a line, an east repeater and a west repeater in said line, repeater gain-adjusting arrangements, and automatically operating means for periodically operatively associating said arrangements with one and with the other of said repeaters in alternation.

17. In a signaling system, a one-way repeater, a source of control current, means operated by said control current, for interchanging the connections of said repeater for enabling it to transmit in each direction alternately, and means controlled by said repeater for altering the transmission characteristics of said system.

18. In a signaling system, a one-way repeater, means for alternately shifting the connections of said repeater to enable it to transmit in either direction through said system, separate transmission-controlling devices for controlling the transmission characteristics of said system for each direction of transmission, said devices being alternately controllable by said repeater depending upon the direction in which said repeater is transmitting.

19. In a signaling system two line sections, two oppositely-directed repeaters included between said sections, a device for effecting an adjustment of a repeater under control of current received from the line, and means for alternately associating said device with said line sections and said repeaters to receive current alternately from said line sections, and to effect an adjustment alternately of said repeaters.

20. In a signaling system a line having

stations, means at a station for periodically alternately transmitting current to said line and receiving current from said line, a pilot amplifier, other amplifying means, and means controlled by said pilot amplifier and by current received over said line for effecting an adjustment of said other amplifying means.

21. In a signaling system terminal stations and one or more repeating stations between said terminal stations, cooperating transmitting arrangements at said terminal stations for alternately transmitting current of a given character through said system, and transmission-controlling devices at said repeater stations controlled by said current for changing the adjustment of said repeater stations.

22. In a signaling system, a line the attenuation of which is subject to variations, one or more repeating stations having two-way repeating paths cooperating with said line for transmission of signals, means for alternately transmitting in one and in the other direction over said line current of a definite character, and means at a said repeater station controlled by said current for adjusting the transmission characteristics of both of the repeating paths at the respective station.

23. In a signaling system, a plurality of transmission circuits each arranged to transmit signaling currents and non-signaling pilot current, repeaters for amplifying the signaling currents received from said lines, a single pilot amplifier, means for associating said pilot amplifier successively with said transmission circuits for amplifying pilot current received from said transmission circuits, and means controlled by said pilot amplifier when associated with any particular transmission circuit for effecting an adjustment of the individual repeater associated with the same transmission circuit.

24. In a signaling system means for controlling the transmission characteristics of the system for signaling current transmitted in one direction and for signaling current transmitted in the opposite direction, means for transmitting non-signaling current alternately in each direction through said system, and means controlled in accordance with the direction of transmission of said non-signaling current for controlling the transmission characteristics of said system for signaling current transmitted in the same direction.

25. In a signaling system a line divided into sections, means to transmit signaling currents and controlling currents thereover, oppositely-directed one-way repeaters included between said sections for repeating signaling currents, an auxiliary repeater included between two line sections for repeating said controlling currents, means for alternately associating the receiving side of said auxiliary repeater with said two sections, and means controlled by said auxiliary repeater and said controlling currents for effecting an adjustment of said signal repeaters alternately.

26. In a controlling system for a transmission system having terminal stations, means at each station for transmitting current in timed periods, arranged when not transmitting to be in condition to receive current from the other station, and when receiving such current to be arrested from transmitting, whereby current is transmitted through the system alternately from said stations, and means associated with the system intermediate said stations variably controlled by said current in accordance with its direction of transmission through said system.

27. In a transmission system having a line composed of sections in series with interposed repeaters, the repeaters between adjacent sections having their receiving sides respectively connected to opposite sections, means for changing the gain of each repeater to compensate for variations in the transmission characteristics of the section from which said repeater receives current, a gain controlling device, and means for alternately operatively associating said device with two adjacent line sections and the repeaters between said sections.

28. In a signaling system, a plurality of repeating stations, signal repeaters and auxiliary repeaters at said stations, automatically operating means for directing the auxiliary repeaters to receive alternately from one and from the opposite direction, means to transmit a control current in series through said auxiliary repeaters alternately in one and in the other direction, and means at each repeating station controlled by said current for effecting an adjustment of said signal repeaters.

29. In a signaling system, a plurality of repeating stations, terminal stations, signal repeaters and auxiliary repeaters at said repeating stations, locally controlled means for directing each auxiliary repeater to receive current alternately from each direction, means at either terminal station for transmitting a characteristic current, means responsive to said characteristic current for arresting an auxiliary repeater in position to receive from the station transmitting said characteristic current and to repeat said current for the succeeding station, and means controlled by said current for effecting a change in the transmission characteristics of said signal repeaters.

30. In a signaling system, a station, a plurality of lines incoming to said station, amplifying means associated with each of said lines for amplifying current received from the line, a gain-controlling mechanism,

and switching means for associating said mechanism with each of said lines in succession and with the amplifying means for that respective line, for altering the characteristics of the amplifying means under control of current received over that respective line.

31. In a carrier current transmission system, a plurality of oppositely directed one-way signaling channels employing distinctive carrier frequencies, separate amplifying means for transmissions in each direction, a controlling channel employing a frequency different from the signaling carrier frequencies, means for transmitting through the control channel alternately in each direction, and means responsive to current received through said control channel for effecting an adjustment of one or another amplifying means depending upon the direction in which the control current is transmitted.

32. In a carrier current transmission system, a plurality of oppositely directed one-way carrier signaling channels, means to separate transmissions of opposite directions, amplifying means for the transmissions of the same direction, a control channel distinguished by its frequency from the other channels, automatic switching means local to said amplifying means and dependent for its action upon received control current through said control channel for directing the transmission of control current alternately in opposite directions through said control channel, and means also responsive to received control current and dependent upon the direction of transmission of said control current for effecting an adjustment of the amplifying means working in the same direction.

33. In a carrier current transmission system, a repeating station, a pair of oppositely directed amplifying repeaters thereat, means to separate oppositely-directed carrier signal transmissions to said respective repeaters, a control channel distinguished by its frequency from the signalling channels, a repeater for said channel at said station, a commutating device for periodically and continually interchanging the leads of said control channel repeater to enable it to repeat alternately in opposite directions, means responsive to the receipt of control current through said control channel for disabling said commutating device and holding the leads of said control-channel repeater in condition to receive continuous incoming control current from either direction and means controlled by said incoming control current for effecting an adjustment of one of said pair of repeaters depending upon the direction of transmission of said control current.

34. In a carrier current transmission system, terminal stations, a series of repeating stations therebetween, carrier-signaling channels, including carrier-signalling repeaters at said intermediate stations, a control channel distinguished by its frequency from the signaling channels, a control channel repeater at each repeating station, locally controlled means at each repeating station for enabling said control-channel repeater to receive alternately from opposite directions, means at either terminal station to transmit a control current through the control channel, means at the first repeating station responsive to said control current for holding said control-channel repeater in condition to repeat said control current through to the second repeating station, similar means at the successive repeating station or stations for repeating said control current, and means at each repeating station responsive to said control current for effecting an adjustment of said carrier-signaling repeaters.

35. In a carrier current transmission system, terminal stations, intermediate stations, means to transmit a control wave of the same definite frequency alternately from one and the other of said terminal stations, a repeater for said control wave at each intermediate station, means for automatically reversing each repeater to enable it to repeat control current received from either terminal station, and adjusting means at the intermediate stations actuated by said control wave.

36. In a signaling system, a signal repeater, another repeater, means controlled by said other repeater for automatically changing the transmission characteristics of both of said repeaters, and a common source of energy for supplying the energy of amplification for both of said repeaters.

37. In a signaling system, a plurality of amplifying repeaters of the electric discharge type having each a cathode, an anode and a control element, means controlled by the amplified current from one of said repeaters for controlling the amplification of received currents by each of said repeaters, and a common source of anode current for all of said repeaters.

38. In a transmission system having a line and stations thereon, means at a station for transmitting control current to said line, including a source of control current and automatically operating means actuated in response to fluctuations in the strength of said current for maintaining the current impressed on said line substantially of constant strength, and means at a distant station operated in accordance with the strength of the control current received over said line from the first station for controlling the transmission characteristics of said system.

In witness whereof, I hereunto subscribe my name this 29th day of December A. D., 1921.

JOSEPH W. HORTON.