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TRANSMISSION REGULATION

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7 Claims. (Cl. 178-44)

The present invention relates to the regulation of transmission in a signaling or other system in which currents or waves are being sent and in which the currents or waves are subject to variations to be compensated for.

The invention will be described and illustrated as embodied in a system for transmitting signals in succession through a number of repeater stations situated along a transmission line, with regulation at the repeater stations to compensate for variations in line characteristic. In particular, the system to be illustrated and described is a multiplex carrier line system transmitting a wide band of frequencies, such as 12 to 60 kilocycles or 10 to 100 kilocycles in which are comprised the frequencies utilized by a number of speech channels, for example 12 to 22, on the basis of 4 kilocycles being allotted to each channel. In this illustrative embodiment, the lines are the pairs within a lead sheathed cable which may be of ordinary or known construction. The attenuation is such as to require a repeater spacing of the order of 10 to 25 miles. In such a system the principal transmission variable is that corresponding to variation in temperature of the cable, the temperature variations being much greater and much more rapid in the case of aerial cables than underground cable.

The variation of transmission loss with temperature is different at different frequencies and in a band as wide as indicated above, the difference in transmission loss between different frequencies in the band is great enough to require correction in a long system. The change in attenuation for given change in temperature is, of course, in the same direction for all frequencies, but in cables observed by applicant it is greatest in the range between 23 and 30 kilocycles. The correction is made by introducing a "flat" change sufficient to correct for the greatest rate of change in attenuation. This means that the "flat" regulator adds too much gain at all frequencies except the frequency or frequencies at which the maximum rate of change with temperature occurs. For long systems a changing loss must be added to the cable loss at all other frequencies than the frequency or frequencies at which the flat regulator compensates. This differential or added correction is referred to as the "twist" correction as distinguished from the flat correction.

In a long cable carrier system there will ordinarily be a number of unattended repeater stations interspersed between attended stations, for example two to four or five unattended stations

between the nearest two attended stations. It is desirable to keep the apparatus at the unattended stations as simple as possible and to locate as much of the corrective mechanism as possible at the attended stations.

For this reason it is desirable to make the flat compensation at each repeater station while the differential or twist correction is made only at attended stations.

A system in general as outlined above is disclosed and claimed in H. S. Black Patent 1,956,547 granted May 1, 1934. The present invention is concerned with various improvement features, including a novel manner of effecting the compensating changes in the repeaters both as to circuits and mechanisms, and various other features more or less incidental thereto. The nature of the invention and its various objects and features will be more clearly understood from the following detailed description taken in connection with the accompanying drawing in which:

Fig. 1 is a simplified schematic drawing, showing the manner of association of the pilot wire lines and the controlling mechanism with a plurality of repeaters in the line; and

Fig. 2 is a schematic circuit diagram of one of the attended repeater stations having both the short pilot line control and the long pilot line control.

In Fig. 1 it is assumed that the line 10 is one of several lines which may be included inside a lead sheath, each line equipped for multiplex carrier telephone transmission employing frequencies in a wide band. Every few miles along the line 10 is an unattended repeater R_1, R_2 , etc. and at longer intervals along the line 10 are attended repeater stations, one of which is shown at RR. A short pilot wire such as PL_1, PL_2 , etc., is associated with each repeater section and terminates in a control C_1, C_2 , etc., for automatically changing the gain of the repeaters R_1, R_2 , etc., in a manner that will be described. A long pilot wire PL_4 spans the entire distance between main or attended repeater stations such as RR and has associated with it a control mechanism C_4 for regulating the repeater characteristic in a manner to be described.

The manner in which the control C_3 regulates the gain of a repeater at the station RR may be the same as that used at each of the unattended stations. The attended station, however, includes a twist compensator network 9 indicated as having its shape controlled by a connection 12 to control mechanism C_4 . That is, the long pilot wire control mechanism operates upon the net-

work 9 to govern the extent of the twist correction to compensate for the unequal change in line transmission characteristic throughout the utilized frequency range. In order to achieve full correction at the repeater station RR by the conjoint action of two controls C₃ and C₄ which exert independent control on the repeater RR, the mechanism C₄ is made to control the mechanism associated with the short pilot wire in some suitable manner as by changing a resistance 11 associated with the short pilot wire regulating mechanism to insure proper cooperative relation between the two controlling mechanisms C₃ and C₄.

Since as noted above the type of pilot wire control mechanism used at each of the unattended repeater stations is the same as the pilot wire control C₃ at the station RR of Fig. 1, a description of the control mechanism C₃ of Fig. 2 will suffice also as a description of the control mechanism such as C₁ or C₂ at unattended stations such as R₁ or R₂.

Referring now to Fig. 2, the line 10 is shown leading inside a shielded compartment 17 to an input transformer 7 for an amplifying repeater 8, the output transformer 13 of which couples to the succeeding section of line 10. Only so much of this figure will be considered at first as involves the control mechanism belonging to the short pilot wire, and as corresponds, therefore, to the mechanism that is used at an unattended station. For the present, then, it will be assumed that the switches 19, 19 are thrown to the left of this figure thus removing the equalizer 18 from the circuit and it will be further assumed that the repeater 20 is absent. One other assumption is necessary, that is, that the switches 27 shown associated with pilot conductor 21 (corresponding to pilot wire PL₃ of Fig. 1) are thrown to their alternate positions thus disconnecting the pilot wire conductors from the conductors 42.

Under these assumptions it will be seen that the repeater 8 is included in the shielded box and connected between two sections of the line 10. Repeater 8 is preferably of the stabilized feed-back type disclosed and claimed in U. S. patent application to H. S. Black Serial No. 606,871, filed April 22, 1932, in which a feed-back leads from the output of repeater 8 through an equalizer network 14 to the input side of repeater 8 for feeding back a relatively large amount of output waves in such manner as to reduce the gain of the repeater circuit. The repeater 8 will, in practice, comprise more than one stage of amplification and will be designed to have the requisite high gain and suitable wide transmission band. Equalizer 14 may be a fixed equalizer network having a transmission characteristic similar to that of a section of the line 10 for enabling the repeater circuit 8 to compensate for unequal attenuation of currents of different frequencies in the utilized band as they are transmitted over the line 10.

The feed-back circuit of the amplifier 8 is shown as including a three-plate condenser 15 and a variable condenser 16. The three-plate condenser 15 is given a fixed setting at the time the amplifier is installed in order to adjust the gain of the repeater to suit the length of the particular repeater section to which the repeater is connected. In practice, repeater sections differ in length, sometimes by several miles so that different amounts of gain are required at different repeaters along the line. When the gain setting has been made to the proper value by con-

denser 15, the condenser setting is left fixed at that value. Variable capacity 16 is then used to control the gain of the repeater circuit as will be described. The combination of the two condensers 15 and 16 used together in this way is specifically claimed in an application of Anderson-Mallinckrodt-Stillwell Serial No. 44,050, filed October 8, 1935. In the application of H. S. Black referred to above, it is pointed out that if the amplification constant or μ of the amplifier 8 and the feed-back coefficient β are so proportioned that the product $\mu\beta$ is very large compared to unity, the total resultant amplification of the repeater may be made to approach the value

$$\frac{1}{\beta}$$

the coefficient β being less than unity, of course. Under these circumstances a variation in the capacity of condenser 16 can be made to produce (in decibels) substantially linear variations in the gain of the repeater circuit as a whole and with proper circuit design the gain change is the same throughout the utilized frequency band. In one case used by applicant the total capacity looking toward the right from the point a, a toward the three-plate condenser 15 was 50 micro-microfarads.

The mechanism for adjusting the condenser 16 is controlled by the pilot wire 21 which with the switches 27 thrown to their alternate position, is connected in one arm of bridge 22 in series with fixed resistance 24. The other arms of the bridge are shown at 23, 25 and 26 with a balancing resistance 28 included between arms 24 and 26. Bridge 22 is supplied with current from battery 30. An automatic galvanometer 29 is connected across a diagonal of the bridge, this galvanometer being preferably of a type known to the trade including a continuously rotating driving motor and a clutch mechanism under control of the galvanometer whereby when the bridge becomes unbalanced it is automatically rebalanced by rotation of shaft 31 through an angle proportional to the amount of unbalance. Rotation of shaft 31 moves the slider over the balancing resistance 28 through the medium of suitable reduction gearing 32, if necessary. Automatic galvanometer mechanism of this general type is disclosed in U. S. patent to Ulrich, 1,647,383 granted November 1, 1927.

Rotation of the shaft 31 to whatever angular extent is necessary to rebalance the bridge moves the rotor of master motor 33 to a corresponding angle. This motor is provided with a stator winding 34 supplied with alternating current from any suitable source. The rotor winding is shown of well-known three-phase construction, three points of which 120 electrical degrees apart, are connected by the three wires 38, 39 and 40 to a similar winding on each driven motor, of which there may be any suitable number depending upon the number of repeaters that are to be controlled from the one pilot conductor 21. One such driven motor is shown as comprising a rotor 35 and a stator 36 included inside the shielded compartment 17, but in a compartment which is carefully shielded from the repeater circuit. The rotor 35 is connected to any suitable reduction gearing 37 that may be necessary or desirable and through this gearing is connected to the rotor of the variable condenser 16 as indicated.

If the temperature of the cable including line 10 changes, a corresponding temperature change occurs in pilot conductor 21 causing the bridge 22 to

become unbalanced. Let it be assumed that the change is toward a higher temperature of the cable requiring an increase in the gain of the repeater 8. When the bridge becomes unbalanced as assumed, the automatic galvanometer mechanism 29 rebalances the bridge by rotation of shaft 31 through a suitable angular distance causing the slider to move along the resistance 28 until the bridge is balanced. This rotates the rotor of the master motor 33 which is electrically interlocked, as described, to the motors associated with all of the repeaters, at the repeater station RR, to be regulated, causing the latter motors to rotate a corresponding amount and take up a corresponding position. This movement of rotor 35 produces movement of the rotor of condenser 16 in such direction as to decrease the amount of voltage that is fed back to the input of the amplifier 8. Since the voltage fed back is in a direction to reduce the gain of the amplifier 8, a decrease in the fed back voltage causes the resultant gain to be increased. The proportionality of the various parts is such that the increase in gain of repeater circuit 8 just compensates for the increase in attenuation of the line 10 that is assumed to have taken place. A decrease in temperature of the cable results in a movement of the motors in a reverse direction to decrease the gain of the repeater by an appropriate amount.

A description will be given of the manner of functioning of the regulating apparatus associated with the long pilot wire PL₁ of Fig. 1 and the cooperation between this regulating apparatus and that already described which is controlled by the short pilot wire. For this purpose it will be assumed that the switches 19 of Fig. 2 are in the position shown in the drawing, thus placing the regulating network 18 in shunt across the line between the repeaters 8 and 20. Switch 27 is also assumed to be in the position shown in the drawing so that the leads 42 are included in series with the pilot conductor 21.

The long pilot wire PL₁ or 50 is shown leading to a bridge 51 which may be similar to bridge 22 already described. Bridge 51 includes a balancing resistance 52 and has connected to its opposite diagonals the battery 56 and an automatic galvanometer 53, respectively. Automatic galvanometer 53 in operating to rebalance the bridge 51 when unbalance occurs, rotates shaft 54 causing the slider to move along the resistance 52 by means of the mechanical connection between the slider and shaft 54 through suitable gear box 55. Shaft 54 leads to the rotor of master motor 57 which is connected to the rotor of the motors 59. Stator windings 58 and 60 are indicated for the master motor and the driven motor, respectively, for supplying alternating current power thereto. Driven motor 59 is connected through suitable gearing 61, if necessary, to shaft 62 which moves sliders over a number of resistances 63, 64 and 65. Resistance 63 is connected to the leads 42 and is therefore inserted in series with pilot conductor 21. Each of the other resistances 64, 65, etc. leads to a different network 18 associated with different repeaters, located at repeater station RR, to be regulated. The variable resistance 64 is for varying the shape of the characteristic of the equalizer 18 to which it is connected by leads 41. With proper design of network 18 its shape is suitably varied by control of a single resistance such as 64, as illustrated. Network 18 may be of the general type, disclosed in U. S. patent of Zobel 1,591,073 issued July 6, 1926 or in U. S. pat-

ent of E. R. Norton No. 2,019,624 issued May 19, 1936, Serial No. 726,471 filed May 19, 1934.

Since the variations in attenuation with change in temperature are greatest at intermediate frequencies of the band (e. g. 28 k. c.) it is necessary that the shape of the equalizer 18 be such as to introduce greatest changes in network attenuation at the two extreme ends of the transmitted band. A succession of characteristic curves of network 18 taken at different adjustments corresponding to different temperatures will therefore appear as a succession of curves with greater separation at their extreme high and low frequency regions than in the region of 28 kilocycles. If it were possible to design network 18 so that the loss at some one frequency, (most desirable frequency being the one at which the flat regulator now operates) remained constant while the shape of its characteristic changed under control of resistance 64, it would not be necessary to interconnect the control mechanisms of the long pilot wire and the short pilot wire for mutual interaction. In practice it is found that when the network is varied to correspond to a temperature change, the network has changed its characteristic at all frequencies in the utilized band as well as having produced the desired shape for connections. In other words, the total attenuation change made by changing the amount of twist of network 18 may be resolved into a flat variation (the same at all frequencies) plus a differential variation which is least in the vicinity of 28 kilocycles and increases for frequencies on either side of this minimum value. The component of this attenuation change which is the same at all frequencies serves no useful purpose and is, in fact, undesired since it is the function of the short pilot wire regulator mechanism to effect all of the flat gain change that is necessary for complete compensation of the cable.

In accordance with this invention the long wire and the short wire regulating mechanisms are so interrelated that the flat gain change introduced by the short pilot wire regulator compensates for the flat component of the change in loss introduced by the network 18 so that the over-all flat gain change for the entire repeater is always kept at the correct value. This is accomplished specifically in the circuit as disclosed by connection of variable resistance 63 in circuit with the short pilot wire 21. Whenever the regulating mechanism operates to vary resistance 64 to change the amount of the twist correction by the network 18 resistance 63 is also varied to control bridge 22 and its regulating mechanism to vary the condenser 16 to effect a flat gain change in the repeater circuit 8 which exactly counteracts the effect of the flat component of the gain change introduced by network 18.

The use of the electrically interlocked motors as described makes for great accuracy of control with simplification of apparatus. In the usual repeater station space is at a premium and it is a great advantage to be able to locate pieces of apparatus where the wiring or other structural features is kept as simple as possible. The motors themselves can be very small since their load consists merely of the rotor of an air condenser and even this small load is reduced through gearing. The three-wire leads can be carried to any amplifier location without complication. Angular movement of the master controller shaft is repeated with great precision. Applicant has found it practicable to drive fifty gain adjusting motors from a single master motor, and this is

not given as a limit but rather as one practical case.

The invention is not to be construed as limited to the details or the specific arrangement or the actual numerical values that have been given in connection with the illustrative embodiment, but it is to be understood that various modifications and departures from the specific disclosure may be made within the spirit and scope of the appended claims.

What is claimed is:

1. In a regulating system for repeaters, a plurality of repeaters to be simultaneously regulated, a mechanism at each repeater regulatable by a continuous movement throughout the extent of movement required to effect regulation, a main control member movable to different extents by a continuous movement, rotors connected individually to said mechanisms and to said control member, and an electrical interlock between said rotors whereby movement of said control member causes like movement of each of said mechanisms.

2. In a transmission regulating system for a line having repeaters at intervals, means at each repeater point for changing the gain of the repeater for a wide range of frequencies in response to a change in line characteristic, means at certain repeater points to change the shape of the overall repeater characteristic to compensate for differences in change in transmission characteristic at different portions of the frequency range, one of said two means at said certain repeater points modifying the operation of the other to more fully compensate for changes in line characteristic throughout the total frequency range.

3. In a transmission regulating system for a line having repeaters at intervals for transmitting waves of a band of frequencies, a short pilot current circuit controlling the gain of a repeater, a long pilot current circuit controlling the shape of the overall characteristic of said repeater, and means controlled by the long pilot current circuit for varying the control exercised by the short pilot current circuit.

4. In a transmission regulating mechanism for a plurality of repeaters at a repeater station common to a plurality of lines, one regulating

mechanism controlling the gain of all of the repeaters, another regulating mechanism controlling the shape of the characteristic of all of said repeaters, and means controlled by one of said mechanisms for varying the control exercised by the other of said mechanisms to prevent over or under regulation of said repeaters at any portion of the transmitted range.

5. In a transmission regulating system, a plurality of repeaters to be regulated, a movable element associated with each repeater for controlling a characteristic of the repeater, a master regulator having a movable regulating member connected to a master motor, a motor associated with each repeater for driving said movable element to effect an adjustment of the repeaters, a winding of each of said motors, including said master motor, having taps at electrically separated points of the winding, the corresponding points of the windings of the several motors being interconnected whereby movement of the rotor of the master motor causes equal movement of the rotor of each of the other motors.

6. In a transmission regulating system, a plurality of repeaters, a variable air condenser associated with each repeater to control its gain, a motor for each repeater for varying the adjustment of such condenser, a master control motor and a three-phase electrical interlocking circuit extending between said master motor and all of the others of said motors.

7. In a transmission regulating system for a broad band transmission system, the combination with a repeater of one pilot wire regulating mechanism for adjusting the gain of said repeater, another pilot wire regulating mechanism for adjusting the shape of the repeater characteristic and incidentally varying its characteristic over the transmitted band, as a whole, and means operated by said other pilot wire regulating mechanism affecting the first-mentioned pilot wire mechanism to modify its gain adjustment to compensate the effect of the variation by said other pilot wire regulating mechanism of the characteristic over the transmitted band as a whole.

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