Sept. 2, 1941. J. H. BOLLMAN 2,254,205

SIGNAL TRANSMISSION SYSTEM

Filed April 3, 1940 2 Sheets-Sheet 1

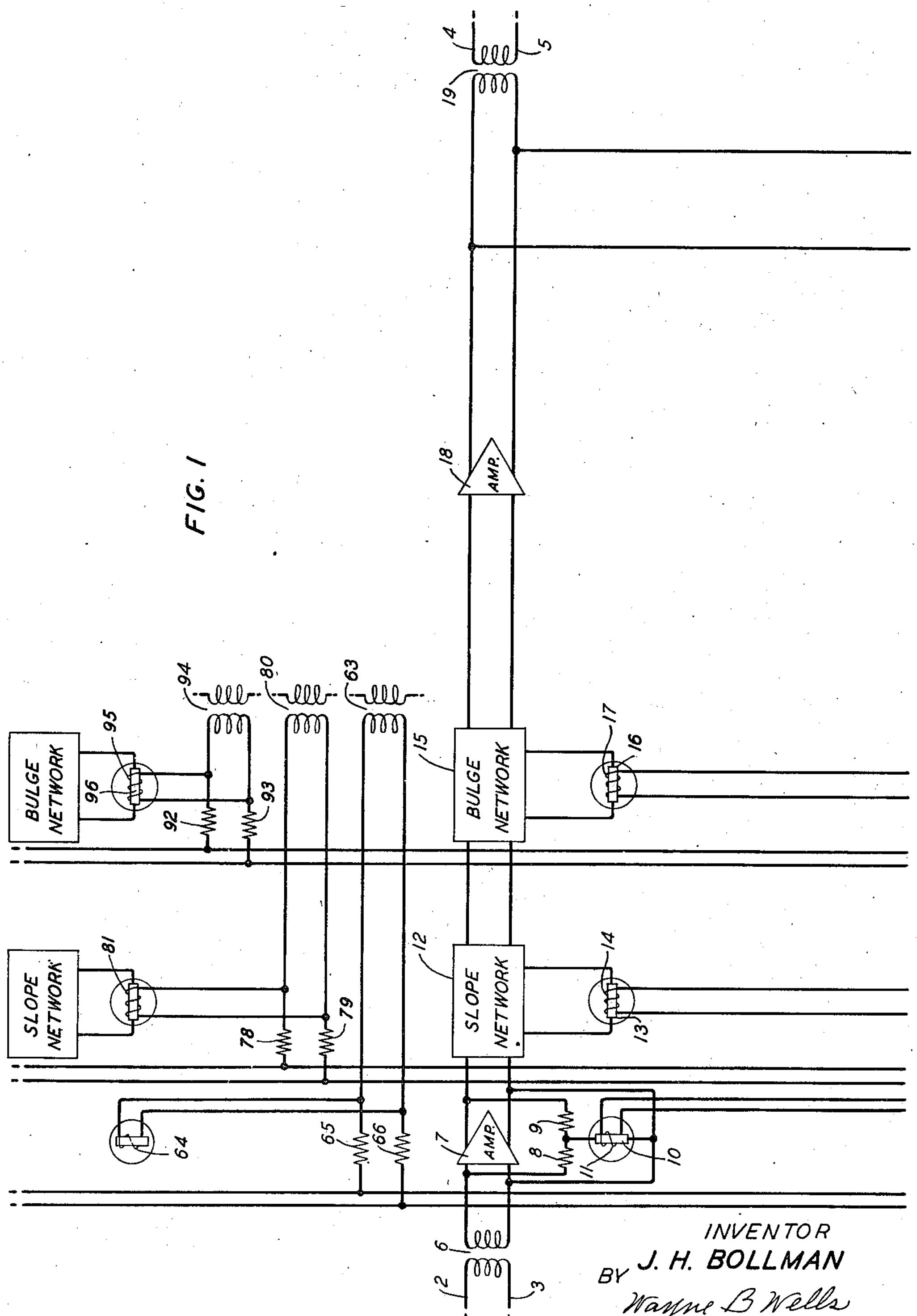

FIG. 1

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Filed April 3, 1940 2 Sheets-Sheet 2

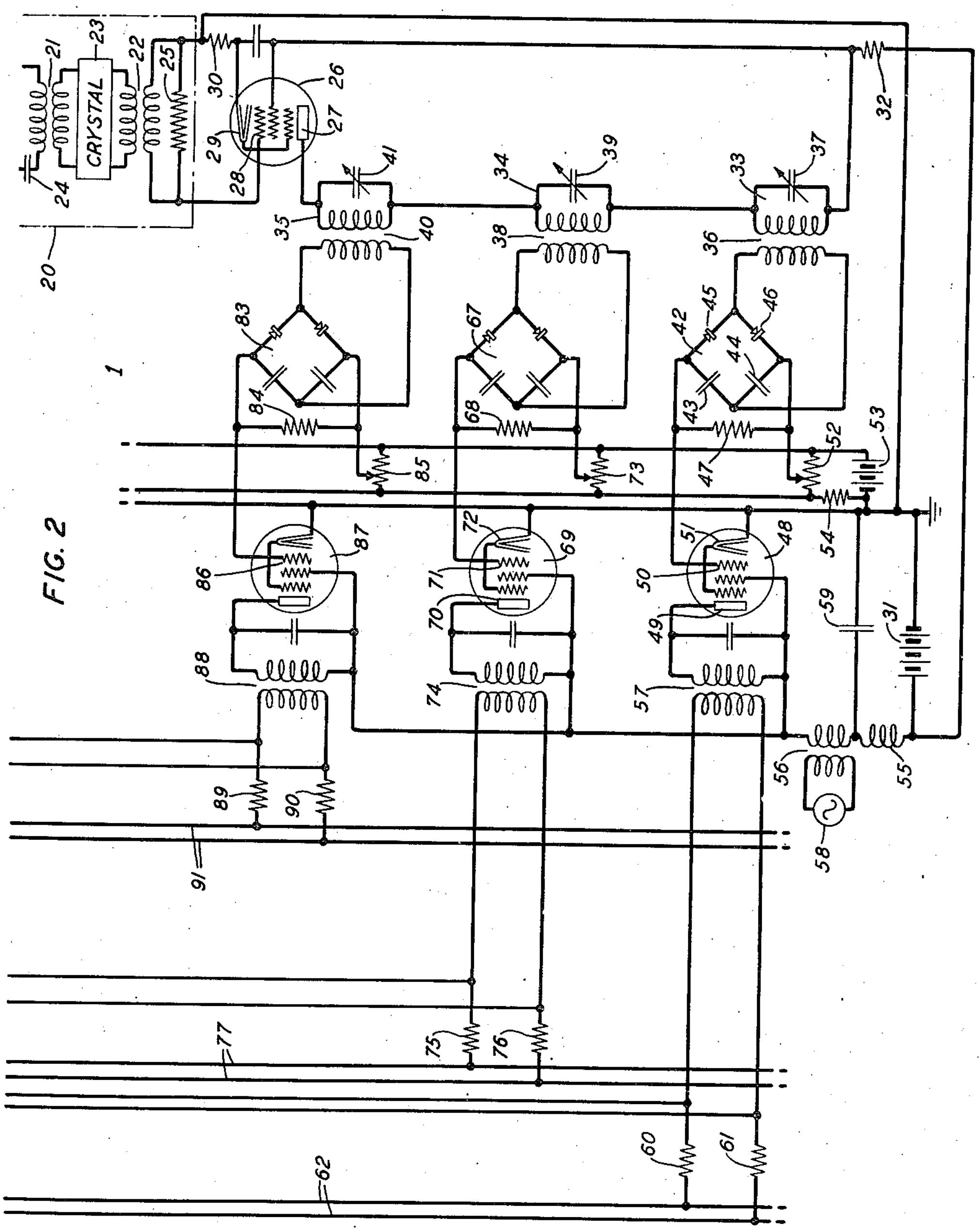

FIG. 2

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UNITED STATES PATENT OFFICE

2,254,205

SIGNAL TRANSMISSION SYSTEM

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Application April 3, 1940, Serial No. 327,574

11 Claims. (Cl. 178—44)

This invention relates to signal transmission systems and particularly to signal transmission systems having control circuits for governing the loss on transmission lines.

One object of the invention is to provide a signal transmission system composed of a number of transmission lines each having carrier and pilot channels thereon that shall control the flat gain and the attenuation characteristic on each transmission line according to the strengths of pilot currents on the respective lines and that shall control the flat gain and the attenuation characteristic on a transmission line according to the strengths of pilot currents on other lines in case of failure of the pilot current control associated therewith.

Another object of the invention is to provide control circuits for a signal transmission system composed of a number of transmission lines each having signal and pilot channels and an amplifier and bulge and slope networks thereon that shall control the amplifier and the bulge and slope networks on each transmission line according to the strengths of pilot currents on the respective lines and that shall control the amplifier and the bulge and slope networks on a transmission line according to the strengths of pilot currents on other lines in case of failure of the pilot current control associated therewith.

A further object of the invention is to provide control circuits for a signal transmission system composed of a number of transmission lines each having carrier and pilot channels and an amplifier and bulge and slope networks thereon that shall control low frequency circuits to govern the amplifier and the bulge and slope networks on each transmission line according to the strengths of pilot currents on the respective lines and that shall control the low frequency circuits governing the amplifier and bulge and slope networks on a transmission line according to the strengths of pilot currents on other lines in case of failure of the low frequency circuits associated therewith.

Transmission systems, for example carrier cable systems, are provided with flat gain and twist pilot wire regulators which are located at intervals along the cable. It has been found that certain over-all losses occur on the pairs of conductors making up a cable which are not corrected for by the distributed flat gain and twist regulators.

According to the invention disclosed in the patent to H. K. Krist, No. 2,246,307, issued June 17, 1941, terminal or deviation regulators, which are controlled by pilot currents, are provided to compensate for the over-all losses. The deviation regulators not only adjust the flat gain but also the slope and bulge of the line attenuation characteristic. In the invention disclosed in the H. K. Krist patent, No. 2,246,307, a gain control amplifier, a slope network and a bulge network are placed on each pair of conductors in a cable at the terminal or deviation station. Each pair of conductors in the cable is not only provided with carrier channels but also with pilot channels. The pilot currents on a pair of conductors respectively control the amplifier, the slope network and the bulge network on the associated pair of conductors.

According to the present invention, provision is made for governing the amplifier, the slope network or the bulge network on a pair of conductors according to the strengths of pilot currents on other pairs of conductors in case of failure of the pilot current control means associated with the pair of conductors. Thus, in case of failure of the pilot current regulating circuits associated with one pair of conductors the amplifier and the bulge and slope networks will be operated approximately to correct operating positions by regulating circuits associated with other pairs of conductors.

In the arrangement employed to describe the invention, two pairs of conductors in a carrier cable system are provided with an amplifier and slope and bulge networks. Each pair of conductors is provided not only with carrier channels but also with three pilot channels. The three pilot currents on each pair of conductors respectively govern the flat grain amplifier, the slope network or equalizer, and the bulge network or equalizer. A pilot filter which selects the three pilot currents on the pair of conductors is connected to the conductors at a point beyond the amplifier and the bulge and slope networks. The selected pilot currents are amplified and then supplied to three auxiliary filters which separate the three pilot currents that govern the operation of the flat gain amplifier, the slope network and the bulge network.

The pilot current which is selected by the auxiliary filter for operating the flat gain amplifier is supplied to a bridge in the form of a voltage doubler rectifier. The output from the voltage doubler rectifier, opposed by a constant potential, supplies negative bias for operating a control space discharge device. The control space discharge device is energized by a direct-current source and a source of alternating current. The control space discharge device governs the operation of a heater coil for controlling a resistance connected across the negative feedback circuit in the flat gain amplifier. The resistance element controlled by the heater coil has a negative temperature coefficient of resistance and preferably is of the type disclosed in the E. F. Dearborn application, Serial No. 280,692, filed June 23, 1939. The resistance element in the feedback circuit of the flat gain amplifier is so controlled as to oppose any change in the strength of the pilot current from normal value. If the pilot current tends to increase in strength, the gain of the feedback amplifier is reduced to bring the strength of the pilot current back to normal value.

The output from the control space discharge device is not only connected to the heater coil for governing the resistance in the feedback circuit of the flat gain amplifier but is also connected through resistance elements to equalizing bus conductors. Other control space discharge devices for governing the heater coils to govern other flat gain amplifiers in other pairs of conductors are also connected to the equalizing bus conductors by resistance elements. Thus, in case of failure of the circuit governing the heater coil for governing a flat gain amplifier on a pair of conductors, current will be supplied from the equalizing bus conductors for operating the heating coil to an approximate value for maintaining the strength of the pilot current on the pair of conductors at approximately correct strength.

The auxiliary filter which selects the pilot current for operating the slope network is connected to a voltage doubler rectifier for controlling the operation of a control space discharge device. The output from the voltage doubler rectifier is opposed by a standard potential source to effect a more than proportional change for any change in the strength of the pilot frequency current. The control space discharge device is energized not only by direct current but also by a low frequency power current. The output from the control space discharge device is connected to a heater coil for governing a resistance in the slope network. The resistance in the slope network controlled by the heater coil has a negative temperature coefficient of resistance and may be of the same type as that employed for controlling the feedback circuit of the flat gain amplifier. The control space discharge device is not only connected to the heater coil for governing the operation of the slope network but is also connected through resistance elements to equalizing bus conductors. The equalizing bus conductors are connected similarly to other control space discharge devices associated with other pairs of conductors so that in case of failure of the control for one slope network the control may be taken over by the equalizing bus conductors.

The auxiliary filter which selects the pilot current for operating the bulge network is connected to a voltage doubler rectifier which in turn controls the negative bias impressed on the grid of a control space discharge device. The output from the voltage doubler rectifier is opposed by a constant potential source to effect a more than proportional change in the operation of the control space discharge device than the changes in strength on the pilot current. The control space discharge device is energized by a direct-current source and by a source of alternating current which, if so desired, may be a commercial source of power. The output circuit of the control space discharge device is connected to a heater coil for operating a resistance element having a negative temperature coefficient of resistance. The resistance element is included in the bulge network on the pair of conductors. This resistance element having a negative temperature coefficient of resistance may be of the same type as that employed in controlling the feedback circuit of the flat gain amplifier. The output circuit of the control space discharge device is not only connected to the heater coil for governing the bulge network but is also connected through resistance elements to equalizing bus conductors. The equalizing bus conductors are connected through resistance elements to other control space discharge devices associated with the bulge networks on other pairs of conductors. Thus in case of failure of the control circuits for operating a bulge network on one pair of conductors, the control of this network may be taken over by the equalizing bus conductors connected to the heater coil which governs the operation of the network.

In the accompanying drawings, Fig. 1 when placed above Fig. 2 discloses a system constructed in accordance with the invention.

Referring to the drawings, a terminal or deviation station 1 is shown connected to a pair of conductors in a carrier cable system having input conductors 2 and 3 and output conductors 4 and 5. The input conductors 2 and 3 are connected by a transformer 6 to a flat gain amplifier 7 of any suitable type. The flat gain amplifier 7 is provided with a negative feedback circuit having series resistance elements 8 and 9 and a shunt resistance element 10. The shunt resistance element 10 has a negative temperature coefficient of resistance and may be of the type disclosed in the above-mentioned application of E. F. Dearborn, Serial No. 280,692. The resistance element 10 is controlled by a heater coil 11 in a manner to be hereinafter described.

The amplifier 7 is connected to a slope equalizer or network 12 which may be of the type disclosed in the H. W. Bode Patent 2,096,027, October 19, 1937, or in the E. L. Norton Patent 2,019,624, November 5, 1935. The slope network 12 is controlled by a resistance element 13 having a negative temperature coefficient of resistance. This resistance element 13 may be of the same type as the resistance element 10 employed to control the flat gain amplifier 7. A heater coil 14 is provided for governing the operation of the resistance element 13 in a manner to be hereinafter set forth.

The slope network 12 is connected to a bulge equalizer or network 15 which may be on the type disclosed in the S. Darlington Patent 2,153,743, April 11, 1939. The bulge network 15 is governed by a resistance element 16 having a negative temperature coefficient of resistance. The resistance element 16 may be of the same type as the resistance element 10 employed to control the flat gain amplifier 7. The resistance element 16 is governed by a heater coil 17 in a manner to be hereinafter set forth. The bulge network 15 is connected by an amplifier 18 and a transformer 19 to the output conductors 4 and 5.

The pair of conductors not only is provided with carrier channels but also with three pilot channels. A pilot filter 20 is connected to the pair of conductors beyond the amplifier 18 for selecting the three pilot currents. The pilot filter 20 comprises two transformers 21 and 22, a crystal 23, a condenser 24 and a resistance element 25 connected across the secondary winding of the transformer 22. The pilot filter 20 is connected to the input circuit of an amplifier 26 in the form of a pentode tube. The amplifier 26 comprises an anode 27, a control grid 28 and a cathode 29. Negative bias for the control grid 28 is supplied by the potential drop across a resistance 30. Potential for the anode 27 is supplied from a battery 31 through a resistance element 32 and auxiliary filters 33, 34 and 35. The auxiliary filters 33, 34 and 35 respectively select the three pilot currents which are employed to control the flat gain amplifier 7, the slope network 12 and the bulge network 15. The filter 33 comprises a transformer 36 and an adjustable condenser 37. The auxiliary filter 34 comprises a transformer 38 and an adjustable condenser 39. The auxiliary filter 35 comprises a transformer 40 and an adjustable condenser 41.

The secondary winding of the transformer 36 which forms a part of the auxiliary filter 33 is connected to two opposite vertices of a bridge circuit 42. The bridge circuit 42 is in the form of a voltage doubler rectifier of the type disclosed in the patent to D. M. Terry, 2,084,115, June 15, 1937. The voltage doubler rectifier comprises two condensers 43 and 44 and two rectifiers 45 and 46 which are preferably of the copper oxide type. The output vertices of the voltage doubler rectifier are connected across a resistance element 47. The potential drop across the resistance element 47 is employed to govern the operation of a control space discharge device 48 in the form of a pentode tube. The device 48 comprises an anode 49, a control grid 50 and a cathode 51. The potential drop across the resistance element 47 which is impressed on the control grid 50 is opposed by a portion of the potential drop across a resistance element 52. The resistance element 52 is connected to a battery 53 through a resistance 54. The potential drop across a portion of the resistance element 52 opposes the potential drop across the resistance element 47 to effect a more than proportional change in the operation of the control space discharge device 48 for changes in strength of the pilot current selected by the auxiliary filter 33.

The anode 49 of the device 48 is supplied with direct potential from the battery 31 by a circuit which extends from one terminal of the battery 31 through a choke coil 55, secondary winding of the transformer 56, primary winding of the transformer 57, anode 49 and cathode 51 to the other terminal of the battery 31. A source of low frequency current 58 is connected to the plate circuit of the device 48 by means of the transformer 56. The alternating-current circuit through the device 48 is completed by a condenser 59.

The low frequency output current from the device 48 is connected by the transformer 57 to the heater coil 11. The heater coil 11, as before set forth, controls the temperature of the resistance element 10 which has a negative temperature coefficient of resistance. The resistance 10 governs the feedback circuit for the flat gain amplifier 7.

If the pilot current on the pair of conductors which controls the flat gain amplifier 7 rises above normal value, the rectified current impressed across the resistance 47 increases to increase the negative bias impressed on the control grid 50 of the device 48. The low frequency output from the device 48 is reduced to reduce the current supplied to the heater coil 11. This reduces the temperature of the resistance element 10 and accordingly increases the resistance value thereof. An increase in the resistance value of the resistance element 10 decreases the gain of the flat gain amplifier 7 to return the strength of the pilot current governing the flat gain amplifier to normal value. If the strength of the pilot current governing the flat gain amplifier 7 falls below normal value, an opposite operation takes place.

The control device 48 is not only connected to the heater coil 11 by the transformer 57 but is also connected through resistance elements 60 and 61 to a pair of equalizing bus conductors 62. The equalizing bus conductors 62 are also connected in a similar manner to the control space discharge devices which govern the operation of other flat gain amplifiers on other pairs of conductors. In Fig. 1 of the drawings, the connection to another control device is indicated. A transformer 63 which is similar to the transformer 57 connects a control device, not shown, not only to a heating coil 64 for governing the feedback on an amplifier for another pair of conductors, but also through resistance elements 65 and 66 to the equalizing bus conductors 62. In case of failure of the low frequency current supplied by the transformer 57 to the heater coil 11 for governing the flat gain amplifier 7, it is apparent control current will be supplied to the heater coil 11 from the equalizing bus conductors 62 through the resistance elements 60 and 61. Thus, in case of failure of the low frequency control circuits for the heater coil governing an amplifier, it is apparent control of the amplifier will be effected from low frequency control circuits associated with other pairs of conductors.

The auxiliary filter 34 which selects the pilot current for governing the slope network 12 is connected by the transformer 38 to two vertices of a voltage doubler rectifier 67. The voltage doubler rectifier 67 is similar in construction and operation to the voltage doubler rectifier 42. The output voltage is impressed across a resistance element 68 which controls the negative grid bias impressed on a control space discharged device 69. The device 69 is in the form of a pentode tube the same as the control space discharge device 48 and comprises an anode 70, a control grid 71 and a cathode 72. The negative bias obtained by the potential drop across the resistance element 68 which is impressed on the control grid 71 is opposed by the potential drop across a portion of a resistance element 73. The resistance element 73 is in circuit with the battery 53 in the same manner as the resistance element 52. The device 69 is energized not only by the battery 31 but also by the low frequency source of power 58.

A transformer 74 connects the output circuit of the device 69 to the heater coil 14 which controls the resistance element 13 in the slope network 12. The transformer 74 also connects the output from the device 69 through resistance elements 75 and 76 to equalizing bus conductors 77. The equalizing bus conductors 77 are also connected in the same manner to the control means for other slope networks associated with other pairs of conductors. One connection to another slope network is indicated in Fig. 1 of the drawings. Two resistance elements 78 and 79 are shown connected to a transformer 80 which is similar to the transformer 74 shown in Fig. 2 of the drawings. The transformer 80 supplies low frequency current controlled according to a pilot current on another pair of conductors. The low frequency current supplied by the transformer 80 is not only connected through the resistance elements 78 and 79 to the equalizing bus conductors 77 but is also connected to a heater coil 81 for governing a slope network on another pair of conductors.

If the strength of the pilot current on the pair of conductors rises above normal value, the potential impressed across the resistance element 68 increases to increase the negative bias impressed on the control grid 71. This reduces the low frequency output current supplied by the transformer 74 to the heater coil 14. Accordingly, the temperature of the resistance element 13 is reduced to increase the resistance value thereof. This increases the loss effected by the slope network 12. If the pilot current on the pair of conductors falls below normal value, an opposite operation takes place. If there is a failure of the circuit supplying low frequency current through the transformer 74 to the heater coil 14, it is apparent that low frequency control current under such condition will then be supplied from the equalizing bus conductors 77 through the resistance elements 75 and 76 to the heater coil 14.

The auxiliary filter 35, which selects the pilot current for governing the operation of the bulge network 15, is connected by the transformer 40 to a voltage doubler rectifier circuit 83. The voltage doubler rectifier circuit 83 is similar in construction and operation to the voltage doubler rectfier circuit 42. The output from the rectifier circuit 83 is impressed across a resistance element 84. The potential drop across the resistance element 84 opposed by a portion of the potential drop across the resistance element 85 is impressed on the control grid 86 of the control space discharge device 87. The resistance element 85 is in circuit with the battery 53. The control space discharge device 87 is energized from the battery 31 and the low frequency source 58 in the same manner as the control space discharge device 48.

A transformer 88 connects the output circuit of the device 87 not only to the heater coil 17 but also through resistance elements 89 and 90 to equalizing bus conductors 91. The heater coil 17 controls the resistance element 16 included in the bulge network 15.

In case the strength of the pilot current which governs the operation of the bulge network 15 increases above normal value, then an increased potential will be impressed across the resistance element 84. This increases the negative bias on the control grid 86 and reduces the output from the control space discharge device 87. A reduction in the output from the control space discharge device 87 lowers the temperature of the resistance element 16 to increase the resistance value thereof and to increase the loss effected by the bulge network 15. In case the strength of the pilot current falls below normal value, an opposite operation to that described above takes place.

The equalizing bus conductors 91 are connected through resistance elements 92 and 93 to a transformer 94. The transformer 94 is similar to the transformer 88 and is connected to control circuits for governing a bulge network on another pair of conductors. The secondary winding of the transformer 94 is shown connected to a heater coil 95 for controlling a resistance element 96. The equalizing bus conductors 91 operate to control a bulge network in case of failure of the control circuit therefor in the same manner as the equalizing bus conductors govern the operation of a flat gain amplifier in case of failure of the control circuit therefor.

Modifications in the circuits and in the arrangement and location of parts may be made within the spirit and scope of the invention, and such modifications are intended to be covered by the appended claims.

What is claimed is:

1. In a signal system, a plurality of pairs of signal conductors having carrier currents and pilot currents on each of said pairs of conductors, a network for changing the attenuation characteristic and an amplifier on each of said pairs of conductors, control means for governing the network and the amplifier on each pair of conductors by different pilot currents on the pair of conductors, and means in case of failure of the control means governing the network or the amplifier on a pair of conductors for governing the network or the amplifier from the control means associated with other pairs of conductors.

2. In a signal system, a plurality of pairs of signal conductors having carrier currents and pilot currents on each of said pairs of conductors, a slope network and a bulge network on each of said pairs of conductors, control means for governing the slope network and the bulge network on each pair of conductors by different pilot currents on the pair of conductors, and means in case of failure of the control means governing the slope network or the bulge network on a pair of conductors for governing the slope network or the bulge network from the control means associated with other pairs of conductors.

3. In a signal system, a plurality of pairs of signal conductors having carrier currents and pilot currents on each of said pairs of conductors, an amplifier and slope and bulge networks on each of said pairs of conductors, control means for governing the amplifier and the slope and bulge networks on each pair of conductors by different pilot currents on the pair of conductors and means in case of failure of the control means governing the amplifier, the slope network or the bulge network on a pair of conductors for governing the amplifier, the slope network or the bulge network from the control means associated with other pairs of conductors.

4. In a signal system, a plurality of pairs of signal conductors having carrier signal and pilot currents on each of said pairs of conductors, control means on each of said pairs of conductors for governing a characteristic of the transmitted signal currents, circuit means for governing each control means according to the strength of a pilot current on the associated pair of conductors, and means in case of failure of the circuit means associated with one pair of conductors for governing the control means governed thereby from the circuit means associated with other of said pairs of conductors.

5. In a signal system, a plurality of pairs of conductors each having carrier currents and pilot currents thereon, a slope network for adjusting the slope of the transmission attenuation characteristic and a bulge network for adjusting the

bulge of the transmission attenuation characteristic on each pair of conductors, means comprising a low frequency circuit connected to each of said slope and bulge networks for governing the operation thereof, means for respectively controlling the low frequency circuits associated with the slope network and the bulge network of a pair of conductors by two pilot currents on that pair of conductors, and means for connecting in parallel the low frequency circuits connected to all said slope networks and for connecting in parallel all the low frequency circuits connected to the bulge networks.

6. In a signal system, a plurality of pairs of conductors each having carrier currents and pilot currents thereon, a network for changing the attenuation characteristic and an amplifier on each of said pairs of conductors, means comprising a low frequency circuit connected to each of said amplifiers and networks for governing the operation thereof, means for respectively controlling the low frequency circuits associated with the amplifier and network of a pair of conductors, and means for connecting in parallel the low frequency circuits connected to all said amplifiers and for connecting in parallel all the low frequency circuits connected to the networks.

7. In a signal system, a plurality of pairs of conductors having carrier currents and three pilot currents on each of said pairs of conductors, an amplifier and slope and bulge networks on each of said pairs of conductors, means comprising a low frequency circuit connected to each of said amplifiers and networks for governing the operation thereof, means for respectively controlling the three low frequency circuits associated with the amplifier and networks of a pair of conductors by the three pilot currents on that pair of conductors, and means for connecting in parallel the low frequency circuits connected to all said amplifiers for connecting in parallel all the low frequency circuits connected to the slope networks and for connecting in parallel all the low frequency circuits connected to the bulge networks.

8. In a signal system, a plurality of pairs of signal conductors having carrier currents and three pilot currents on each of said pairs of conductors, an amplifier and slope and bulge networks on each of said pairs of conductors, a control thermistor associated with each of said amplifiers and networks, a separate low frequency circuit for controlling each of said thermistors, means controlled by the pilot currents on each pair of conductors for respectively governing the low frequency circuits connected to the thermistors of the amplifier and networks for that pair of conductors, means for connecting all the low frequency circuits associated with said amplifiers in parallel through resistance elements, for connecting all the low frequency circuits associated with said slope networks in parallel through resistance elements and for connecting all the low frequency circuits associated with said bulge networks in parallel through resistance elements.

9. A cable having a plurality of pairs of conductors, a number of said pairs of conductors having carrier currents and three relatively high frequency currents thereon, an amplifier and slope and bulge networks on each of a number of said pairs of conductors, a circuit having a low frequency current thereon for each amplifier and network on each of said number of pairs of conductors, and means for respectively controlling the low frequency circuits associated with the amplifier and networks on each pair of conductors by the three pilot currents on each pair of conductors to respectively govern the flat gain and slope and bulge of the attenuation characteristics of the cable pairs of conductors, and means for adjusting the amplifier, slope network or bulge network of a pair of conductors according to adjustment of similar apparatus on other pairs of conductors in case of failure of the low frequency circuit controlling the amplifier, slope network or bulge network.

10. A cable having a plurality of pairs of conductors, each of said pairs of conductors having carrier currents and three relatively high frequency pilot currents thereon, an amplifier and slope and bulge networks on each of said pairs of conductors, means comprising circuits having low frequency current thereon for separately governing the amplifier, the slope network and the bulge network on each of said pairs of conductors to control respectively the flat gain, the slope of the attenuation characteristic and the bulge of the attenuation characteristic on each of said pairs of conductors, means controlled by the three pilot currents on a pair of conductors for respectively governing the strengths of the low frequency currents controlling the amplifier, the slope network and the bulge networks of the pair of conductors to maintain the energy levels of the different frequency currents on the pair of conductors the same at a desired level, and means for connecting together the low frequency circuits governing the amplifiers of all pairs of conductors to insure control of an amplifier in case of failure of the low frequency current effecting control thereof for connecting together the low frequency circuits governing the slope networks of all pairs of conductors to insure control of a slope network in case of failure of the low frequency current effecting control thereof and for connecting together the low frequency circuits governing the bulge network of all pairs of conductors to insure control of a bulge network in case of failure of the low frequency current effecting control thereof.

11. In a signal system, a plurality of pairs of signal conductors having carrier and pilot currents on each pair of conductors, a plurality of control means on each pair of conductors for respectively governing a number of different characteristics of the transmitted currents, a number of circuit means respectively controlled by the pilot currents on a pair of conductors for separately governing the control means on the pair of conductors, and means in case of failure of the control means governing a characteristic of the transmitted current on a pair of conductors for governing the control means by circuit means associated with other pairs of conductors.

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