Dec. 6, 1938. J. P. KINZER ET AL 2,139,236

GAIN CONTROL CIRCUIT

Filed May 28, 1937 2 Sheets-Sheet 1

FIG. 1

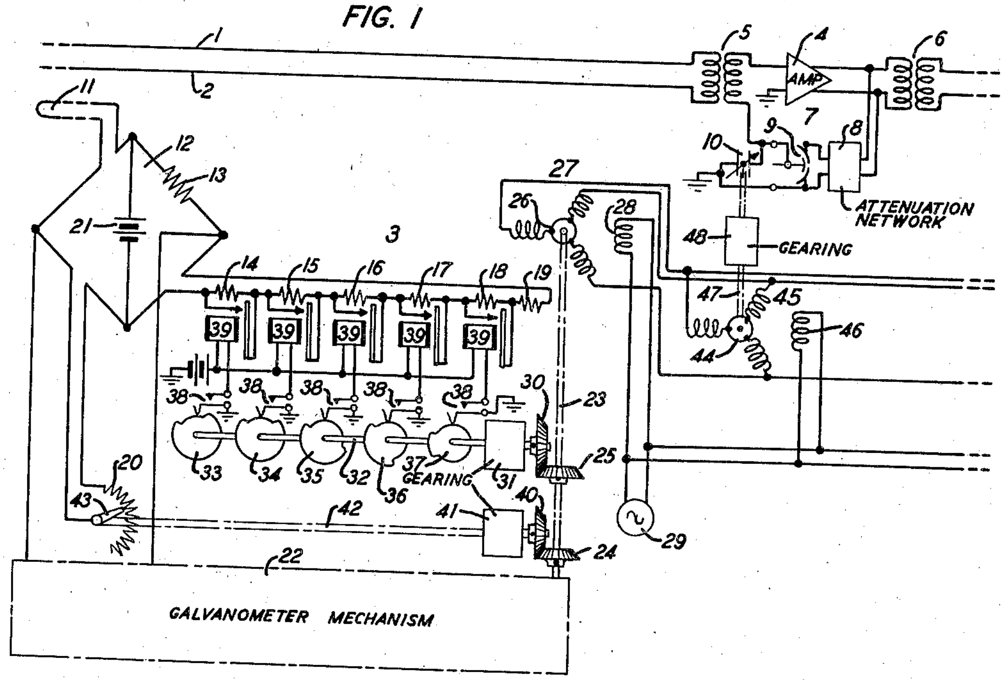

FIG. 2

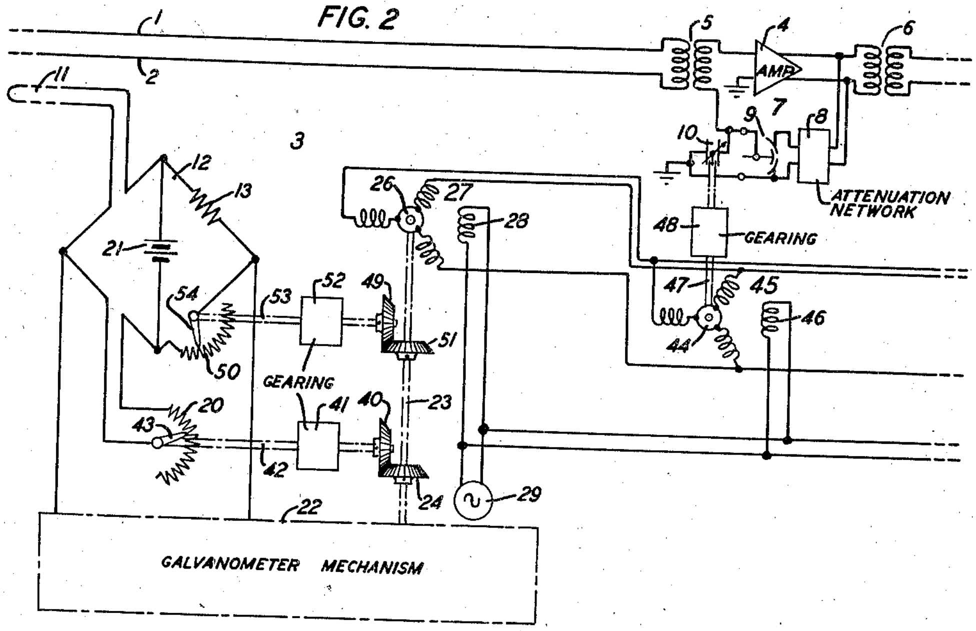

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FIG. 3

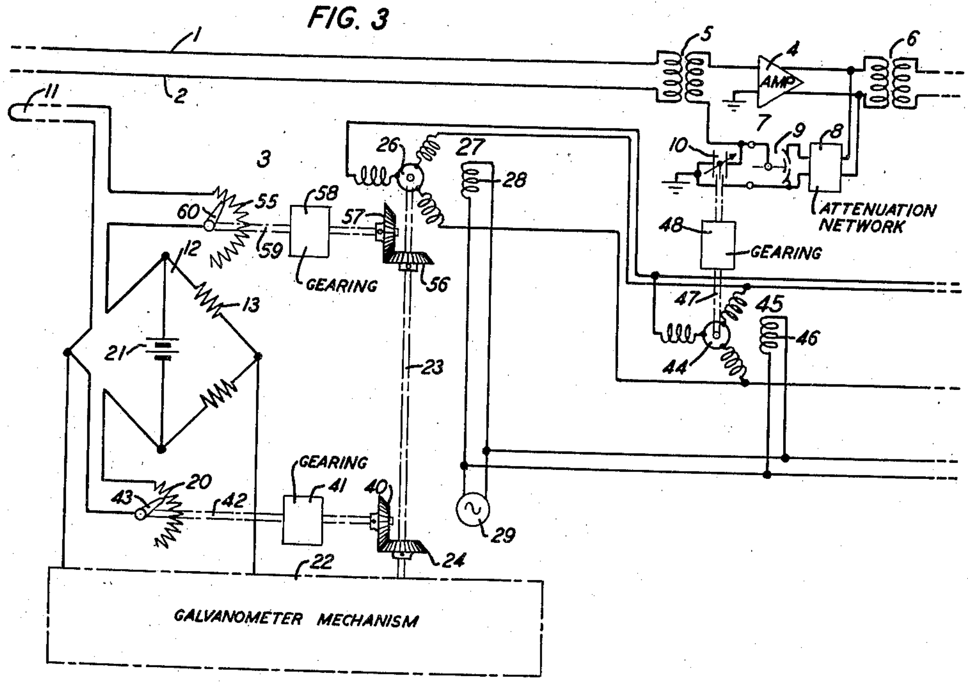


FIG. 4

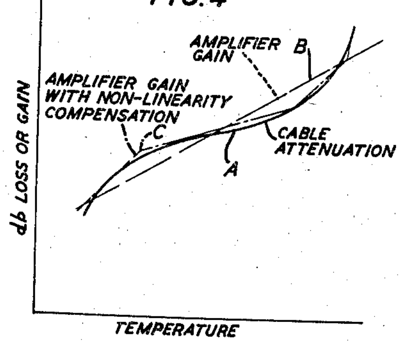


FIG. 5

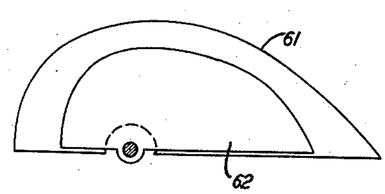
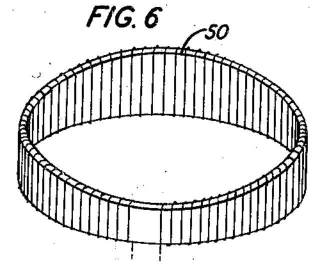


FIG. 6



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2,139,236

GAIN CONTROL CIRCUIT

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Application May 28, 1937, Serial No. 145,202

10 Claims. (Cl. 178—44)

This invention relates to gain control circuits and particularly to gain control circuits for maintaining constant attenuation on a transmission line.

One object of the invention is to provide a signal transmission line with a gain control circuit having a linear operation with temperature changes that shall control the transmission line attenuation while compensating for the non-linear attenuation variations of the transmission line with temperature changes.

Another object of the invention is to provide a signal transmission line with a pilot-line gain control circuit having a linear operation with temperature changes and including a bridge circuit operating galvanometer mechanism to control the transmission line attenuation that shall compensate for the non-linear attenuation variations of the transmission line with temperature changes.

A further object of the invention is to provide a signal transmission line with a pilot-line gain control circuit having a linear operation with temperature changes and including a bridge circuit operating galvanometer mechanism to control the transmission line attenuation that shall vary the bridge circuit operation to compensate for the non-linear attenuation variations of the transmission line with temperature changes.

The attenuation of a signal transmission line is in many cases controlled and maintained substantially constant by means of the so-called pilot-line gain control circuit. A pilot line is associated with the signal transmission line so as to be subjected to the same temperature varying conditions as the transmission line and forms one arm of a bridge circuit. The bridge circuit operates a galvanometer which in turn operates a galvanometer control mechanism either to control the gain of an amplifier in the transmission line or to control pads in the transmission line.

The variation of attenuation in a transmission line with temperature changes has been found to be non-linear. The resistance variation of the pilot line with temperature changes is linear. The resistance variation of the pilot line governs the bridge circuit which, by means of the galvanometer and the galvanometer mechanism, govern the attenuation of the transmission line. Thus the galvanometer and the galvanometer control mechanism have linear operation with temperature changes and effect linear changes in the attenuation of the transmission line. Accordingly a small error will be included in the operation of the gain control circuit unless compensation is made in the gain control circuits for the non-linear attenuation variations of the transmission line with temperature changes. A gain control circuit of the type under consideration is shown in the patent to F. A. Brooks, No. 2,075,975, April 6, 1937.

In accordance with the invention, provision is made to insure that the corrections made to the transmission line attenuation vary according to the non-linear attenuation variations of the transmission line with temperature changes. In one form of the invention, a variable resistance in one arm of the bridge circuit is controlled according to the operation of the galvanometer control mechanism to compensate for the non-linear variations of the transmission line attenuation with temperature changes.

The term "pilot line" as used in the specification is intended to cover not only a pilot line comprising a separate pair of wires but also to cover a pilot line comprising a direct-current path on the pair of wires comprising the transmission line.

In the accompanying drawings, Fig. 1 is a diagrammatic view of a pilot-line gain control circuit constructed in accordance with the invention.

Fig. 2 is a diagrammatic view of a modification of the gain control circuit shown in Fig. 1 of the drawings.

Fig. 3 is a diagrammatic view of a modification of the circuit shown in Fig. 1 wherein the resistance of the pilot line is varied to compensate for the non-linear attenuation variations of the transmission line with temperature changes.

Fig. 4 is a set of curves showing the non-linear attenuation variations of the transmission line with temperature changes.

Fig. 5 is a diagrammatic view of a condenser that may be employed in the feedback circuit of the line amplifier to compensate for the non-linear attenuation variations of the transmission line with temperature changes.

Fig. 6 is a diagrammatic view of the variable resistance employed in the circuit of Fig. 2 to compensate for the non-linear attenuation variations of the transmission line with temperature changes.

Referring to Fig. 1 of the drawings, a transmission line comprising conductors 1 and 2, which may be a pair of wires in a cable, has the attenuation variations thereof corrected by means of gain control circuits 3. The gain control circuits 3 control the attenuation variations of the transmission line by governing the operation of a line amplifier 4. A transformer 5 is connected to the input circuit of the amplifier 4 and a transformer 6 is connected to the output circuit of the amplifier 4. The amplifier 4 is provided with a feedback circuit 7 joining the output and input circuits of the amplifier. The feedback circuit comprises an attenuation network 8, a manually adjustable condenser 9 and a condenser 10 which is controlled by the gain control circuits 3.

The gain control circuits 3 comprise a pilot line 11 which forms one arm of a bridge circuit 12. The pilot line 11 is shown as comprising a separate pair of wires. However, it is to be understood that if so desired, the pilot line 11 may be a direct-current path on the transmission conductors 1 and 2. The bridge circuit 12 comprises in addition to the pilot line arm a resistance arm 13, a variable resistance comprising sections 14 to 19, inclusive, and a variable resistance 20. The variable resistance 20 is operated to rebalance the bridge after each operation of the gain control circuits. The resistance sections 14 to 19, inclusive, are controlled to compensate for the non-linear attenuation variations of the transmission line with temperature changes. A battery 21 is connected between two opposite vertices of the bridge 12 and a galvanometer control mechanism 22 is connected across the other two vertices of the bridge 12. The galvanometer control mechanism may be of the type disclosed in detail in the patent to J. A. Coy et al. 2,017,654, October 15, 1935, or in the patent to Ulrich 1,647,383, dated November 1, 1927. The mechanism 22 operates a shaft 23 in accordance with the operation of the bridge circuit 12. The shaft 23 carries two beveled gear wheels 24 and 25 and the rotor winding 26 of a master motor 27. The master motor 27 is provided with a stator winding 28 directly connected to a source of alternating current 29.

The beveled gear wheel 25 meshes with a beveled gear wheel 30 which is connected through a set of gearing 31 to a shaft 32 carrying cam members 33 to 37, inclusive. The cam members 33 to 37, inclusive, control the operation of switch members 38 to selectively operate relays 39. The relays 39 respectively complete circuits for short-circuiting the resistance sections 14 to 19, inclusive. If the shaft 32 is continuously operated in a counterclockwise direction, as viewed in Fig. 1 of the drawings, the relays 39 will be successively operated to successively short-circuit the resistance elements 14 to 19, inclusive. The beveled gear wheel 24 meshes with a beveled gear wheel 40 which in turn is connected through gearing 41 to a shaft 42. The shaft 42 carries a rheostat arm 43 which engages the resistance 20. The resistance 20 is varied to rebalance the bridge 12 for each operation of the galvanometer control mechanism 22.

The three-phase rotor winding 26 of the master motor 27 is connected to the rotor winding 44 of a service motor 45. The service motor 45 is provided with a stator winding 46 which is connected to the source of alternating current 29. The rotor winding 26 of the master motor 27 will be connected similarly to any number of other service motors which it may be desired to operate. The stator windings of any other service motors which may be connected to the master motor will be connected to the source of alternating current 29. The service motor 45, when connected as above described, will follow any movement of the master motor rotor 26. The rotor 44 of the service motor 45 controls the adjustable condenser 10 in the feedback circuit 7 by means of a shaft 47 and gearing 48. A detailed description of the operation of the condenser 10 in controlling the gain of the amplifier 4 is given in the above-mentioned patent to F. A. Brooks, 2,075,975, and, accordingly, a detailed description here is deemed unnecessary.

In case the transmission line comprising conductors 1 and 2 is subjected to a change in temperature, the pilot line 11 will be subjected to a like change which will vary the resistance of the pilot line. The bridge circuit 12 will have its electrical properties varied in accordance with the variation in resistance of the pilot line 11. The bridge circuit 12 in turn effects operation of the galvanometer control mechanism 22. The galvanometer control mechanism 22 would have a linear operation with temperature changes unless compensating means were provided by the resistance sections 14 to 19, inclusive, by reason of the fact that the resistance of the pilot line 11 has a linear variation with temperature changes. The galvanometer control means 22, by means of the shaft 23, beveled gear wheels 25 and 30, and the cam members 33 to 37, inclusive, controls the relays 39 to vary the resistance sections 14 to 19, inclusive, included in one arm of the bridge 12. The resistance sections 14 to 19, inclusive, are of such size as to compensate for the non-linear attenuation variations of the transmission line with temperature changes. The galvanometer control mechanism 22 also adjusts the resistance 20 to effect a rebalancing operation of the bridge 12. The master motor 27 is operated to control the service motor 45 and adjusts the feedback for the amplifier 4 so as to maintain the line attenuation substantially constant.

Referring to Fig. 4 of the drawings, curves are shown to illustrate the non-linear attenuation variations of the transmission line with temperature changes. The curve A in full lines indicates the gain or loss in decibels on the transmission line with changes in temperature. The curve is drawn with temperature variations as abscissas and decibel loss or gain as ordinates. The curve B indicates the normal gain of the amplifier 4 if no compensation were provided for the non-linear attenuation characteristics of the transmission line. The curve C indicates the amplifier gain characteristics where compensation has been effected for the non-linear attenuation characteristics of the transmission line.

In Fig. 2 of the drawings is shown a modification of the circuit shown in Fig. 1 and like parts in Fig. 2, to those shown in Fig. 1, will be indicated by similar reference characters. The bridge circuit 12 in the circuit shown in Fig. 2 has a variable resistance 50 included in one arm thereof in place of the resistance sections 14 to 19, inclusive, shown in Fig. 1 of the drawings. The shaft 23, which is operated by the galvanometer control mechanism 22, carries a beveled gear wheel 51 which is connected through a bevel gear wheel 49 and gearing 52 to a shaft 53 carrying an arm 54 for adjusting the resistance 50. The resistance 50 in the bridge circuit 12 of Fig. 2 of the drawings is shown in detail in Fig. 6 of the drawings. The shape of the resistance 50 is varied in a manner to compensate for the non-linear attenuation variations of the transmission line when the resistance arm 54 is operated linearly in accordance with temperature variations. The circuit shown in Fig. 2 of the drawings operates in the same manner as the circuit shown in Fig. 1 of the drawings with the exception of the control of the resistance which compensates for the non-linear attenuation variations of the transmission line.

In Fig. 3 of the drawings is shown a modification of the invention wherein compensation for non-linear attenuation variation of the transmission line with temperature changes is effected by controlling a resistance **55** in the circuit of the pilot line **11**. The resistance **55** is controlled by the galvanometer control mechanism **22** in the same manner as the resistance **50** in the circuit shown in Fig. 2 is controlled by the galvanometer control mechanism. A beveled gear wheel **56** on the shaft **23** meshes with a beveled gear wheel **57**. The beveled gear wheel **57** is connected through gearing **58** to the shaft **59**. The shaft **59** carries a resistance arm **60** which adjusts the amount of the resistance **55** included in the pilot line **11**.

Like parts in the circuit shown in Fig. 3 to those shown in Figs. 1 and 2 have been indicated by similar reference characters. The operation of the circuit with the exception of the control of the resistance of the pilot line is similar to the operation of the circuits shown in Figs. 1 and 2 of the drawings.

It is also possible to compensate for the non-linear attenuation variations of a transmission line with temperature changes by varying the shape of the condenser plates in the condenser **10**. In Fig. 5 of the drawings, a condenser having the plates thereof varied to compensate for the non-linear attenuation variations is illustrated. The plate **61** is assumed to be stationary whereas the plate **62** is assumed to move in accordance with the operation of the service motor **45**.

Although the invention has been illustrated by showing compensation for non-linear variations of transmission line attenuation with temperature changes in the flat gain regulator shown in the patent to F. A. Brooks, No. 2,075,975 it is to be understood that a similar correction may be made in the twist regulator disclosed in the Brooks application.

Modifications in the circuits and in the arrangements 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. A signal transmission line having pilot means associated therewith and subjected to the same temperature changes as the line, a bridge circuit having one arm thereof formed by said pilot means to be controlled according to the temperature changes of said means, galvanometer control mechanism governed by said bridge circuit to have linear operation according to temperature changes of said means, and means controlled by said galvanometer mechanism for governing the transmission line attenuation, for rebalancing the bridge upon each operation and for compensating for the non-linear variations of the line attenuation with temperature changes.

2. A signal transmission line having a pilot path associated therewith and subjected to the same temperature changes as the transmission line, a bridge circuit having one arm thereof formed by said pilot path, mechanism controlled by said bridge according to the resistance variations of the pilot path with temperature changes and means controlled by said mechanism for governing the line attenuation while compensating for non-linear variations of the line attenuation with temperature changes whereby the line attenuation is held constant irrespective of temperature changes.

3. A signal transmission line having non-linear variations in attenuation with temperature changes, pilot means associated therewith and having linear resistance changes with temperature changes, a bridge circuit having one arm formed by said pilot means, mechanism governed by said bridge and having a linear operation according to temperature changes affecting the transmission line and the pilot line, and electrical means operated by said mechanism for compensating the non-linear variations of the line attenuation with temperature changes and for controlling the line attenuation to maintain the transmission line attenuation constant irrespective of temperature changes.

4. A signal transmission line having non-linear variations in attenuation with temperature changes, a pilot line associated with said transmission line and subjected to the same temperature changes as said transmission line, a bridge circuit having one arm thereof formed by said pilot line and varied according to the resistance changes of the pilot line with temperature changes, a variable compensating resistance forming another arm of said bridge circuit, galvanometer mechanism controlled by said bridge to have linear operation according to temperature changes of the pilot line, and means operated by said galvanometer mechanism for varying said compensating resistance to compensate for non-linear variations in the cable attenuation with temperature changes, for rebalancing said bridge and for maintaining the line attenuation constant.

5. A signal transmission line having non-linear variations in attenuation with temperature changes, a pilot line associated with said transmission line and subjected to the same temperature variations as said transmission line, a bridge circuit having one arm thereof formed by said pilot line and varied according to the resistance changes of the pilot line with temperature changes, galvanometer mechanism controlled by said bridge to have linear operation according to temperature changes of the pilot line, and means operated by said galvanometer mechanism for controlling said bridge to compensate for the non-linear variations in the transmission line attenuation with temperature changes, for rebalancing the bridge and for maintaining the attenuation of the transmission line constant.

6. A signal transmission line having non-linear variations in attenuation with temperature changes, pilot means associated with said transmission line and subjected to the same temperature variations as said transmission line, a bridge circuit having one arm thereof formed by said pilot means and controlled according to the resistance changes of the pilot means with temperature changes, mechanism controlled by said bridge to have linear operation according to temperature changes of the pilot means, and means controlled by said mechanism for governing said bridge so as to compensate for non-linear variations in the transmission line attenuation with temperature changes and for maintaining the transmission line attenuation constant.

7. A signal transmission line having non-linear variations in attenuation with temperature changes, a pilot line associated with said transmission line and subjected to the same temperature changes as said transmission line, a bridge circuit having one arm formed by said pilot line and varied according to the resistance variations of the pilot line with temperature changes, a compensating resistance divided into sections and in-

cluded in one arm of said bridge, relays for respectively short-circuiting said resistance sections, mechanism controlled by said bridge to have linear operation according to temperature changes of the pilot line, and means controlled by said mechanism for selectively operating said relays to compensate for non-linear variations in the transmission line attenuation with temperature changes and for maintaining the transmission line attenuation constant.

8. A signal transmission line having non-linear variations in attenuation with temperature changes, a pilot line associated with said transmission line and subjected to the same temperature changes as said transmission line, a bridge circuit having one arm formed by said pilot line and varied according to the resistance changes of said pilot line, a compensating resistance divided into sections and included in one arm of said bridge, relays respectively associated with said resistance sections for completing short-circuit connections around the resistance sections, means comprising cam members for selectively operating said relays, galvanometer mechanism controlled by said bridge to have linear operation according to temperature changes of the pilot line, and means controlled by said mechanism for operating said cams to control said resistance sections and compensate for non-linear variations in the transmission line attenuation with temperature changes, for rebalancing the bridge circuit, and for maintaining the transmission line attenuation constant.

9. A signal transmission line having non-linear variations in attenuation with temperature changes, a pilot line associated with said transmission line and subjected to the same temperature variations as said transmission line, a bridge circuit having one arm formed by said pilot line and varied according to the resistance changes of the pilot line with temperature changes, galvanometer mechanism controlled by said bridge to have linear operation according to temperature changes of the pilot line, and means controlled by said galvanometer mechanism for varying the resistance of said pilot line to compensate for non-linear variations in the transmission line attenuation with temperature changes, for rebalancing the bridge circuit and for maintaining the transmission line attenuation constant.

10. A signal transmission line having a pilot path associated therewith, the transmission line and the pilot path being subjected to the same temperature variations, said path having linear resistance variations according to temperature changes and said transmission line having non-linear attenuation variations with temperature changes, control means governed by the resistance variations of said pilot path with temperature changes of the pilot path for governing the transmission line attenuation, and means governed by said control means to compensate the non-linear variations of the transmission line attenuation with temperature changes to maintain the line attenuation constant.

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