

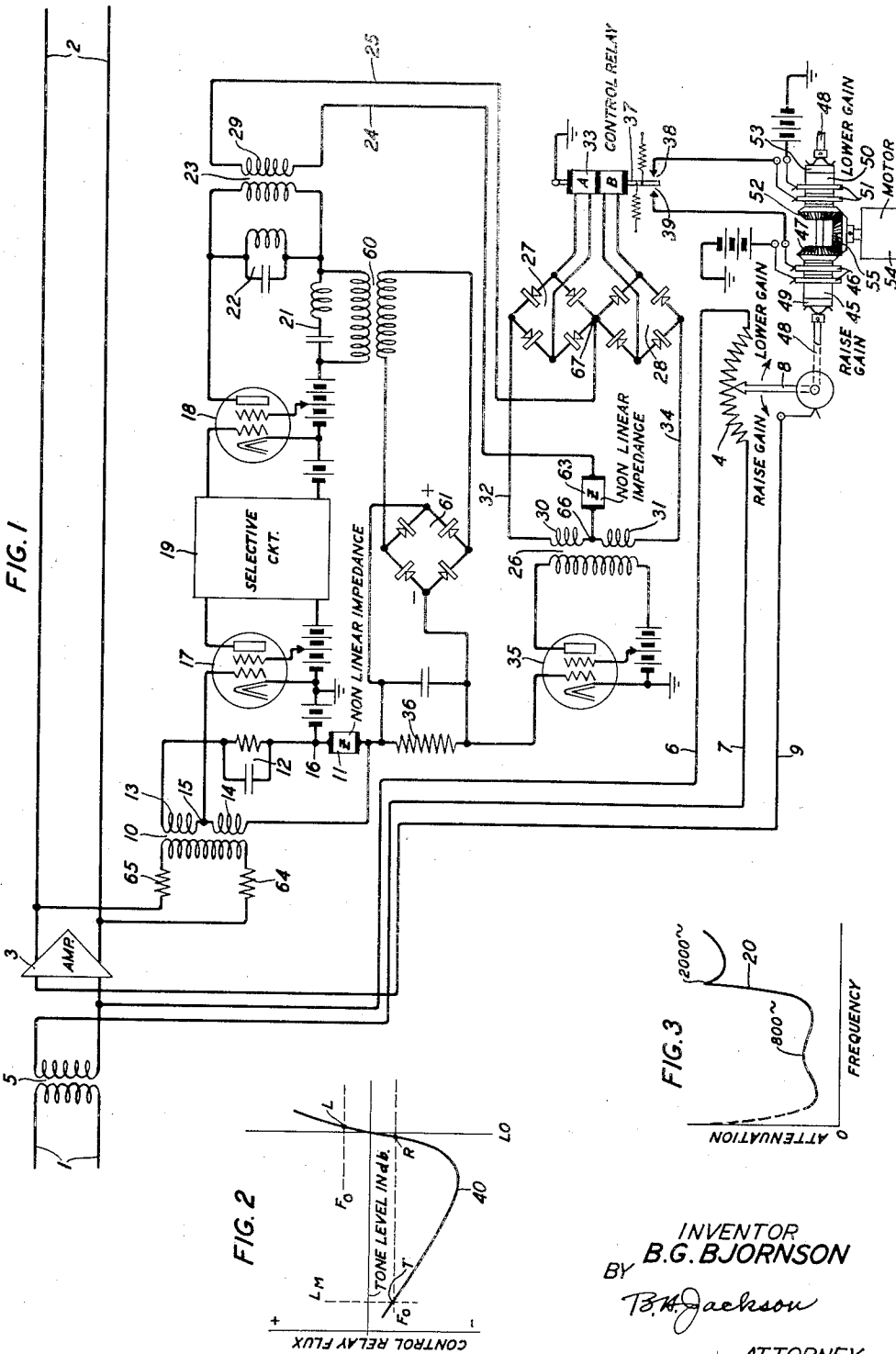
Sept. 27, 1938.

B. G. BJORNSON

2,131,580

CONTROL CIRCUITS

Filed May 14, 1937



INVENTOR
BY **B.G. BJORNSON**
B.H. Jackson

ATTORNEY

UNITED STATES PATENT OFFICE

2,131,580

CONTROL CIRCUITS

Bjorn G. Bjornson, New York, N. Y., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

Application May 14, 1937, Serial No. 142,538

14 Claims. (Cl. 178—44)

This invention relates to control circuits and more particularly to control circuits adapted to measure variations in an electrical characteristic and if desired, compensate for said variations in a suitable manner.

More specifically, one application of the invention has to do with the maintenance of the transmission efficiency of long telephone lines by compensating for variable transmission losses incidental to the operation of such lines.

A known arrangement in a telephone transmission line, designated as a "tonlar" circuit, involves sending over the line, while there is no speech present, a tone of a definite frequency, measuring at an intermediate point the loss or attenuation of such tone and, depending upon the variation of such attenuation from an arbitrary value, automatically varying the gain introduced by repeaters at such point to restore the transmission level to the desired amplitude.

The present invention is particularly applicable to such "tonlar" arrangements in that it translates slight variations in attenuation into large control currents and also determines the direction of such variations as well as the amount.

In accordance with the invention, advantage is taken of a characteristic of a material which has become quite widely known as "thyrite" covered by Patent 1,822,742, granted to K. B. McEachron, September 8, 1931, and which possesses in a very marked degree a non-linear voltage current characteristic. The resistance of thyrite varies instantaneously as a function of the current passing therethrough. If such a material is connected in to form one arm of a Wheatstone bridge, the other three arms being linear resistances or impedances, and if the frequency is maintained constant, as for instance impressing a constant one across the bridge, there will be only one point at which the bridge can be balanced and that is the point where the voltage current characteristic of one of the fixed arms crosses the voltage current characteristic of the non-linear resistance material. At either side of this point the bridge will be balanced and unbalanced by an increasing amount represented by the difference between the two curves. Furthermore, if voltage applied across the bridge is gradually increased toward the point of intersection or balance point there will be a gradual decrease in the unbalance currents flowing across the bridge until, at the balance point, zero is reached after which there will be a reversal in phase and

the unbalance current will build up. If such a Wheatstone bridge is connected across a transmission line and the characteristics are chosen so that for a given loss or voltage a balance will be attained, then any variation from this loss will be translated into a current flow across the bridge which will be proportional to the amount of deviation from the balance point. Therefore, if at a given point in a telephone transmission line it is desired to maintain a fixed or standard transmission level, it is apparent that by sending a standard frequency from the other end of the line, any variation in this level produced by losses intermediate the sending and the pick-up point would be translated by the bridge into an unbalance current of the standard frequency which may be used to control the transmission level.

One way for controlling the transmission level in accordance with the unbalance current of the standard frequency from the above described bridge circuit is to amplify the unbalance current and apply the amplified current to control a motor-driven potentiometer for the line in such a manner that for an unbalance current defining an undesired low level in the line or defining an undesired high level in the line the motor will be actuated to vary the potentiometer in the proper direction until the desired level is reached, whereupon the bridge will be balanced and the potentiometer held in its new position. Such a motor-driven potentiometer in a tonlar circuit is shown, for example, in the United States Patent to A. M. Curtis, No. 2,096,450, October 19, 1937.

A preferred way of selectively operating the motor-driven potentiometer is based on the previously described characteristic of the bridge circuit that the unbalance current of the standard frequency due to an undesired low level will be approximately 180 degrees out of phase with the unbalance current due to an undesired high level. One way of utilizing this phase reversal of the unbalance current of the said standard frequency to define the direction the potentiometer should be adjusted, is to combine it with a current of the standard frequency the phase of which is independent of the direction the bridge is unbalanced. The combining circuit can be readily adjusted, for example, so that for an unbalance current due to an undesired high transmission level the two currents will be substantially in phase with each other while for an unbalance current due to an undesired low transmission level the two currents will be opposed in phase. Thus, the two above mentioned cur-

rents may be impressed upon a two-branch circuit in such a manner that for one phase relation due, for example, to an undesired high transmission level in the line the two currents will be in phase in one branch and opposed in phase in a second branch, while for an undesired low transmission level the two currents will be in phase in the second branch and opposed in phase in the first branch. Now, if we include in each branch a full wave detector and one winding of a two-winding polarized relay it will be apparent with the above assumptions that for an undesired high transmission level the rectified current in the relay winding in the first branch will be greater than the rectified current in the relay winding in the second branch, and hence the first winding will control the relay armature to move it in a certain direction to enable contacts to be closed to cause the potentiometer setting to be decreased; while for an undesired low transmission level the current in the relay winding in the second branch will be the greater, and hence will move the relay armature in the opposite direction to enable contacts to be closed to cause the potentiometer setting to be increased. In either event the change in the potentiometer setting will adjust the gain of the line repeater to restore the transmission level to the desired value, whereupon the unbalance current will be substantially zero resulting in equal current flow through the two relay windings, thereby causing the relay armature to be restored to its neutral position.

Referring to the drawing,

Fig. 1 discloses a tonlar circuit embodying this invention for automatically maintaining a desired transmission level in a signaling line;

Fig. 2 is a curve illustrating the flux variations which may be produced in the control relay of Fig. 1; and

Fig. 3 is a curve showing a desired characteristic of a selective circuit employed in Fig. 1.

Referring more particularly to Fig. 1, a repeater station is shown for a signaling transmission line comprising incoming line section 1 and outgoing line section 2. Between the two sections is a suitable amplifying repeater 3 the gain of which may be controlled by gain adjusting potentiometer 4 connected in shunt to the secondary winding of input transformer 5 by leads 6 and 7, while the amplifier 3 is connected across an adjustable amount of the potentiometer due to motor-driven arm 8 and conductor 9. It will be apparent that if it is desired to increase the gain of amplifier 3 to compensate for increased attenuation in line section 1, potentiometer arm 8 should be moved to the left while if it is desired to decrease the gain of amplifier 3, potentiometer arm 8 should be moved to the right.

In order to automatically maintain a desired transmission level at the output of amplifier 3 in spite of variations in the attenuation of line section 1 it will be assumed that a standard frequency at a definite amplitude is impressed upon the far end of the line at times when the line is not being used for speech transmission, so that the level of this tone frequency at the output of amplifier 3 will tend to vary with the undesired variations in the attenuation of the line. The output of amplifier 3 is bridged by conductors leading to the primary winding of a transformer 10 the secondary of which is divided into two equal portions 13 and 14 to form two arms of a Wheatstone bridge, while the other two arms comprise a non-linear resistance 11 such as thyratron and a resistance-condenser network 12. The

arrangement is preferably such that for the desired transmission level of the tone frequency at the output of amplifier 3 the impedance of network 12 equals the impedance of the non-linear resistance 11 so that the bridge is balanced and points 15 and 16 are at the same potential. But when the level of the tone frequency in the output of amplifier 3 is substantially different from the desired value due, for example, to changes in the attenuation of line section 1, the tone frequency current through resistance 11 will be different in magnitude and consequently resistance 11 will have a different value of resistance, thereby upsetting the balance of the bridge and creating a potential difference between points 15 and 16 which may be impressed upon a suitable amplifier 17, 18. It has been previously described that such a Wheatstone bridge will be balanced for only one value of the tone frequency amplitude impressed thereon which balance indicates that the amplifier 3 is producing the desired gain for signal transmission. If we start with an undesired low level of the tone frequency voltage impressed on the bridge and gradually increase this voltage the unbalance potential across bridge points 15, 16 will gradually decrease until at the balance point the unbalance potential is zero, after which there will be a reversal in phase of the unbalance potential with further increase in the applied tone frequency voltage and the potential difference between points 15 and 16 will be proportional to the amount of the deviation from the balance point. In other words, the tone frequency potential impressed upon amplifier 17 for an undesired low level in amplifier output 3 will be of the opposite phase to such potential developed because of an undesired high level in amplifier output 3 and the magnitude of the unbalance current will be proportional to the amount of deviation from the desired level in the line.

If we assume that the test frequency is 800 cycles for example, it is desirable to provide amplifier 17, 18 with a suitable selective circuit 19 such as a band-pass filter which will discriminate in favor of 800 cycles but will provide high attenuation for certain other frequencies, particularly the third harmonic of the tone frequency. For example, a selective circuit 19 may have an attenuation-frequency characteristic as shown by curve 20 of Fig. 3 where the attenuation is plotted against frequency, the curve showing relatively low attenuation for the desired frequency of 800 cycles and a relatively high attenuation for frequencies of 2000 cycles or higher. The output of the last stage of amplifier 17, 18 includes a series tuned circuit 21 and a shunt connected anti-resonant circuit 22 both tuned to the tone frequency of 800 cycles. Connected across the anti-resonant circuit 22 is the primary winding of a transformer 23 which has its secondary winding 29 connected by conductors 24, 25 between the mid-point of the secondary winding of another transformer 26 and the junction of two similar full wave rectifiers 27, 28. There are, therefore, two parallel paths for any unbalance current in secondary winding 29, one path being from conductor 24, secondary winding 30, conductor 32, full wave rectifier 27, winding A of control relay 33 and conductor 25, while the other path comprises conductor 24, secondary winding 31, conductor 34, full wave rectifier 28, relay winding B, and conductor 25.

The primary winding of transformer 26 is connected in the output circuit of an amplifier 35 75

which through a high resistance 36 has its input connected across the non-linear resistance 11. The output transformer 26, therefore, receives in amplified form the tone frequency current with a phase relation which is not changed by the balanced or unbalanced condition of the Wheatstone bridge and in particular with a phase relation which is not changed when the transmission level of the tone frequency at the output of amplifier 3 is changed from an undesired low level to an undesired high level. It will be apparent that the unbalance current from transformer 23 flows through secondary windings 30, 31 in opposite directions while current from amplifier 35 will flow through secondary windings 30, 31 in the same direction. It may be assumed that the transformers of the circuits are so poled that for an unbalanced current due to an undesired high level the two currents are aiding in winding 31 and are opposed in winding 30. Hence, relay winding B which is in circuit with rectifier 28 will be traversed by a greater current than relay winding A, so that armature 37 is moved under the control of winding B, for example, to close contacts 38 and cause the motor-operated potentiometer 4 to be adjusted to decrease the gain. As the gain is decreased there will be a proportionate decrease in the unbalance current in secondary winding 29 until the unbalance current is so small that the resulting difference between the current in winding A and the current in winding B is insufficient to operate relay 33, whereupon armature 37 will return to its neutral position, holding potentiometer 4 at its new setting. On the other hand, if we assume an unbalance current in the output of transformer 29 due to an undesired low level at the output of amplifier 3 the phase relations of the standard current and the unbalance current in the two secondary windings 30, 31 will be reversed and the two currents will now be aiding in winding 30 and opposing in winding 31. Hence, relay winding A which is in circuit with rectifier 27 will be traversed by a greater current than winding B so that the armature 37 is now moved under control of winding A to close contacts 39 and cause the potentiometer 4 to be adjusted to increase the gain. As the gain of amplifier 3 is increased, there will be a proportionate decrease in the unbalance current in secondary winding 29 until the unbalance current is so small that the resulting difference between the current in winding A and the current in winding B is insufficient to operate relay 33, whereupon armature 37 will be restored to its neutral position and potentiometer 4 held at its new setting.

As long as the tone frequency level at the output of amplifier 3 remains substantially at the desired value it will be apparent that there will be insufficient unbalance current to produce sufficient difference in the opposing fluxes in relay windings A and B to move the armature to one contact or the other. With no unbalance current from transformer 23 the reference current from transformer 26 will give equal currents in relay windings A and B with opposing fluxes. It may be assumed that means are provided to insure that the tone frequency level at the output of amplifier 3 never will reach such a low value as to be unable to produce an unbalance of sufficient magnitude to operate relay 33. Thus, in Fig. 2 we have a curve 40 showing the relation between the net relay flux due to windings A and B and the current level in decibels at the input of transformer 10. It will be assumed that the

net flux in relay 33 must be equal to or greater than the value indicated by the dotted lines F_0 in Fig. 2 in order to operate the relay, and that the maximum attenuation of line section 1 will be limited to a value sufficient to produce a net flux in relay 33 of a value equal to F_0 or greater. In Fig. 2 the assumed tone frequency level at the input of transformer 10 for maximum attenuation in line section 1 is represented by the value designated L_M . Thus for any undesired low value of the tone level at the output of amplifier 3 the net flux in relay 33 will lie some place along curve 40 between the points T and R and will be, say, of such a polarity as to cause relay 33 to close contacts 39 and raise the gain of amplifier 3. When the gain has been increased to give a tone level beyond the value for the point R on the curve the next flux through relay 33 will be insufficient to operate the relay. Hence, if the tone level at the output of transformer 23 lies between the values for points R and L on curve 40, the relay 33 will remain unoperated. But if the tone level should suddenly increase to a value higher than the value for point L the net flux in relay 33 now being in the opposite direction will be sufficient to operate relay 33 to reduce the gain. As long as the tone frequency level at the input of transformer 10 remains between the values for points R and L the armature of control relay 33 will remain in its neutral position but when the tone frequency level exceeds these values the net flux in relay 33 is sufficient to change the gain to restore the output level of amplifier 3 to the desired value. The line L_0 in Fig. 2 represents the mid-point of the permissible range of variation in the magnitude of the current in the input of transformer 10.

As previously stated, the motor-driven potentiometer disclosed in Fig. 1 is similar to that of the above-mentioned Curtis patent. The clutch magnet 45 and slip rings 46 are connected to a beveled gear wheel 47 and are rotatably mounted on a shaft 48. A disc 49 which is fixedly mounted on shaft 48 is attracted by the clutch magnet 45 when energized by the closing of contacts 39 to connect the clutch magnet 45 and gear wheel 47 to shaft 48. The clutch magnet 50 and the slip rings 51 are connected to a beveled gear wheel 52 and are rotatably mounted on shaft 48. A disc 53 which is fixedly mounted on shaft 48 serves to connect the gear wheel 52 and clutch magnet 50 to shaft 48 when clutch magnet 50 is energized by the closing of contacts 38. The gear wheels 47 and 52 are connected to a constantly rotating motor 54 by means of beveled gear 55. The operating arm 8 of potentiometer 4 is connected to the shaft 48 in order to adjust the potentiometer setting in accordance with the movement of shaft 48. If desired, the motor-driven potentiometer just described may be provided with suitable alarm circuits for indicating abnormal conditions as disclosed, for example, in the above-mentioned Curtis patent.

It will be readily understood that the above-described arrangement for maintaining substantially constant output level at amplifier 3 should function to adjust the potentiometer 4 only in response to the application of the special tone frequency to the line and the potentiometer setting should not be disturbed during the transmission of speech or other signals over the line. In the above example, it has been assumed that the tone frequency is 800 cycles and that each of the circuits 21, 22 in the output of amplifier 18 is tuned to that frequency. In order to pre-

vent the 800 cycle component of speech or other signals from disturbing the potentiometer setting a transformer 60 has its primary winding bridged across circuit 21 and has its secondary winding connected across one diagonal of a full wave rectifier 61 and the rectified output from rectifier 61 is impressed across resistance 36 with such a polarity as to make the grid of tube 35 negative with respect to its cathode. It follows from such an arrangement that when speech is present in line sections 1, 2 the amplified speech in the output of amplifier 19 will have frequencies differing substantially from 800 cycles, thereby building up a potential difference across the terminals of circuit 21, and this rectifier potential will be sufficient to render the grid of tube 35 so negative as to prevent space current flow in its output circuit. No harm can now be done by the 800 cycle speech component impressed by transformer 23 upon the full wave rectifiers 27, 28 since the currents in windings A and B will now be equal in magnitude and opposite in phase in the absence of the standard current from amplifier 35. However, when the pure tone frequency of 800 cycles is received in the absence of speech on the line the primary winding of transformer 60 will be practically short-circuited by the tuned circuit 21 and hence the previously described function of amplifier 35 to supply the tone frequency current of standard phase to rectifiers 27, 28 will not be affected.

It will be noted that a non-linear resistance 63 made of thyrite, for example, is included in series with the secondary winding 29 to give a steep relation between the tone frequency input level across winding 29 and the net relay flux of relay 33 as shown by a curve 40 of Fig. 2 between the points L and R. With the non-linear resistance 63 omitted, the circuit disclosed will operate satisfactorily but a greater variation from the desired transmission level in line 1, 2 will be needed before relay 33 will be operated to adjust potentiometer 4 to compensate for the change in level.

In order that transformer 10 will have no undesired shunting effect across line 2 for speech currents it will generally be preferable to include suitable resistances 64, 65 in series with the primary winding of the transformer to increase the impedance of the shunt circuit.

The full wave rectifiers 27, 28 and 61 may be of the copper oxide type although other types may be employed if desired. It should also be noted that the steepness of the operating portion of curve 40 is due in part to the push-pull arrangements of rectifiers 27 and 28 in the phase reversal detector. Since thyrite, the preferred material for the non-linear resistance 11, has a negative temperature coefficient of resistance it may be desirable to insure that element 11 is maintained at a substantially constant temperature so as not to permit temperature variations to affect the normal transmission level maintained by the apparatus at the output of amplifier 3.

It will be understood that the present invention may possess embodiments differing widely from that disclosed above without departing in any wise from the scope of this invention as defined in the appended claims.

What is claimed is:

1. A system for the transmission of electrical energy comprising a controlled circuit, controlling means for automatically adjusting an electrical characteristic of said circuit, measuring

means responsive to a variation of said characteristic from a predetermined desired value for effecting voltage changes in amount and phase to measure the amount and the direction of said variation, and means controlled by said characteristic but non-responsive to the directional sense of any change of said characteristic from said desired value cooperating with said measuring means according to the changes of voltage in amount and phase to selectively control said adjusting means.

2. In combination, a signal transmission line having a control current impressed thereon, a signal station connected to said line, variable loss controlling means at said station for controlling the net loss of the line, measuring means responsive to a change in said control current from a predetermined value for producing a more than proportional voltage change and a phase change to measure the amount and the direction of said change, and means responsive to said control current independently of the directional sense of any change in said current from said predetermined value for cooperating with said measuring means according to the voltage and phase changes thereby to jointly control said loss controlling means.

3. A measuring circuit comprising a Wheatstone bridge having as one arm thereof an element with a non-linear resistance-current characteristic, means for applying a variable voltage across one diagonal of said bridge, said bridge being balanced for a predetermined value of said applied voltage, means connected across the other diagonal of said bridge for indicating the magnitude of the departure of said voltage from said predetermined value, and means responsive to the input voltage to said bridge cooperating with said second means to indicate whether said applied voltage is above or below said predetermined value.

4. In combination, a signal transmission line having a control current impressed thereon, an amplifier in said line responsive to said control current whereby the output level of said amplifier tends to change with variations in the magnitude of said control current from its normal value, means comprising a non-linear impedance responsive to the output of said amplifier for producing a voltage whose magnitude is proportional to said change and whose phase is controlled by the direction of said change from the normal value, and means controlled by said first means for controlling the gain of said amplifier.

5. In combination, a signal transmission line having a control current impressed thereon, a signal station connected to said line, variable loss controlling means at said station for controlling the net loss in said line, a bridge circuit connected to said line and comprising a non-linear resistance for effecting a more than proportional change in the energy variation of the received control current and a phase change to determine the operation of said loss controlling means, and means jointly controlled by the received control current and the output from said bridge for effecting operation of said loss controlling means.

6. In combination, a signal transmission line having a control current impressed thereon, a signal station connected to said line, a bridge circuit connected to the line at said station for indicating the energy level of said control current at said station, said bridge circuit comprising in one arm a non-linear resistance and a phase reversal detector comprising a differential relay

having two coils respectively connected to two rectifier circuits with the rectifier circuits connected parallelly to the bridge input and oppositely to the bridge output for indicating whether the received level of said control current is above or below a prescribed value.

7. In combination, a signal transmission line having a control current impressed thereon, a signal station connected to said line, a bridge circuit at said station for indicating the energy level of said control current at said station, said bridge circuit comprising in one arm a non-linear resistance, a phase reversal detector connected to said bridge for indicating whether the received level of said control current is above or below a prescribed value, said detector comprising two rectifier circuits oppositely connected to the output of said bridge and parallelly connected to the input voltage supplied to the bridge and auxiliary means differentially operated by said rectifier circuits for indicating voltage change and the direction of change in the voltage supplied to the bridge, and variable loss controlling means at said station controlled by said auxiliary means for controlling the net loss in said line.

8. In combination, a signal transmission line having a control current impressed thereon, a signal station connected to said line, a bridge circuit at said station for indicating the energy level of said control current at said station, said bridge circuit comprising in one arm a non-linear resistance, said bridge circuit being balanced when the energy level of said control current at said station is at a prescribed value, means for comparing the phase of the input voltage to said bridge with the phase of the output voltage of said bridge, and means controlled by said comparing means for varying the transmission efficiency of said line.

9. In combination, a signal transmission line having impressed thereon at different times a control current of a definite frequency and a signaling current of a band of frequencies, a signal station connected to said line, a bridge circuit at said station for measuring the energy level of said control current at said station, said bridge circuit including in one arm a non-linear resistance, said bridge being balanced when the energy level of said control current at said station is at a prescribed value, means connected to the output of said bridge for suppressing harmonics of said definite frequency, means for comparing the phase of the input voltage to said bridge with the phase of the output voltage from said bridge, means responsive to said comparing means for varying the net loss in said line, and means for rendering said responsive means inoperative when said station receives said signaling current of a band of frequencies.

10. In combination, a signal transmission line having a pulse of control current impressed thereon at intervals, a signal station connected to said line, variable loss controlling means in said line at said station, a bridge circuit connected to said line and normally balanced when the voltage of

said control current impressed on said bridge is of a prescribed value, said bridge circuit comprising in one arm a non-linear resistance the resistance of which varies instantaneously as a function of the current passing therethrough, an amplifier connected to the output of said bridge, a phase reversal detector connected to said amplifier for comparing the phase of the output of said bridge with the phase of the input to said bridge, and means responsive to said detector for controlling said loss controlling means.

11. In combination, a transmission line having a control current impressed thereon, a measuring circuit connected to said line comprising a Wheatstone bridge circuit having in one arm a non-linear resistance, said bridge being balanced for a certain energy level of said control current, means connected to said bridge for producing a rectified current of one polarity when said bridge is unbalanced by an energy level above said certain value and for producing a rectified current of the opposite polarity when said bridge is unbalanced by an energy level below said certain value, each of said rectified currents having a magnitude controlled by any variation of said control current from said certain level and indicating means selectively controlled by either of said rectified currents.

12. In combination, a measuring device comprising a Wheatstone bridge circuit having in one arm thereof a non-linear resistance, means for impressing upon said bridge a voltage subject to variations, said bridge being balanced for only one value of said impressed voltage, two rectifier circuits oppositely connected to the output from said bridge and parallelly connected to the voltage input to the bridge and means differentially operated by said rectifier circuits for indicating voltage change and the direction of change in the voltage supplied to the bridge.

13. A measuring device comprising a Wheatstone bridge circuit having in one arm thereof a non-linear resistance, means for impressing on said bridge a voltage subject to variations, said bridge being balanced for only one value of said impressed voltage, and means for comparing the phase of the output voltage from said bridge with the phase of the input voltage to said bridge to indicate the magnitude and directional sense of a change in said input voltage from said one value.

14. A measuring device comprising a Wheatstone bridge circuit having in one arm thereof a non-linear resistance, means for impressing on said bridge a voltage subject to variations, said bridge being balanced for only one value of said impressed voltage, means for comparing the phase of the output voltage from said bridge with the phase of the input voltage to said bridge to indicate the magnitude and directional sense of a change in said input voltage from said one value, and means controlled by said second means for controlling the magnitude of the input voltage impressed on said bridge.

BJORN G. BJORNSON.