

Oct. 19, 1937.

A. M. CURTIS

2,096,450

CONTROL CIRCUIT

Filed May 16, 1935

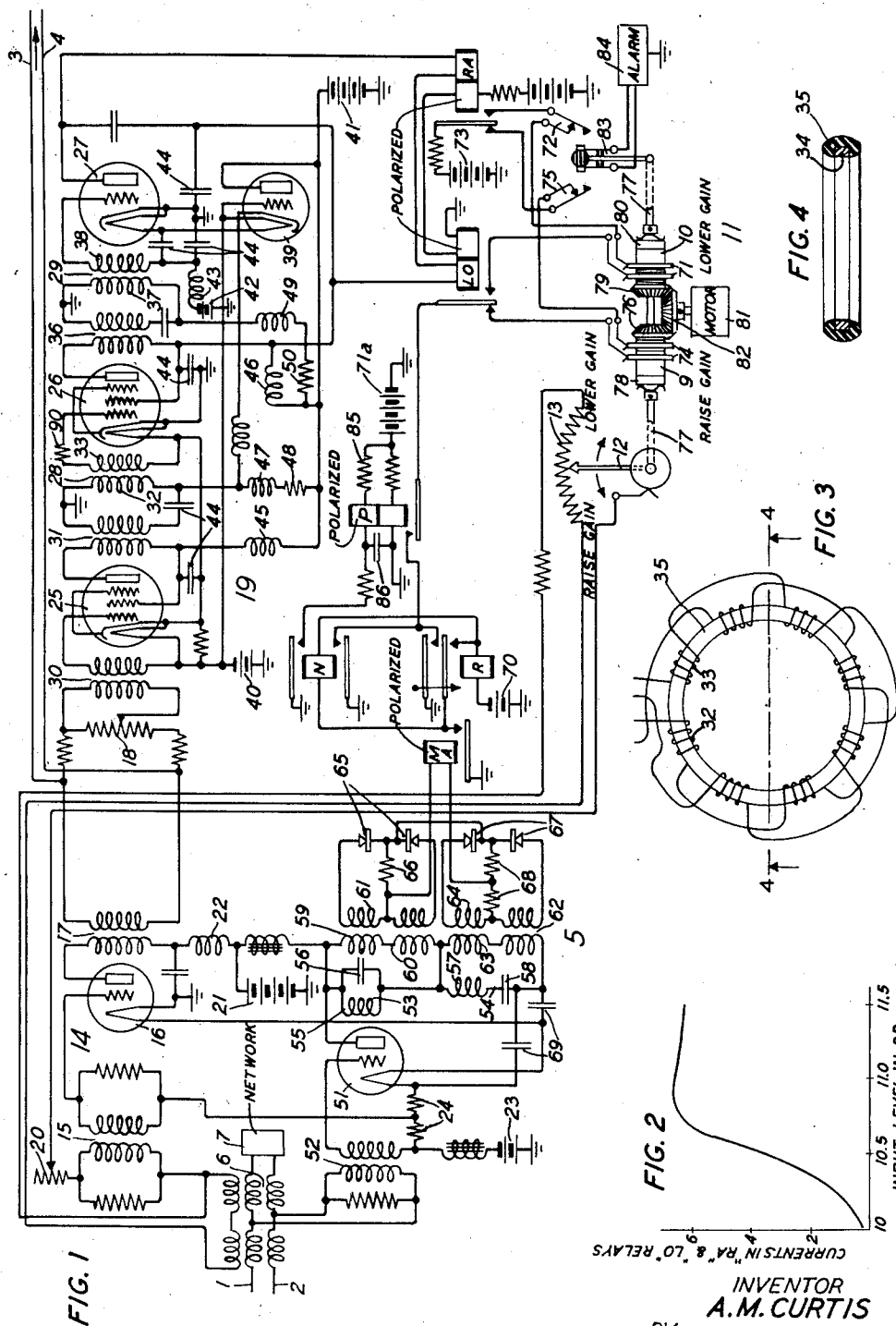


FIG. 1

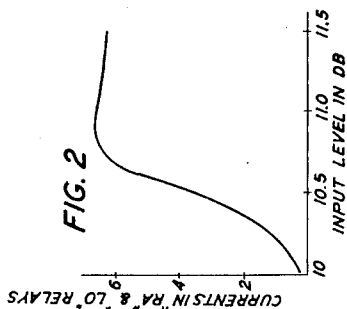


FIG. 2

INVENTOR
A. M. CURTIS
BY
Wayne B Wells
ATTORNEY

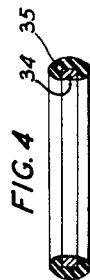


FIG. 4

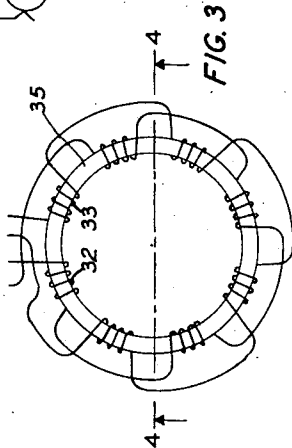


FIG. 3

UNITED STATES PATENT OFFICE

2,096,450

CONTROL CIRCUIT

Austen M. Curtis, East Orange, N. J., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application May 16, 1935, Serial No. 21,835

22 Claims. (Cl. 178-44)

This invention relates to control circuits and particularly to control circuits for adjusting the net loss on a transmission line.

One object of the invention is to provide a signal station on a transmission line with control circuits that shall adjust the net loss on the line in accordance with the strength of received control current and that shall adjust the net loss on the line only when a pure control current free from currents of other frequencies is received at the station.

Another object of the invention is to provide a measuring circuit for governing the adjustment of the net loss on a line that shall effect a more than proportional change in a control current transmitted to the measuring circuit for governing the adjustment of the net loss on the line in an improved manner.

Another object of the invention is to provide a signal station on a transmission line with control circuits that shall adjust the net loss on the line in accordance with the peak values of a received control current.

A further object of the invention is to provide a signal station on a transmission line with control circuits that shall effect a more than proportional change in the variations of a received pulse of control current for governing the adjustment of the net loss on the line in accordance with the peak values of the control current.

In long transmission lines it is necessary to adjust the gain at various repeater stations to correct for variations in the line impedance. Variations in the line impedance are chiefly caused by temperature change. Pilot wire regulators of the type disclosed in the patent to J. A. Coy et al., No. 2,017,654, October 15, 1935 may be employed to control the gain at the repeater stations. There is a small error in the operation of each of the pilot wire regulators and when the regulators operate in the same direction the errors add together. In a very long transmission line the added errors of the regulators may be appreciable.

In accordance with the present invention means are provided for correcting for the variations in attenuation on a long transmission line at intermediate and terminal stations. Net loss adjusting means preferably in the form of a motor-operated potentiometer are provided at terminal and intermediate stations for adjusting the net loss on the line. The potentiometer at each station is operated in accordance with the strength of a received control current at the station. The control current is transmitted over the

line at intervals for fixed lengths of time and preferably has a frequency within the voice frequency range. A signal system having means for transmitting control currents is disclosed in the patent to L. G. Abraham and A. F. Grenell, No. 2,060,843, issued November 17, 1936.

A control current which is received at a station is supplied to a measuring circuit for governing the operation of a motor-operated potentiometer in accordance with the peak values of the received control current. The measuring circuit in the disclosed station comprises an amplifier of the space discharge type having the output circuit thereof coupled by a transformer to a so-called impulse transformer which serves to effect a more than proportional change in the variations of the peak voltage of the received control current. The secondary winding of the impulse transformer is connected to the input circuit of a second space discharge amplifier and the output circuit of the second amplifier is coupled by a transformer to a second impulse transformer. The secondary winding of the second impulse transformer is connected to the input circuit of a detector tube which is preferably of the gas-filled type and the output circuit from the detector tube controls the operation of two marginal relays.

Each of the two impulse transformers has two windings and a high permeability core of restricted cross-section. The cores of the transformers preferably comprise thin ribbons of an alloy of nickel, iron and molybdenum wound in a box of ceramic insulating material. The primary and secondary windings of the impulse transformers each have windings of the order of 1600 turns. The core of each impulse transformer is magnetized normally to substantially saturation by current supplied from the plate battery for the two space discharge amplifiers. The magnetizing circuit for each of the two transformers is preferably connected to the primary windings. The magnetizing circuit for the first impulse transformer is in circuit with a regulating space discharge tube for compensating for variations not only in the source of plate current but also for variations in the source employed to supply grid bias to the two space discharge amplifiers.

The space discharge regulator tube having an input circuit and an output circuit has the input circuit thereof connected across the source which supplies biasing potential to the grids of the space discharge amplifiers and has the output circuit thereof connected across a regulating im-

pedance in the magnetizing circuit for the first impulse transformer. If the source of supply for impressing biasing potential on the grids of the amplifiers varies, it is apparent that the potential on the grid of the regulator tube varies to vary the impedance of the regulator tube which is connected across the regulating impedance in the magnetizing circuit for the first impulse transformer. The variation in impedance of the regulating tube changes the operating level of the bias for the first impulse transformers to compensate for the variation in the grid biasing potential supplied to the amplifier tubes. If there is a variation in the source connected to the plates of the amplifier tube, there is also a variation in the bias impressed on the first impulse transformer and the variation in the bias of the first impulse transformer compensates for the variations in potential on the plates of the amplifier tubes.

The strength of current on the line at the station is controlled by a potentiometer which is operated at times by means of a constantly rotating motor. Two magnetically operated clutches under the control of a raise gain relay and a lower gain relay are provided for effecting operation in either direction of the potentiometer by the constantly rotating motor. The gain relays are in the form of marginal relays and are controlled by the measuring circuit in accordance with the peak values of the received control current. If both the gain relays are released a circuit is partially completed for operating the magnetic clutch to reduce the loss in the line. If only one of the gain relays is operated, no operation of the potentiometer will take place. If both the gain relays are operated, a circuit is partially completed for energizing the magnetic clutch to effect operation of the potentiometer to raise the net loss on the line.

The control current, which is received at the station, also operates a starting circuit which controls a master relay. The starting circuit comprises a space discharge amplifier, a resonant circuit, and an anti-resonant circuit. The resonant and anti-resonant circuits are series connected in the output circuit of the amplifier tube. The resonant circuit and the anti-resonant circuit are tuned to the frequency of the control current which is employed for controlling the line equivalent. Preferably the control current has a frequency of 800 cycles. The primary winding of a transformer is shunted around the anti-resonant circuit and the primary winding of a second transformer is shunted around the resonant circuit. Rectifier means is connected to the secondary windings of each of these transformers. The master relay is connected oppositely to the rectifiers in the secondary winding circuits of the two transformers so that in case current of the frequency of the control current in combination with currents of other frequencies are transmitted over the line, no operation of the master relay will take place. If a pure control current is received over the line free from currents of other frequencies, the master relay will be operated. The master relay is in the form of a polarized relay so that if no current of the frequency of the control current is received over the line and currents of other frequencies are received, no operation of the master relay will take place.

The master relay operates a relay for momentarily supplying ground to a slow releasing relay in a so-called pulse clipping circuit. The slow releasing relay completes a circuit through a relay

controlled by the master relay and the contacts of the gain relays for operating one or the other of the magnetic clutch magnets to raise or lower the line loss. This operation, of course, takes place only in case both the gain relays are released or both the gain relays are operated. The pulse of control current which is received over the line for controlling the motor-operated potentiometer has a length of the order of .5 of a second or .7 of a second. If a mutilated pulse is received, it is apparent the master relay releases to prevent operation of the motor-operated potentiometer.

The relay in the pulse clipping circuit which is provided with a hangover operation serves to open the circuit through the contacts of the gain relays prior to the termination of a pulse in order to prevent adjustment of the line impedance in accordance with the strength of the control current near the end of a pulse. The end of a pulse of control current will in many cases be tailed out because of the delay distortion of the line which causes different frequencies in the start or end of an impulse to be received at different times and if the adjustment were made on this tailing current, the adjustment would often be such as to obtain too much gain. A similar clipping circuit is disclosed and claimed in the patent to I. E. Cole, No. 2,067,519, issued January 12, 1937.

In the accompanying drawing,

Fig. 1 is a diagrammatic view of a signal station having control circuit constructed in accordance with the invention;

Fig. 2 is a curve showing the relationship between the input level and the output current of the measuring circuit;

Fig. 3 is a detail diagrammatic view of one of the impulse coils employed in the measuring circuit; and

Fig. 4 is a cross-section of the core and supporting box therefor in the coil shown in Fig. 3 of the drawing.

Referring to the drawing a signal station is shown connected to a transmission line having input conductors 1 and 2 and output conductors 3 and 4. A starting circuit 5 is connected to the input conductors 1 and 2 by means of a hybrid coil 6. The hybrid coil 6 is provided with the usual network 7. The starting circuit 5 controls a master relay MA according to the frequency of the currents on the transmission line and effects operation of the master relay only when a pure control current of a fixed frequency is received. In the system under consideration the master relay MA is operated when a pure control current of 800 cycles is received. The master relay MA controls a circuit partially completed by marginal polarized relays LO and RA for controlling the operation of clutch magnets 9 and 10. The clutch magnets 9 and 10 form a part of a clutch mechanism 11 which controls the operation of a potentiometer arm 12 for a potentiometer 13.

A repeater circuit 14 is provided between the incoming conductors 1 and 2 and the outgoing conductors 3 and 4 of the transmission line. The repeater circuit comprises a transformer 15 having the primary winding thereof connected by the potentiometer 13 to the hybrid coil 6. The secondary winding of the transformer 15 is connected to the input circuit of a space discharge device 16. The output circuit of the device 16 is connected by a transformer 17 through a resistance network comprising a potentiometer 18 to a measuring circuit 19. The repeater circuit 14 is preferably designed to produce a zero equivalent between the incoming conductors 1 and 2

and the outgoing conductors 3 and 4 when the arm 12 of the potentiometer 13 is set at a mid-point. An adjustable resistance 20 is provided in the circuit of the potentiometer arm 12 for effecting an adjustment of the potentiometer. A battery 21 is provided for supplying plate potential through a choke coil 22 to the device 16. Filament heating current is supplied to the device 16 from a battery 23. Grid bias for the tube 16 is provided by the drop across a portion of a resistance element 24. The output conductors 3 and 4 of the transmission line are connected across the secondary winding of the transformer 17 which is connected to the output circuit of the space discharge device 16.

The measuring circuit 19 comprises two pentode space discharge devices 25 and 26, a detector tube 27 and two impulse coils 28 and 29. The measuring circuit 19 serves to control the operation of the marginal relays LO and RA according to the peak values of a control current on the transmission line. The lower gain relay LO and the raise gain relay RA are both released in order to raise the setting of the potentiometer 13 and are both operated to effect operation of the potentiometer 13 to lower the gain on the transmission line. The relays LO and RA are so adjusted that the net loss on the transmission line is held within a predetermined range. If the peak values of the control current go above this predetermined range, the relays LO and RA are both operated to lower the gain and if the peak values of the control current on the transmission line fall below the fixed range both relays LO and RA are released to control the potentiometer 13 to raise the gain. If either relay LO or RA is operated alone, no change in the potentiometer setting takes place. The relay RA is released when the peak values of the control current fall below the upper limit of the fixed range and the relay LO is released when the peak values of the control current fall below the lower limit of the fixed range.

A transformer 30 connects the potentiometer 18 to the input circuit of the pentode tube 25. The output circuit of the pentode tube 25 is connected by a transformer 31 to the first impulse coil 28. The impulse coil 28 which is shown in detail in Figs. 3 and 4 of the drawing comprises a primary winding 32 and a secondary winding 33. The two windings 32 and 33 are mounted on a core member 34 secured in a box of ceramic insulating material 35. The core 34 comprises approximately 12 turns of an alloy of nickel, iron and molybdenum having ends thereof connected together. The core 34 may be composed of 30 to 85 per cent nickel with the remainder iron and heat treated to have a high permeability or may be composed of 30 to 85 per cent nickel, 7 per cent molybdenum and the remainder iron. The core is secured in an annular groove formed in the box 35 as indicated in Fig. 4 of the drawing. The ribbon of molybdenum permalloy is approximately 3 thousandths of an inch thick and 123 thousandths of an inch wide. The box 35 is approximately an inch and a half in diameter. The primary and secondary windings each have approximately 1600 turns.

The secondary winding 33 of the impulse coil 28 is connected in circuit with a resistance element 90 to the input circuit of the pentode space discharge device 26. The resistance element 90 serves to prevent loss of discrimination by the loading of the transformer with rectified grid current. The output circuit of the device 26 is

connected by a transformer 36 to the primary winding 37 of the second impulse coil 29. The secondary winding 38 of the impulse coil 29 is connected to the input circuit of the detector tube 27. The output circuit of the detector tube 27 is connected to the operating coils of the marginal polarized relays LO and RA. Filament heating current for the pentode amplifier devices 25 and 26, the detector tube 27 and a regulator space discharge device 39 is supplied by a battery 40. Plate potential for the amplifier devices 25 and 26, the detector 27 and the regulator device 39 is provided by a battery 41. The regulator space discharge device 39 serves to compensate the measuring operation for variations in voltage of the batteries 40 and 41. Grid bias is also supplied by the battery 40 to the amplifier devices 25 and 26 and the regulator device 39. A battery 42 is provided for supplying grid bias through a choke coil 43 to the grid of the detector tube 27. The condensers 44 in the drawing serve as blocking condensers. Choke coils 45 and 46 are provided in the connections of the battery 41 to the plates of the devices 25 and 26.

The primary windings 32 and 37 of impulse coils 28 and 29 are energized by circuits from the battery 41. The circuit through the primary winding 32 of the impulse coil 28 extends from ground through the primary winding 32, inductance 47, resistance 48 and battery 41 to ground return. The circuit through the primary winding 37 of the impulse coil 29 extends from ground through the winding 37, inductance 49, resistance 50 and battery 41 to ground return. The core of each of the impulse coils is energized by current of about 15 milliamperes from the battery 41. This biasing current through the primary windings of the impulse coils reduces the differential permeability to a low value. The direct coupling between the primary and secondary windings of each impulse coil is negligible so that each impulse coil is ineffective as a transformer except when the alternating current supplied to the primary windings produces a flux which opposes and is very nearly equal to the flux produced by the biasing current from the battery 41. The magnetization curve of nickel, iron and molybdenum alloy is similar to the curve shown in Fig. 2 of the drawing. The portion of the magnetization curve up to the knee thereof is much steeper than the curve for iron and steel. The impulse coils are so constructed that when the core is operated above the knee of the magnetization curve the peak values of the control currents on the transmission line are below the lower limit of the predetermined range. When the cores of the impulse coils are operated above the knee or at the knee of the saturation curve, the two marginal relays LO and RA are released. When the peak values of the control current on the transmission line rise above the upper fixed range, the cores of the impulse coils 28 and 29 are operated somewhat below the knee of the saturation curve, so that suitable current is supplied to both the marginal relays LO and RA and such relays are operated to increase the gain of a transmission line. The output circuit from the detector tube 27 through the coils of the relays LO and RA may be traced from the plate of the detector tube 27 through the coil of the relay RA, coil of the relay LO, choke coil 46, battery 41 and ground to the filament of the detector device 27.

The regulator space discharge device 39 which is supplied with grid bias from the battery 40 and plate potential from the battery 41 serves to

compensate for variations in the operation of the amplifier devices 25 and 26 caused by variations in the voltage of the batteries 40 and 41. If the voltage of the battery 40 increases, it will be noted 5 the bias on the grid of the regulator device 39 increases and this decreases the biasing current which is supplied to the primary winding 32 of the impulse coil 28. Such is the fact because the regulator tube 39 is connected across the inductance 47 and the resistance 48 in the biasing circuit for the winding 32 of the impulse coil 28. The decrease in the bias on the impulse coil 28 serves to compensate for the variations in the grid bias on the devices 25 and 26 caused by the increase of the voltage of the battery 40. If there is a change in the voltage of the battery 41, for example, an increase in the voltage, then there is an increase in the current flow through the regulator device 39 and an increase in the bias supplied to the impulse coil 28. At the same time, however, the plate potential supplied to the amplifier devices 25 and 26 increases. The increase in the bias on the impulse coil 28 compensates for the increase in plate potential on the amplifier devices 25 and 26.

The starting circuit 5 which controls the master relay MA comprises an amplifier space discharge device 51 which is connected to the hybrid coil 6 by means of a transformer 52. A circuit 30 53 anti-resonant to the 800 cycle control current and a circuit 54 resonant to the 800 cycle control current are provided in the output circuit of the amplifier device 51. The anti-resonant circuit 53 comprises an inductance 55 and a condenser 56. The resonant circuit comprises an inductance 57 and a capacity 58. A transformer 59 having a primary winding 63 and a divided secondary winding 61 has the primary winding 60 connected in shunt to the anti-resonant circuit 40 53. A transformer 62 having a primary winding 63 and a divided secondary winding 64 has the primary winding thereof connected in shunt to the resonant circuit 54. The divided secondary winding 61 of the transformer 59 is connected to rectifiers 65 preferably of the copper oxide type in circuit with a resistance 66. The divided secondary winding 64 of the transformer 62 is connected to rectifiers 67 in circuit with a resistance 69. The rectifiers 67 are also preferably of the copper oxide type. The winding of the master relay MA is connected in circuit with the resistance element 66 and a portion of the resistance element 68. The operating coil of the master relay is so connected to the resistance elements 55 66 and 68 that the potential drops across the resistance elements oppose each other. Plate potential for the device 51 is supplied by the battery 21 and filament heating current is supplied by the battery 23. Condensers 69 serve as blocking condensers.

If a pure control current of 800 cycles is received over the transmission line, the current in the output circuit of the device 51 will tend to flow through the primary winding 60 of the transformer 59 rather than in the anti-resonant circuit 65 53 and, on the other hand, will tend to flow through the resonant circuit 54 rather than the primary winding of the transformer 62. Consequently, there will be considerable potential drop across the resistance element 66 and little drop across the resistance element 68. Under such condition, the polarized relay MA is operated. If currents of other frequencies than the 800 cycle control current either with or without 70 the 800 control current are received, then some-

what of the current in the output circuit of the device 51 will flow through the primary winding 63 of the transformer 62. The energization of the transformer 62 serves to place potential drop across the resistance element 68. This assists the bias on the polarized relay MA and prevents operation of the relay.

Assuming a control current of 800 cycles is received over the transmission line and that the peak values of the control current are above 10 the upper limit of a fixed range, the apparatus shown on the drawing is operated to reduce the gain and increase the net loss at the station. The master relay MA is operated by the starting circuit 5 for completing a circuit from the battery 70 to effect operation of the relays N and R. The relay N is momentarily operated for completing a circuit from the battery 71a operating the polarized relay P. The relay R is slow to operate and upon operation completes a shunt 20 around the operating coil of the relay N to effect release of this relay. The polarized relay P when operated completes a circuit from ground obtained either from the relay N or the relay R through the relays LO and RA for selectively 25 operating the clutch magnets 9 and 10 of the clutch device 11 to control the potentiometer 13.

It has been assumed that the peak values of the control current received at the station are above the upper limit of the fixed range. Accordingly, the measuring circuit 19 will supply current for operating both the relays LO and RA. The circuit completed by the polarized relay P extends from ground through an armature of the relay R, armature of the polarized relay P, armature of relay LO, slip rings 71 35 connected to the clutch magnet 10, limit switch 72, armature of the relay RA, battery 73 and ground return to the armature of the relay R. If both the relays LO and RA were released as would be the case when the peak values of the control current fall below the lower limit of the fixed range, then the circuit completed by the polarized relay P would extend from ground through an armature of the relay R, armature of the relay P, armature of the relay LO, slip rings 74 45 connected to the clutch magnet 9, limit switch 75, armature of the relay RA, battery 73 and ground return to the armature of the relay R.

The clutch magnet 9 and slip ring 74 are connected to a beveled gear wheel 76 and are rotatably mounted on a shaft 77. A disc 78 which is fixedly mounted on the shaft 77 is attracted by the clutch magnet 9 when energized for connecting the clutch magnet and gear wheel 76 to the shaft 77. The clutch magnet 10 and the slip rings 71 are connected to a beveled gear wheel 79 and are rotatably supported on the shaft 77. A disc 80 which is fixedly mounted on the shaft 77 serves to connect the gear wheel 79 and the clutch magnet 10 to the shaft 77 when the clutch magnet 10 is energized. The gear wheels 76 and 79 are connected to a constantly rotating motor 81 by means of a beveled gear wheel 82. The operating arm 12 of the potentiometer 13 is connected to the shaft 77 in order to adjust the potentiometer 13 in accordance with the rotation of the shaft 77. An arm 83 is also mounted on the shaft 77 for opening the limit switches 75 and 72 whenever the potentiometer reaches either of its extreme limits. When the switch 75 or the switch 72 is opened by the arm 83 an alarm 84 is operated.

The curve shown in Fig. 2 of the drawing indicates the operation of the measuring circuit 75

19 in controlling the marginal relays LO and RA. The abscissae of the curve indicate the input to the measuring circuit and the strength of the control current. The ordinates represent the output of the measuring circuit and the current supplied to the marginal relays LO and RA.

In the situation assumed where the peak values and the control current are above the fixed range, so that relays LO and RA are operated, the clutch magnet 10 is energized and the switch arm 12 as shown in the drawing is rotated by the motor 81 in a direction towards the right to lower the gain. The circuit energizing the clutch magnet 10 is controlled by the master relay MA which controls the relay R. The relay P is only momentarily energized by the operation of the relay N. However, a hangover circuit is provided for the relay P to maintain it in operative position for a predetermined length of time. The hangover circuit for the relay P comprises a resistance element 85 and a condenser 86. When the relay N is operated a circuit is complete for energizing the coil of the polarized relay P from the battery 71a. The condenser 86 which is normally charged from the battery 71a through the resistance element 85 and a coil of the polarized relay P is discharged when the relay N is operated to operate the polarized relay P. When the relay N releases the condenser 86 is again charged and the time taken to charge the condenser determines the hangover period of the relay P.

The pulses of control current which are employed for operating the apparatus shown in Fig. 1 to govern the setting of the potentiometer 13 are each transmitted for fixed periods of time. It is undesirable to have the potentiometer 13 adjusted according to the strength of a pulse of control current near the end thereof. The end of a pulse of control current will in many cases be tailed out because of the delayed distortion of the line. The relay P insures that no adjustment of the potentiometer 13 will take place at or near the end of a pulse of control current. If a mutilated pulse of control current is received the master relay MA is released to stop any setting of the potentiometer.

Modifications in the control 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 combination, a signal transmission line having control current impressed thereon, a signal station connected to said line, variable loss controlling means at said station for controlling the net loss on the line, means comprising a measuring circuit for effecting a more than proportional change in the energy variation of the received control current for determining the operation of said loss controlling means, and means operated by the received control current for effecting operation of said loss controlling means under control of said measuring circuit 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 in the line at said station, selecting means for determining the operation of said loss controlling means, means comprising a measuring circuit for effecting a more than proportional change in the energy variations of a received control current to govern said selecting

means, and means operated by the control current received at said station for effecting operation of said loss controlling means under control of said selecting means to adjust the net loss on the line according to the strength of the received control current.

3. 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 the line at said station, selecting means for determining the operation of said loss controlling means, means comprising a measuring circuit for effecting a more than proportional change in the energy variations of a received pulse of control current to govern said selecting means, and means operated upon receipt of a pulse of control current at said station for effecting operation of said loss controlling means under control of said selecting means to adjust the net loss on the line according to the strength of a received pulse of control current.

4. In combination, a signal transmission line having control current impressed thereon, a signal station connected to said line, variable loss controlling means at said station for controlling the net loss on the line, gain control relays selectively operated to govern the operation of said loss controlling means, means comprising a measuring circuit for effecting a more than proportional change in the energy variations of received control current to selectively operate said gain control relays, and means operated by the control current for effecting operation of said loss controlling means according to the operation of said relays to adjust the net loss on the line according to the energy level of the received control current.

5. 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 the line at said station, gain control relays selectively operated to govern the operation of said loss controlling means, means comprising a measuring circuit for effecting a more than proportional change in the energy variations of a received pulse of control current to selectively operate said gain control relays, and means operated upon receipt of a pulse of control current for effecting operation of said loss controlling means according to the operation of said relays to adjust the net loss on the line according to the strength of the received control current.

6. In combination, a signal transmission line having control current impressed thereon, a signal station connected to said line, variable loss controlling means for adjusting the loss on the line at said station, means comprising a measuring circuit for effecting a more than proportional change in the energy variations of the control current, means comprising an operating circuit controlled according to the operation of said measuring circuit to determine the operation of said loss controlling means, and means operated by the control current for completing said operating circuit to adjust said loss controlling means according to the strength of the control current.

7. In combination, a signal transmission line having a pulse of control current impressed thereon at times, a signal station connected to said line, variable loss controlling means for adjusting the loss on the line at said station, means comprising a measuring circuit for effecting a more than proportional change in the energy

variations of a received pulse of control current, means comprising an operating circuit controlled according to the operation of said measuring circuit to determine the operation of said loss controlling means, and means operated upon receipt of a control current for completing said operating circuit to adjust said loss controlling means according to the energy level of said received control current.

8. In a signal transmission line, a signal station, a motor operated potentiometer at said station for adjusting the net loss on the line, a circuit for controlling the operation of said potentiometer, means comprising a measuring circuit for effecting a more than proportional change in the energy variations of a pulse of control current received over said line, means controlled by said measuring circuit for partially completing said potentiometer control circuit, and means controlled by the received pulse of control current for completing said potentiometer control circuit to operate said potentiometer and adjust the line attenuation according to the strength of the received control current.

9. In combination, a signal transmission line having a control current impressed thereon at intervals, a signal station connected to said line, a potentiometer for controlling the line attenuation at said station, means comprising two marginal relays for determining the direction of operation of said potentiometer, means comprising a measuring circuit for effecting a more than proportional change in the energy variations of a received control current to selectively operate said marginal relays, and means operative upon receipt of a control current at said station for effecting operation of said potentiometer under control of said marginal relays to adjust the line attenuation according to the strength of the received control current.

10. A measuring circuit for obtaining a more than proportional change in the energy variations of a received control current comprising a transformer having primary and secondary windings and a core having a high permeability, and means for constantly energizing said primary winding to maintain said core normally saturated and to prevent effective operation of said transformer until a received control current supplied to the transformer has sufficient strength to overcome the transformer bias.

11. A measuring circuit for obtaining a more than proportional change in the energy variations of a received control current comprising a transformer having primary and secondary windings and a core comprising an alloy of nickel, iron and molybdenum having a high permeability, and means for constantly energizing said primary winding to maintain said core normally saturated and to prevent effective operation of said transformer until a received control current supplied to the transformer has sufficient strength to overcome the transformer bias.

12. A measuring circuit for obtaining a more than proportional change in the energy variations of a received control current comprising a transformer having primary and secondary windings and a core comprising an alloy of nickel and iron having a high permeability, and means for constantly energizing said primary winding to maintain said core normally saturated and to prevent effective operation of said transformer until a received control current supplied to the transformer has sufficient strength to overcome the transformer bias.

13. A measuring circuit comprising a transformer having primary and secondary windings wound to effect a one to one transformation ratio, a core for said transformer composed of a material having a high permeability, means for supplying a control current to said transformer, and means for normally energizing the primary winding of said transformer to maintain the core substantially saturated, said transformer serving to prevent any substantial transfer of the control current therethrough until the control overcomes said core saturation and to effect a more than proportional change in the energy variations of the component of the control current appearing at the output of said measuring circuit.

14. A measuring circuit supplied with a control current and comprising a space discharge device for amplifying the received control current, an impulse transformer coupled to the output circuit of said device and serving to effect a more than proportional change in variations of the received control current, said transformer having primary and secondary windings and a core having a high permeability, potential means for supplying potential to said discharge device and for normally energizing said primary winding to substantially saturate the core of said transformer, and means for controlling the saturation of the core of said transformer to compensate for variations of said potential means.

15. A measuring circuit supplied with a control current and comprising a space discharge device for amplifying said control current, an impulse transformer having primary and secondary windings and a core having a high permeability, a transformer coupling the output circuit of said space discharge device to the primary winding of said impulse transformer, a source of potential connected to the plate of said discharge device and normally energizing the primary winding of said impulse transformer to substantially saturate the transformer core, a source of potential for heating the filament of said discharge device, a regulator space discharge device, and means for connecting said regulator discharge device to the connections between said sources and the amplifier device and the impulse transformer to vary the saturation of the impulse transformer to compensate for variations in potential of said sources.

16. A measuring circuit supplied with a control current and comprising a space discharge device having a grid, filament and plate for amplifying the control current, an impulse transformer coupled to the output circuit of said device and serving to effect a more than proportional change in variations of the received control current, said transformer having primary and secondary windings and a core having a high permeability, a source of direct current for supplying plate potential to said device and for energizing the primary winding of said transformer to substantially saturate the transformer core, an impedance in the connection between said source and the transformer primary winding, a second source of direct current for heating the filament of said device, and a regulator space discharge device having an input circuit connected across said second source and an output circuit connected across said impedance to compensate for variations in potentials of said sources.

17. In combination, a transmission line having a control current transmitted thereover, a signal station connected to said line, loss con-

trolling means at said station for adjusting the line attenuation, measuring means for controlling the adjustment of said loss controlling means according to the strength of the received control current, and means for insuring the adjusting of said loss controlling means under control of said measuring means only when a pure control current free from other frequency currents is received at said station.

18. In combination, a transmission line having a pulse of control current transmitted thereover at intervals, a signal station connected to said line, loss controlling means at said station for adjusting the attenuation of the line, means comprising a measuring circuit for effecting a more than proportional change in variations of a received pulse of control current for controlling the adjustment of said loss controlling means according to the strength of the control current, a master relay, means comprising a starting circuit for effecting operation of said master relay only when a pure control current free from other frequency currents is received over said line, and means operated by said master relay for adjusting said loss controlling means under control of said measuring circuit means.

19. In combination, a transmission line having a pulse of control current transmitted thereover at intervals, a signal station connected to said line, loss controlling means at said station for adjusting the line attenuation, means comprising marginal relays for governing the adjustment of said loss controlling means, means comprising a measuring circuit for effecting a more than proportional change in variations of a received control current to selectively operate said marginal relays, a master relay, means comprising a starting circuit for effecting operation of said master relay only when a pure control current free from other frequency currents is received at the station, and means operated by the master relay under control of said marginal relays for adjusting said loss controlling means.

20. A circuit for measuring an electric quantity comprising a space discharge device for amplifying the received electrical quantity, an impulse transformer coupled to the output circuit of said device and serving to effect a more than

proportional change in variations of the received electrical quantity, said transformer having primary and secondary windings and a core having a high permeability, potential means for supplying potential to said discharge device and for normally energizing said transformer to substantially saturate the core, and means for controlling the saturation of the core of said transformer to compensate for variations of said potential means.

21. In a measuring circuit for obtaining a more than proportional change in the variations of a received electrical quantity, a space discharge device for amplifying the received electrical quantity, an impulse transformer having primary and secondary windings and a core having a high permeability, the primary winding of said transformer being coupled to the output circuit of said device, a second space discharge amplifier having the grid circuit thereof connected to the secondary winding of said transformer, a resistance element in circuit with the transformer secondary winding and the second amplifier grid to prevent loss of discrimination by loading up the transformer with rectified grid current, a second impulse transformer similar to the first impulse transformer and having the primary winding coupled to the output circuit of the second amplifier, and means for constantly energizing said transformers to maintain the cores thereof normally saturated and to prevent effective operation of the transformers until a received electrical quantity overcomes the bias of the transformers.

22. A measuring circuit for obtaining a more than proportional change in the variations of a received electrical quantity comprising a transformer having primary and secondary windings and a core having a high permeability, means for constantly energizing one of the windings of said transformer to maintain said core normally saturated and to prevent effective operation of said transformer until a received electrical quantity overcomes the transformer bias, and a biased non-linear space discharge detector having the input circuit thereof connected to the secondary winding of said transformer.

AUSTEN M. CURTIS.