Oct. 31, 1939. R. R. BLAIR 2,178,333

GAIN CONTROL CIRCUITS

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FIG. 1

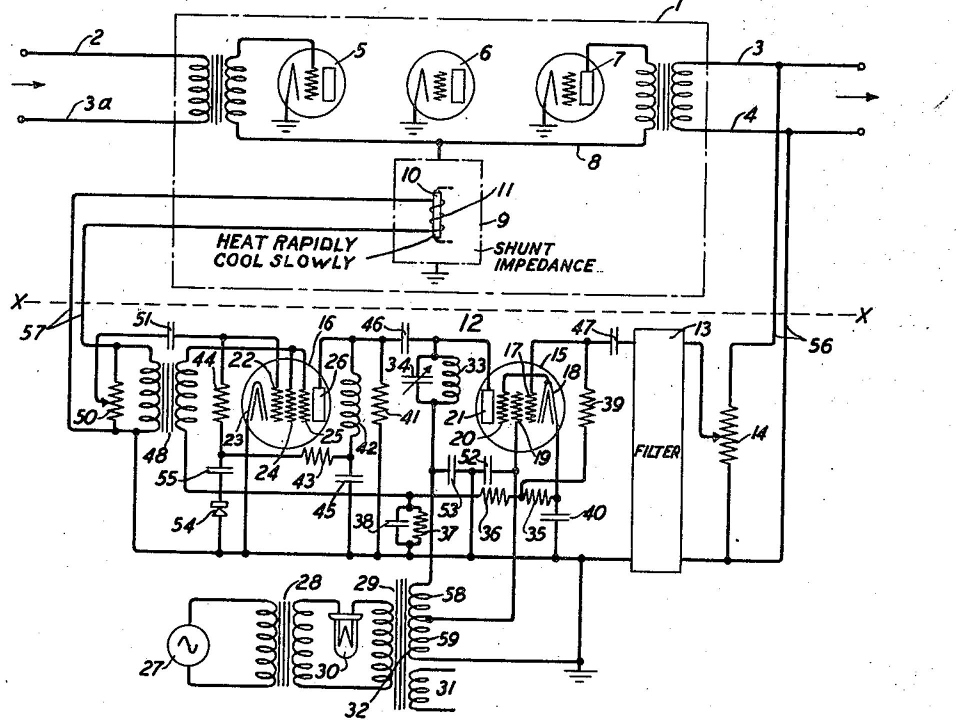
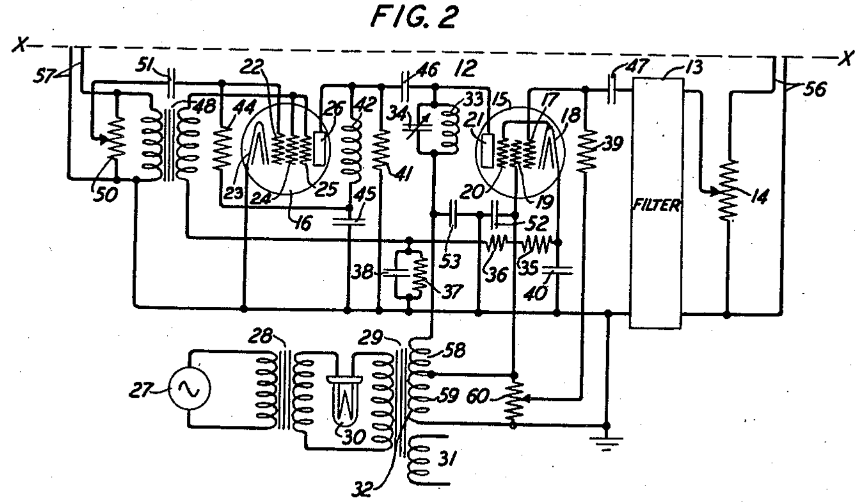


FIG. 2



INVENTOR
R.R.BLAIR
BY
Wayne B Wells
ATTORNEY

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FIG. 3

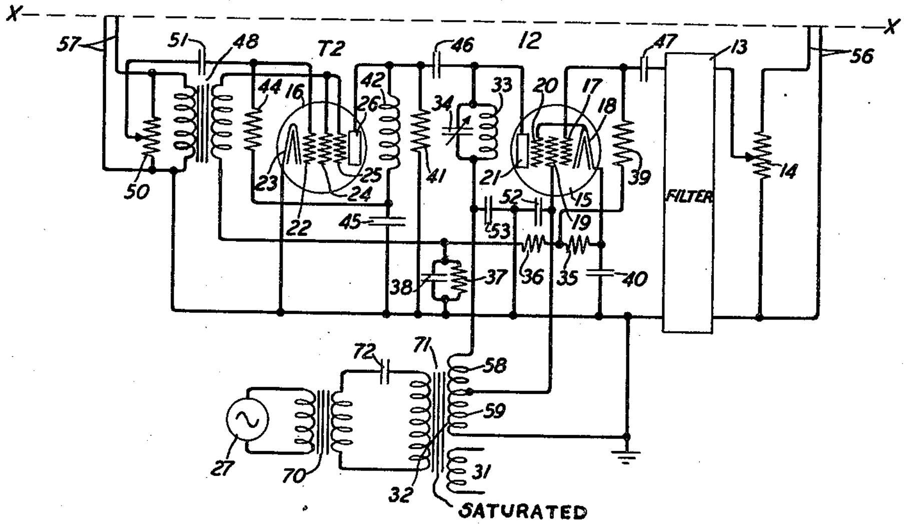
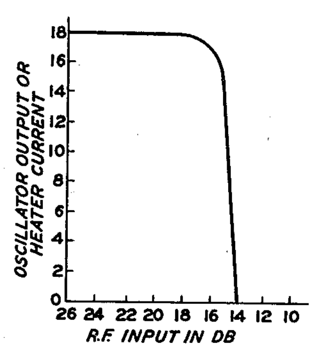


FIG. 4



INVENTOR
R. R. BLAIR
BY Wayne B Wells
ATTORNEY

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GAIN CONTROL CIRCUITS

Royer R. Blair, New York, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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11 Claims. (Cl. 178—44)

This invention relates to gain control circuits and particularly to gain control circuits for governing the energy level of signals on transmission lines.

One object of the invention is to provide gain control circuits having an oscillator operating on a steeply inclined cut-off portion of its characteristic curve that shall govern an amplifier on a signal transmission line in an improved manner.

Another object of the invention is to provide a signal transmission line with gain control circuits having an oscillator operating on a steeply inclined cut-off portion of its characteristic curve that shall control the oscillator for producing an output which builds up slowly and reduces quickly to control an amplifier in the transmission line.

In a long transmission line it is necessary to provide repeaters or amplifiers at intervals along the line and to control the amplifiers to maintain the energy level of the signals on the transmission line substantially constant. The energy level of the signals on a transmission line may be controlled by governing an impedance in the transmission line or by governing an amplifier in the transmission line. The gain control circuits may be governed according to the energy level of currents carried by the transmission line.

The invention has been illustrated by means of a carrier current system having a pilot current for governing the operation of gain control circuits. The gain control circuits are governed according to the energy level of a pilot current for controlling an amplifier of the type disclosed in the patent to H. S. Black No. 2,102,671, December 21, 1937.

In one form of the invention the beta circuit of an amplifier in the transmission line is controlled by gain control circuits according to the energy level of the pilot current on the transmission line beyond the amplifier. A resistance element which has a high temperature coefficient of resistance and which may be composed of silver sulphide is connected across the beta circuit of the amplifier. The heating of the silver sulphide element is controlled by the gain control circuits.

The gain control circuits comprise a filter connected to the transmission line beyond the amplifier therein to select the pilot current. The selected pilot current is amplified by a pentode tube which not only serves as an amplifier but also as a rectifier of 60-cycle power current. Regulated 60-cycle power current is supplied not only to the anode of the pentode tube but also to the screen grid thereof. Rectified alternating current in the anode circuit of the pentode tube is employed as grid bias for the pentode tube and plate current for an oscillator.

A second space discharge device comprising a control grid, a cathode and two anodes serves not only as a rectifier but also as an oscillator. This second space discharge device may be a pentode tube, if so desired, with the screen grid and the suppressor grid connected together to form one of the anodes. The amplified pilot current supplied by the amplifier tube is rectified by the rectifier portion of the second space discharge device. The rectified potential serves to impress negative potential on the grid in the oscillator portion of the second space discharge device. The oscillator portion of the second space discharge device operates with an input-output characteristic curve having a steeply inclined cut-off portion. The oscillator portion, when controlled according to the rectified pilot current, operates on the steeply inclined portion of the characteristic curve. The output from the oscillator controls the heating of a silver sulphide element located in the beta circuit of the line amplifier.

It has been found that certain types of silver sulphide elements have a tendency to heat ripidly and to cool relatively slowly. This variation in the heating and cooling of the silver sulphide element has a tendency to cause the gain control circuits to hunt. In order to counteract this tendency to hunt when silver sulphide elements of certain types are employed, the oscillator portion of the second space discharge device in the gain control circuits is constructed so that the output from the oscillator builds up slowly and reduces fairly quickly.

In some cases it may be desirable to have the amplifier tube of the gain control circuits supplied with alternating current bias from the regulated voltage. When the amplifier tube is supplied with alternating current bias it is found that the gain control circuits are less sensitive to power or voltage variations, particularly if the variations are rapid.

In the accompanying drawings:

Fig. 1 is a diagrammatic view of gain control circuits constructed in accordance with the invention;

Figs. 2 and 3 are diagrammatic views illustrating modifications of the gain control circuits shown in Fig. 1;

Fig. 4 is a curve diagrammatic showing the characteristic curve of the control circuits shown in Figs. 1, 2 and 3.

Referring to Fig. 1 of the drawings, an amplifier 1 of the feedback type is shown on a transmission line, having input conductors 2 and 3a and output conductors 3 and 4. The amplifier 1 may be of the type disclosed in the above-mentioned patent to H. S. Black No. 2,102,671, December 21, 1937. The amplifier 1 is operated by means of three tubes 5, 6 and 7, which may be of any suitable type. The beta circuit 8 of the amplifier 1 has a shunt impedance 9 connected across it. A portion of the shunt impedance 9 comprises a resistance element 10 having a high negative temperature coefficient of resistance. The resistance element 10 is heated by a coil 11 under control of gain control circuits 12. The transmission line carries not only carrier currents which may be of radio frequency but also a pilot current. The pilot current controls the operation of the gain control circuits 12.

The gain control circuits comprise a filter 13 of any suitable type which is connected across the conductors 3 and 4 by means of a potentiometer 14. The filter 13 selects the pilot current on the transmission line. The potentiometer 14 serves as a sensitivity control for the gain control circuits. Two space discharge devices 15 and 16 are provided in the gain control circuits 12 which are controlled by the pilot current output from the filter 13. The space discharge device 15 is in the form of a pentode tube having a control grid 17, a cathode 18, a screen grid 19, a suppressor grid 20 and an anode 21. The tube 15 serves not only as an amplifier of the selected pilot current but also as a low frequency rectifier. The second space discharge device 16 is shown in the form of a pentode tube having a control grid 22, a cathode 23, a screen grid 24, a suppressor grid 25 and an anode 26. The screen grid 24 and the suppressor grid 25 are shown connected together to substantially form an additional anode. If so desired the space discharge device 16 may be formed with two anodes, a cathode and a control grid.

A source of alternating current 27 is provided for supplying power to the pentode tube 15. The source 27 is directly connected to a transformer 28 which in turn is connected to a transformer 29 through a ballast lamp 30. The ballast lamp 30 connected to the secondary winding of the transformer 28 insures a substantially constant current supply for the transformer 29. The transformer 29 should be designed to keep both core and copper losses low. The transformer 29 may supply filament current to both the space discharge devices 15 and 16 as well as plate and screen grid potential to the pentode tube 15. The connections of the filaments for the cathodes of the devices 15 and 16 to the secondary winding 31 of the transformer 29 have been omitted from the drawings for the sake of simplicity.

The anode circuit for the pentode tube 15 may be traced from one terminal of the secondary winding 32 for the transformer 29 through inductance 33 and capacity 34 in parallel, anode 21, cathode 18, resistance elements 35 and 36, resistance element 37 and capacity 38 in parallel and shunted by the primary winding of transformer 48, grids 24 and 25, and cathode 23, and ground return to the other terminal of the secondary winding 32. The capacity 34 and the inductance 33 serve to tune the circuit of the pentode tube 15 to the frequency of the pilot current. The potential drop across the resistance element 35 serves to provide potential bias for the control grid 17. A resistance element 39 which is connected between the control grid 17 and the junction of the resistance elements 35 and 36 serves as a grid lead. A low frequency filter of the power current on the pentode tube 15 is provided by means of the resistance elements 35 and 36 in combination with the condenser 38 and a condenser 40.

The output from the pentode tube 15, which is the radio frequency pilot current plus 60-cycle modulation products, is impressed between the plate 26 and cathode 23 of the second space discharge device 16. Rectification of the pilot current is effected and the rectified potential is impresed across a resistance element 41. The potential drop across the resistance 41 is employed to govern the oscillator portion of the space discharge device 16. The input circuit to the oscillator portion of the space discharge device 16 may be traced from one terminal of the resistance 41 through an inductance 42, a resistance 43, a resistance 44, the grid 22 and the cathode 23 to the other terminal of the resistance 41. The unwanted modulation products which would greatly dull the cut-off of the oscillator portion of the tube 16 are removed by means of the condenser 45. Condensers 46 and 47 in the gain control circuits 12 serve as blocking condensers.

The output from the oscillator portion of the space discharge device 16 is connected by a transformer 48 to the heater coil 11. The output circuit of the oscillator, which includes the primary winding of the transformer 48, may be traced from one terminal of the primary winding of the transformer 48 through grids 24 and 25, cathode 23, and condenser 38 shunted by the resistance element 37, to the other terminal of the primary winding for the transformer 48. The voltage drop across the resistance 37 supplies plate potential to the grids 24 and 25, which in the oscillator portion of the device 16 serve as an anode. The voltage drop across the resistance 37 is obtained from the anode circuit of the space discharge device 15.

The feedback necessary for the oscillation of the pentode 16 is obtained from a potentiometer 50 connected across the secondary winding of the transformer 48. The potentiometer 50 may also be employed to control the output of the gain control circuits and to some extent the performance of the gain control circuit. Reduced feedback and output results in a sharper cut-off and also higher plate current. By reason of this fact the output from the oscillator should be fairly close to the desired value by impressing the proper voltage from the transformer 29 on the anode of tube 15 rather than by reducing the feedback of the potentiometer 50 upon the control grid 22 of the oscillator. The feedback on the control grid 22 from the potentiometer 50 is effected by means of a condenser 51. The radio frequency output circuit from the pentode amplifier tube 15 may be traced from the anode 21 through the condenser 34 shunted by the inductance 33, by-pass condenser 53, and condenser 40 to the cathode 18. The diode or rectifier portion of the tube 16 comprising the anode 26 and the cathode 23 is coupled to the output circuit of the tube 15 by means of the condenser 46.

A copper oxide rectifier 54 and a condenser 55 are connected across the input circuit of the oscillator portion of the device 16 for controlling the building up and reducing of the oscillator output. The copper oxide rectifier 54 and the condenser 55, which are connected between the cathode 23 and the control grid 22, serve to insure that the oscillator output builds up relatively slowly and reduces relatively fast. This action on the part of the oscillator is only necessary in case certain types of resistance elements are employed in the beta circuit of the transmission line amplifier. Certain types of silver sulphide elements have the tendency to heat very rapidly and to cool fairly slowly. Unless some means is taken to counteract this action on the part of the silver sulphide element, hunting on the part of the gain control circuits will take place. Slow building up of the output from the oscillator and fast reduction in the output of the oscillator will compensate for the rapid heating and slow cooling of a copper oxide element.

In the system above described assume that the signal currents on the conductors 3 and 4 beyond the amplifier 1 are reduced below normal value and that the energy value of the pilot current is reduced at the same time. The pilot current selected by the filter 13 is impressed across the input circuit of the pentode tube 15. The amplified pilot current is then rectified by the diode portion of the device 16 comprising anode 26 and cathode 23. The rectified pilot current is then impressed on the resistance element 41 for controlling the oscillator portion of the device 16. Inasmuch as the energy value of the pilot current is assumed to be reduced, then the potential drop across the resistance element 41 is reduced. Consequently, the negative bias on the grid 22 is reduced to increase the oscillator output impressed on the transformer 48. The output from the oscillator is increased slowly. An increased current is then supplied by the transformer 48 to the heater coil 11. The temperature of the resistance element 10 is then increased to decrease the resistance thereof and lower the feedback through the beta circuit 8 to increase the output from the amplifier 1.

In case the energy level of the signals on the transmission line beyond the amplifier 1 go above normal value, the pilot current also goes above normal value and operates the gain control circuits to reduce the output from the line amplifier 1. The pilot current is selected by the filter 13 and impressed on the pentode tube 15. The output from the pentode tube 15 is rectified by the rectifier portion of the device 16. The oscillator portion of the device 16 is controlled according to the potential of the rectified pilot current. The oscillator output in the case under consideration reduces relatively fast by reason of the action of the condenser 55 and the copper oxide rectifier 54. A reduction in the oscillator output reduces the current flow of the heater coil 11 and consequently reduces the temperature of the resistance element 10. This increases the resistance value of the element 10 to increase the feedback through the beta circuit 8. This in turn reduces the output from the line amplifier 1. In the above manner the output from the amplifier 1 is maintained substantially constant.

Referring to Fig. 2 of the drawings, a modification of the circuit shown in Fig. 1 is illustrated wherein alternating current bias is impressed on the grid of the first amplifier tube. Like parts in the circuits shown in Fig. 2 to those shown in Fig. 1 have been indicated by similar reference characters. The conductors 56 in Fig. 2 of the drawings are connected to the output conductors 3 and 4, and conductors 57 are connected to the heater coil 11. The portion of the circuits shown in Fig. 1 above the dot and dash line XX may be applied to the circuit shown in Fig. 2.

Bias for the control grid 17 of tube 15 in the circuit shown in Fig. 2 is not obtained from the drop across the resistance element 35, as in the circuit shown in Fig. 1 but is obtained from the secondary winding 32 of the transformer 29. The secondary winding 32 of the transformer 29 is divided into two sections 58 and 59. A potentiometer 60 which is connected across the transformer section 59 is connected through the grid leak 39 to the control grid 17. The screen grid 19 is connected between the sections 58 and 59 of the secondary winding 32, as in the circuit shown in Fig. 1.

The secondary winding 31 supplies current of the order of 6.3 volts to the filaments of the space discharge devices 15 and 16. The secondary winding 32 supplies potential of the order of 400 volts to the anode 21 and approximately a potential of 250 volts is supplied to the screen grid 19. However, the above voltages do not appear entirely across the first space discharge device since the cathode 18 is approximately 110 volts off ground. The potentiometer 60 is varied in order to control the regulated output. When operating the first amplifier tube 15 with alternating current 5, the amplifier was found to be less sensitive to power voltage variations and particularly to rapid fluctuations. This circuit, aside from the bias on the tube 15, operates in exactly the same manner as the circuit shown in Fig. 1 with one exception. Provision is not provided in the circuit of Fig. 2 for operating the oscillator part of the device 16 to build up the output slowly and to reduce the output fairly fast. It is to be understood, however, that the copper oxide element 54, the condenser 55 and the resistance elements 43 and 44 may be added to the circuit shown in Fig. 2, if desired. The oscillator portion of the device 16 operates with the characteristic output-input curve having a steeply inclined cut-off portion the same as the oscillator shown in Fig. 1. The characteristic input output curve of the oscillator portion of the device 16 has a steeply inclined cut-off portion similar to the steeply inclined portion of the curve shown in Fig. 4 of the drawings. The oscillator operates along the steeply inclined cut-off portion so that for any change in the pilot current on the transmission line a more than the proportional change is obtained in the output from the oscillator. The abscissae for the curve shown in Fig. 4 represents input in decibels to the device 15 of the gain control circuit whereas the ordinates represent output from the oscillator and current supplied to the heater coil. The steeply inclined cut-off portion of the input-output characteristic curves of the oscillators shown in Figs. 1, 2 and 3 is similar to the steeply inclined portion of the curve shown in Fig. 4.

The circuit shown in Fig. 3 of the drawings is a modification of the circuit shown in Fig. 1 of the drawings and like parts will be indicated by similar reference characters. The conductors 56 in Fig. 3 of the drawings may be connected to the output conductors 3 and 4, and the conductors 57 may be connected to the heater coil 11.

In the circuit shown in Fig. 3 of the drawings, the source of alternating power 27 is connected to a transformer 70 which in turn is coupled to a transformer 71 by means of a condenser 72. The core of the transformer 71 is saturated and the condenser 72 tunes the circuit of the two transformers to the frequency of the power current. The tuning effect, while permitting large primary currents to flow, results in a substantially constant output from the secondary winding of the transformer 71. The secondary winding of the transformer 71 is similar to the secondary winding 32 of the transformer 29 shown in Fig. 1 of the drawings and is connected to like parts of the circuit. The system shown in Fig. 3 of the drawings operates in the same manner as the system shown in Fig. 1 of the drawings except that no provision is made for making the output from the oscillator portion of the device 16 build up slowly and reduce fairly fast. It is to be understood that the resistance element 43, condenser 55 and the copper oxide rectifier 54 shown in the circuits of Fig. 1 of the drawings may be added to the circuit of Fig. 3 of the drawings, if so desired.

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

What is claimed is:

1. A transmission line carrying signal and pilot currents and having an amplifier therein, a space discharge device serving as an oscillator and a rectifier, means for filtering and amplifying the pilot current on the transmission line, means for rectifying the amplified pilot current by the rectifier portion of said device, means to adjust the oscillator portion of said device to have a characteristic output-input curve with a steeply inclined cut-off portion and for operating the oscillator portion of the device on the steeply inclined portion of the characteristic curve, means for operating the oscillator portion of said device according to the output from the rectifier portion and means controlled by the oscillatory output for governing the amplifier in the transmission line to maintain the amplifier output constant.

2. A transmission line carrying signal and pilot currents and having an amplifier therein, a space discharge device serving as an oscillator and a rectifier and comprising a control grid, a cathode and two anodes, means for filtering and amplifying the pilot current on the transmission line, means for rectifying the amplified pilot current by the rectifier portion of said device, means for adjusting the oscillator portion of said device to have a characteristic output–input curve with a steeply inclined cut-off portion and for operating the oscillator portion of the device on the steeply inclined cut-off portion of the characteristic curve, means for impressing negative potential from said rectified pilot current on the grid of said device to control the oscillatory output, and means controlled by the oscillatory output for governing the amplifier in the transmission line to maintain the amplifier output constant.

3. A transmission line carrying signal and pilot currents and having an amplifier therein, a filter for selecting the pilot current from said line beyond the amplifier therein, an amplifier tube for amplifying the selected pilot current, means for operating said tube with alternating anode potential, a space discharge device serving as as oscillator and a rectifier and comprising a control grid, a cathode and two anodes, means for supplying the anode of the oscillator portion of said device with rectified potential from the anode circuit of said tube, means for adjusting the oscillator portion of said device to have a characteristic curve with a steeply inclined cut-off portion and for operating the oscillator portion of said device on the steeply inclined cut-off portion of the characteristic curve, means for rectifying the amplified pilot current by the rectifier portion of said device for supplying a negative bias to the grid of said oscillator portion of said device to control the oscillator output, and means controlled by the oscillator output for governing the amplifier in the transmission line to maintain the amplifier output constant.

4. A transmission line carrying signal and pilot currents and having an amplifier therein, a pentode tube serving as an amplifier, a space discharge device serving as as oscillator and a rectifier, the oscillator portion of said device operating with a characteristic curve having a steeply inclined cut-off portion and operating on the steeply inclined cut-off portion of the characteristic curve, means for amplifying the pilot current by the amplifier pentode tube, means for supplying alternating anode potential to said pentode tube, means for supplying alternating plate potential rectified by said tube as anode potential to the oscillator portion of said device, means comprising the rectifying portion of said device for rectifying the amplified pilot current from said tube and for impressing negative potential from said rectified pilot current on the grid of the oscillator portion of said device to control the oscillator output, and means controlled by the oscillatory output for governing the amplifier in the transmission line to maintain the amplifier output constant.

5. A transmission line carrying signal and pilot currents and having an amplifier therein, a filter for selecting said pilot current from the line beyond the amplifier therein, an amplifier tube for amplifying the selected pilot current, a source of regulated alternating current power supplied to the amplifier tube, a space discharge device serving as an oscillator and a rectifier and comprising a control grid, a cathode and two anodes, means for supplying the anode of the oscillator portion of said device with rectified potential from the anode circuit of said amplifier tube, means for rectifying the amplified pilot current by the rectifier portion of said device to supply potential to the grid of the oscillator portion of said device for controlling the oscillator output, and means controlled by the oscillator output for governing the amplifier in the transmission line to maintain the amplifier output constant.

6. A transmission line carrying signal and pilot currents and having an amplifier therein, a filter for selecting said pilot current from the line beyond the amplifier therein, an amplifier tube comprising an anode, a cathode and a control grid for amplifying the selected pilot current, a source of alternating current for supplying anode potential to said amplifier tube, means for coupling said source to the anode of the amplifier tube and comprising two transformers one of which has a saturated core and a condenser between the secondary winding of the first transformer and the primary winding of the second transformer for tuning the transformers to the frequency of the alternating current, a space discharge device comprising a grid, two anodes and

a cathode and serving as an oscillator and a rectifier, means for supplying the oscillator portion of said device with rectified anode potential from the anode circuit of said amplifier tube, means for rectifying the amplified pilot current by the rectifier portion of said device to supply potential to the grid of the oscillator portion of said device to control the oscillator output and means controlled by the oscillator output for governing the amplifier in the transmission line to maintain the amplifier output constant.

7. A transmission line carrying signal and pilot currents and having an amplifier therein, a space discharge device serving as an oscillator and a rectifier, means for filtering and amplifying the pilot current on the transmission line, means for rectifying the amplified pilot current by the rectifier portion of said device, means for controlling the oscillator portion of said device according to the rectified potential supplied by the rectifier portion of said device, means for controlling the oscillator portion of said device to build up the output slowly and to reduce the output relatively fast, and means controlled according to the oscillator output for governing the amplifier in the transmission line to maintain the amplifier output constant.

8. A transmission line carrying signal and pilot currents and having an amplifier therein, means comprising a resistance element of silver sulphide for controlling said amplifier, said resistance element having the characteristic of heating rapidly and cooling slowly, an oscillator space discharge device, means for adjusting said oscillator to have an output-input characteristic curve with a steeply inclined cut-off portion, means for controlling said oscillator according to the energy level of the pilot current on the transmission line, means for operating the oscillator to build up the output slowly and to reduce the output relatively fast, and means for heating said element of silver sulphide according to the oscillator output to maintain the output of the transmission line amplifier substantially constant.

9. A transmission line carrying signal and pilot currents and having an amplifier therein, means comprising a resistance element having a high negative coefficient of resistance for controlling said amplifier, said resistance element having the characteristic of heating rapidly and cooling slowly, a space discharge oscillator having a control grid, means for impressing potential on said grid according to the energy level of said pilot current to control said oscillator and effect a more than proportional change in the oscillator output upon pilot current change, means for controlling said oscillator to build up the output slowly and to reduce the output relatively fast, and means for heating said resistance element according to the oscillator output to maintain the output of the transmission line amplifier substantially constant.

10. A controlled circuit having a characteristic thereof maintained substantially constant, a space discharge oscillator having a control grid, means for impressing a variable potential on said grid according to the characteristic of said circuit, means for operating said oscillator on a steeply inclined portion of the output-input characteristic curve thereof when controlled by the potential impressed on the grid, means for controlling said oscillator to build up the output slowly and to reduce the output relatively fast, and means controlled according to the output from said oscillator for maintaining the characteristic of the controlled circuit substantially constant.

11. A signal transmission line having an amplifier therein, a space discharge oscillator having a control grid, means for impressing potential on said grid according to the energy level of the signals for controlling said oscillator to effect a more than proportional change in the oscillator output upon signal energy change, means comprising capacity and copper oxide elements connected across the input circuit of said oscillator for controlling the oscillator to build up the output slowly and to reduce the output relatively fast, and means controlled according to the oscillator output for governing the amplifier in the transmission line to maintain the amplifier output constant.

ROYER R. BLAIR.