

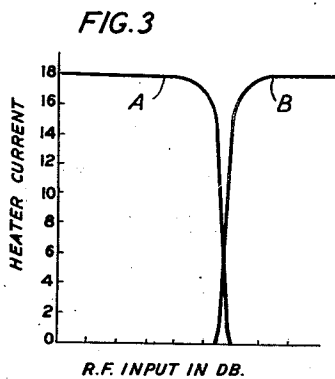
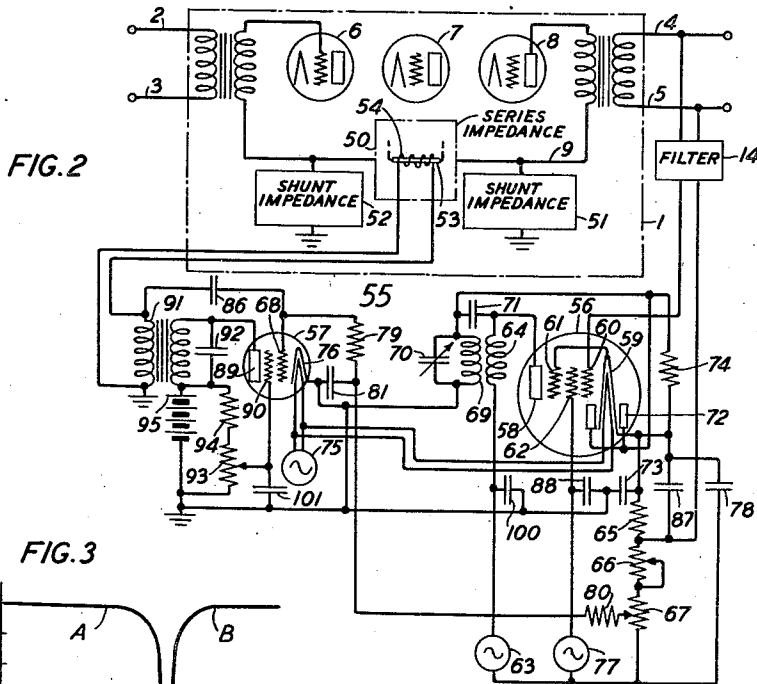
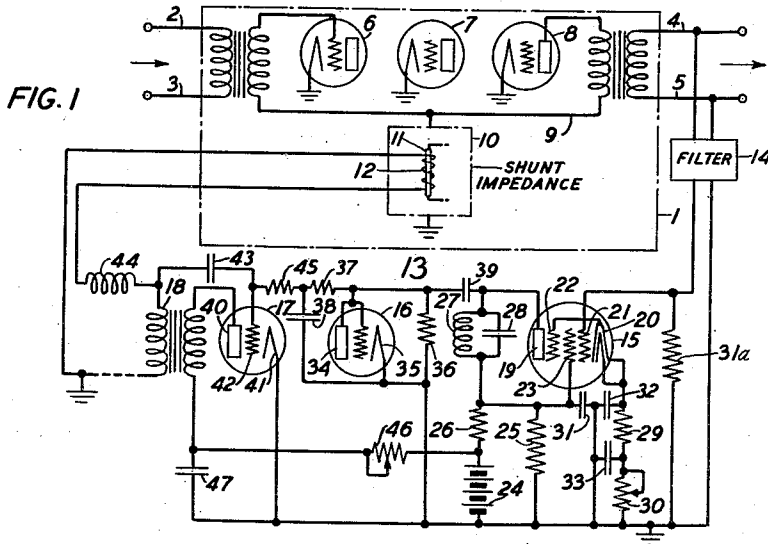
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GAIN CONTROL CIRCUITS

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GAIN CONTROL CIRCUITS

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This invention relates to regulator circuits and particularly to circuits for effecting automatic regulation of the gain on signal transmission systems.

5 One object of the invention is to provide regulator circuits having an oscillator operating on a steeply inclined portion of its characteristic curve for maintaining a characteristic of a controlled circuit substantially constant.

10 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 gain of an amplifier on the transmission line according to the oscillator output for maintaining the amplifier output substantially constant.

15 A further object of the invention is to provide a signal transmission line having an amplifier therein with gain control circuits of the above-indicated character that shall control the beta circuit of the amplifier in an improved manner to maintain the amplifier output constant.

20 In long signal transmission lines it is necessary to provide amplifiers or repeaters at intervals along the line to maintain the energy level of the signals above a predetermined level. Regulator or gain control circuits are required at certain of the repeater stations to hold the energy level of the signals substantially constant. The regulator or gain control circuits may be controlled in accordance with the energy level of the signals or in accordance with the energy level of a pilot current.

25 This invention has been illustrated by means of a system transmitting high frequency carrier current signals. A pilot current is transmitted with the carrier currents for governing the gain on the transmission system.

30 According to the system employed to describe the invention, a feedback amplifier of the type disclosed in the patent to H. S. Black No. 2,102,671, December 21, 1937, is controlled to maintain the energy level of signals on the transmission line substantially constant. In one form of the invention a resistance element having a high negative temperature coefficient of resistance is connected across the beta circuit of the amplifier. The resistance element is heated according to the energy level of the pilot current on the transmission line for so governing the amplifier as to maintain the output thereof substantially constant. The resistance element in the beta circuit of the amplifier is preferably composed of silver sulphide but may be com-

posed of any other well-known resistance material having a high temperature coefficient of resistance.

The regulator or gain control circuits which control the heating of the resistance element in the beta circuit of the amplifier are connected to the transmission line beyond the amplifier therein. The gain control circuits comprise a filter connected to the transmission line for selecting the pilot current. The output circuit of the filter is connected to the input circuit of a space discharge device. The space discharge device is preferably in the form of a pentode tube and amplifies the selected pilot current. The output circuit of the pentode tube is tuned to the frequency of the pilot current. The output from the pentode tube is rectified for supplying a negative bias to be impressed on the grid of a low frequency space discharge oscillator. The oscillator, which is controlled by the rectified pilot current, has an input-output characteristic curve with a steeply inclined cut-off portion. The oscillator is operated on the steeply inclined portion of its characteristic curve so that a small change in the energy level of the pilot current causes a great change in the output of the oscillator. The output of the oscillator is employed for heating a resistance element connected across the beta circuit of the line amplifier.

35 An increase in the energy level of the pilot current on the transmission line will cause an increase in the negative bias impressed on the grid of the low frequency oscillator. A small change in the negative bias on the low frequency oscillator causes a more than proportional change in the output from the oscillator. The change in output from the oscillator causes a large change in the resistance connected across the beta circuit to control the line amplifier and reduce the energy level of the signals on the transmission line. A decrease in the energy level of the pilot current causes an opposite effect. By the above means the output from the line amplifier is maintained substantially constant.

40 In a modification of the invention the resistance element is connected in series with the beta circuit of the line amplifier. In the modified circuit the amplifier output is reduced by reducing the negative bias on the grid of the low frequency oscillator in place of increasing the negative bias. Thus, in the modification an increase in the energy level of the pilot current would cause a decrease in the negative bias on the grid of the oscillator to reduce the output from the oscillator.

In the accompanying drawing,

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

Fig. 2 is a diagrammatic view of a modification of the circuits shown in Fig. 1;

Fig. 3 is a curve diagrammatically illustrating the characteristic curves of the regulator circuits shown in Figs. 1 and 2.

Referring to Fig. 1 of the drawing, an amplifier 1 of the feedback type is shown in a transmission line having input conductors 2 and 3 and output conductors 4 and 5. The amplifier 1 may be of the type disclosed in the patent to H. S. Black No. 2,102,671, December 21, 1937. The amplifier 1 is shown comprising three tubes 6, 7, and 8 which may be of any suitable type. An impedance pad 10 is shown connected across the beta circuit 9 of the amplifier 1. One element of the impedance pad 10 comprises a resistance element 11 having a high negative temperature coefficient of resistance. The resistance element 11 is controlled by a heater element 12. An increase in the current flow through the heater element 12 decreases the resistance of the resistance element 11 for decreasing the feedback through the beta circuit 9 to increase the gain of the amplifier. A decrease in the current flow through the heater coil 12 produces an opposite action.

Regulator circuits 13 are provided for controlling the heater element 12 to maintain the output from the amplifier 1 substantially constant. The transmission line transmits not only carrier currents, but also a pilot current. The pilot current is employed for controlling the operation of the regulator or gain control circuits 13. The transmission line may be a coaxial cable or a cable carrying carrier frequency currents. The control circuits 13 comprise a filter 14 which is preferably of the crystal type. The filter selects the pilot current which controls the operation of the regulator circuits. The output from the filter 14 is connected to a tuned radio frequency pentode amplifier 15. The amplified radio frequency output from the pentode 15 is rectified by a space discharge device 16 for controlling the amplitude of the output from a low frequency oscillator 17. The output from the oscillator 17 is connected by a transformer 18 to the heating element 12.

The pentode amplifier 15 comprises an anode 19, a cathode 20, a control grid 21, a suppressor grid 22 and a screen grid 23. Plate potential for the pentode 15 is supplied by a battery 24 through a potential divider comprising resistance elements 25 and 26. The plate circuit for the pentode tube may be traced from one terminal of the battery 24 through resistance element 25, inductance 27 shunted by a condenser 28, anode 19, cathode 20, resistance elements 29 and 30 and ground return to the other terminal of the battery 24. The gain of the pentode tube 15 is controlled by varying the resistance element 30. The resistance element 29 prevents the possibility of reducing the bias on the pentode 15 to zero. A resistance 31a is connected across the input circuit of the pentode 15 to provide a grid return path when the circuit of the filter 14 is not completed. The resistance elements 25 and 26 perform the function of voltage dividers to reduce the potential impressed on the anode 19 and the screen grid 23. The inductance 27 and the capacity 28 serve to tune the amplifier 15 to the frequency of the selected pilot current. Three condensers 31, 32 and 33 serve as by-passing condensers in the operation of the pentode amplifier 15.

The rectifier 16 which is preferably of the space discharge type comprises an anode 34 and a cathode 35. The direct current component obtained by the rectifier 16 from the output of the amplifier 15 appears across a resistance element 36. A resistance element 37 in combination with a capacitance 38 serve as a low-pass filter. The radio frequency output circuit from the amplifier 15 may be traced from the anode 19 through a condenser 39, rectifier 16 and condenser 32 to the cathode 20.

The oscillator space discharge device 17 comprises an anode 40, a cathode 41, a grid 42. The oscillator 17 is an audio frequency oscillator and preferably oscillates at approximately 2500 cycles per second. The transformer 18 which couples the oscillator 17 to the heater coil 12 also provides the necessary grid excitation for the oscillator 17 through a condenser 43. An inductance 44 in the secondary circuit of the transformer 18 is a radio frequency choke which may be a part of a cross-talk filter in the feedback amplifier 1. Negative bias for the grid 42 of the oscillator 17 may be transmitted through a grid leak resistance 45.

The oscillator 17 is adjusted to have an output-input characteristic curve with a sharply inclined cut-off portion. The oscillator is operated along the sharply inclined cut-off portion of its characteristic curve so that a small change in bias on the grid 42 of the oscillator causes a more than proportional change in the output from the oscillator.

In Fig. 3 of the drawing the curve A shows the characteristic curve of the regulator circuit shown in Fig. 1. The abscissae represent the decibels input to the amplifier 15 and the ordinates represent the output from the oscillator 17 which is supplied to the heater coil 12. The output from the oscillator 17 is controlled by means of an adjustable resistance 46. The condenser 47 serves as a by-pass condenser. The oscillator 17 operates with an input-output characteristic curve having a steeply inclined cut-off portion similar to the steeply inclined portion of the curve A shown in Fig. 3 of the drawing.

If the output signals from the repeater or amplifier 1 tend to increase, the energy level of the pilot current will tend to increase. An increase in the energy level of the pilot current will increase the potential appearing across the resistance element 36. The potential across the resistance 36 represents the rectified output from the pentode amplifier 15. An increase in the potential across the resistance element 36 increases the negative bias impressed on the grid 42 of the oscillator 17. Increase in the negative potential on the grid of the oscillator reduces the output from the oscillator to reduce the current flow through the heater element 12. This reduces the temperature of the heat element 11, which is preferably composed of silver sulphide. The resistance of the element 11 is increased to increase the feedback through the beta circuit 9 from the amplifier 1. This reduces the gain of the amplifier.

If the energy level of the signals beyond the amplifier 1 falls below normal value the reduced energy level of the pilot current which is selected by the filter 14 and amplified by the amplifier 15 produces a lower potential drop across the resistance element 36. The negative bias on the grid 42 of the oscillator 17 is reduced to increase the current flow through the heater element 12. An increase in the current flow from the heater

element 12 increases the temperature of the resistance element 11 to decrease the resistance thereof. The feedback on the amplifier 1 is thereby reduced to increase the gain by the amplifier 1. In the above-described manner the gain of the amplifier 1 is controlled to maintain the amplifier output substantially constant.

Referring to Fig. 2 of the drawing a modification of the invention is shown wherein the beta circuit of a line amplifier is controlled by means of a resistance element connected in series therewith. Like parts in the circuit shown in Fig. 2 to those shown in Fig. 1 of the drawing will be indicated by similar reference characters. The feed-back amplifier 1 in the transmission line is connected to input conductors 2 and 3 and output conductors 4 and 5. The beta circuit 9 is shown having a series impedance network 50 and shunt impedance networks 51 and 52. A portion of the series impedance network 50 comprises a resistance element 53 which is similar to the resistance element 11 shown in Fig. 1 of the drawing and preferably is composed of silver sulphide. The resistance element 53 is controlled by a heater element 54. The heater element 54 is controlled by regulator circuits 55 in accordance with the energy level of a pilot current on the output conductors 4 and 5.

A filter 14 which is similar to the filter 14 shown in Fig. 1 of the drawing selects a pilot current and impresses the same on a space discharge device in the form of a tuned pentode-diode 56. The pentode portion of the device 56 amplifies the radio frequency pilot current. The diode portion of the device 56 rectifies the amplified pilot current to supply rectified potential for controlling an oscillator device 57. The output from the oscillator 57 controls the current flow through the heater element 54.

The pentode portion of the device 56 comprises an anode 58, a cathode 59, a control grid 60, a suppressor grid 61 and a screen grid 62. Anode potential for the pentode of the device 56 is supplied from a suitable source of alternating current 63. The anode circuit may be traced from one terminal of the source 63 through an inductance 64, the anode 58, the cathode 59, and resistance elements 65, 66 and 67 to the other terminal of the source 63. Biasing potential for the control grid 60 is obtained by the potential drop across the resistance element 65. Initial negative bias for the control grid 68 of the oscillator device 57 is obtained from the potential drops across the resistance elements 65, 66 and 67. This initial negative bias on the grid of the oscillator device 57 is at least large enough to prevent the device from oscillating. Radio frequency signals must be impressed upon the amplifier 56 before oscillation of the device 57 can take place as will be hereinafter explained.

The inductance coil 64 in combination with an inductance coil 69 are tuned by an adjustable condenser 70 to the frequency of the pilot current admitted by the filter 14. A condenser 71 serves as a blocking condenser. The radio frequency output circuit from the pentode portion of the device 56 may be traced from the condenser 70 shunted by inductance 69 through plate 72 of the diode portion of the device 56, cathode 59, condenser 73 and grounded return to the other terminal of the condenser 70 shunted by the inductance element 69. The rectified current obtained from the diode portion of the device 56 appears across the resistance element 74. The

drop across the resistance element 74 subtracts from the initial negative bias upon the grid 68 of the oscillator device 57. A source of alternating current 75 is provided not only for heating the cathode 59 of the device 56 but also for heating the cathode 76 of the oscillator device 57. A source of alternating potential 77 is provided for impressing potential on the screen grid 62 of the pentode-diode device 56.

The pentode-diode space discharge device 56 performs three functions: first, a radio frequency amplifier for amplifying pilot current supplied by the filter 14; second, a half-wave 60-cycle rectifier for supplying negative grid bias to the oscillator 57 by the potential drop across the resistance elements 65, 66 and 67, and third, a diode detector for rectifying the radio frequency output of the pentode portion of the device. A condenser 78 serves to filter the rectified output of the device 56 appearing across the resistance elements 65, 66 and 67. A filter comprising resistance element 80 and capacity elements 73, 81 and 86 is provided for removing any 60-cycle modulation products that may be in the biasing circuit for the oscillator 57. Condenser 87 serves as a filter condenser for the bias on device 56 and condensers 88, 100, 101 and 73 serve as by-pass condensers.

The oscillator device 57 comprises an anode 89, a cathode 76, the control grid 68 and a screen grid 90. The output from the oscillator 57 is connected by a transformer 91 to the heating coil 54. The bias on the control grid 68 is governed according to the negative potential across the resistance elements 65, 66 and 67 opposed by the positive potential drop across the resistance element 74. The positive potential drop across the resistance element 74 varies according to the energy level of the pilot current of the transmission line. The grid circuit for the oscillator 57 may be traced from one terminal of the resistance element 67 through resistance element 80, resistance element 79, grid 68, cathode 76, inductance element 69, resistance element 74 and resistance elements 65 and 66 to the other terminal of the resistance element 67. The transformer 91 and a condenser 92 connected across the primary winding of the transformer determine the frequency at which the oscillator 57 oscillates. The condenser 86 provides the necessary feedback path from the secondary winding of the transformer to the control grid 68. The maximum output of the oscillator 57 is controlled by the screen grid potential obtained from the potential drop across the resistance element 93. The resistance element 93 in series with a resistance element 94 is connected across a battery 95. Oscillator outputs from zero to any given maximum are obtained by varying the bias on the control grid 68 through the associated grid leak resistance 79. The radio frequency input voltage at which the oscillator cuts off is controlled by varying the bias on the oscillator 57 by means of the resistance elements 66 and 67. A fine adjustment may be made by the resistance element 66 and a coarse adjustment may be made by means of the resistance element 67.

If the signals on the output conductors 4 and 5 are above normal value, the pilot current selected by the filter 14 will have an amplitude above normal value. The pilot current amplified by the pentode portion of the device 56 will be rectified by the diode portion of the device 56 and impressed on the resistance element 74. Increasing the positive potential bias obtained from the

drop across the resistance element 74 increases the output from the oscillator device 57. As before set forth, negative bias is impressed on the grid 68 of the oscillator by the potential drop across resistance elements 65, 66 and 67. A positive bias in opposition to negative bias will be obtained by the potential drop across the resistance element 74. An increase in the oscillator output increases current flow through the heater element 54. This increases the temperature of the resistance element 53 and lowers the resistance thereof. Lowering the resistance in the beta circuit 9 increases feedback and lowers the amplifier output to bring the signal energy level to normal.

In case the signals on the output conductors 4 and 5 fall below normal value the amplified rectified pilot current impressed on the resistance element 74 is reduced to reduce the output from the oscillator 57. A reduction in the output from the oscillator 57 reduces the current flow through the heater element 54. This reduces the temperature of the resistance element 53 and increases the resistance thereof. This reduces the feedback of the amplifier 1 to increase the output therefrom. In the above-described manner the output from the amplifier 1 is maintained substantially constant.

The curve B shown in Fig. 3 of the drawing illustrates the characteristic of the regulator circuit shown in Fig. 2 of the drawing. The abscissae represent decibels input to the amplifier 56 and the ordinates represent the output from the oscillator which is supplied to the heater coil 54. The oscillator 57 operates with an input-output characteristic curve having a steeply inclined cut-off portion similar to the steeply inclined portion of the characteristic curve B shown in Fig. 3 for the regulator circuits illustrated in Fig. 2 of the drawing. The oscillator 57 operates on the steeply inclined cut-off portion of the characteristic curve. The oscillator 57 shown in Fig. 2 of the drawing, the same as the oscillator 17 shown in Fig. 1 of the drawing, serves to effect an output which is more than proportional to any change in the pilot current on the transmission line.

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

What is claimed is:

1. 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 input-output characteristic curve thereof when controlled by the potential impressed on the grid, and means controlled according to the output from said oscillator for maintaining the characteristic of the controlled circuit substantially constant.

2. A transmission line carrying signal and pilot currents and having an amplifier therein, a space discharge oscillator having a control grid, means for governing the potential on said grid according to the energy level of said pilot current, means for operating the oscillator on a steeply inclined portion of the input-output characteristic curve thereof when controlled according to the energy level of the pilot current, and means for control-

ling said amplifier according to the output from said oscillator.

3. A signal transmission line having an amplifier therein, a space discharge oscillator having a control grid, said oscillator having an input-output characteristic curve with a portion thereof which effects a more than proportional change in the output for a change in the input, means for impressing potential on said grid according to the energy level of the signals on the line for controlling said oscillator, means for operating said oscillator to effect a more than proportional change in the oscillator output upon signal energy change when controlled according to the energy level of the signals on the line, and means governed according to the oscillator output for controlling said amplifier to maintain substantially constant amplifier output.

4. A signal transmission line, an amplifier in said transmission line having a beta circuit, a space discharge oscillator having a control grid, means for impressing varying potential on said grid according to the energy level of the signals on said line, means for adjusting said oscillator to have an input-output characteristic curve with a steeply inclined cut-off portion and for operating the oscillator on the steeply inclined portion of the characteristic curve when controlled by the varying potential impressed on the grid, and means for controlling said beta circuit according to the output from said oscillator to maintain the amplifier output substantially constant.

5. A transmission line carrying signal and pilot currents and having an amplifier therein, means comprising a resistance element having a high negative temperature coefficient of resistance for controlling said amplifier, a heater element for controlling said resistance element, a space discharge oscillator having a control grid, said oscillator having an input-output characteristic curve with a portion thereof which effects a more than proportional change in the output for a change in the input, means for impressing potential on said grid according to the energy level of said pilot current for controlling said oscillator, means for operating said oscillator to effect a more than proportional change in the oscillator output when controlled according to pilot current change, and means governed according to the oscillator output for controlling said heater element to maintain the amplifier output substantially constant.

6. A transmission line carrying signal and pilot currents, an amplifier having a beta circuit in said line, means comprising a resistance element in said beta circuit for controlling the amplifier, said resistance element having a high temperature coefficient of resistance, a heater element for controlling said resistance element, a space discharge oscillator having a control grid, means for impressing potential on said grid which varies according to the energy level of said pilot current on the line beyond said amplifier, means for adjusting said oscillator to have an input-output characteristic curve with a steeply inclined cut-off portion and for operating the oscillator on the steeply inclined portion of the characteristic curve when controlled by the varying potential impressed on the grid, and means for controlling said resistance element by said heater element according to the output from said oscillator to maintain the amplifier output substantially constant.

7. A transmission line carrying signal and pilot

currents, an amplifier in said line, a space discharge oscillator having a control grid, means for impressing negative potential on said control grid which varies according to the energy level of said pilot current, means for adjusting said oscillator to have an input-output characteristic curve with a steeply inclined cut-off portion and for operating the oscillator on the steeply inclined portion of the characteristic curve, and means for controlling said amplifier according to the output from said oscillator to maintain the amplifier output substantially constant.

8. A transmission line carrying signal and pilot currents, an amplifier in said line, a space discharge oscillator having a control grid, means for filtering said pilot current from said line beyond the amplifier and for amplifying and rectifying the filtered pilot current to impress negative potential on the grid of said oscillator, means for adjusting said oscillator to have an input-output characteristic curve with a steeply inclined cut-off portion and for operating the oscillator on the steeply inclined portion of the characteristic curve, and means for controlling said amplifier according to the output from said oscillator.

9. A signal transmission line, an amplifier in said line having a beta circuit, means comprising a resistance element connected across said beta circuit for controlling said amplifier, said resistance element having a high negative temperature coefficient of resistance, a heater element for controlling said resistance element, a space discharge oscillator having a control grid, means for impressing negative potential on said grid which varies according to the energy level of the signals on said line, means for adjusting said oscillator to have an input-output characteristic curve with a steeply inclined cut-off portion and for operating the oscillator on the steeply inclined portion of the characteristic curve, and means for controlling said heater element according to the output from said oscillator to maintain the amplifier output substantially constant.

10. A transmission line carrying signal and pilot currents of radio frequency, an amplifier in said line, a filter connected to said line beyond said amplifier for selecting said pilot frequency, an amplifier tuned to said pilot frequency and connected to said filter, a space discharge oscillator having a control grid, means for rectifying the output from said tuned amplifier to impress negative potential on the grid of said oscillator which varies according to the energy level of the pilot current on said line, means for adjusting said oscillator to have an input-output characteristic curve with a steeply inclined cut-off portion and for operating the oscillator on the steeply inclined portion of the characteristic curve when controlled by said rectifying means, and means for controlling said line amplifier according to the output from said oscillator to maintain the line amplifier output substantially constant.

11. A signal transmission line, an amplifier in said line having a beta circuit, means comprising a resistance element series connected in said

beta circuit for controlling the amplifier, said resistance element having a high negative temperature coefficient of resistance, a heater element for controlling said resistance element, a space discharge oscillator having a control grid, means for impressing less negative potential on said grid which varies according to the energy level of the signals on said line, means for adjusting said oscillator to have an input-output characteristic curve with a steeply inclined cut-off portion and for operating the oscillator on the steeply inclined portion of the characteristic curve, and means for controlling said heater element according to the output from said oscillator to maintain the amplifier output substantially constant.

12. A transmission line carrying signal and pilot currents, an amplifier in said line, a space discharge oscillator having a control grid, means for filtering said pilot current from the line beyond said amplifier and for amplifying and rectifying the filtered pilot current to impress less negative potential on the grid of said oscillator, means for adjusting said oscillator to have an input-output characteristic curve with a steeply inclined cut-off portion and for operating the oscillator on the steeply inclined portion of the characteristic curve, and means for controlling said amplifier according to the output from said oscillator to maintain the amplifier output substantially constant.

13. A transmission line carrying signal and pilot currents, an amplifier in said line, a space discharge oscillator having a control grid, means for impressing a negative bias on said control grid, means for impressing a less negative potential on said control grid which varies according to the energy level of said pilot current, means for adjusting said oscillator to have an input-output characteristic curve with a steeply inclined cut-off portion and for operating the oscillator on the steeply inclined portion of the characteristic curve, and means for controlling said amplifier according to the output from said oscillator to maintain the amplifier output substantially constant.

14. A transmission line carrying signal and pilot currents, an amplifier in said line, a space discharge oscillator having a control and a screen grid, means for impressing potential on said screen grid to limit the maximum output of said oscillator device, a space discharge device comprising diode and amplifier portions, means for impressing alternating space potential on the amplifier portion of said device, means for filtering the pilot current on said line and for impressing the selected pilot current on the input circuit of the amplifier portion of said device, means for impressing negative potential from the plate circuit of said device on the control grid of said oscillator, means for rectifying the output from amplifier portion of said device by the diode portion thereof to impress a variable less negative potential on the control grid of said oscillator, and means for controlling said line amplifier according to the output from said oscillator.

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