May 24, 1938. S. DOBA, JR 2,118,175

CONTROL CIRCUITS

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FIG. 1

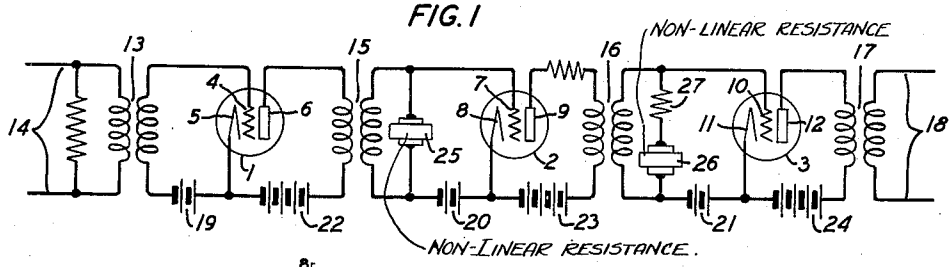

FIG. 2

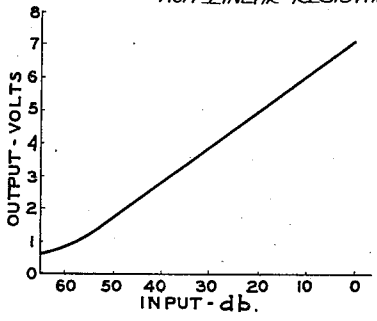

FIG. 3

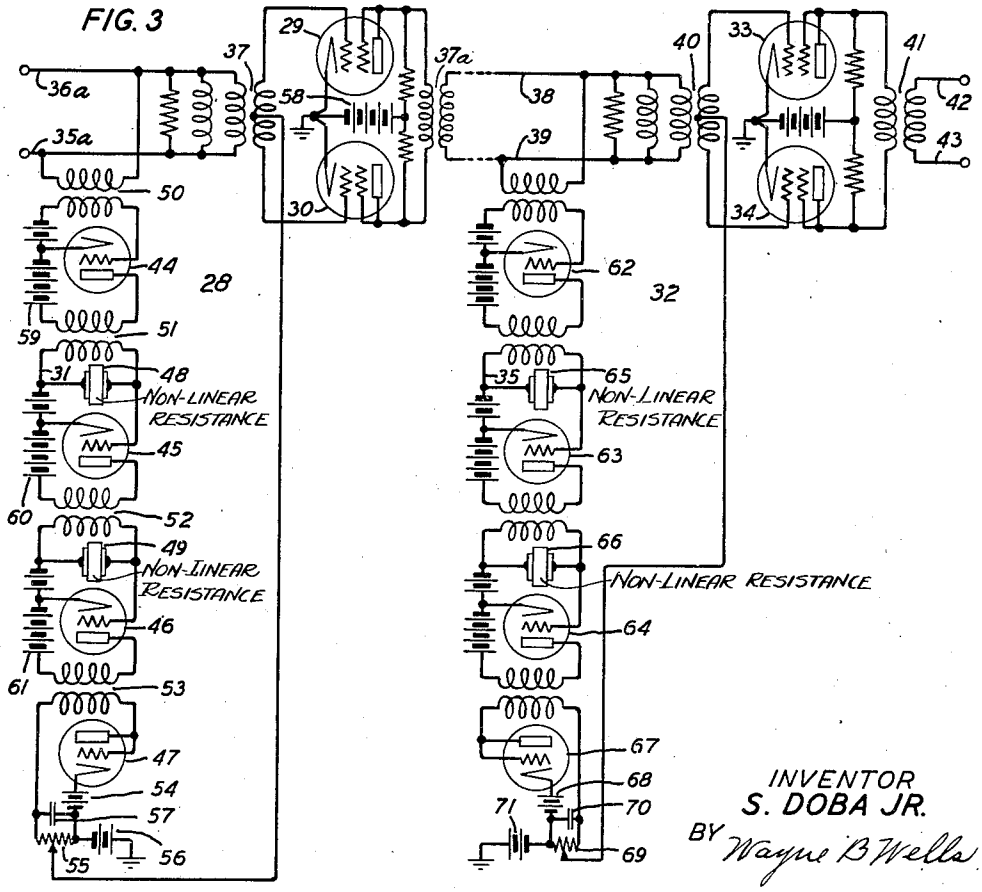

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FIG. 4

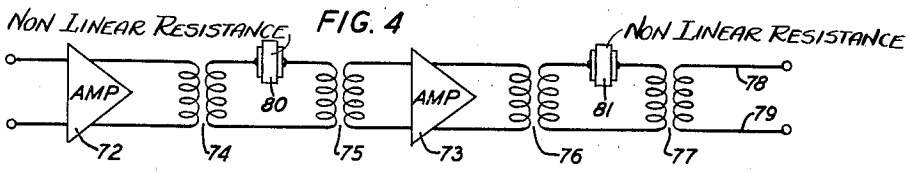


FIG. 5

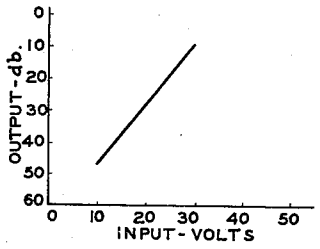
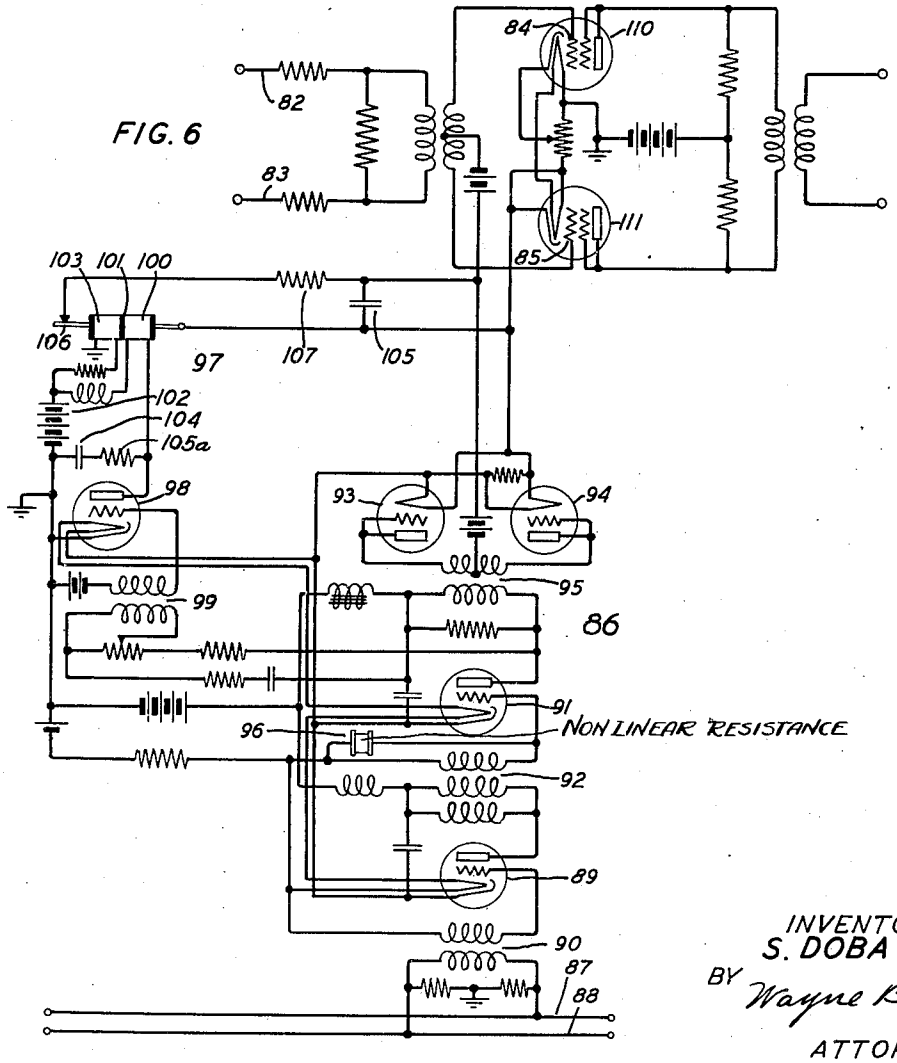


FIG. 6



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UNITED STATES PATENT OFFICE

2,118,175

CONTROL CIRCUITS

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Application April 20, 1935, Serial No. 17,427

18 Claims. (Cl. 178—44)

This invention relates to control circuits having distorting amplifiers and particularly to control circuits having distorting amplifiers for governing the compression and expansion of signals.

One object of the invention is to provide a control circuit that shall have a distorting amplifier to produce a characteristic output in a new and improved manner.

Another object of the invention is to provide a control circuit with a distorting amplifier that shall have an output voltage varying according to a logarithm of the input voltage to the amplifier.

Another object of the invention is to provide a space discharge device in a signal transmission line with a forward acting control circuit having an amplifier producing a voltage output which is proportional to a logarithm of the voltage input thereto that shall govern the grid bias on said device to vary the volume of the signals beyond the device with respect to the volume of the signals on the line before the device according to a fixed ratio.

Another object of the invention is to provide a space discharge device in a signal transmission line with a forward acting control circuit having an amplifier producing a voltage output which is proportional to a logarithm of the voltage input thereto that shall impress a variable negative bias on the grid of said device to compress the signal volume beyond the device with respect to the signal volume before the device according to a fixed ratio.

A further object of the invention is to provide a space discharge device in a signal transmission line at the transmitting end thereof with a forward or backward acting control circuit having a distorting amplifier for impressing a variable negative bias on the grid of said device to compress the signal volume beyond said device with respect to the signal volume before the device according to a fixed ratio and to provide a second space discharge device in the transmission line at the receiving end thereof with a forward acting control circuit having a distorting amplifier for impressing a variable positive bias on the grid of the second device to expand the signal volume beyond the second device to the signal volume before the first device.

In many cases signals received for transmission over a line have a volume range larger than can be efficiently transmitted. Signal systems are generally limited as to the volume range which can be satisfactorily transmitted. Satisfactory transmission of signals has an upper limit to avoid overloading of line apparatus, such as repeaters, and has a lower limit by reason of interference from line noises. Like difficulties are encountered in recording signals as, for example, musical programs on a film or a phonograph record.

The present invention discloses a control circuit having a distorting amplifier therein that may be employed to govern the compression and expansion of signals on a transmission line, that may be employed to govern the recording of signals on a film and a phonograph record and that may be employed in circuits, such as echo suppressor circuits. In a compressor circuit controlled according to the present invention, the volume of the transmitted signals is held within the upper and lower limits of satisfactory transmission by changing the shape of the signal waves at the transmitting end of a line. At the receiving end of the line the signals are restored to their original shape.

In accordance with the present invention, a control circuit is provided with a distorting amplifier. The amplifier which is preferably a space discharge device has an element connected to the input circuit thereof for effecting distortion in the output circuit. The element which is employed for effecting distortion in the amplifier output circuit comprises silicon carbide crystals and a binder material. An element of this type is disclosed in the patent to K. B. McEachron, No. 1,822,742, September 8, 1931. If an element of silicon carbide crystals and a binder material is connected across the input circuit of an amplifier, the output voltage of the amplifier is proportional to the logarithm of the input voltage. The amplifier in the control circuit may have a number of stages, any number of which may be provided with distorting elements connected across the input circuits.

An amplifier of this type may be useful for indicating purposes where it is desirable to measure or show gains or volumes in decibels by means of a linear voltage indicator. Equal increments of input in decibels will be spread out uniformly on a voltage measuring device. Another use of the amplifier may be a signal shaping device for control of voice operated circuits. By employing a variable μ or exponential space discharge device in a transmission line, it is possible to obtain compression of the output with respect to the input of the device according to various ratios by adjusting the grid bias of the device under control of a distorting amplifier. The same type of circuit may be used as an expander of signals on a transmission line by reversing the polarity

of the grid bias applied to the variable μ space discharge device in the line. Another type of distoring amplifier may be provided by connecting an element of silicon carbide crystals and a binder material in series with the input circuit of a space discharge device. In such a distorting amplifier, the characteristic is approximately exponential, that is, the output voltage varies as the anti-logarithm of the input voltage.

In a signal amplitude compressor constructed in accordance with the present invention, a variable μ space discharge device is connected in series with the transmission line at the transmitting end thereof. If so desired, two devices may be connected in the line in push-pull relationship. A forward acting control circuit is provided for controlling the bias on the grid of the space discharge device in the line to effect a compression of the signals so that the signals beyond the device are compressed with respect to the signals before the device according to a fixed ratio. The forward acting control circuit is provided with a distorting amplifier preferably having at least two stages in order to extend the range of control. Each stage of the amplifier comprises a thermionic tube having an element composed of silicon carbide crystals and a binder material connected across the input circuit thereof. The last stage of the amplifier has the output circuit thereof connected to a rectifier and a potentiometer. The potentiometer impresses a variable negative bias on the grid of the space discharge device in the line. In addition to the variable negative bias which is impressed on the grid of the device in the line, a fixed negative bias of low value is impressed on the grid. The compression which is effected by the control circuit acting on the space discharge device in the line may be varied by varying the connection of the grid of the device to the potentiometer in the control circuit.

At the receiving end of the line it is desirable to expand the volume of the signals to their original value so that the signals will not be distorted. A space discharge device at the receiving end of the transmission line is provided with a forward acting control circuit very similar to the control circuit employed for governing the grid bias on the device at the transmitting end of the line. At the receiving end of the line the space discharge device of the variable μ type is connected to the potentiometer of the control circuit so as to impress a variable positive potential bias on the grid. At the receiving end of the line, preferably a relatively high fixed negative bias is impressed on the grid of the space discharge device.

A compressor of the above indicated type may also be used in an echo suppressor circuit. The distorting amplifier circuit may be controlled from a receiving path in a four-wire circuit for controlling a device in the transmitting path and vice versa. As before set forth, a compressor of the type above indicated may be employed for recording signals on a film or a phonograph record and an expander of the above indicated type may be employed for reproducing the signals from the film or the phonograph record.

In the accompanying drawings, Figure 1 is a diagrammatic view of a control circuit constructed in accordance with the invention;

Fig. 2 is a curve showing the relation of the input voltage to the output voltage in the circuit shown in Fig. 1;

Fig. 3 is a diagrammatic view of a transmission line having a compressor circuit and an expander circuit therein controlled in accordance with the invention;

Fig. 4 is a diagrammatic view of a modified controlled circuit;

Fig. 5 is a curve showing the relation of the input voltage to the output voltage in the circuit shown in Fig. 4; and

Fig. 6 is a diagrammatic view of an echo suppressor circuit controlled in accordance with the invention.

Referring to Fig. 1 of the drawings, an amplifier circuit is shown comprising space discharge devices 1, 2 and 3. The device 1 comprises a grid 4, a cathode 5 and an anode 6. The device 2 comprises a grid 7, a cathode 8 and an anode 9. The device 3 comprises the grid 10, cathode 11 and an anode 12. The input circuit of the device 1 is connected by a transformer 13 to input conductors 14. The output circuit of the device 1 is connected to the input circuit of the device 2 by a transformer 15 of relatively high impedance. The output circuit of the device 2 is connected to the input circuit of the device 3 by means of transformer 16 of relatively high impedance, and the output circuit of the device 3 is connected by transformer 17 to the output conductors 18. Grid biasing batteries 19, 20 and 21 are provided for the devices 1, 2 and 3, and batteries 22, 23 and 24 are connected to the anodes of the devices 1, 2 and 3.

An element 25 which is composed of silicon carbide crystals and a binder material is connected across the input circuit of the device 2. A similar element 26 composed of silicon carbide crystals and a binder material is connected in series with the resistance element 27 across the input circuit of the device 3. The elements 25 and 26, respectively connected to the input circuits of the devices 2 and 3, have a resistance characteristic which falls upon increase of potential in the circuit. The characteristics of these elements are disclosed in the above mentioned patent to K. B. McEachron, No. 1,822,742, September 8, 1931. The elements 25 and 26 connected across the input circuits of the space discharge devices 2 and 3 serve to effect operation of the devices as distorting amplifiers. An amplifier having an element of the type above mentioned connected across the input circuit thereof will have an output voltage proportional to the logarithm of the input voltage. A control circuit having an amplifier that will produce a voltage in the output circuit proportional to the logarithm of the input voltage is useful for controlling compressor and expander circuits in a transmission line, for controlling echo suppressor circuits and for controlling gain indicating devices.

In Fig. 2 of the drawings is shown a curve indicating the relation of the input to the output of an amplifier device having an element of silicon carbide crystals and a binder material connected across the input circuit. The curve in Fig. 2 has been drawn for the control circuit shown in Fig. 1 of the drawings. The abscissae of the curve represents the input to the circuit in decibels. The ordinates of the curve represent voltage output from the circuit. Two distorting amplifier devices are shown in the circuit of Fig. 1 in order to extend the range of the circuit.

Referring to Fig. 3 of the drawings, a so-called compandor circuit is shown for compressing the range of signals before transmission over a line and then for expanding the signals to their original range at the receiving end of the line. The

compressor 28 shown in Fig. 3 comprises two space discharge devices 29 and 30 of the variable μ type connected to the line in push-pull relationship and a forward acting control circuit 31 for controlling the devices 29 and 30. It is to be understood that the control circuit 31 may be backward acting if so desired and that a forward acting control circuit is only shown to illustrate the invention. An expander 32 at the receiving end of the line comprises two space discharge devices 33 and 34 of the variable μ type connected to the line in push-pull relationship, and a forward acting control circuit 35 for governing the devices 33 and 34. The control circuit 35 may be backward acting if so desired. The input circuit of the devices 29 and 30 in the compressor are connected to input conductors 35a and 36a by means of a transformer 37. The output circuits of the devices 29 and 30 are connected by a transformer 37a to line conductors 38 and 39. The conductors 38 and 39 are connected to the input circuits of the devices 33 and 34 in the expander 32 by means of a transformer 40. The output circuits of the devices 33 and 34 are connected by transformer 41 to the output conductors 42 and 43.

The control circuit 31 supplies a variable negative bias to the control grids of the devices 29 and 30 for compressing the signals received over the conductors 36 and 35 so that the volume of the signals beyond the devices 29 and 30 is compressed with respect to the signal volume before the devices 29 and 30 according to a fixed ratio. The circuit 31 comprises a three-element amplifier tube 44, a three-element amplifier tube 45, a three-element amplifier tube 46, and a thermionic rectifier 47. The amplifier tubes 45 and 46 respectively have elements 48 and 49 composed of silicon carbide crystals and a binder material connected across their input circuits. The distorting elements 48 and 49 control the amplifier tubes 45 and 46 so that the output voltage supplied to the rectifier 47 is proportional to a logarithm of the voltage received from the supply conductors 35 and 36. The input circuit of the amplifier 44 is coupled to the conductors 36 and 35 by means of a transformer 50. The output circuit of the tube 44 is coupled to the input circuit of tube 45 by means of transformer 51 of relatively high impedance. The output circuit of the tube 45 is coupled to the input circuit of the tube 46 by means of transformer 52 of relatively high impedance. The output circuit of the tube 46 is coupled to the rectifier 47 by means of a transformer 53. The rectifier 47 is connected in series not only with the secondary winding of the transformer 53 but also in series with the battery 54 and a potentiometer 55. A connection is effected from the potentiometer 55 to the midpoint of the secondary winding of the transformer 37 for supplying a variable negative bias to the control grids of the devices 29 and 30. The devices 29 and 30 are of the variable μ type so that the gain in decibels varies linearly with the grid bias on the devices. The combination of the variable μ devices 29 and 30 with the control circuit 31 having a distorting amplifier of the above described type insures a compression ratio by the compressor directly under control of the potentiometer 55.

A grounded battery 56 is connected to the potentiometer 55 for impressing a relatively low fixed negative bias on the control grids of the devices 29 and 30. A condenser 57 is connected across the potentiometer 55 for smoothing out the ripples in the rectified current. The ratio between the range of signal volume supplied to the input circuits of the devices 29 and 30 to the range of signal volume in the output circuits of the devices 29 and 30 may be varied by changing the position of the connection of the control grids for the devices 29 and 30 to the potentiometer 55. Space current for the devices 29 and 30 is supplied by the battery 58. Space currents for the tubes 44, 45 and 46 are respectively supplied by the batteries 59, 60 and 61.

The control circuit 35 employed in the expander 32 at the receiving end of the line is similar in construction to the control circuit 31 employed in the compressor at the transmitting end of the line except that a variable positive bias is supplied to the grids of the devices 33 and 34 in place of a variable negative bias as is supplied by the control circuit 31 to the grids of the devices 29 and 30. The control circuit 35 comprises amplifier tubes 62, 63 and 64 which are similar to the amplifier tubes 44, 45 and 46 in the circuit 31. The amplifier tubes 63 and 64 have elements 65 and 66 composed of silicon carbide crystals and a binder material connected across their input circuits. The output circuit of the amplifier tube 64 is connected to a rectifier 67. In circuit with the rectifier 67 is a battery 68 and a potentiometer 69. A condenser 70 is connected across the potentiometer 69 for smoothing out ripples in the rectifier current. The rectifier 67 is so connected to the grids of the devices 33 and 34 as to impress a variable positive potential on them. A grounded battery 71 is connected to the potentiometer 69 for impressing a relatively high negative bias on the grids of the devices 33 and 34.

In an expander constructed as above set forth, the range of signal volume beyond the devices 33 and 34 is expanded at a fixed ratio with respect to the range of the signal volume before the devices 33 and 34 so that the range of the signal volume is restored to its original range.

Referring to Figs. 4 and 5 of the drawings, another complementary type of distorting amplifier is disclosed. The circuit shown in Fig. 4 comprises two space discharge amplifiers 72, 73. Only two amplifier stages are shown in the circuit but it is to be understood that other stages may be provided if so desired. The output circuit of the amplifier 72 is connected by transformers 74 and 75 to the input circuit of the amplifier device 73. Transformers 76, 77 are provided for connecting the output circuit of the amplifier device 73 to the output conductors 78, 79. Between the transformers 74 and 75 is connected an element 80 composed of silicon carbide crystals and a binder material. A similar element 81 is shown connected between the transformers 76 and 77. An element connected in series with the input circuit of an amplifier device as shown in Fig. 4 of the drawings, serves to vary the output voltage of the amplifier proportionally to the logarithm of the input voltage. This relation is shown by the curve in Fig. 5 of the drawings. The abscissae represent input volts and the ordinates represent output in decibels. In the circuit shown in Fig. 4, the same as in the circuit shown in Fig. 1, it will be noted that the resistance value of the elements composed of silicon carbide crystals and a binder material is controlled by the signals themselves and not by an auxiliary current.

Referring to Fig. 6 of the drawings, a proportional losser echo suppressor is shown employing a logarithmic compressor. A proportional losser

echo suppressor operates to insert a loss in an echo path which is proportional to the amplitudes of the received speech syllables. In Fig. 6 of the drawings, two space discharge devices 110 and 111 of the variable μ type and in the form of a balanced repeater, are inserted in the transmitting channel comprising conductors 82 and 83. The control grids 84 and 85 of the devices 110 and 111 have a variable negative bias impressed on them under control of a compressor circuit 86. The compressor circuit 86 is connected to the receiving path conductors 87 and 88.

The compressor circuit 86 comprises an amplifier tube 89 which is connected to the conductors 87 and 88 by a transformer 90, a logarithmic amplifier tube 91 having the input circuit thereof connected to the output circuit of the tube 89 by means of a transformer 92 of relatively high impedance and two rectifier tubes 93 and 94 which are connected to the output circuit of the logarithmic amplifier tube 91 by means of a transformer 95. An element 96 composed of silicon carbide crystals and a binder material is connected across the input circuit of the logarithmic amplifier tube 91. A distorting amplifier tube is thus produced which has a voltage output proportional to a logarithm of the voltage input. This amplifier tube 91 is similar to the amplifier tubes 2 and 3 shown in Fig. 1 of the drawings.

When speech currents are on the receiving channel comprising the conductors 87 and 88, a portion of such currents are amplified by the tube 89 distorted by the logarithmic amplifier 91 and rectified by the devices 93 and 94 for impressing negative bias on the grids 84 and 85 of the devices 110 and 111. The loss of the devices 110 and 111 is raised to prevent an echo. An auxiliary circuit 97 is provided for maintaining the bias on the grids 84 and 85 for a predetermined length of time in order to prevent an echo after the speech currents on the receiving channel have ceased to flow.

The auxiliary circuit 97 comprises a gas-filled detector tube 98 having the input circuit thereof connected by a transformer 99 to the output circuit of the distorting amplifier tube 91. The output circuit of the gas-filled tube 98 is connected to an operating coil 100 for a polarized relay 101. Relay 101 is polarized by means of a battery 102 which is connected to a polarizing coil 103. The battery 102 also supplies plate potential to the gas-filled tube 98. A condenser 104 and a resistance element 105 are connected across the output circuit of the gas-filled tube 98 for effecting a hangover in the operation of the relay 101.

Normally, when the gas-filled tube 98 is not broken down, the condenser 104 is charged by a circuit from the battery 102 including the coil 100 of the relay 101. When the gas-filled tube 98 is broken down by speech currents on the receiving channel comprising a low resistance path through the tube is provided for discharging the condenser 104. At the same time the coil 100 of the relay 101 will be energized. However, if the tube 98 is extinguished, the relay 101 will not be immediately released because a hangover period will prevent any release of the relay 101 for a predetermined period. The hangover period is the time required to charge the condenser 104.

A condenser 105 is connected across the circuit between the rectifiers 93 and 94 and the grids 84 and 85 of the devices 110 and 111. This condenser 105 retains a charge for maintaining a negative bias on the grids 84 and 85. The armature 106 of the relay 101 completes a circuit through a resistance element 107 for discharging the condenser 105 when the relay is in released position. The hangover in the operation of the relay 101 insures any discharge of the condenser 105 until a predetermined period after the voice currents have ceased to flow on the receiving channel comprising conductors 87 and 88. A similar circuit to that shown in Fig. 6 of the drawings may be provided for controlling the receiving channel from the transmitting channel.

The 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. In a control system, an amplifier comprising a space discharge device having input and output circuits and operating with a linear characteristic, a coupling transformer having the secondary winding thereof connected to said input circuit, and means comprising a distorting element free from bias and connected across said secondary winding to obtain an instantaneous voltage output from the device which is approximately the cube root of the voltage input to the device and proportional to the logarithm of the instantaneous voltage input to the device over an extended range.

2. In a signal system, an amplifier comprising a space discharge device having input and output circuits and operating with a linear characteristic, and distorting means comprising an element free from bias and composed of silicon carbide crystals and a binder material connected across the input circuit of said device, the resistance value of said element being varied directly by the signal currents supplied to the device to obtain an instantaneous output from the device which is proportional to the logarithm of the instantaneous voltage input to the device.

3. In a control system, an amplifier comprising a space discharge device having input and output circuits and operating with a linear characteristic, and distorting means comprising an element free from bias and composed of silicon carbide crystals and a binder material connected across the input circuit of said device to obtain an instantaneous voltage output from the device which is proportioned to the logarithm of the instantaneous voltage input to the device.

4. In a control system, an amplifier comprising a plurality of tandem connected space discharge devices each having input and output circuits and each operating with a linear characteristic, and distorting means comprising an element free from bias and composed of silicon carbide crystals and a binder material connected across the input circuit of each of said devices to obtain an instantaneous voltage output from the amplifier which is proportional to the logarithm of the instantaneous voltage input to the amplifier.

5. In a signal control system, an amplifier comprising a plurality of space discharge devices each having input and output circuits and each operating with a linear characteristic, a transformer coupled to the input circuit of each device, and a distorting element comprising an element composed of silicon carbide crystals and a binder material connected to the input circuit of each device for effecting a characteristic distorted output from the device and an output from said amplifier which is proportional to the logarithm of the input to the amplifier over an extended range, the resistance value of each dis-

torting element being varied directly by the signal currents supplied to the device.

6. In a signal control system, an amplifier comprising a space discharge device having input and output circuits and operating with a linear characteristic, coupling means connected to said input circuit and distorting means free from bias, connected across said coupling means and comprising an element composed of silicon carbide crystals and a binder material, the resistance value of said distorting element being varied directly by the signal currents supplied to the device to obtain an instantaneous voltage output from the device which is proportional to the logarithm of the instantaneous voltage input to the device.

7. In a volume compressor, a line having a space discharge device effectively connected in series therewith, and means controlled by the signals on said line for varying the grid bias on said device to obtain a compression of the signal volume beyond the device with respect to the signal volume before the device according to a fixed ratio, said means comprising a space discharge amplifier having an element composed of silicon carbide crystals and a binder material connected across the input circuit of the amplifier and a rectifier for rectifying the potential from the amplifier supplied to the grid of said device.

8. In a volume compressor, a line having a space discharge device effectively connected in series therewith, and means comprising an amplifier connected to the line for impressing a variable potential of fixed polarity on the grid of said device to obtain a compression of the volume of the signals beyond said device with respect to the volume of the signals before said device according to a fixed ratio, said amplifier having an instantaneous voltage output which is proportional to the logarithm of the instantaneous voltage input thereto.

9. In a volume compressor, a line, space discharge devices in push-pull relation connected in series with said line, and means comprising a control circuit connected to the line for impressing a variable bias of one polarity on the devices to compress the signal volume beyond the devices with respect to the signal volume before the devices according to a fixed ratio, said control circuit having an amplifier with a distorting element connected across the input circuit thereof to obtain an output voltage from the amplifier which is proportional to the logarithm of the voltage input to the amplifier.

10. In a volume compressor, a line having a space discharge device connected in series therewith, means for impressing a relatively low negative bias on the grid of said device and control means comprising an amplifier connected to the line for impressing a variable negative bias on the grid of said device to obtain a compression of the volume beyond said device which is a fixed fraction of the volume before the device, said amplifier having a voltage output which is proportional to the logarithm of the voltage input thereto.

11. In a volume compressor, a line having a control space discharge device connected in series therewith, said device having a control grid, and means for impressing a variable negative bias on said grid to obtain a compression of the signal volume beyond the device with respect to the volume of the signals on the line before the device according to a fixed ratio, said means comprising a space discharge device having an input circuit connected to the line, an element composed of silicon carbide crystals and a binder material connected across the input circuit of said second mentioned device to obtain an output voltage from the second mentioned device which is proportional to the logarithm of the voltage input thereto, a rectifier and a potentiometer connected to the output circuit of said second mentioned device and a connection from the potentiometer to the grid of said control device.

12. In combination, a line having a control space discharge device effectively connected in series therewith, said device having a control grid, a cathode and an anode, and control means connected to said line ahead of said device for controlling the bias impressed on the grid of the device, said means comprising a distorting space discharge device having a distorting element connected across the input circuit of the distorting device to obtain a voltage output from the distorting device which is proportional to the logarithm of the voltage input to the distorting device, a rectifier coupled to the output circuit of said distorting device, and means comprising a potentiometer in circuit with said rectifier for controlling the grid bias on said first mentioned device to compress the signal volume beyond the control device with respect to the signal volume before the control device according to a fixed ratio.

13. In a volume expander, a line having a space discharge device connected in series therewith, and means comprising an amplifier connected to the line for impressing a positive potential on the grid of said device to obtain an expansion of the volume of the signal beyond said device with respect to the signal volume before said device according to a fixed ratio, said amplifier having a voltage output which is proportional to the logarithm of the voltage input thereto.

14. In a volume expander, a line having a space discharge device connected in series therewith, and means for impressing a variable positive potential on the grid of said device to obtain an expansion of the signal volume beyond said device with respect to the signal volume before the device according to a fixed ratio, said means comprising a space discharge amplifier having an element composed of silicon carbide crystals and a binder material connected across the input circuit of the amplifier.

15. In a volume expander, a line having a space discharge device connected in series therewith, means for impressing a relatively high negative bias on the grid of said device, and control means comprising an amplifier connected to the line for impressing a variable positive potential on the grid of said device to obtain an expansion of the signal volume beyond said device with respect to the signal volume before the device according to a fixed ratio, said amplifier having a voltage output which is proportional to the logarithm of the voltage input thereto.

16. In a volume compressor and expander, a line having a space discharge device connected in series therewith at the transmitting end, control means comprising an amplifier connected to the line for impressing a variable negative bias on the grid of said device to obtain a compression of the signal volume beyond the device with respect to the signal volume before the device according to a fixed ratio, said amplifier having a voltage output which is proportional to the logarithm of the voltage input thereto, a second space discharge device connected in series therewith at

the receiving end thereof, and expander control means comprising an amplifier connected to the line for impressing a variable positive potential on the grid of said second device to expand the signal volume before the first device, said second amplifier having a voltage output which is proportional to the logarithm of the voltage input thereto.

17. In a volume compressor and expander, a line having a space discharge device connected in series therewith at the transmitting end, means for impressing a relatively low negative bias on the grid of said device, control means comprising an amplifier connected to the line for impressing a variable negative potential on the grid of said device to obtain a compression of the signal volume beyond said device with respect to the signal volume before the device according to a fixed ratio, said amplifier having a voltage output which is proportional to the logarithm of the voltage input thereto, a second space discharge device connected in series therewith at the receiving end thereof, means for impressing a relatively high negative bias on the grid of said second device, and expander control means comprising an amplifier connected to the line for impressing a variable positive potential on the grid of said second device to obtain an expansion of the signal volume beyond the second device to the original signal volume before the first device, said second amplifier having a voltage output which is proportional to the logarithm of the voltage input thereto.

18. In a volume controller, a line, a space discharge device effectively connected in series with said line, and a control circuit connected to said line for impressing a variable potential of fixed polarity on the grid of said device to obtain variation of the signal volume beyond said device with respect to the volume of the signals before said device according to a fixed ratio, said control circuit comprising an amplifier having a voltage output which is proportional to a logarithm of the voltage input thereto, a rectifier connected to said amplifier, and a potentiometer connected to said rectifier and adjustable to vary the fixed ratio of the input volume with respect to the output volume of said device.

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