Oct. 17, 1933. S. DOBA, JR 1,931,063

SIGNAL TRANSMISSION SYSTEM

Filed Jan. 28, 1932 2 Sheets-Sheet 1

FIG. 1

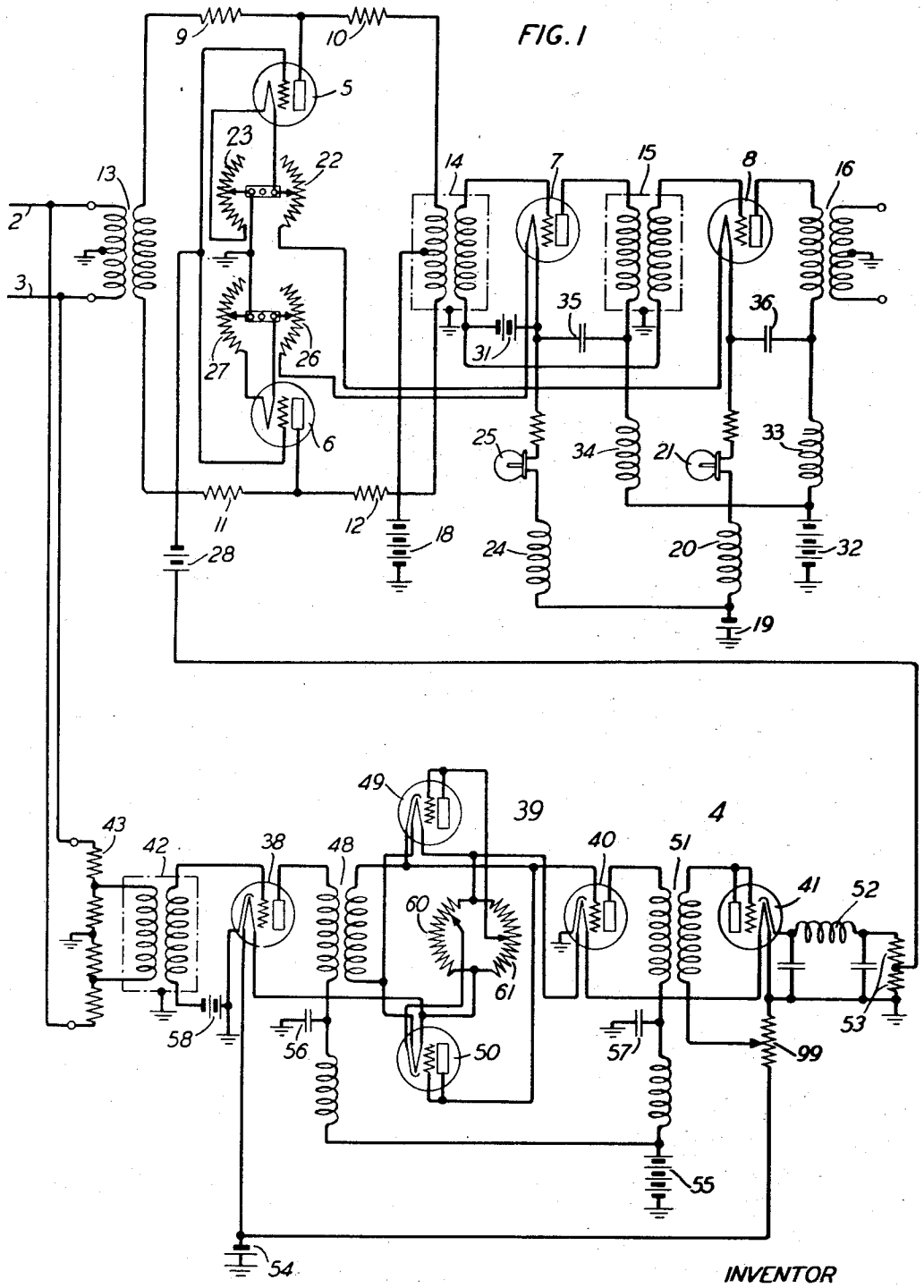

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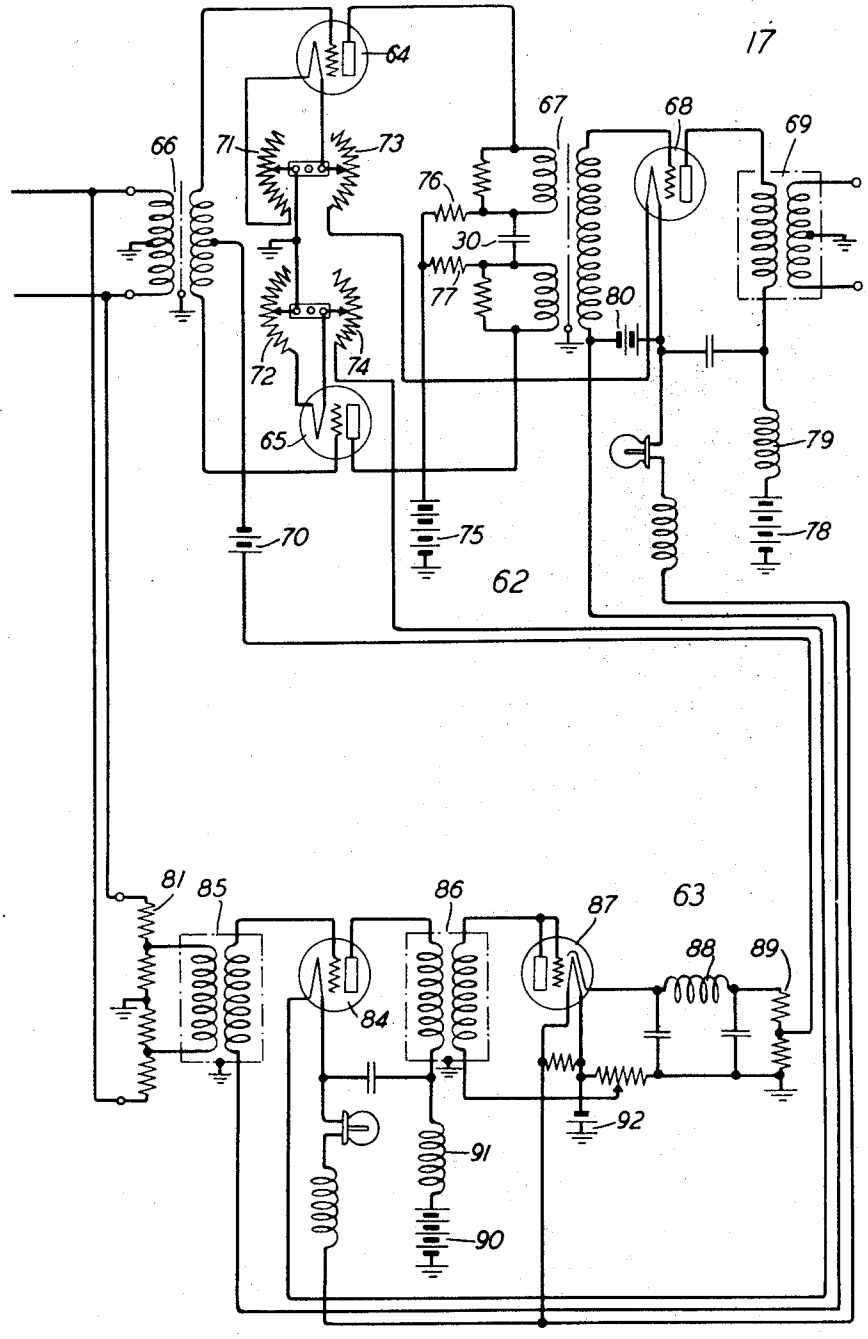
FIG. 2



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SIGNAL TRANSMISSION SYSTEM

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9 Claims. (Cl. 178—44)

This invention relates to systems for the transmission of signals and particularly to the control of the volume of the signals.

One object of the invention is to provide a signal transmission system that shall in an improved manner compress the signal waves within a limited range before transmission and expand the signals to the original range after transmission.

Another object of the invention is to provide a system that shall compress the received signals before transmission over a line and expand the transmitted signals to the original volume range, that shall control the compression of the signals by apparatus governed according to a root of the original signals and that shall adjust the operating characteristics of the various parts of the system in a new and improved manner.

A further object of the invention is to provide a system employing space discharge devices symmetrically connected across a transmission line for varying the volume range of the transmitted signals that shall impress a potential bias on the grids of the devices and vary the bias at will to change the characteristics of the devices and that shall impress a potential on the grids of the devices by apparatus varying according to a root of the original volume of the signals.

In signal systems for the transmission of speech and radio broadcast programs, it is often desirable to transmit signals having an extremely wide volume range. However, signal systems are limited as to the range of volume which can be satisfactorily transmitted. Satisfactory transmission of signals has an upper limit to avoid distortion overloading line apparatus such as repeaters and interference with other circuits and has a lower limit by interference from line noises.

The present invention discloses a system wherein the volume range 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 the line and restoring the signal waves to the original shape at the receiving end of the line. The invention is an improvement over the system disclosed in the N. C. Norman application, Serial No. 511,504 filed January 27, 1931 and employs a rooter device of the type disclosed in the patent to G. Crisson, No. 1,737,830, dated December 3, 1929.

The signals in a system constructed in accordance with the present invention are compressed by a variable gain amplifier in which the gain is a function of the input volume. If G is the gain in *db* units V_1 the input volume in *db* units and V_0 some arbitrary reference level, it is desired in the present system to have

$$G=1/2(V_0-V_1),$$

V_0, the arbitrary reference level, usually the maximum input volume, may be given a value of zero. If the reference level is given a value of zero then

$$G=-1/2V_1, \quad (1)$$

The output volume V_2 from the compressor or variable gain amplifier is obtained from the above equations.

$$V_2=V_1+G=1/2V_1. \quad (2)$$

The compressor at the transmitting end of the transmission line is designed and adjusted to change the input volume for transmission over the line according to the above equations. The compressor essentially consists of two parts, a variable repeater and a control circuit. The variable repeater comprises two gain control space discharge devices connected across the line and two amplifier space discharge devices in the line beyond the gain control devices. The gain control space discharge devices are connected across the line symmetrically between impedance elements with the direct plate circuit of each device including one of said impedance elements and a portion of a winding of a transformer in the line beyond the gain control space discharge devices.

The relation between the plate current of each gain control device and the gain may be determined to satisfy the above equations. In all cases, the minimum value of plate current has been taken as about 0.04 mils. The corresponding relation between the gain and the grid bias for each of the gain control devices may also be determined to satisfy the above equations. From a curve plotted between grid bias and gain for each of the gain control devices, the following typical empirical equation may be derived.

$$G=20\left[1-\log_{10}\left(\frac{E_g+E_0}{E_0}\right)^N\right]. \quad (3)$$

A constant bias E_0 volts is assumed to be acting at all times on the grids of the gain control devices, since the gain is limited to some finite value. The effective grid bias on the gain control devices will always be the actual grid bias E_g used in the above equation and supplied by the control circuit plus the constant grid bias of E_0 volts.

In order to satisfy Equations (1) and (3) set forth above, the following relation is obtained:

$$20N \log\left(\frac{E_0+E_0}{E_0}\right)=20+1/2V_1$$

If

$$V_1=20 \log\left(\frac{e_1}{e_0}\right)$$

where e_1 is the input voltage and e_0 is the maximum input, then

$$\frac{E_0+E_0}{E_0}=10^{1/N}\left(\frac{e_1}{e_0}\right)^{1/2N}. \quad (4)$$

The relationship expressed in Equation (4) must be satisfied by the control circuit which governs the grid bias on the gain control devices. The amount of rooting required by the rooter in the control circuit is indicated by the exponent 1/2N in the above Equation (4).

The control circuit which may also be called the rooter circuit employs a rooter of the type disclosed in the patent to G. Crisson, No. 1,737,830 and the application of N. C. Norman, Serial No. 511,504. The rooter circuit is connected to the transmission line ahead of the gain control devices and comprises a linear amplifier stage, a rooter or distorting device, an amplifier and a linear rectifier. The control or rooter circuit controls the grid bias on the gain control devices to effect a gain variation of minus one-half the volume variation at the input to the gain control devices as set forth in Equation (1).

In the rooter circuit, the rooting action may be controlled by two factors, the impedance of the source of electromotive force and the initial bias on the rooter tubes. By experiments it is found that the rooting action may be varied by two methods. The impedance of the amplifier preceding the rooter tubes may be varied to produce wide or coarse adjustments and the initial currents of the rooter tubes may be controlled to effect small or fine adjustments.

The expander at the receiving end of the line is also in the form of a variable gain amplifier. The expander at the receiving end of the line should be complementary to the compressor at the transmitting end of the line so that the output volume V_3 of the expander is equivalent to the input volume of the compressor for all values of input over the working range.

$$V_3=V_1$$

Hence, if the input volume of the expander is the same as the output volume V_2 of the compressor, the expander output volume is

$$V_3=V_2+G_2$$

where G_2 is the gain of the expander,

From Equation (2)

$$V_1=2V_2$$

therefore

$$V_3=V_2+G_2=2V_2$$

or

$$G_2=V_2.$$

The above relation in the expander may be realized by employing a linear rectifier in a control circuit for the variable repeater and by proper design of the variable repeater.

The expander comprises a variable gain repeater and a control circuit. The variable gain repeater comprises two variable gain control devices connected effectively in series with the transmission line and an amplifier. The control circuit comprises an amplifier tube and a rectifier tube.

In the present system wherein the compressor reduces the volume output therefrom so that the gain variation is minus one-half the volume variation at the input, under the control of a rooter circuit, it is necessary to effect very fine adjustment of the rooter and the variable gain devices. A very fine adjustment of the rooting action is obtained by varying the bias across the rooter tubes. A fine adjustment of the gain control devices in the compressor is effected by varying the grid bias obtained from the filament heating circuit for such devices. The gain control devices may also be adjusted by varying the resistance in the direct current plate circuit.

In the accompanying drawings Figure 1 is a diagrammatic view of the compressor for reducing the volume range of the transmitted signals.

Fig. 2 is a diagrammatic view of the expander for restoring the transmitted signals to the original volume range.

Referring to Fig. 1 of the drawings a variable repeater 1 connected in a transmission line comprising conductors 2 and 3 is controlled by a rooter circuit 4 to reduce the volume range of the signals so that the gain variation is minus one-half the volume variation at the input to the compressor. The variable repeater 1 comprises two sets of gain control discharge devices 5 and 6, an amplifier 7 and a second amplifier 8. The gain control devices 5 and 6 are in the form of three-element space discharge tubes and are symmetrically connected to the line conductors between impedance elements 9, 10, 11 and 12. The impedance elements 9 to 12, inclusive, are connected in the line between two transformers 13 and 14. The amplifier 7 is in the form of a three-element space discharge device having its input circuit connected to the transformer 14 and its output circuit connected to the amplifier 8 by means of a transformer 15. The output circuit of the amplifier 8 is connected by a transformer 16 and the line conductors to the expander 17 at the receiving end of the transmission line.

The gain control devices 5 and 6 are connected across the line conductors so that the volume of the transmitted signals is controlled according to the impedances of the devices 5 and 6. The direct current plate circuits for the devices 5 and 6 extend from a grounded battery 18 through opposite halves of the primary of the transformer 14 and the resistance elements 10 and 12. The including of the resistance elements 10 and 12 in the direct current plate circuit of the gain control devices 5 and 6 renders it possible to control characteristics of the gain control devices by varying the impedance elements 10 and 12. A coarse or rough adjustment of the devices 5 and 6 is effected by varying the resistance elements 10 and 12. The heating circuit for the filaments of the gain control device 5 and the amplifier 8 extends from a grounded battery 19 through a reactance 20, ballast lamp 21, filament of the amplifier tube 8, resistance element 22, filament of the device 5 and a resistance element 23 to ground. The heating circuit for the filaments of the gain control device 6 and the amplifier 7 extends from the battery 19 through reactance 24, ballast lamp 25, filament of the amplifier tube 7, resistance element 26, filament of the gain control device 6 and the resistance element 27 to ground.

The resistance elements 23 and 27 in the filament heating circuits for the devices 5 and 6 serve to provide potential drop for impressing a potential bias on the grids of the gain control devices 5 and 6. A fine adjustment of the devices 5 and 6 is effected by varying the resistance elements 23 and 27. A battery 28 normally impresses a biasing potential on the grids of the devices 5 and 6 and the adjustable resistance elements 23 and 27 serve as means to adjust the potential on the grids in accordance with operating conditions. The resistance elements 23 and 27 may be adjusted to compensate for variations in the voltage of the batteries 28, 18 and 19 and may be varied to adjust the characteristics of the gain control devices to agree with the operation of the rooter circuit to be described. The resistance elements 22 and 26 are complementary to the resistance elements 23 and 27 and are varied in accordance with the variation of resistance elements 23 and 27 so that there will be no variation in the heating current when any adjustment is made in the grid bias of devices 5 and 6.

A battery 31 is provided for impressing a biasing potential on the grids of the two amplifier tubes 7 and 8. A battery 32 supplies plate potential through the choke coils 33 and 34, for the amplifier tubes 7 and 8. The condensers 35 and 36 serve as by-pass condensers.

The control or rooter circuit 4 impresses a variable potential on the grids of the gain control devices 5 and 6 in order to vary the gain of the devices so that the transmitted signals have a volume range of one-half the volume of the signals as received. The rooter circuit comprises an amplifier 38, a rooter 39, an amplifier 40 and a rectifier 41. The amplifier 38 is a space discharge tube of the four-element type having the input circuit thereof connected by a transformer 42 to a potentiometer 43. The potentiometer 43 is connected across the line conductors 2 and 3 before the transformer 13. The output circuit of amplifier 38 is connected by a transformer 48 to the rooter 39. The rooter 39 comprises two four-element space discharge tubes 49 and 50 having the grids and plates of each tube directly connected together. The rooter 39 is directly connected to the amplifier 40 which is in the form of a four-element space discharge device. The output circuit of the space discharge device 40 is connected by a transformer 51 to the rectifier 41 which is in the form of a four-element space discharge tube having the plate and grid thereof connected together. The rectifier 41 is connected through a filter 52 to grounded resistance elements 53. Grid bias from the resistance element 99 for the tube 41 prevents any variations in grid bias on the devices 5 and 6 when the input volume falls below a predetermined level. The potential drop across a portion of the resistance elements 53 is the potential impressed on the grids of the gain control devices 5 and 6 for controlling the operation of the compressor. The filter 52 serves to smooth out ripples in the potential supplied by the rectifier 41 to the grids of the gain control devices 5 and 6.

The heating elements of the amplifier tubes 38 and 40, the rooter tubes 49 and 50 and the rectifier tube 41 are supplied with current from a grounded battery 54. Plate potential for the amplifier tubes 38 and 40 is supplied by a grounded battery 55, suitable by-pass condensers 56 and 57 being connected to the plate circuits of the amplifiers. A battery 58 is provided for impressing a biasing potential on the grid of the amplifier tube 38.

Resistance elements 60 and 61 are provided for adjusting the biasing potential across the rooter tubes 50 and 49. It will be noted that the resistance elements 60 and 61 are connected across the heating elements for the rooter tubes and that the circuits completed through the rooter tubes include the heating elements. The adjustable resistance elements 60 and 61 permit a very fine adjustment of the rooting action. The rooter tubes have been described in detail in the Crisson Patent 1,737,830 dated December 3, 1929 and a detailed description here is deemed unnecessary.

The expander 17 at the receiving end of the transmission line comprises a variable repeater 62 and a control circuit 63. The expander serves to restore the volume range of the received signals to their original range before they were acted on by the compressor. As set forth before the gain effected by the variable repeater of the expander will be equal to the output volume of the compressor at the transmitting end of the line.

The variable repeater comprises two gain control devices 64 and 65 in the form of three-element space discharge tubes. The tubes 64 and 65 are effectively connected in series with the transmission line, the input circuits of the tubes 64 and 65 being connected to a transformer 66 in the line and the output circuits of the tubes 64 and 65 being connected by a transformer 67 to an amplifier 68 in the form of a three-element space discharge device. The output circuit of the amplifier tube 68 is connected to the transformer 69.

Grid bias for the gain control devices 64 and 65 is supplied by a battery 70 and by the drop across resistance elements 71 and 72 included in the heating circuit for the filaments of the tubes 64 and 65. Resistance elements 73 and 74 are complementary to the resistance elements 71 and 72 and are included in the heating circuit for the filaments of the gain control devices. The resistance elements 73 and 74 are varied in accordance with the variation of the resistance elements 71 and 72 so as to insure against any variation in the heating current supplied to the filaments of the gain control devices. Plate potential for the gain control devices 64 and 65 is supplied by a grounded battery 75 through resistance elements 76 and 77 and the primary winding of the transformer 67. Condenser 30 acts as an A. C. by-pass across resistance elements 76 and 77. Plate potential for the amplifier tube 68 is supplied from a ground battery 78 through a choke coil 79. A battery 80 is provided for biasing the grid of the amplifier tube 68. The resistance elements 76 and 77 may be adjusted to effect a coarse adjustment of the gain by the devices 64 and 65.

The control circuit 63 which governs the potential on the grids of the gain control devices 64 and 65 comprises a potentiometer 81 connected across the transmission line ahead of the transformer 66. An amplifier 84 in the form of a three-element space discharge tube has its input circuit connected by a transformer 85 across a portion of the potentiometer 81. The output circuit of the amplifier 84 is connected by transformer 86 to a rectifier 87. The rectifier 87 is connected to a filter 88 and a potentiometer 89. Part of the potential drop across the potential 89 is supplied to the grids of the gain control devices 64 and 65. The rectifier 87 is in the form

of a four-element space discharge device having the grid and plate connected together. The amplifier tube 84 is supplied with plate potential from a battery 90 through a choke coil 91. A battery 92 is provided for supplying current to the heating element of the rectifier 87 and for supplying filament current to the amplifier 84, amplifier 68 and the filaments of the gain control devices 64 and 65. The battery 80 which supplies grid bias to the amplifier tube 68 also supplies grid biasing potential to the tube 84.

In a system constructed as heretofore described the volume range of signals is reduced by the compressor due to the fact that the gain variation produced by the compressor is minus one-half the volume variation of the input to the compressor. The control of the compressor is effected by a rooter of the type disclosed in the above mentioned Crisson patent. In order to effect operation of the compressor so as to effect compression of the signals in a fixed relation or in accordance with the fixed equation it is necessary to effect accurate adjustment of the rooting operation as well as the operation of the gain control devices. Means was disclosed whereby the operation of the rooting or the controlling circuit and the operation of the variable repeater may be adjusted quickly, and with precision. Furthermore, the variable gain of control devices in the compressor and in the expander are symmetrically connected to the line so as not to needlessly interfere with the transmission of signals.

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

What is claimed is:

1. In a signal system, a transmission channel, impedance elements symmetrically placed in opposite sides of the transmitting channel, two three-element space discharge devices connected across the transmitting channel between said impedance elements to shunt the signal current according to the impedances of the tubes, the path of the direct plate current for said devices including a portion of said channel, a heating circuit for the filaments of said devices having an adjustable grid biasing resistance therein, means for adjusting the drop across said resistances impressed on the grids of said devices to vary the constant bias on said grid, and means for automatically varying the potential on the grids of said devices according to a root of the volume of the signals supplied to the transmission channel.

2. In a signal system, a transmission channel, impedance elements symmetrically placed in opposite sides of the transmission channel, a transformer connected in the transmission channel beyond the impedance elements, two three-element space discharge devices connected across the transmission channel between said impedance elements with the direct plate current path of each of the devices including one of said impedance elements and a portion of one winding of said transformer, means for impressing a bias on the grids of said devices from the filament heating circuit of said tubes and for varying the bias impressed on the grids of the devices without varying the heating of the filaments, and means for automatically varying the potential on the grids of said devices according to a root of the volume of the signals supplied to the transmission channel.

3. In a signal system, a transmission channel, impedance elements symmetrically placed in opposite sides of the transmission channel, two three-element space discharge devices connected across the transmitting channel between said impedance elements to shunt the signal current according to the impedances of the tubes, means comprising two space discharge tubes, each having a filament, a heating element and an anode for automatically controlling the grid potentials of said three-element space discharge devices according to a root of the volume of the signals supplied to the transmission channel, means employing the resistance of said heating elements for placing a constant bias across said space discharge tubes, and means for impressing adjustable potentials across said space discharge tubes from the circuit of said heating elements.

4. In a signal system, a transmission line, two three-element space discharge devices connected across the transmitting channel to shunt the signal current and control the volume of the signals according to the impedances of the devices, means comprising two space discharge tubes for automatically controlling the grid potentials of said three-element space discharge devices according to a root of the volume of the signals supplied to the transmission channel, and means for impressing an adjustable potential bias on each of said space discharge tubes.

5. In a signal system, a transmission line, two three-element space discharge devices connected across said line to shunt the transmitted signals and control the volume of the signals according to the impedances of the tubes, means comprising two space discharge tubes for controlling the grid potentials of said three-element space discharge devices according to a root of the volume of the signals supplied to the line, means for impressing an adjustable potential on each of said space discharge tubes for controlling the characteristics thereof, means comprising two three-element expander tubes connected effectively in series with said line at the receiving end thereof, and means for controlling the potential on the grids of said expander tubes according to the volume of the signals received by the expander to control the expander tubes and restore the signals to the original volume.

6. In a signal system, a transmission line, two three-element space discharge devices connected across said line to control the volume of the signals according to the impedances of the tubes, means for controlling the grid potentials of said devices according to a root of the volume of the signals supplied to the line, means comprising two three-element expander tubes connected symmetrically and effectively in series with said line at the receiving end thereof, and means for controlling the potential on the grids of said expander tubes according to the volume of the signals received by the expander to control the expander tubes and restore the signals to the original volume.

7. In a signal system, a transmission line, three-element space discharge devices connected across said line for controlling the volume of the transmitted signals according to the impedances of the devices, means for automatically controlling the grid potentials of said devices according to a root of the volume of the signals supplied to the line, and means comprising expander tubes connected symmetrically and effectively in series with the line at the receiving end thereof for restoring the signals to the original volume.

8. In a signal system, a transmission line, three-element space discharge devices connected across said line for controlling the volume of the transmitted signals according to the impedances of the devices, means for controlling the grid potentials of said devices according to a root of the volume of the signals supplied to the line, means comprising three-element expander tubes connected symmetrically and effectively in series with the line at the receiving end thereof for restoring the signals to the original volume, and means for adjusting the characteristics of said expander tubes by impressing potential on the grids thereof from the filament heating circuit.

9. In a signal system, a transmission line, three-element space discharge devices connected across the line for controlling the volume of the transmitted signals according to the impedances of the devices, means comprising space discharge tubes for controlling the grid potentials of said devices according to a root of the volume of the signals supplied to the line, means for impressing an adjustable potential bias on each of said space discharge tubes for controlling characteristics thereof, and means comprising expander tubes connected symmetrically and effectively in series with the line at the receiving end thereof for restoring the signals to the original volume.

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