Oct. 22, 1935. S. DOBA, JR 2,018,489

SIGNAL TRANSMISSION SYSTEM

Filed Aug. 12, 1932

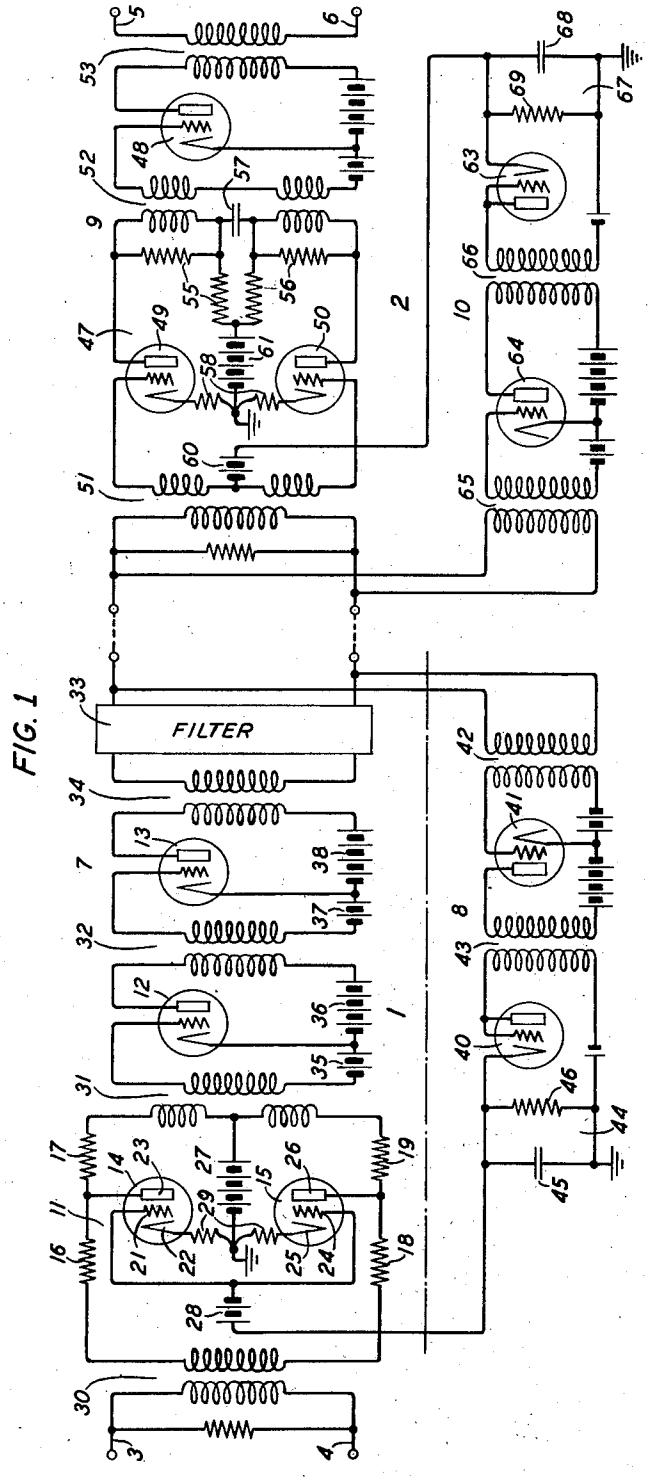

FIG. 1

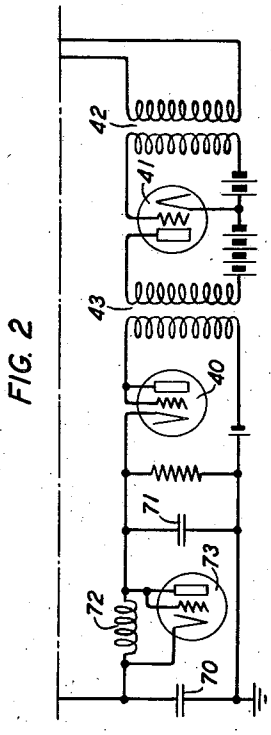

FIG. 2

INVENTOR
S. DOBA JR.
BY
Wayne B Wells
ATTORNEY

Patented Oct. 22, 1935 2,018,489

UNITED STATES PATENT OFFICE

2,018,489

SIGNAL TRANSMISSION SYSTEM

Stephen Doba, Jr., New York, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application August 12, 1932, Serial No. 628,505

20 Claims. (Cl. 178—44)

This invention relates to signal transmission systems and particularly to the control of the volume range of the signals on transmission systems.

One object of the invention is to provide a signal system that shall in an improved manner compress the signals a fraction of the original volume range before transmission over a line and expand the signals at the receiving end of the transmission line to the original volume range.

Another object of the invention is to provide a signal system that shall compress the signals a fraction of the original volume range at the transmitting end of a line under the control of a backward acting circuit and expand the signals to the original volume range at the receiving end of the line.

A further object of the invention is to provide a signal system that shall compress the volume range of signals a fraction of the original volume range before transmission over a line by three-element space discharge devices connected across the line under the control of a backward acting circuit and that shall expand the volume range of the signals to the original range at the receiving end of the line by three-element space discharge devices connected effectively in series with the line under the control of a forward acting circuit.

The signals received for transmission over a line in many instances have a volume range larger than can be efficiently transmitted. Signal systems are 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 interference with other circuits and has a lower limit by reason of 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 S. Doba, Jr. Patent No. 1,931,063, dated October 17, 1933 and the patent to S. Doba No. 1,854,828 dated April 19, 1932.

In the present invention, the compressor for reducing the volume range of the signals a fraction of the original volume range comprises two three-element space discharge devices connected across the transmission line and a backward acting circuit for controlling the grid bias on the devices. The backward acting control circuit includes a linear operating rectifier. The characteristic of the rectifier and the characteristics of the two space discharge devices have a definite relation to compress the volume range of the signals a fraction of the original volume range. The characteristics of the space discharge devices may be adjusted in the manner disclosed in the patent to S. Doba, Jr., No. 1,931,063, dated October 17, 1933. If the control circuit for the compressor impedance devices is backward acting, it is unnecessary to employ rooter devices of the type disclosed in the patent to G. Crisson No. 1,737,830 dated December 3, 1929 to compress the volume range of the signals a half of the original volume range.

The expander at the receiving end of the line for expanding the volume range of the signals to the original volume range is very similar in construction and operation to the expander disclosed in the above mentioned patent to S. Doba, Jr., No. 1,931,063. The impedance means employed by the expander comprises two three-element space discharge tubes which are effectively connected in series with the line. The grid bias on the space discharge tubes is controlled by a forward acting circuit having a linear acting rectifier. The characteristics of the space discharge tubes and the rectifier are adjusted in the manner disclosed in the S. Doba, Jr. Patent No. 1,931,063.

In a compressor of the type employed in this invention a fixed relation is maintained between the characteristics of the space discharge devices comprising the impedance element and the characteristic of the rectifier in the backward acting control circuit for the impedance element. The relation between the characteristics of the impedance element and the rectifier is set forth below.

If the current voltage characteristic of the impedance element is

$$I=KE^{n}$$

then

$$\frac{1}{R_0}=\frac{DI}{DE}$$

the impedance, is

$$R_0=\frac{1}{nKE^{n-1}}$$

E is the potential impressed on the grids of the impedance element and K is a constant.

In a shunt type of variable repeater which is

employed in the compressor, the amplification is directly proportional to the impedance of the variable impedance element.

$$A=\frac{K_1}{nKE^{n-1}}=\frac{K_2}{E^{n-1}} \quad (1)$$

A is the voltage amplification, K_1 and K_2 are constants and the gain in decibels is:

$$G=20\log_{10}A=20\log K_2-(n-1)\,20\log E \quad (2)$$

If E is obtained from a rectifier circuit with a characteristic

$$E=K_3e_0n_1$$

where E is the output voltage of the rectifier circuit and e_0 is the input voltage of the rectifier circuit and the output voltage of the variable repeater, then

$$20\log E=20\log K_3+n_1 20\log e_0$$

$(20\log e_0)$ may be called the output volume V_0 of the variable repeater, hence

$$20\log E=20\log K_3+n_1V_0 \quad (3)$$

Combining Equations (2) and (3)

$$G=20\log K_2-(n-1)\,(20\log K_3+n_1V_0=K_4-(n-1)n_1V_0 \quad (4)$$

The output volume of the variable repeater is the input volume plus the gain or

$$V_0=V_1+G \quad (5)$$

where V_1 is the input volume to the variable repeater in decibels.

Substituting the value of G Equation (4) in Equation (5)

$$V_0=V_1+K_4-(n-1)n_1V_0=\frac{V_1+K_4}{1+(n-1)n_1} \quad (6)$$

The constant K_4 may be arbitrarily given a value of zero in Equation (6) and

$$V_0=\frac{V_1}{1+(n-1)n_1} \quad (7)$$

If the output volume range of the variable repeater is to vary as a fraction F of input volume range,

$$F=\frac{1}{1+(n-1)n_1} \quad (8)$$

The value of n may be varied by the means disclosed in the patent to S. Doba, Jr., No. 1,931,063 or by using more than one stage of impedance elements in tandem. The value of n_1 may be controlled by means of rooter devices or squarer devices as disclosed in the patent to G. Crisson No. 1,737,830 dated December 3, 1929. The amount of rooting or squaring may be controlled by the means disclosed in the above mentioned S. Doba, Jr., Patent No. 1,931,063.

In the present application of the invention, the value of F is assumed to be ½ and the variable impedance element to be adjusted so that n has a value of 2. The value n_1 derived from Equation (8) is 1.

If it were desired to have a value for F of ⅓, when n is equal to 2, then Equation (8) gives a value for n_1 of 2.

In considering the characteristics of the impedance element and the rectifier circuit of the expander at the receiving end of the line it should be noted the rectifier circuit is forward acting and the space discharge tubes of the impedance element are connected effectively in series with the line.

The current-voltage characteristic of the impedance element is the same as in the compressor.

$$I=KE^n$$

The impelance R_0 is:

$$R_0=\frac{1}{nKE^{n-1}}$$

In the expander where the space discharge tubes are connected in series with the line, the amplification is inversely proportional to the impedance of the variable impedance element.

$$A=K_1nKE^{n-1}=K_2E^{n-1} \quad (9)$$

The gain in decibels is:

$$G=20\log A=20\log K_2+(n-1)\,20\log E \quad (10)$$

If E is obtained from a rectifier circuit with a characteristic,

$$E=K_3e_in_1$$

where E is the output voltage of the rectifier circuit and e_i is the input voltage of the rectifier circuit and also the input voltage to the variable impedance element, then

$$20\log E=20\log K_3+n_1 20\log e_i$$

The value $(20\log e_i)$ may be called the input volume V_i to the variable impedance element. Substituting V_i for $20\log e_i$

$$20\log E=20\log K_3+n_1V_i \quad (11)$$

Substituting for 20 log E Equation (11) in Equation (10)

$$G=20\log K_2+(n-1)\,(20\log K_3+n_1V_i)=K_4+(n-1)n_1V_i \quad (12)$$

The output volume from the variable repeater of the expander is the input volume plus the gain.

$$V_0=V_i+G \quad (13)$$

The output volume V_0 is given in decibels.

Substituting the value of G Equation (12) in Equation (13)

$$V_0=V_i+K_4+(n-1)n_1V_i=K_4+V_i[1+(n-1)n_1] \quad (14)$$

The constant K_4 may be arbitrarily given a value of zero in Equation (14)

$$V_0=V_i[1+(n-1)n_1]$$

If the output volume from the variable repeater of the expander varies inversely according to a fraction F

$$1/F=1+(n-1)n_1 \quad (15)$$

The values of n and n_1 may be varied in the same manner as the values of n and n_1 in the compressor. The expander in operation is complementary to the operation of the compressor.

In a compressor having a backward-acting control circuit as employed in the present invention there is no over-accentuation of the initial part of the syllables which start with percussive consonants. In a compressor having a forward-acting control circuit there is a tendency for the compressor and expander in tandem to over-accentuate the initial part of the syllables that start the percussive consonants. The compressors and expander in the present invention have no such tendency by reason of the compressor having a backward-acting control circuit and the expander having a forward-acting control circuit. Signals having identically the same variations in volume range are applied to the two control circuits. The term "signal" when used

in the specification and claim is intended to refer not only to the communication of intelligence but also to the transfer of music and other programs.

In the accompanying drawing,

Fig. 1 is a diagrammatic view of a compressor-expander circuit constructed in accordance with the invention;

Fig. 2 is a diagrammatic view of a modified circuit for controlling the compressor.

Referring to Fig. 1 of the drawing a compressor 1 and an expander 2 are shown connected to a transmission line having input conductors 3 and 4 and output conductors 5 and 6. The compressor 1 comprises a variable repeater 7 under the control of a backward-acting rectifier circuit 8. The expander 2 comprises a variable repeater 9 under the control of a forward-acting rectifier circuit 10.

The variable repeater 7 in the compressor 1 comprises an impedance element 11 and two amplifiers 12 and 13. The amplifiers 12 and 13 are preferably of the pure electron discharge type. The impedance element 11 comprises two three-element space discharge devices 14 and 15 which are symmetrically connected across the line circuit between resistance elements 16, 17, 18 and 19. The resistance elements 17 and 19, serve to effect a rough adjustment of the characteristics of the space discharge devices 14 and 15 in the manner disclosed in the above mentioned patent to S. Doba, Jr., No. 1,931,063.

The device 14 comprises a grid 21, a cathode 22 and a plate 23. The device 15 comprises a grid 24, a cathode 25 and a plate 26. A battery 27 is provided for supplying plate current to the devices 14 and 15 and a battery 28 is provided for supplying negative bias to the grids 21 and 24 of the devices 14 and 15. A variable grid bias for the devices 14 and 15 is supplied by the control or rectifier circuit 8. Resistance elements 29 are provided in the grid-filament circuits of the devices 14 and 15 to effect a fine adjustment of the characateristics of the devices 14 and 15.

The impedance element is connected to the input conductors 3 and 4 by means of a transformer 30 and is connected to the amplifier 12 by means of a transformer 31. The amplifier 12 is connected to the amplifier 13 by a transformer 32. The amplifier 13 is connected to a high-pass filter 33 by means of a transformer 34. Preferably, the filter 33 will pass waves only in the speech band to prevent the operation of the rectifier circuit 8 by the transients due to the unbalance of the devices 14 and 15 or the unbalance of the primary windings of the transformer 31. The amplifier 12 is provided with a grid biasing battery 35 and plate battery 36. The amplifier 13 is provided with a grid biasing battery 37 and a plate battery 38.

The rectifier circuit 8 comprises a rectifier 40 of the space discharge type and an amplifier 41 of the space discharge type. The input circuit of the amplifier 41 is connected by a transformer 42 to the line circuit beyond the high-pass filter 33. The output circuit of the amplifier 41 is connected by a transformer 43 through the rectifier 40 and a resistance condenser network 44 to the grids 21 and 24 of the space discharge devices 14 and 15. The resistance condenser network 44 preferably comprises a condenser 45 and a resistance element 46. This network serves to smooth out the ripples in the rectified current supplied to the grids of the space discharge devices 14 and 15. A low-pass filter as shown in the patent to S. Doba, Jr., No. 1,931,063 may also be employed.

The variable repeater 9 in the expander 2 comprises an impedance element 47 and an amplifier 48. The impedance element 47 comprises two space discharge tubes 49 and 50 which are connected effectively in series with the line circuit. In the compressor circuit it will be noted the two space discharge devices 14 and 15 are connected across the line circuit. A transformer 51 is connected to the input circuits of the space discharge tubes 49 and 50 and the output circuits of the space discharge tubes are connected by a transformer 52 to the amplifier 48. The amplifier 48 which is preferably of the pure electron discharge type is connected by a transformer 53 to the output conductors 5 and 6. Resistance elements 55 and 56 are provided for effecting a rough adjustment of the characteristics of the space discharge tubes 49 and 50. A condenser 57 is provided as an alternating current bypass across the resistance elements 55 and 56. Resistance elements 58 are provided in the grid-filament circuits of the space discharge tubes 49 and 50 for effecting a fine adjustment of the characteristics of the tubes. The tubes 49 and 50 are provided with a grid biasing battery 60 and a plate battery 61. Variable grid bias for the tubes 49 and 50 is provided by the forward-acting rectifier or control circuit 10.

The rectifier circuit 10 comprises a rectifier 63 of the space discharge type and an amplifier 64 preferably of the space discharge type. The input circuit of the amplifier 64 is connected to the line ahead of the transformer 51 by means of a transformer 65. The output circuit of the amplifier is connected by transformer 66 through the rectifier 63 and a condenser resistance network 67 to the grids of the space discharge tubes 49 and 50. The resistance condenser network 67 is the same type as the network 44 in the rectifier circuit 8 and comprises a condenser 68 and the resistance element 69. By making the networks at the transmitting and receiving ends of the line identical, any delay in compressing action at the transmitting end of the line is balanced by an equal delay at the receiving end of the line in expanding. In this way over accentuation of percussive consonants is avoided. A low-pass filter may also be used here when one is used in the compressor for the same reason.

In the compressor-expander circuit above described the compressor 1 compresses the volume range of the signals received from the conductors 3 and 4 by one-half. The characteristics of the impedance element 11 and the rectifier circuit 8 are adjusted together in order to obtain the correct compression. Inasmuch as the rectifier circuit is backward-acting, it is unnecessary to provide rooter devices of the type disclosed in the above mentioned Crisson patent in order to obtain an output from the variable repeater 7 which has an output in decibels which is half the input to the variable repeater. The expander 2 operates in the same manner as the expander disclosed in patent to S. Doba, Jr., No. 1,931,063.

In Fig. 2 of the drawing is disclosed a modified rectifier or control circuit for the variable repeater of the compressor. The same circuit may also be used for the expander. Similar parts in the control circuit shown in Fig. 2 to those shown in Fig. 1 will be indicated by like reference characters. In the control circuit shown in Fig. 2 of the drawing a network comprising condensers

70, 71, inductance element 72 and rectifier 73 is substituted for the resistance capacity network 44 shown in the control circuit 8 in Fig. 1 of the drawing. The resistance capacity network 44 shown in Fig. 1 of the drawing is quick-acting so that the control follows the envelope of the speech waves without causing any appreciable delay. However, in such a circuit the gain does not remain constant at any time but is continuously changing. The network shown in Fig. 2 of the drawing has the advantage of the quick action of the network 44 shown in Fig. 1 of the drawing and does not have the disadvantage of the network 44 in that the gain is changing at all times. In the network shown in Fig. 2 of the drawing the condensers 70 and 71 are charged up practically simultaneously upon the application of a signal to the input of the rectifier circuit due to the short circuiting of the inductance 72 by the cathode-anode impedance of the rectifier tube 73. When the input to the rectifier circuit is removed the flow of current through the network is reversed and the impedance of rectifier tube 73 becomes infinite. The discharge of the condensers 70 and 71 must then take place through the inductance 72 which will slow up the discharge sufficient to prevent audible modulation of speech.

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

What is claimed is:

1. In combination, a signal path, an impedance element connected to said path, a rectifier circuit connected to said path beyond the connection of the impedance element to the path for controlling the impedance element, and means for effecting a definite relation between the characteristics of the impedance element and the rectifying circuit to obtain a variation in volume output on the path beyond the impedance element which is a fixed fraction of the variation in volume input on the path before the impedance element.

2. In combination, a signal line, impedance means comprising three-element space discharge devices connected to said line, means comprising a control circuit having a rectifier circuit connected to said line beyond said impedance means for controlling the impedance means, and means for effecting a definite relation between the operating characteristics of said space discharge devices and the operating characteristic of said rectifier circuit to obtain a variable output volume on the line beyond said impedance means which is a fixed fraction of the range of the input signal volume expressed in decibels on the line before the impedance means.

3. In combination, a signal line, impedance means comprising three-element space discharge devices connected across the line, means comprising a backward acting control circuit connected to the line beyond said impedance means for controlling the bias on the grids of said devices, and means for maintaining a fixed relation between the operating characteristic of the impedance means and the operating characteristic of said control circuit to obtain a variable output volume on the line beyond said impedance means which is a fixed fraction of the range of the input signal volume expressed in decibels on the line before the impedance means.

4. In combination, a signal line, impedance means comprising three-element space discharge devices connected across said line, and means comprising a backward-acting control circuit connected to said line beyond said impedance means and having a linear acting rectifier for controlling the bias on the grids of said devices, the operating characteristics of said space discharge devices and the operating characteristic of said rectifier having a definite relation to obtain an output on the line beyond said impedance means which is half the range of signal volume expressed in decibels on the line before the impedance means.

5. In combination, a signal line, an impedance element connected across said line, and means comprising a linear acting rectifier element connected to said line beyond the connection of the impedance element to the line and having a definite relation between its operating characteristic and the operating characteristic of said impedance element for controlling the impedance element to obtain an output on the line beyond said impedance element which is half the range of signal volume expressed in decibels on the line before the impedance element.

6. In combination, a signal line, impedance means comprising two three-element space discharge devices connected across said line, a backward-acting control circuit connected to said line beyond said impedance means and having a rectifier for controlling the bias on the grids of said devices and means for maintaining a fixed relation between the characteristics of said space discharge devices and said rectifier to obtain a variation in volume output on the line beyond said impedance means which is a fixed fraction of the variation in volume input on the line before the impedance means.

7. In a signal system, a transmission line, two space discharge devices connected across said line at the transmitting end thereof, means comprising a backward-acting control circuit connected to said line beyond said discharge devices for controlling the devices to obtain an output on the line beyond said devices which is a fractional part of the range of signal volume expressed in decibels on the line before the devices, two space discharge tubes connected effectively in series with the line at the receiving end thereof, and means comprising a forward-acting control circuit connected to said line before said space discharge tubes for controlling the tubes to obtain an output on the line beyond the tubes having the same volume range as the volume input to said devices at the transmitting end of the line.

8. In a signal system, a transmission line, three-element space discharge devices connected across said line at the transmitting end thereof for controlling the volume range of the transmitted signals, means comprising a backward-acting control circuit having a rectifier connected to said line beyond said discharge devices for controlling the devices, the operating characteristics of said devices and the operating characteristic of said control circuit having a definite relation to obtain a variable volume output on the line beyond said devices which is a fixed fraction of the variations in the input signal volume expressed in decibels on the line before the devices, three-element space discharge tubes connected effectively in series with the line at the receiving end thereof, and means comprising a forward-acting control circuit connected to said line before said tubes for controlling the tubes to obtain an output on the line beyond the tubes

having the same volume range as the volume input to said devices at the transmitting end of the line.

9. In a signal system, a transmission line, impedance means connected to the line at the transmitting end thereof for reducing the range of the transmitted signals, impedance means at the receiving end of the line for expanding the volume range of the transmitted signals, control means governed according to the volume range on the line beyond the impedance means at the transmitting end of the line for controlling the impedance means at the transmitting end of the line to obtain a fractional reduction in the volume range of the transmitted signals, and control means at the receiving end of the line governed according to the same volume range governing the control means at the transmitting end of the line for controlling the impedance means at the receiving end of the line to obtain an output beyond the impedance means at the receiving end of the line having the same volume range as the input to the impedance means at the transmitting end of the line.

10. In a signal system, a transmission line, space discharge devices connected across the line at the transmitting end thereof for reducing the range of the transmitted signals, a backward-acting control circuit for controlling said device to obtain an output on the line beyond said devices which is a fractional part of the range of signal volume expressed in decibels on the line before the devices, space discharge tubes connected effectively in series with the line at the receiving end thereof for expanding the range of the transmitted signals, and control means at the receiving end of the line governed according to the same volume range supplied to said backward-acting circuit for controlling said discharge tubes to obtain an output beyond the tubes having the same volume range as the input to the devices at the transmitting end of the line.

11. In combination, a signal line, space discharge impedance means in said line for controlling the impedance on said line, means comprising a rectifier circuit connected to said line beyond the impedance means and having an output proportional to the output on the line beyond the impedance means for controlling the impedance means, and means for effecting a definite relation between the characteristics of the impedance means and the rectifier circuit to obtain a variation in volume output on the line beyond the impedance means which is a fixed fraction of the variation in volume on the line before the impedance means.

12. In combination, a signal line, space discharge impedance means in said line for controlling the impedance on the line, a control circuit connected to the line beyond said impedance means and comprising a rectifier and a filter for controlling said impedance means, and means for effecting a definite relation between the characteristics of the impedance means and the control circuit to obtain variation in volume output on the line beyond the impedance means which is a fixed fraction of the variation in volume input on the line before the impedance means.

13. In combination, a signal line, space discharge impedance means in said line for controlling the impedance on the line, means comprising a control circuit having a rectifier and a filter and connected to the line beyond said impedance for controlling the impedance means, the output from said rectifier being proportional to the output on the line beyond the impedance means, and means for effecting a definite relation between the operating characteristics of said impedance means and the operating characteristics of said control circuit to obtain a variable output volume on the line beyond said impedance means which is a fixed fraction of the range of the input signal volume expressed in decibels on the line before the impedance means.

14. In combination, a signal line, impedance means in said line, means comprising a rectifier circuit connected to said line beyond the impedance means for controlling the impedance means, a network in said rectifier circuit comprising a capacity and an inductance shunted by a rectifier for varying the time of charging the capacity as compared with the time of discharging the capacity, and means for effecting a definite relation between the characteristics of the impedance element and the rectifier circuit to obtain a variation in volume output on the line beyond the impedance means which is a fixed fraction of the variation in volume input on the line before the impedance means.

15. In combination, a control circuit, an inductance element connected in series with said circuit, a capacity element connected across said circuit beyond said inductance element, and a one-way rectifier connected across said inductance element to insure charging and discharging of the capacity element at different rates.

16. In combination, a control circuit, means for applying direct current impulses to said circuit, an inductance element connected in series with said circuit, capacity means connected across said circuit adjacent to said inductance element, and a rectifier connected across said inductance element for transmitting said direct current impulses in one direction to insure charging and discharging of the capacity means at different rates.

17. In combination, a signal line, impedance means connected to the signal line, control means governed according to the volume range on the signal line beyond said impedance means for controlling said impedance means, means for relating the characteristics of said impedance means and the control means to obtain a signal volume range beyond said impedance means which has a fixed ratio with respect to the signal volume range before said impedance means, an expandor line having signals supplied thereto that have the same volume range as the output beyond the first mentioned impedance means, a second impedance means connected to the expandor line, a second control means governed by the same wave shape as said first mentioned control means for controlling said second impedance means, and means for relating the characteristics of said second impedance means and the second control circuit to obtain an output beyond the second impedance means having the same volume range as the input to the first mentioned impedance means.

18. The method of controlling the volume range of signals on a signal line having an impedance connected thereto and a control circuit therefor and an expandor line having a second impedance conected thereto and a second control circuit therefor which consists in governing said signal-line control circuit according to the signal output beyond said signal line impedance, in controlling the signal-line impedance by the signal-line con-

trol circuit, in relating the characteristic of the signal-line impedance to the characteristic of the signal-line control circuit to obtain a signal volume beyond said signal-line impedance which has a fixed ratio to the signal volume range before said signal-line impedance, in governing the expandor-line control circuit by the same wave shape as controls said signal-line control circuit, in supplying said expandor with signals corresponding to the output from the signal-line impedance, in controlling the expandor-line impedance by the expandor-line control circuit, and in relating the characteristic of the expandor-line impedance to the expandor-line control circuit to obtain a volume range output beyond the expandor-line impedance which is the same as the volume range of the signals before the signal-line impedance.

19. The method of controlling the volume range of signals on a signal line having an impedance connected thereto and a control circuit which consists in governing the control circuit according to the output beyond the impedance, in controlling said impedance by the control circuit, and in relating the characteristic of the impedance to the characteristic of the control circuit to obtain a signal volume beyond said impedance which has a fixed ratio to the signal volume range before said impedance.

20. In combination, a signal line, impedance means connected to the signal line, a control circuit connected to the signal line beyond said impedance means to be governed according to the signals beyond the impedance means for controlling the impedance means, means for relating the characteristic of the impedance means with respect to the characteristic of the control circuit to obtain a signal volume range beyond said impedance means which has a fixed ratio with respect to the signal volume range before said impedance means, an expandor line having signals supplied thereto that have the same volume range as the output beyond the first mentioned impedance means, a second impedance means connected to the expandor line, a second control circuit connected to the expandor line before said second impedance means and having the same characteristic as the first mentioned control circuit for controlling said second impedance means, and means for relating the characteristic of second impedance means to the characteristic of the second control circuit to obtain an output beyond the second impedance means having the same volume range as the input to the first mentioned impedance means.

STEPHEN DOBA, JR.