

May 2, 1939.

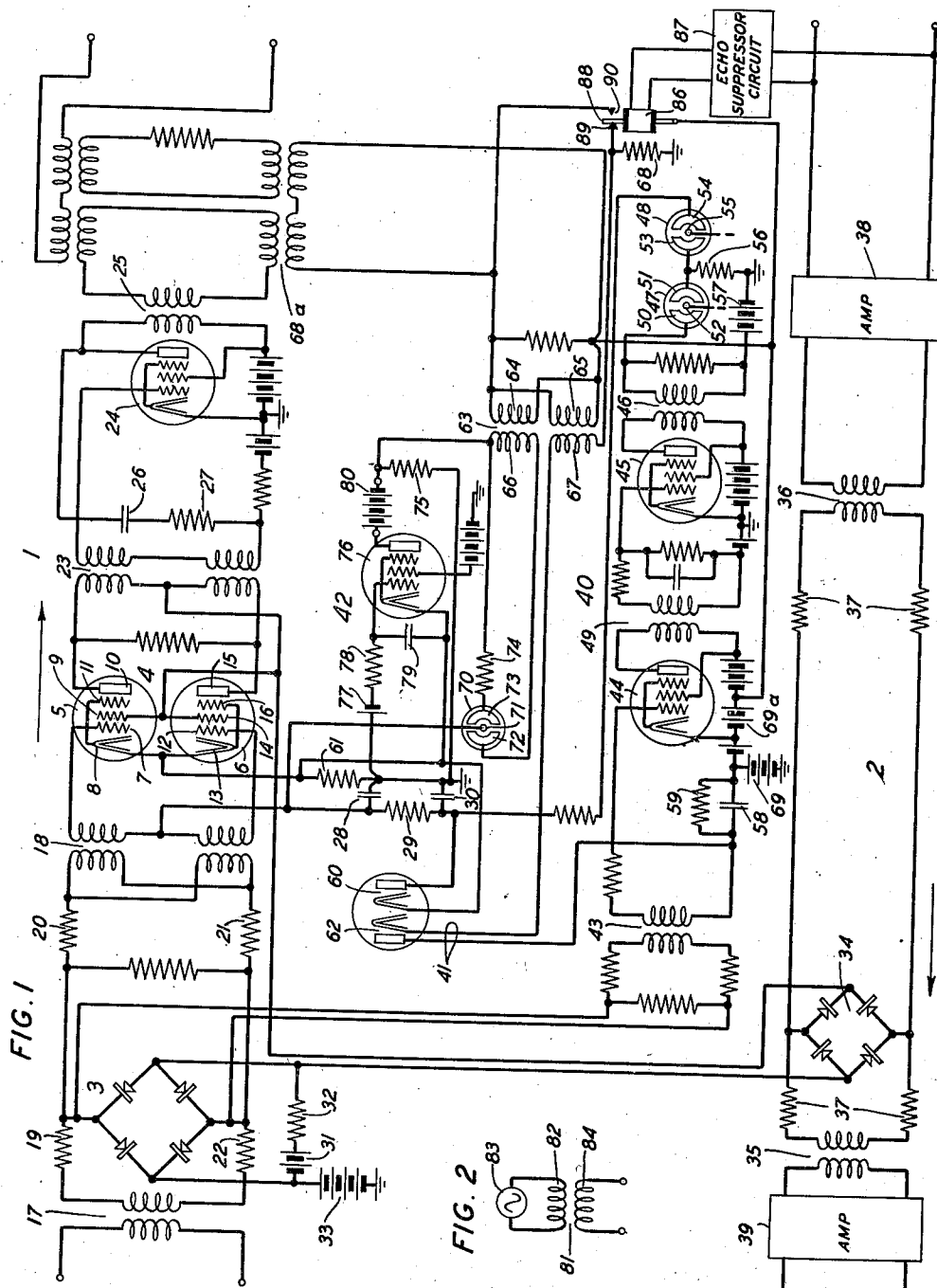
S. DOBA, JR

2,156,622

SIGNAL TRANSMISSION SYSTEM

Filed Nov. 17, 1937

2 Sheets-Sheet 1



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FIG. 3

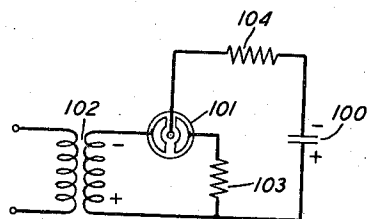


FIG. 4

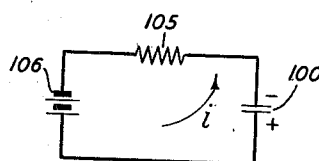


FIG. 5

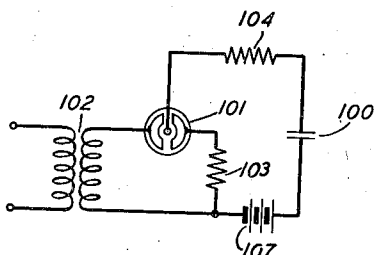
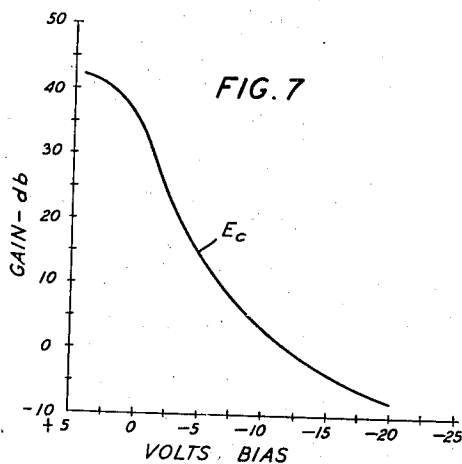
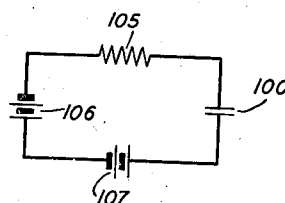


FIG. 6



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2,156,622

SIGNAL TRANSMISSION SYSTEM

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Application November 17, 1937, Serial No. 174,948

17 Claims. (Cl. 178—44)

This invention relates to signal transmission systems and particularly to gain control circuits for signal transmission systems.

One object of the invention is to provide a signal transmission system with voice-operated gain control circuits that shall be operated in an improved manner to maintain constant volume on a transmitting channel.

Another object of the invention is to provide a transmitting channel with two separate gain control devices having different characteristics that shall be controlled according to the charge on a control condenser to maintain constant volume on the transmitting channel beyond the gain control devices.

Another object of the invention is to provide a gain decreaser circuit for a transmitting channel of the above-indicated character that shall vary the charging rate of the control condenser in an improved manner to maintain the rate of gain change constant and that shall maintain the sensitivity of the gain decreaser circuit constant irrespective of the charge on the control condenser.

A further object of the invention is to provide a transmitting channel with two separate gain control devices having different characteristics and controlled to maintain constant volume on the channel beyond the devices that shall have a gain increaser circuit operated when the energy level of the signals on the channel between said devices is above a predetermined lower level to raise the gain on the channel and that shall have a gain increase disabler circuit for blocking the gain increaser circuit when the energy level of the signals on the channel beyond said devices is above a predetermined low level.

In a radio system which is connected to a telephone system it is desirable to have the telephone currents supplied to the radio transmitter at constant volume in order to prevent overloading the apparatus in the radio transmitter. In a radio transmitter it is simple to effect amplification and over-ride the noise level encountered in radio systems when constant volume signals are supplied to the transmitter.

In a telephone system voice currents controlled by different types of talkers are transmitted. In one extreme case may be the very loud talker and in the other extreme case may be the very weak talker. The volume range between the very loud talker and the very weak talker may be such as to cause overloading of the apparatus in a radio transmitter by the strong talker when the volume of the weak talker is raised to a satisfactory level. In order to prevent overloading the apparatus in the radio transmitter, the signal currents produced by the weak talker and the strong talker are controlled by a voice-operated gain adjusting device so that constant volume is

supplied to the radio transmitter. One type of voice-operated gain adjusting device is disclosed in the application of S. Doba, Jr., Serial No. 166,723, filed October 1, 1937.

In the voice-operated gain adjusting circuits employed to describe the invention two gain control means are connected to the transmitting channel of a four-wire system and one gain control means is connected to the receiving channel. One gain control means in the transmitting channel comprises two space discharge devices in push-pull relationship. The control grids of the two space discharge devices have potential impressed on them according to the charge on two condensers. One of the condensers is relatively small and the other condenser is relatively large. The charge on the two condensers is governed by a gain decreaser circuit, a gain increaser circuit and a gain increase disabler circuit.

The second gain control means in the transmitting channel comprises a bridge composed of copper-oxide rectifier elements. Two opposite vertices of the bridge are connected across the transmitting channel ahead of the two space discharge devices, which are effectively connected in series with the transmitting channel. A source of potential is connected across the other two vertices of the bridge, in order to effectively place a positive bias upon the bridge. A resistance element in the circuit of the plate potential source for the two space discharge devices is connected to the two vertices of the bridge having a positive bias impressed on them. The resistance element connected across the two vertices of the bridge is so connected in the plate circuit of the two space discharge devices that a variable negative potential is impressed on the bridge to oppose the positive potential bias thereon. When the two space discharge devices draw a maximum plate current, the bias across the bridge is negative and the loss caused by the bridge on the transmitting channel is at a minimum value. When the plate current for the two space discharge devices decreases, bias on the bridge reverses and the loss introduced by the bridge in the transmitting channel increases rapidly. As the plate current for the two space discharge devices is still further decreased, the bridge losses on the transmitting channel reach a maximum and further gain reductions on the transmitting channel must be effected by means of the two space discharge devices alone.

A gain increaser circuit is provided for impressing a positive charge on the two control condensers to increase the gain when the energy level on the transmitting channel between the bridge and the two space discharge devices is above a predetermined minimum level. The gain increaser circuit is provided with a cold cathode tube which operates in the manner of similar

tubes disclosed in the application of S. Doba, Jr., Serial No. 166,723, filed October 1, 1937. A gain increase disabler circuit is provided for blocking the gain increaser circuit when the energy level of the signals on the transmitting channel beyond the bridge and the two space discharge devices is above a predetermined minimum level. A rectifier element is connected across the two control condensers in a direction to draw current whenever the condensers are charged positively.

The gain decreaser circuit comprises a cold cathode gas-filled tube having a breakdown circuit and a main discharge circuit. In the particular circuit shown on the drawing the breakdown circuit is operated at 70 volts and the main discharge circuit is operated at approximately 75 volts. The gain decreaser circuit charges the control condensers negatively when the energy level of the signals on the transmitting channel beyond the bridge and the two space discharge devices is above a predetermined maximum value.

It has been found that the rate of gain change varies according to the charge on the control condensers. Moreover, the sensitivity of the gain decreaser circuit or the signal voltage at which charging of the control condensers takes place by the gain decreaser circuit has been found to vary with the charge on the control condensers. In order to maintain the sensitivity of the gain decreaser circuit constant and to maintain the rate of gain change constant, irrespective of the charge on the condensers, provision has been made to impress a variable bias on the main discharge circuit of the gas-filled tube in the gain decreaser circuit. The variable bias in the gain decreaser circuit is controlled according to the plate current supplied to the two space discharge devices serving as a vario-repeater in the transmission channel.

A bridge circuit composed of copper-oxide rectifier elements is connected across the receiving channel in order to vary the impedance of the receiving channel oppositely to any change in impedance effected in the transmitting channel by the gain control circuits. The bridge circuit in the receiving channel is controlled according to the plate current supplied to the two space discharge devices serving as a vario-repeater in the transmitting channel.

A relatively small condenser shunted by a resistance element and a relatively large condenser impress a variable bias on the control grids of the two space discharge devices serving as a vario-repeater in the transmitting channel. The two condensers are charged according to the energy level of the signals on the transmitting channel for controlling the two gain control means in the transmitting channel to maintain constant volume on the transmitting channel. The smaller control condenser is charged and discharged quickly and takes care of sudden changes of energy. The larger condenser is charged and discharged by prolonged changes in energy.

In the accompanying drawings:

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

Fig. 2 is a diagrammatic view showing a modified plate potential source in the gain decreaser circuit;

Figs. 3, 4, 5 and 6 are diagrammatic views employed to explain the compensation required in the gain decreaser circuit;

Fig. 7 is a curve showing the relation between the gain and the charge on the control condensers.

Referring to Fig. 1 of the drawings, a four-wire signal transmission system is illustrated having a transmitting channel 1 and a receiving channel 2. The transmitting channel 1 is provided with two gain control means or devices 3 and 4 for adjusting the gain on the transmission channel to maintain the volume of the signals constant. The gain control means 3 is in the form of a bridge composed of copper-oxide rectifier elements. Two opposite vertices of the bridge are connected across the transmitting channel. The gain control means 4 is in the form of two variable mu pentode space discharge devices 5 and 6. The device 5 comprises a control grid 7, a cathode 8, a screen grid 9, an anode 10 and a suppressor grid 11. The device 6 comprises a control grid 12, a cathode 13, a screen grid 14, an anode 15 and a suppressor grid 16.

The bridge circuit 3, comprising copper-oxide rectifier elements, is connected across the transmitting channel 1 between transformers 17 and 18. Resistance elements 19, 20, 21 and 22 which form a resistance pad in the transmitting channel are placed on opposite sides of the connection of the bridge 3 to the transmitting channel. The secondary winding of the transformer 18 is connected to the grids 7 and 12 of the devices 5 and 6 which are effectively connected in series with the transmitting channel 1. The output circuits of the devices 5 and 6 are connected by a transformer 23 to the input circuit of a pentode space discharge amplifier device 24. A transformer 25 is connected to the output circuit of the device 24. The device 24 is provided with a negative feedback circuit comprising a condenser 26 and a resistance element 27.

A relatively small control condenser 28, which is shunted by a resistance element 29 and a relatively large condenser 30, impresses a variable bias on the grids 7 and 12 of the devices 5 and 6 to control the gain on the transmitting channel 1 so as to maintain the signals beyond the transformer 25 at constant volume. The two condenser arrangement for controlling the bias on the devices 5 and 6 is disclosed in the patent to S. Doba, Jr., 1,880,889, October 4, 1932 and in the application of S. Doba, Jr., Serial No. 166,723, filed October 1, 1937. The condensers serve to prevent large permanent changes in gain due to short peaks of speech. This arrangement has the advantage of preventing wide hunting by the control circuits while permitting narrow hunting or compression on short peaks of speech.

A battery 31 is connected in series with a resistance element 32 to the two vertices of the copper-oxide bridge 3 which are not connected across the transmitting channel 1. Plate potential for the devices 5 and 6 is supplied from a source 33 in series with the resistance element 32. The current flow through the resistance element 32, due to the plate current drawn by the devices 5 and 6, is in a direction to provide a potential drop across the resistance element 32 in opposition to the bias of the battery 31 on the copper-oxide bridge.

The gain variations on the transmitting channel are due not only to the gain control means comprising the devices 5 and 6 but also to the variable shunting action of the copper-oxide bridge by reason of the control of the bridge by the plate current supplied to the devices 5 and 6. When maximum plate currents are supplied to the devices 5 and 6 the bias impressed

on the bridge 3 is negative and the loss effected thereby is at a minimum. When the plate current supplied to the devices 5 and 6 is decreased the bias impressed on the bridge 3 reverses and the loss introduced by the bridge circuit 3 on the transmitting channel 1 increases rapidly. When the plate current supplied to the devices 5 and 6 is still further decreased the biasing current supplied to the bridge 3 reaches a maximum and subsequent gain reductions must be effected solely by the devices 5 and 6. The use of a bridge circuit in shunt to the transmitting channel and two space discharge devices effectively in series with the transmitting channel results in a favorable gain characteristic, as shown by the curve in Fig. 7 of the drawings. The curve in Fig. 7 of the drawings is drawn with decibels gain as ordinates and volts bias on grids 7 and 12 as abscissae. At low gains and high potential biases on the devices 5 and 6 the rate of gain change with bias is quite low, with the result that the rate of gain increase due to leakage tends to be uniform over the whole operating range.

The receiving channel 2 is provided with a copper-oxide rectifier bridge 34 for effecting loss changes in the channel 2 opposite to the loss changes effected in the transmitting channel 1 by the bridge circuit 3 and the two space discharge devices 5 and 6. The bridge circuit 34 has two opposite vertices thereon connected across the receiving channel 2 between transformers 35 and 36 and the other vertices connected in series with the plate potential circuit for the space discharge devices 5 and 6. The shunting action of the bridge 34 is controlled in accordance with the plate current supplied to the devices 5 and 6 so that the loss of the receiving channel 2 is varied oppositely to the changes in loss of the transmitting channel 1. Resistance elements 37 are placed on opposite sides of the bridge 34 between the transformers 35 and 36. A suitable amplifier 38 is connected in the receiving channel 2 before the transformer 36 and a suitable amplifier 39 is connected to the receiving channel 2 beyond the transformer 35.

A gain increaser circuit 40 is provided for impressing a positive charge on the control condenser 28 and 30 to increase the gain on the transmitting channel 1 when the energy level of the signals on the transmitting channel between the bridge 3 and the devices 5 and 6 is above a predetermined lower level. A gain increase disabler circuit 41 is provided for blocking the gain increaser circuit 40 when the energy level of the signals on the transmitting channel 1 beyond the transformer 25 is above a predetermined minimum level. A gain decrease circuit 42 is provided for impressing a negative charge on the control condensers 28 and 30 to reduce the gain on the transmitting channel 1 when the energy level of the signals on the transmitting channel beyond the transformer 25 is above a predetermined maximum level.

The gain increaser circuit 40 comprises a transformer 43, two pentode space discharge amplifier devices 44 and 45, a transformer 46 and two cold-cathode, gas-filled space discharge devices 47 and 48. The primary winding of the transformer 43 is connected across the transmitting channel 1 between the bridge 3 and the space discharge devices 5 and 6. The secondary winding of the transformer 43 is connected to the input circuit of the amplifier device 44. The output circuit of the amplifier 44 is connected to the input cir-

cuit of the amplifier device 45 by means of a transformer 49.

The gas-filled tube 47 comprises two cathodes 50 and 51 and an anode 52. The gas-filled tube 48 comprises two cathodes 53 and 54 and an anode 55. The tube 47 is connected to the secondary winding of the transformer 46 in series with a coupling resistance 56 and a biasing battery 57. The battery 57 lowers the voltage at which the tube 47 breaks down and insures the operation of the tube by one polarity only. The gas-filled tube 48 is coupled across the resistance element 56 in circuit with the control condensers 28 and 30.

A condenser 58, shunted by a resistance element 59, is included in the input circuit of the amplifier device 44. The condenser is controlled by the gain increase disabler circuit 41 for disabling the gain increaser circuit 40 when the receiving channel 2 is in use and when the energy level of the signals on the transmitting channel 1 beyond the transformer 25 are above a predetermined lower limit. A diode space discharge device 60 is connected across the condensers 28 and 30 in series with a resistance element 61 to prevent the grids 7 and 12 of the space discharge devices 5 and 6 being driven positive by the gain increaser circuit 40. The gain increaser circuit 40 is controlled by the signals on the transmitting channel 1 just beyond the bridge 3 to increase the sensitivity for weak talkers with the consequent improved regulation.

If the signals on the transmitting channel 1 before the bridge 3 are above that of the weakest talker potential will be supplied to the gain increaser circuit 40 for raising the gain on the transmitting channel 1 when the gain increase disabler circuit 41 is not in operation. The signal energy obtained from the transmitting channel 1 beyond the bridge 3 is amplified by the amplifiers 44 and 45 to break down the cold-cathode, gas-filled space discharge tube 47. The breakdown circuit of the tube 47 includes the coupling resistance 56. The potential drop across the coupling resistance 56 serves to break down the tube 48 which in turn charges the control condensers to insert bias on the grids 7 and 12 in a positive direction.

The gain increase disabler circuit 41 comprises a diode 62 which rectifies current received from the transformer 63 for blocking the gain increaser circuit 40 when the signals on the transmitting channel beyond the transformer 25 are above a predetermined lower limit. A negative bias of the order of 10.5 volts is impressed on the diode 62 from a battery 69a in circuit with the armature of a relay 86. The transformer 63 comprises two primary windings 64 and 65 and two secondary windings 66 and 67. The primary windings 64 and 65 are connected by a transformer 68a to the transmitting channel 1 beyond the two gain control means therein. The secondary winding 67 of the transformer 63 is included in the gain increase disabler circuit 41. The gain increase disabler circuit 41 may be traced from one terminal of battery 69a through armature 88, contact member 89, secondary winding 67 of the transformer 63, diode 62 and resistance element 59 in parallel with the condenser 58 to the other terminal of battery 69a.

When the energy level of the signals on the transmitting channel 1 beyond the two gain control means therein is above a predetermined lower limit the gain increase disabler circuit is completed through the diode 62 to charge the condenser 58. The charge on the condenser 58 75

blocks the pentode amplifier 44 in the gain increaser circuit 40 to prevent any further gain increase by means of the gain increaser circuit. The resistance 59 shunted across the condenser 58 serves to provide a hangover of about one second after a signal great enough to operate the gain decrease circuit. The tone sensitivity of the gain increase disabler circuit 41 is about 10 decibels greater than that of the gain decreaser circuit 42.

The gain decreaser circuit 42 comprises a cold-cathode, gas-filled space discharge device 70 having an anode 71 and two cathodes 72 and 73. The breakdown circuit for the tube 70 includes the two cathodes 72 and 73, a resistance element 74 and the secondary winding 66 of the transformer 63. The main discharge circuit for the tube 70 may be traced from ground through the control condensers 28 and 30, anode 71, cathode 72 of the tube 70, secondary winding 66 and a compensating resistance 75 to ground. The main charging circuit through the tube 70 is operated at 75 volts if substantially no charge is on the control condensers. If the gap between the electrodes 72 and 73 were not broken down in the tube under consideration a potential of 175 volts would be required to break down the main charging circuit. The gain decreaser circuit 42 impresses a negative charge on the control condensers to reduce the gain effected on the transmitting channel 1 when the energy level of the signals beyond the two gain control means 3 and 4 is above a predetermined upper limit.

It has been found that the sensitivity of the gain decreaser circuit 42 and also the rate of charge of the control condensers by the gain decreaser circuit varies with the charge on the control condensers. In order to maintain the sensitivity constant and the rate of change by the gain decreaser circuit 42 constant a potential is impressed on the compensating resistance 75 which varies according to the charge on the control condensers. A resistance element 61 which is included in the plate current circuit for the devices 5 and 6 controls the input circuit of a pentode-amplifier device 76. The output circuit of the amplifier device 76 includes the compensating resistance 75. A battery 77 is provided for biasing the grid of the device 76 and a filter comprising a resistance element 78 and a condenser 79 is provided in the input circuit of the device 76. A floating battery 80 is provided for supplying plate potential to the device 76. However, if so desired, the floating battery 80 may be replaced by any suitable source of alternating current. In Fig. 2 of the drawings a transformer 81 is shown with the primary winding 82 thereof connected to a suitable source of alternating current 83. The secondary winding 84 of the transformer 81 is connected in the plate circuit of the device 76 to replace the floating battery 80.

In the operation of the circuits above described charge on the control condensers 28 and 30 is governed by the gain increaser circuit 40 when the energy level of the signals beyond the bridge 3 in the transmitting channel is above a predetermined lower limit. The operation of the gain increaser circuit is stopped by the gain increase disabler circuit 41 when the energy level of the signals on the transmitting channel 1 beyond the two gain control means is above a predetermined lower limit. The gain decreaser circuit operates to place a negative charge on the control condensers to lower the gain on the

transmitting channel 1 when the energy level of the signals on the transmitting channel beyond the two gain control means therein is above a predetermined upper limit. The control circuits govern the charge on the control condensers so as to maintain substantially constant volume on the transmitting channel 1 beyond the two gain control means therein. The two space discharge devices 5 and 6 which are controlled according to the charge on the control condensers govern the operation of the bridge 3, the impedance of the receiving channel and the compensation effected in the main charging circuit of the gain decreaser circuit 42. The bridge 3 is controlled by the potential drop across the resistance 32 in the plate circuit for the devices 5 and 6 and the compensation for the gain decreaser circuit is controlled by the potential drop across the resistance element 61 in the plate circuit of the devices 5 and 6. The impedance in the receiving circuit is controlled by the bridge 34 which also is included in the plate current circuit of the devices 5 and 6.

A relay 86 is controlled from the receiving channel 2 by means of echo supressor circuits 37. When the receiving channel is in operation the armature 88 is moved out of connection with the contact member 89 and into connection with the contact member 90. When the armature 88 engages the contact member 90 the input to the gain decrease circuit 42 is short-circuited to prevent any operation of the gain decreaser circuit. At the same time a bias is placed upon the condenser 58 from the battery 69 to block the gain increaser circuit 40. The circuit for charging the condenser 58 may be traced from grounded battery 69 through condenser 58 shunted by the resistance 59, diode 62, secondary winding 67, resistance element 68 and ground return to the battery 69.

In regulating the output volume of voice-operated gain adjusting circuits of the above-indicated character to maintain constant volume on the transmitting channel, the gain decreaser circuit has two characteristics which determine the output on the transmitting channel. These characteristics are sensitivity and speed of operation. Sensitivity may be defined as the signal voltage above which operation of the gain decreaser circuit takes place. The speed of operation may be defined as the rate of change in gain with time. In the circuits under consideration it is necessary, as before set forth, to keep the output volume constant on the transmitting channel irrespective of the input volume and thus irrespective of the gain. Consequently, the sensitivity and the speed of operation of the gain decreaser circuit should be constant.

In the gain decreaser circuit 42 the drop across the resistance element 75 is employed to place a variable bias on the main discharge circuit of the cold-cathode, gas-filled tube 70. This variable bias serves to compensate the operation of the gain decreaser circuit 42 and to maintain the sensitivity and the speed of operation of the gain decreaser circuit constant irrespective of the charge on the two control condensers 28 and 30. It has been found in the gain decreaser circuit 42 above described that the potential drop across the resistance element 75 should be approximately double the drop across the control condensers 28 and 30 to give satisfactory operation. In brief the potential drop across the resistance element 75 should be twice that across the control condensers to hold the sensitivity and the rate of

operation of the gain decriaser circuit 42 constant.

Referring to Figs. 3, 4, 5 and 6 of the drawings, an explanation will be given as to the need for compensating the gain decriaser circuit 42 to maintain the sensitivity and rate of operation constant and the amount of compensation required. The rate of change in gain with time may be represented as

$$\frac{dG}{dt}$$

where G may be the gain in decibels or any other suitable units and t the time in seconds. The gain in the dircuit under consideration is a function of the condenser bias and the condenser bias is a function of time. The rate of change in gain with time may then be represented as:

$$\frac{dG}{dt} = \frac{dG}{dE} \frac{dE}{dt} \quad (1)$$

Referring to Fig. 3 of the drawings, a simplified circuit similar to the gain decriaser circuit 42 is shown comprising a condenser 100, a cold-cathode, gas-filled tube 101, a transformer 102, a resistance element 103 in the breakdown circuit of the tube 101 and a resistance 104 representing the resistance of the main discharge circuit for the tube 101. The sensitivity of the circuit shown in Fig. 3 is represented by the character E' and is the voltage supplied by the transformer 102 to break down the anode-cathode gap of the tube 101 and overcome the bias or charge E on the condenser 100. If the tube 101 breaks down at 70 and 75 volts, the voltage at which charging of the condenser 100 will just take place is:

$$E' = 75 + E$$

Accordingly, it is apparent that sensitivity will not be constant for different charges on the condenser and that the higher the condenser charge the lower will be the sensitivity.

Referring to Fig. 4 of the drawings, consideration will be given to the electromotive forces in the condenser circuit during charging of the condenser. The condenser 100 may be condenser shown in Fig. 3. A resistance element 105 is shown to indicate the complete resistance of the circuit which is equal to R . A battery 106 for charging the condenser 100 is assumed to have a voltage

$$e = E' - 75$$

The current in the circuit is

$$i = \frac{e - E}{R}$$

The current i flowing in the direction indicated will be less for larger values of E , the charge on the condenser 100.

The condenser bias is:

$$E = 1/C \int i dt$$

and

$$i = C \frac{dE}{dt} \quad (2)$$

where C is the capacity of the condenser. Accordingly, it is apparent in the circuit shown in Fig. 3 that not only is the sensitivity decreasing as the bias or condenser charge increases but the speed of operation tends to decrease.

Thus in a gain decriaser circuit without compensation there is a marked tendency for the output voltage on the transmission channel to be higher when higher charges are on the control condensers.

Fig. 5 is similar to Fig. 3 with the exception that a compensating or an enabling battery 107 has

been added. The battery 107 is assumed to have a voltage E_1 . The sensitivity or the voltage at which charging of the condenser 100 just takes place is:

$E' = 75 + E - E_1$ provided E' is greater than 70. If the compensating voltage E_1 is always at least 5 volts greater than E , the sensitivity will remain constant independent of the charge E on the condenser 100.

In order to maintain the speed of operation constant, the voltage E_1 is made variable. In Fig. 6 the effective electromotive forces are shown for charging the condenser 100, shown in Fig. 5. Fig. 6 is the same as Fig. 4 except for the addition of the battery 107. The current for charging the condenser 100, shown in Fig. 6, is:

$$i = \frac{e + E_1 - E}{R} \quad (3)$$

According to Equation 2

$$\frac{dE}{dt} = \frac{i}{C} \quad (4)$$

Substituting the value of i Equation 3 in Equation 4

$$\frac{dE}{dt} = \frac{e + E_1 - E}{RC} \quad (5)$$

Substituting the value of

$$\frac{dE}{dt}$$

Equation 5 in Equation 1

$$\frac{dG}{dt} = \frac{dG}{dE} \frac{e + E_1 - E}{RC} \quad (6)$$

The factor

$$\frac{dG}{dE}$$

in Equation 6 may be obtained from the gain against condenser charge curve, shown in Fig. 7, for the circuits under consideration. A fair approximation of the curve is

$$\frac{dG}{dE} = \frac{a}{1 + bE}$$

where a and b are constants. Since

$$\frac{dG}{dt}$$

as a whole is to be constant, the factor $(e + E_1 - E)$ must be made to vary as the factor $(1 + bE)$. Therefore,

$$\frac{dG}{dt} = \frac{a}{1 + bE} \frac{e + E_1 - E}{RC} = K \quad (7)$$

Since consideration is concerned chiefly with the speed of operation at a point where the gain is nearly at the right value, e may be given a small fixed value and Equation 7 may be put in the form:

$$\frac{dG}{dt} = \frac{1 + \frac{E_1 - E}{e}}{1 + bE} \left(\frac{ae}{RC} \right) = K$$

The above equation indicates that E_1 should vary as E or that $E_1 = ME$ where M is a constant and greater than unity. Under the above conditions we have

$$\frac{dG}{dt} = \frac{1 + E \left(\frac{M-1}{e} \right)}{1 + E(b)} \left(\frac{ae}{RC} \right)$$

The factor

$$\frac{dG}{dt}$$

is a constant independent of E if the factor

$$\frac{M-1}{e} = b$$

In the circuits under consideration, the desired

condition is obtained if (M) is given a value of 2. This means that the potential drop across the resistance element 75 in Fig. 1 of the drawings must be twice the charge on the control condensers.

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 signal system, a transmission channel, a bridge composed of solid elements with non-linear voltage current characteristics and having two opposite vertices connected across said channel, a space discharge device effectively connected in series with said channel, the bridge and said device serving to control the gain on said channel, and means operated according to the energy level of the signals on the channel for jointly controlling said bridge and said device to effect different relative changes in gain by the bridge and the device at different points of the operating range of the bridge and the device and to maintain constant volume on the channel beyond the bridge and the device.

2. In a signal system, a transmission channel, a pad composed of copper-oxide elements and connected to said channel, a space discharge device effectively connected in series with said channel, means comprising a gain increaser circuit connected to said channel between said pad and the space discharge device for governing said device when the signals on the channel beyond said pad are above a lower limit to increase the gain on the channel, said gain increaser circuit operating at high sensitivity for low signals and at low constant sensitivity for high signals, means operated when the energy level of the signals on the channel beyond said device is above an upper level for controlling said device to decrease the gain on the channel, means for disabling said gain increaser circuit when the energy level of the signals on said channel beyond said device is above a lower level, and means governed by said device for controlling said pad to vary the loss caused by the pad with respect to the gain by the device and to maintain constant volume on the channel beyond the pad and the device.

3. In a signal system, a transmission channel, a resistance pad composed of solid elements with non-linear voltage current characteristics and connected to said channel for controlling the loss on the channel, means for placing a positive bias on said pad, a space discharge device effectively connected in series with said channel and having a control grid, means for opposing the positive bias on said pad according to the plate current drawn by said device for varying the loss caused by said pad with respect to the gain by the device, and means operated according to the energy level of the signals on the channel for controlling the potential on the grid of said device to govern the change in gain by the pad and said devices and maintain constant volume on said channel.

4. In a signal system, a transmission channel, a bridge composed of solid elements with non-linear voltage current characteristics and having two opposite vertices thereof connected across said channel, a source of potential connected across the other two vertices of the bridge for placing a positive bias on the bridge to increase the shunting action thereof on said channel, a

space discharge device effectively connected in series with said channel and having a control grid, means connecting the plate potential circuit of said device to said bridge for providing a potential varying according to the plate current of said device to oppose the positive bias on the bridge and to vary the change in gain caused by the bridge with respect to the change in gain caused by said device, and means operated according to the energy level of the signals on the channel for controlling the potential on the grid of said device to maintain constant volume on said channel.

5. In a signal system, a transmission channel, a bridge composed of copper-oxide rectifier elements and having two opposite vertices connected across said channel, a source of potential connected in series with a resistance element across the other two vertices of the bridge, said source of potential placing a positive bias on the bridge to increase the shunting action of the bridge on the channel, a space discharge device effectively connected in series with said channel and having a control grid, means for connecting the plate potential circuit of said device in series with said resistance element so that the potential drop across the resistance element opposes said biasing potential to vary the change in gain caused by the bridge with respect to the change in gain caused by said device, and means operated according to the energy level of the signals on the channel for controlling the potential on the grid of said device to maintain constant volume on said channel.

6. In a signal system a transmission channel, gain control means in said channel, capacity means for governing said control means according to the charge thereon, a gain decreaser circuit for charging said capacity means to effect decreased gain when the energy level on said channel beyond said gain control means is above a predetermined upper level, and means controlled according to the operation of said gain control means to maintain constant the signal energy point at which the decreaser circuit starts charging said capacity means irrespective of the charge on the capacity means.

7. In a signal system, a transmission channel, gain control means on said channel, a condenser for governing said gain control means according to the charge thereon, a gain decreaser circuit for charging said condenser to effect a decreased gain when the energy level of the signals on said channel beyond said gain control means is above a predetermined upper level and means controlled according to the operation of said gain control means for varying the rate of charge of said condenser by said circuit.

8. In a signal system for maintaining signals at constant volume, a transmission channel, a space discharge device effectively connected in series with said channel and having a control grid, a condenser for controlling the potential on said grid according to the charge thereon, a gain decreaser circuit for charging said condenser to effect decreased gain when the energy level on said channel beyond said device is above a predetermined upper limit, and means controlled according to the operation of said device for varying the rate of charge of said condenser by said circuit to maintain the rate of gain change constant and for maintaining constant the signal energy point at which the circuit starts charging said condenser.

9. In a signal system, a transmission channel, 75

a space discharge device effectively connected in series with said channel and having a control grid, a condenser for controlling the potential on said grid according to the charge thereon, a gain 5
decreaser comprising a cold cathode gas-filled tube having a breakdown circuit and a main circuit for charging said condenser to reduce the gain, said tube being operated when the signal energy on said channel beyond said device is 10
above a predetermined maximum value, and means controlled according to the space current of said device for compensating the main circuit of said gain decreaser to vary the rate of charge of said condenser and to maintain constant the 15
signal energy point at which the gain decreaser starts charging the condenser irrespective of the charge on the condenser.

10. In a signal system, a transmission channel, a space discharge device effectively connected in series with said channel and having a control 20
grid, a condenser for controlling the potential impressed on the grid of said device according to the charge thereon, a gain decreaser comprising a three-element cold cathode tube having a main 25
circuit for charging said condenser to reduce the gain and a breakdown circuit, means for operating said tube by the energy level of the signals on the channel beyond said device, and means controlled according to the space current of said 30
device for assisting the main circuit of said tube to maintain the time rate of gain change by the gain decreaser circuit constant and to maintain constant the signal energy point at which the gain decreaser starts charging the condenser.

35 11. In a signal system, a transmission channel, two gain control devices on said channel for controlling the gain, means comprising a control condenser for governing said devices to effect 40
varying changes in gain by said devices with respect to each other according to the charge thereon, means comprising a gain increaser circuit for charging said condenser to raise the gain on said channel when the energy level on the channel between 45
said devices is above a predetermined lower level, and means for blocking the operation of said gain increaser circuit when the energy level of the signals on the channel beyond said devices is above a predetermined lower level.

12. In a signal system, a transmission channel, 50
a space discharge device effectively connected in series with said channel, a condenser for governing said device according to the charge thereon to control the gain on said channel, a gain increaser circuit comprising a space discharge device and a cold cathode gas-filled tube for charging 55
said condenser to increase the gain when the signal level on the channel before said first-mentioned space discharge device is above a predetermined lower level, and means comprising a 60
gain increase disabler circuit for blocking the device in said gain increaser circuit when the signals on the channel beyond the device therein are above a predetermined lower energy level.

13. In a signal system, a transmission channel, 65
a bridge composed of solid elements with non-linear voltage current characteristics and having two opposite vertices connected across said channel, a space discharge device effectively connected in series with said channel, means comprising a 70
control condenser for varying the gain control by the bridge with respect to the gain control by

the device to control the gain on the channel according to the charge on the condenser, a gain increaser circuit comprising a cold cathode gas-filled tube for charging said condenser to raise 5
the gain on said channel when the energy level on the channel between said bridge and said device is above a predetermined lower limit, and means for blocking the operation of said gain increaser circuit when the energy level of the signals on the channel beyond said device is above 10
a predetermined lower level.

14. In a signal system, a transmission channel, two gain control devices on said channel for controlling the gain, means comprising a control condenser for governing said devices to effect vary- 15
ing changes in gain by the two devices with respect to each other according to the charge thereon, a gain decreaser circuit for impressing a negative charge on said condenser when the energy level of the signals on the channel beyond said devices is above a predetermined upper value, a 20
gain increaser circuit for impressing a positive charge on said condenser when the energy level of the signals on the channel between said devices is above a lower limit, and a gain increase 25
disabler circuit for blocking said gain increaser circuit when the energy level of the signals on the channel beyond said devices is above a lower limiting value.

15. In a signal system, a transmission channel, 30
a space discharge device effectively connected in series with said channel and having a control grid, a condenser for impressing potential on said grid according to the charge thereon to control 35
the gain on the channel, a gain decreaser circuit for impressing a negative charge on said condenser when the energy level of the signals on the channel beyond said device is above a predetermined upper limit, a gain increaser circuit for 40
impressing a positive charge on said condenser when the energy level of the signals before said device in the transmitting channel is above a predetermined low level, a gain increase disabler 45
circuit for blocking said gain increaser circuit when the energy level of the signals beyond the device in the channel is above a predetermined lower level, and means comprising a rectifier connected across said condenser for drawing current 50
when the condenser has a positive charge thereon.

16. In combination a transmission line having 50
control means therein, a condenser for governing said control means according to the charge thereon, a control circuit for charging said condenser when the energy of the currents on said line has a predetermined value and means controlled 55
according to the operation of said control means for varying the rate of charge of said condenser by said control circuit.

17. In combination a transmission line having 60
control means therein, a condenser for governing said control means according to the charge thereon, a control circuit for charging said condenser when the energy level of the currents on said line has a predetermined value, and means controlled 65
according to the operation of said control means for maintaining constant the energy value of the currents on said line at which the control circuit starts charging said condenser irrespective of the charge on the condenser.