

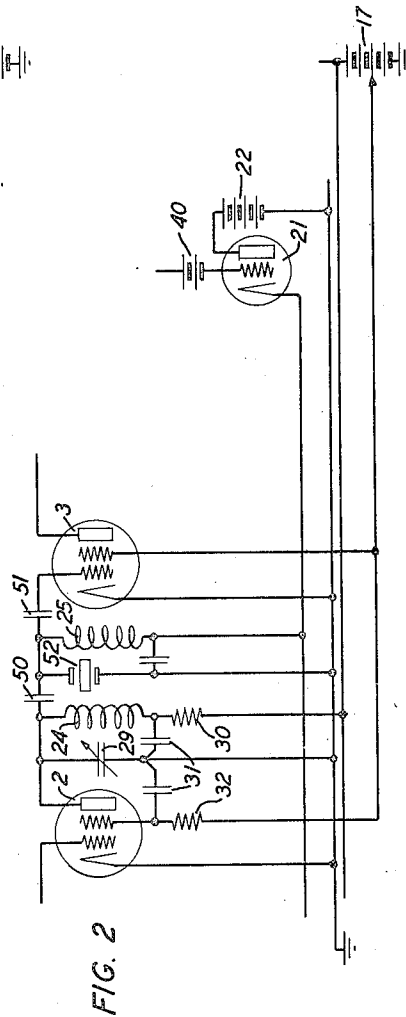
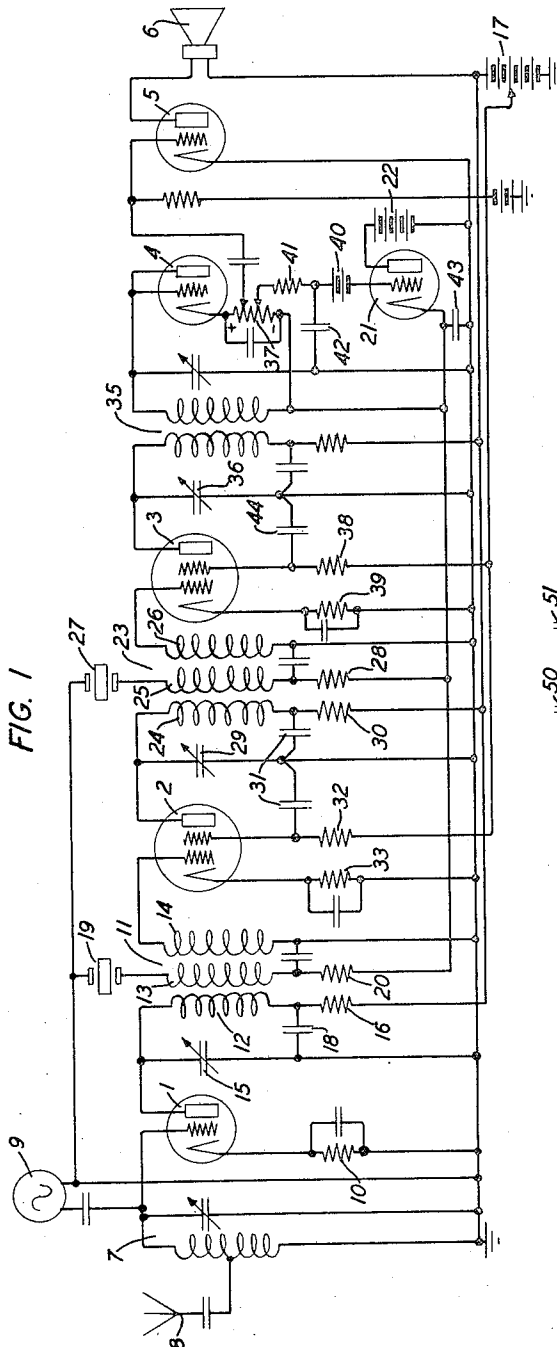
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VOLUME CONTROL CIRCUITS

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VOLUME CONTROL CIRCUITS

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This invention relates to volume control circuits for governing the gain of amplifiers.

One object of the invention is to provide a signal receiver with gain control circuits that shall govern the gain of an amplifier in the receiver by varying the load impedance in an improved manner.

Another object of the invention is to provide gain control circuits for varying the gain of space discharge devices arranged in tandem by governing the coupling circuit impedance between the space discharge devices.

A further object of the invention is to provide a receiver with gain control circuits that shall vary the gain of an amplifier in the receiver by varying the alternating current load impedance according to the direct current supplied to an element having a non-linear resistance characteristic.

In the majority of volume control circuits now in use the gain of a space discharge amplifier is governed by varying the plate impedance or the amplification constant or both of the space discharge device. The plate impedance is generally varied by controlling the potential on the grids or shields of the space discharge devices. The varying of the plate impedance is accompanied by changes in the plate current with the resulting distortion and non-linearity at low gains.

In volume control circuits constructed in accordance with the invention the alternating current load impedance is controlled independently of the plate impedance of the space discharge device to control the gain effected. The plate impedance of the space discharge device is not varied to control the gain so that the space discharge device may be operated with normal voltages and currents at all times.

In a space discharge device employed as a voltage amplifier the gain is,

$$\frac{E_2}{E_1} = \frac{\mu Z_p}{R_0 + Z_p}$$

where Z_p is the load impedance, E_2 is the voltage developed across the plate load impedance Z_p , E_1 is the voltage applied to the grid, and R_0 is the plate impedance of the device.

In the usual methods of controlling the gain of an amplifier the plate impedance R_0 is varied and to a lesser extent amplification factor μ is varied. If the plate impedance R_0 and the amplification constant μ are held constant the gain of an amplifier may be controlled by varying the load impedance Z_p . In an amplifier space dis-

charge device having load impedance Z_p in the form of an anti-resonant circuit, the impedance at resonance is

$$\left[\frac{\omega L}{R} \right]^2$$

where R is the series resistance in the tuned circuit. Accordingly a variation of the resistance R will vary the gain of the amplifier.

In the present invention the effective series resistance R is varied by controlling the current flow through a control element composed of silicon carbide crystals and a binder material included in a circuit that is closely coupled to the tuned circuit in the plate circuit of the space discharge device. The direct current flow through the control element may be varied at will or may be varied automatically. Changes in the resistance of the control element vary the direct current flow through the control element and thus vary the effective resistance R in the tuned circuit. A control element composed of silicon carbide crystals and a binder material is disclosed in the patent to K. B. McEachron, 1,822,742 dated September 8, 1931.

The invention is illustrated by means of a radio receiving circuit. The radio receiving circuit comprises a detector tube, two intermediate frequency amplifier tubes, a rectifier and an audio-frequency amplifier tube which is connected to a suitable loud-speaker. Between the detector tube and the first intermediate frequency amplifier tube and between the two intermediate frequency amplifier tubes are inserted inductance coils each comprising three closely coupled windings. The windings of each inductance coil serve as a single conductor for alternating currents and as separate conductors for direct currents. One winding of the inductance coil positioned between the detector tube and the first intermediate frequency amplifier tube is connected in the plate circuit of the detector tube. Another winding of this inductance coil is connected in the input circuit of the first intermediate frequency amplifier tube. The third winding of the inductance coil is connected in series with an element having a non-linear resistance characteristic and preferably a control element composed of silicon carbide crystals and a binder material.

The inductance coil between the two intermediate frequency amplifiers is provided with three windings connected similarly to the windings of the inductance coil between the detector tube and the first amplifier tube. The windings of the two inductances which are connected in series with the control elements are supplied with direct

current according to the output from the rectifier beyond the intermediate frequency amplifier tubes. The variation in the resistance of the control element according to the voltage impressed thereon changes the impedance of the inductive elements.

The winding of the inductance element between the detector tube and the first intermediate frequency amplifier tube that is connected in the plate circuit of the detector tube forms an anti-resonant circuit with an adjustable condenser. The variation of the impedance of the inductance element between the detector and first intermediate frequency amplifier tube by variation in the current flow through the control element serves to vary the effective resistance of the anti-resonant circuit. An increase of the current flow through the control element serves to increase the series resistance in the anti-resonant circuit and thus to decrease the load impedance. The control element connected to the inductance disposed between the two intermediate frequency amplifier tubes operates in a like manner to control the load impedance on the first intermediate frequency amplifier tube. In this manner the gain of the radio receiver is controlled.

In the accompanying drawing, Fig. 1 is a diagrammatic view of a radio receiver provided with a gain control circuit constructed in accordance with the invention; and

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

Referring to the drawing the radio receiver comprises a detector tube 1 of the three-element space discharge type, an intermediate frequency amplifier tube 2 of the screen grid space discharge type, an intermediate frequency amplifier tube 3 of the screen grid space discharge type, a rectifier 4 and an audio-frequency amplifier tube 5 of the space discharge type which is connected to a suitable loud-speaker 6. The input circuit of the detector tube 1 is provided with a tuned circuit 7 connected to a suitable antenna 8. An oscillator 9 is connected across the input circuit of the detector tube 1 for beating down the frequency of the received waves. A bias for the grid of the detector tube 1 is provided by the resistance element 10.

An inductance element 11 comprising three windings 12, 13 and 14 is provided between the detector tube 1 and the intermediate frequency amplifier tube 2. The three windings 12, 13 and 14 are closely coupled together so as to serve as a single conductor for alternating current and as separate conductors for direct current. The winding 12 is included in the output circuit of the detector tube 1 and the winding 14 is included in the grid circuit of the intermediate frequency amplifier tube 2. The winding 13 forms an anti-resonant circuit with an adjustable condenser 15. Anode current for the detector tube 1 is supplied through the winding 12 in series with a resistance element 16 from a battery 17. A condenser 18 is provided in the detector output circuit for by-passing alternating currents.

The winding 13 of the inductance element 11 is connected in a series circuit comprising a control element 19 composed of silicon carbide crystals and a binder material, a resistance element 20, a three-element tube 21 and a battery 22. The tube 21 which is of the three-element type is controlled in a manner to be hereinafter set forth for varying the potential impressed on the con-

trol element 19 to vary the current flow there-through. The variation in the current flow through the winding 13 of the inductance element 11 varies the resistance in the anti-resonant circuit comprising the winding 12 and the condenser 15 and accordingly varies the load impedance on the detector tube.

An inductance element 23 comprising three windings 24, 25 and 26 is positioned between the intermediate frequency amplifier tube 2 and the intermediate frequency amplifier tube 3. The windings 24, 25 and 26 are closely coupled so as to serve as a single conductor for alternating current while serving as separate conductors for direct current. The winding 24 is connected in the output circuit of the intermediate frequency amplifier tube 2 and the winding 26 is connected in the input circuit of the intermediate frequency amplifier tube 3. The winding 25 is connected in series with a control element 27 composed of silicon carbide crystals and a binder material and a resistance element 28 to the tube 21 and the battery 22. The winding 24 forms an anti-resonant circuit with an adjustable condenser 29. Plate current for the intermediate frequency amplifier tube 2 is supplied from the battery 17 through a resistance element 30 and the winding 24. By-pass condensers 31 are associated with the intermediate frequency amplifier tube 2. The screen grid of the intermediate frequency amplifier tube 2 is connected through a resistance element 32 to a tap from the battery 17. Bias for the grid of the intermediate frequency amplifier tube 2 is provided by a resistance element 33.

The intermediate frequency amplifier 3 is coupled to the rectifier 4 by means of a transformer 35. The primary winding of the transformer 35 forms a tuned circuit with a condenser 36 in the output circuit of the amplifier 3 and the secondary winding of the transformer is connected in series with a resistance element 37 and the rectifier 4. The screen grid of the intermediate frequency amplifier tube 3 is connected through a resistance 38 to a tap from the battery 17. Bias for the grid of the amplifier tube is provided by the drop across the resistance 39.

The grid circuit for the audio-frequency amplifier 5 is connected across a portion of the resistance element 37 and the input circuit for the tube 21 is connected through a resistor 41 across a portion of the resistance element 37. The resistance element 41 and a condenser 42 serve as a filter and control the time constant of the gain control circuit. An opposing battery 40 is included in the input circuit for the tube 21 for preventing operation of said tube until the received signals in the circuit of the rectifier 4 are above a predetermined level. The tube 21 as heretofore set forth controls the potential impressed on the control elements 19 and 27. The control elements control the load impedance on the detector tube and the intermediate frequency amplifier tube 2. Condensers 43 and 44 serve as by-pass condensers in the circuits.

In a radio receiver provided with a gain control circuit as above set forth the load impedance on the detector tube 1 and on the intermediate frequency amplifier tube 2 is varied by the circuits including the control elements 19 and 27 to take care of fading. This method of gain control varies only the alternating current impedances of the coupling circuits between the tubes

and accordingly permits the tubes to operate at all times with normal voltages and currents.

In Fig. 2 of the drawing a modification is shown wherein capacity coupling is employed between the tubes of the receiver. The modification has been illustrated by the coupling means between the radio frequency amplifier tubes 2 and 3. Similar parts in Fig. 2 to those shown in Fig. 1 have been indicated by like reference characters.

The radio frequency amplifier tubes 2 and 3 shown in Fig. 2 of the drawing are coupled together by means of the condensers 50 and 51. The tube 2 is supplied with anode current from the battery 17 in the same manner as the tube 2 in Fig. 1 is supplied with anode current from the battery 17. With the exception of the gain-control circuit the other circuits for the tubes 2 and 3 in Fig. 2 are the same as the circuits shown in Fig. 1 of the drawing.

The tube 21 in Fig. 2 of the drawing is controlled in the same manner as the tube 21 in Fig. 1 of the drawing is controlled. The output circuit for the tube 21 in Fig. 2 may be traced from ground through the battery 22, anode and cathode of the tube 21, coil 25, control element 52 and ground. The control element 52 composed of silicon carbide crystals and a binder material is connected across the line to control the coupling impedance. The variations in impedance in the tube 21 control the gain-control circuit through the control element 52 to vary the coupling impedance between the tubes 2 and 3.

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 a radio receiver, a circuit comprising space discharge devices arranged in tandem for transmission of signal currents, and electrical means comprising control elements composed of silicon carbide crystals and a binder material located between said devices and free from moving parts for varying the load impedance of the space discharge devices to control the volume of the signals while insuring against varying the impedances of the devices.

2. In a radio receiver, a circuit comprising space discharge devices arranged in tandem for transmission of signal currents, electrical means comprising a control element composed of silicon carbide crystals and a binder material in a circuit of one of said devices for varying the load impedance while insuring against varying the impedance of the device, and means for varying the current flow through said element according to the volume of the signals to maintain the signal volume substantially constant.

3. In a receiving circuit, a space discharge device having an output circuit, a coil in said output circuit comprising a number of closely coupled conductors which serve as a single conductor for alternating current and as separate conductors for direct current, and an element having a non-linear resistance characteristic series connected with one of said conductors in a direct current circuit independent of said output circuit for varying the load impedance on said output circuit according to the direct current flow through said conductor and element.

4. In a receiving circuit, a space discharge device having an output circuit, electrical means comprising a coil having a number of closely coupled conductors which serve as a single conduc-

tor for alternating current and as separate conductors for direct current, one of said conductors being included in the direct current plate circuit of said device, and an element composed of silicon carbide crystals and a binder material series connected with a second one of said conductors in a direct current circuit for controlling the load impedance on the output circuit independently of the impedance of said device.

5. In a receiver, two space discharge devices each having input and output circuits, a coil disposed between said devices comprising a number of closely coupled conductors serving as a single conductor for alternating current and as separate conductors for direct current, one of said conductors being included in the direct current plate circuit of one of said devices and another of said conductors being included in the input circuit of the second device, an element having a non-linear resistance characteristic series connected with the third conductor in a direct current circuit, and means for varying the direct current flow through said element and the third conductor for varying the volume of the signal supplied to the second device.

6. In a receiving circuit, a space discharge device supplied with signals of variable volume and having an output circuit, a coil in the output circuit of said device comprising a number of closely coupled conductors, said conductors serving as separate conductors for direct currents and as a single conductor for alternating current, and means for effecting a variable direct current flow through one of said conductors to vary the alternating current impedance and control the volume of the signal currents.

7. In a receiving circuit, a space discharge device supplied with signals of variable volume and having an output circuit, a coil in the output circuit of said device comprising a number of closely coupled conductors, said conductors serving as separate conductors for direct current and as a single conductor for alternating current, means for supplying the anode of said device with potential by a circuit including one of said conductors, an element having a non-linear resistance characteristic connected in series with a second one of said conductors, and means for varying the direct current flow through said second conductor to control the volume of the signals beyond said coil.

8. In a radio receiver, a circuit comprising space discharge devices arranged in tandem for the transmission of signal currents, a circuit comprising a control element composed of silicon carbide crystals and a binder material, means for inductively coupling said last mentioned circuit to the output circuit of one of said devices for varying the load impedance on such device according to the current flow through said control element, and means for varying the current flow through said element according to the volume of said signals to maintain the signal volume substantially constant.

9. In a volume control system, a circuit comprising space discharge devices arranged in tandem for transmission of signal currents, a coil in the output circuit of one of said devices and in the input circuit of another one of said devices, said coil comprising a number of conductors which serve as a single conductor for transmitting alternating current and as separate conductors for transmitting direct currents, an element having a non-linear resistance characteristic series connected with one of said conductors in a

direct current circuit independent of said output and said input circuit for varying the load impedance on said output circuit according to the direct current flow through said conductor and element, and means for varying the direct current flow through said element according to the volume of the signals to maintain the signal volume substantially constant.

10. In a receiver, a circuit comprising space discharge devices arranged in tandem for the transmission of signal currents, a coil in the output circuit of one of said devices and in the input circuit of the next succeeding device, said coil comprising three closely coupled conductors which serve as a single conductor for alternating current and as individual conductors for direct current, one of said conductors being included in the plate circuit of the first mentioned device, a second conductor being in the input circuit of the second mentioned device and the third conductor being included in a direct current circuit with a

control element composed of silicon carbide crystals and a binder material, and means for varying the direct current flow through said control element according to the volume level of the signals beyond said second device to control the load impedance of the first device and maintain the volume level of the signals beyond the first device substantially constant.

11. In a radio receiver, a circuit comprising space discharge devices arranged in tandem for the transmission of signal currents, coupling means between two of said space discharge devices, a control circuit comprising a control element composed of silicon carbide crystals and a binder material, means for connecting said control element to vary the impedance of the coupling means between said two space discharge devices, and means for varying the current flow through said control circuit according to the energy volume of the signals.

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