June 2, 1936. K. C. BLACK 2,043,092

AUTOMATIC VOLUME CONTROL

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Fig. 1

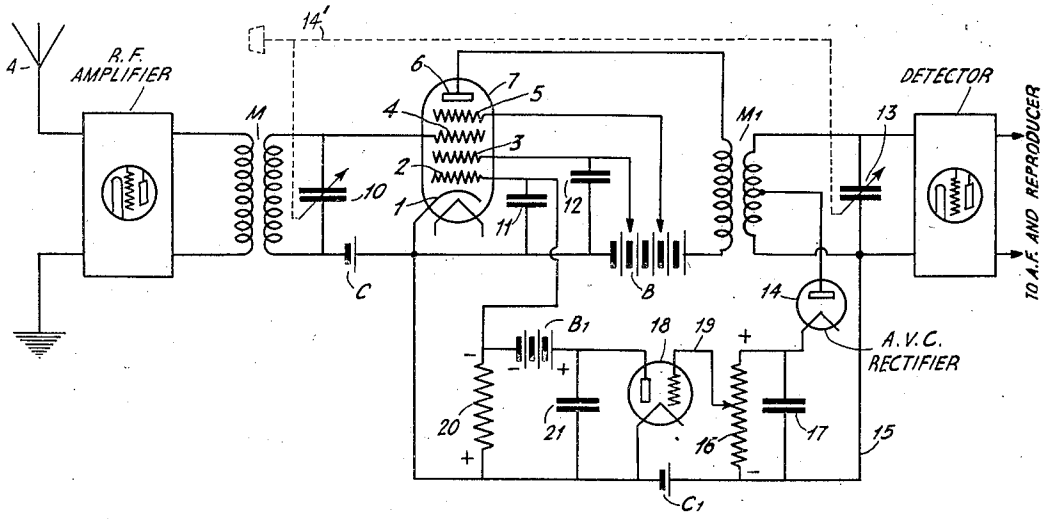
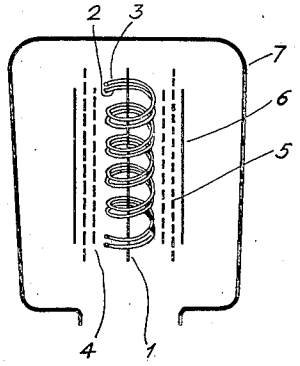


Fig. 2



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AUTOMATIC VOLUME CONTROL

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17 Claims. (Cl. 250—20)

This invention relates to a novel method of, and apparatus for, controlling the operation of vacuum tube devices, such as amplifiers, oscillators and modulators.

In my U. S. Patent No. 1,869,536, patented August 2, 1932, various circuit arrangements have been shown for the control of vacuum tube amplifiers wherein the bias on a vacuum tube grid may be adjusted from positive to negative values by the action of a controlling tube. More specifically, the said patent disclosed methods of employing one tube to control the operation of a second tube by adjusting the bias voltage applied to a grid thereof which is normally operated at a positive potential. It has been shown in my said patent that the space charge grid of a space charge radio frequency amplifier pentode furnishes a convenient means of amplifier gain control. A gain control which makes use of a space charge grid for control purposes gives, in general, a very smooth type of control which can vary the gain between extremely wide limits, and which, at the same time, does not cause great increase in the distortion of signals as the gain in the amplifier tube decreases. This is a very useful characteristic.

Accordingly, it was proposed in my said patent to connect the source of gain control voltage to the input electrodes of the control tube, and connect the said control tube in series with the grid cathode impedance of the controlled tube, it thus being possible to adjust the positive voltage on the space charge grid of the controlled tube between predetermined negative and positive values. However, the conventional types of automatic volume control circuits employed in broadcast receivers are of the type wherein a portion of the input to the detector circuit is rectified, and the rectified potential utilized as the control voltage. With this type of automatic volume control arrangement the most efficient operation is secured when the rectified potential is utilized for controlling the bias of an electrode of an amplifier to be controlled which is normally at a negative potential. Objections are usually raised when amplifier gain control by means of a positive electrode is suggested because most of the conventional gain or volume control circuits are best suited to the control of the voltage on an electrode with a negative potential.

Accordingly, I have devised a method of, and furnished means for, combining the best features of the system shown in my aforesaid patent, and the conventional and well known automatic volume control circuits. Briefly, while a space charge radio frequency amplifier pentode is still the controlled tube, the control voltage is actually applied to an auxiliary grid in the tube which is employed particularly for volume control purposes, and is, at the same time, always maintained at a negative potential in respect to the cathode of the tube.

Hence, it may be stated that is one of the main objects of my present invention to provide an amplifier gain control system wherein the controlled tube includes a positive space charge grid and a special automatic volume control grid operating at negative potentials, the source of gain control voltage being connected to the automatic volume control grid in such a manner that the effective operation of the controlled tube is such that the gain of the controlled tube will depend on the combined effect of the voltages on the space charge grid and the automatic volume control grid.

Another important object of the present invention is to provide an amplifier system including a pentode tube of the type provided with a space charge grid and volume control grid which are inter-meshed, and a control tube having its output circuit connected in shunt with the volume control grid, the input circuit of the control tube being arranged for connection to a source of potential for controlling the gain of the amplifier pentode tube.

Still other objects of this invention are to improve the efficiency of amplifier gain control systems, and to particularly provide such an arrangement which is not only reliable in operation, but readily adapted for use with conventional broadcast receivers.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims, the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically one circuit arrangement whereby my invention may be carried into effect.

In the drawing—

Fig. 1 diagrammatically shows a conventional receiver circuit embodying the present invention,

Fig. 2 shows a different embodiment of the invention.

Referring now to the accompanying drawing wherein like reference characters in the different figures represent similar circuit elements, in

Fig. 1 the present invention is shown applied to a conventional type of radio receiver comprising a means for collecting signal energy, such as a grounded antenna circuit A, a stage of radio frequency amplification coupled, as at M, to the tunable input circuit of a second stage of radio frequency amplification embodying the present invention, the output of the second stage being coupled, as at M_1, to the tunable input circuit of a detector stage, the output of the detector being utilized in any desired manner, as by audio frequency amplification and reproduction. The second radio frequency amplifier stage includes an electron discharge tube within whose envelope 7 are disposed the usual cathode 1, preferably of the indirectly heated type, a control grid 4, a screen grid 5, a space charge grid 3, and the special automatic volume control purpose grid 2, the latter being disposed between the space charge grid 3 and the cathode 1.

The variable tuning condenser 10 is connected in the usual manner across the secondary coil of the coupling transformer M, and the control grid 4 is maintained more negative than the negative side of the cathode 1 by the usual and conventional biasing potential source C. A source of positive potential B furnishes the necessary positive potential for the anode, the screen grid, and the space charge grid respectively. The numerals 11 and 12 designate radio frequency by-pass condensers connected between the leads to grids 2 and 3 and the negative side of cathode 1.

The secondary coil of the anode circuit of the coupling transformer M_1 has shunted across it the variable tuning condenser 13, and dotted lines 14' are shown connecting the two variable tuning condensers 10 and 13 to show that the rotors of these two condensers may be mechanically coupled for the well known unicontrol tuning. The detector stage may be of any desired type, and is not shown since those skilled in the art are well aware of different types of detector circuits.

A portion of the input to the detector stage is impressed upon the automatic volume control rectifier circuit, the circuit comprising, for example, a diode rectifier 14 having its anode connected to a point on the secondary coil of the transformer M_1 somewhat below the high potential side of the coil in order to lessen the load on the tuned input circuit of the detector stage. A lead 15 connects the low potential side of the tuned detector input circuit to the negative side of resistor 16, the positive side of the latter resistor being connected to the cathode of the diode 14, a radio frequency by-pass condenser 17 being shunted across the resistor 16. A control tube 18, of the triode type if desired, has its control grid connected by an adjustable tap 19 to the resistor 16, adjustment of the tap 19 on the resistor 16 being used for adjusting the "stiffness" of the automatic volume control action.

A resistor 20 is connected in series between the volume control grid 2 and the cathode 1 of the tube 7, and a potential source B_1 has its negative terminal connected to the negative side of the resistor 20, while the positive terminal of the source B_1 is connected to the anode of the control tube 18. The cathode of the tube 18 is connected to the positive side of resistor 20, and a biasing potential source C_1 has its negative terminal connected to the cathode of tube 18, and its positive terminal connected to the low potential side of resistor 16. A condenser 21 is connected in shunt between the anode and cathode of tube 18 in order to by-pass radio frequencies.

The operation of the control tube 18 is controlled by adjusting the bias voltage established by the rectifier 14 through the resistor 16. It will now be seen that the amplification of tube 7 is determined by the direct current bias established on the grid 2 by the source B_1 and the control tube 18. The operation of the arrangement shown in Fig. 1 can now be described.

While the operation will be explained with particular reference to the control of the amplification stage utilizing tube 7, it is to be clearly understood that the preceding amplifier stage could very well be included in the control circuit, and that the present invention is not limited in any way to the particular automatic volume control system described herein, since the specific arrangement shown is merely employed for the purpose of illustration. Assuming now, that the automatic volume control arrangement has been adjusted so that the automatic gain control of the amplifier does not commence until the signal input to the detector varies above a predetermined signal intensity level, suppose that the signal energy collected at A increases above the said level for some particular reason. The input to the diode rectifier 14 will therefore increase, and the potential drop across the resistor 16 will accordingly increase. This results in the grid of the tube 18 becoming more positive, and the potential drop across the resistor 20 becoming greater, the point on the resistor 20 to which the volume control grid 2 is connected becomes more negative.

This results in an increase in the negative potential of the volume control grid 2, and a consequent decrease of the gain of the amplifier stage including the tube 7. The design of grids 2 and 3, it being again pointed out that the latter grid 3 is the normal positive space charge grid, must be such that with approximately zero, or any desired negative, potential on the grid 2, and with some positive potential on grid 3, the characteristic of the tube is that of a normal space charge radio frequency amplifier pentode. When the gain is to be reduced by the volume control action the potential on grid 2 is made more negative as has been already pointed out.

Whereas the gain of a normal pentode, as disclosed in my aforementioned patent, is determined by the direct current voltage on the space charge grid, in tube 7 the gain will depend on the combined effect of the voltages on grids 2 and 3. Hence, the effect of putting a more negative voltage on the volume control grid 2 will be the same as causing the voltage on the space charge grid 3 to go from its normal positive value towards zero.

It will now be seen that the present invention provides a simple and efficient arrangement for combining the desirable features of the space charge volume control arrangement of my aforesaid patent and the negative potential automatic volume control arrangements of conventional receivers. In fact, the positive voltage of the space charge grid is sufficiently neutralized by the variable negative potential of the special volume control grid so that there is obtained much the same control that is obtained by running a space charge grid from a positive value to the cut-off. This effect is most efficiently secured by intermeshing the grids 2 and 3, that is disposing them in coplanar fashion, as shown in Fig. 2.

It will be noted that the grids 2 and 3 are here shown surrounding the cathode 1, the heater fil-

ament being omitted for simplicity, the grids 2 and 3 being understood to be of the same diameter. This construction shown in Fig. 2 not only results in a smooth type of control which can vary the gain between extremely wide limits, and which, at the same time, does not cause great increase in the distortion of signals as the gain in the tube decreases, but furnishes a compact and economical type of tube since the grids 2 and 3 occupy the same amount of space around the cathode 1.

It is to be noted that the two grids 2 and 3 may be placed either in the order shown in Fig. 1, or in the reversed order. That is the space charge grid 3 may well be the grid immediately adjacent the cathode, and between the grid 2 and the cathode. Again, the space charge and screen grid leads have been shown adjustably connected to the potential source B, and those skilled in the art well realize that either of these adjustable leads can be used for manual volume control, it being again pointed out that the tap 19 can be shifted on the resistor 16 to adjust the action of the automatic volume control circuit.

Furthermore, as shown in my aforesaid patent, the present invention is readily adapted to oscillators and modulators; in the case of modulators, the control voltage impressed across the resistor 16 will be of an audio or other modulating frequency. Modulation may also be effected when the signal circuits of tube 7 cause the same to operate as an oscillator, the intensity of the oscillation being varied at a lower frequency by the alternating voltage impressed upon the control tube 18.

As stated heretofore, the present system of control may, of course, be extended in the usual manner to impress the controlling voltage upon a plurality of controlled tubes. The manner of controlling a plurality of amplifier tubes arranged for cascade amplification has been disclosed in my aforementioned patent. While I have described a control obtained by adjustment of the bias voltage applied to space charge grid, it will be obvious that the same principles apply equally well when the control is applied to any positive accelerating electrodes, and it should also be clearly understood that the volume control grid can be used for performing some other function.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention as set forth in the appended claims.

What I claim is:

1. The combination with a vacuum tube having a cathode, a plate, a signal grid and at least two auxiliary grids; and means including a vacuum tube controlling the bias applied to one of said auxiliary grids, said means impressing solely a negative bias on said one grid, said auxiliary grids being disposed between the cathode and signal grid, means for maintaining the other grid at a substantially constant positive potential with respect to the cathode.

2. The combination with a vacuum tube having a cathode, a plate, a signal grid and at least two auxiliary grids; and means including a vacuum tube controlling the bias applied to one of said auxiliary grids, said means impressing solely a negative bias on said one grid, said auxiliary grids being disposed between the cathode and signal grid, means for maintaining the other auxiliary grid at a substantially constant positive potential with respect to the cathode, said controlling tube having its cathode-plate impedance connected to said one grid and said cathode.

3. The combination with a vacuum tube having a cathode, a plate, a signal grid and at least two extra grids, means for maintaining one of the extra grids at a positive potential with respect to the signal grid and the other grid, the two extra grids being disposed between the signal grid and cathode, of means including a vacuum tube having its plate-cathode impedance in shunt with the less positive extra grid-cathode impedance of said first tube for adjusting the bias on said less positive extra grid solely between predetermined potential values which are negative with respect to the cathode of the first tube.

4. The combination with a vacuum tube having a cathode, a plate, a signal control grid, a screen grid, a second grid, and a special purpose grid at a negative potential with respect to the cathode, and circuit elements connecting said cathode to said control grid and plate to establish signal circuits, of means for impressing a positive potential on the screen grid, of means maintaining said second grid at a positive potential with respect to the cathode, and means including a vacuum tube in shunt with the special purpose grid and cathode for controlling the bias on said special purpose grid.

5. A receiver comprising an amplifier of the space charge radio frequency amplifier pentode type, a detector coupled to the output circuit of said amplifier, a volume control grid disposed within said pentode and adapted to be biased to a negative potential with respect to the space charge grid of the pentode, and means connected to the volume control grid circuit of the amplifier and to said detector for varying the negative potential of said volume control grid in accordance with signal level variations in the detector input circuit.

6. In combination with a wave amplifier including a tube having a cathode, an anode, a signal electrode and a pair of co-planar grids disposed between the cathode and said signal electrode, means for maintaining one of the grids at a positive potential with respect to the cathode, and additional means for adjusting the gain of the amplifier by varying the potential of the remaining grid through a negative direct current potential range.

7. In combination with a vacuum tube wave amplifier having a cathode, a plate, control grid, and a pair of inter-meshed grids surrounding the cathode, of means for maintaining one of the inter-meshed grids at a positive potential with respect to the cathode, and amplifier gain control means impressing a variable negative direct current bias on the other one of the intermeshed grids.

8. In a radio receiving system, an electron discharge tube provided with a cathode, a signal grid, an anode, a negative cold electrode, and at least two auxiliary positive cold electrodes, a signal input network connected to the signal grid, a detector coupled to the anode circuit of said tube, and an automatic volume control arrangement comprising a rectifier adapted to produce a negative direct current potential from signal energy fed to said detector, and a direct current connection between said rectifier and said negative electrode for impressing said negative potential upon the latter.

9. In a radio receiving system, an electron discharge tube provided with a cathode, a signal grid, an anode, a negative cold electrode, and at least two auxiliary positive cold electrodes, said negative cold electrode and one of said auxiliary electrodes being co-planarly arranged, a signal input network connected to the signal grid, a detector coupled to the anode circuit of said tube, and an automatic volume control arrangement comprising a rectifier adapted to produce a negative direct current potential from signal energy fed to said detector, and a direct current connection between said rectifier and said negative electrode for impressing said negative potential upon the latter.

10. In a radio receiving system, a signal transmission tube provided with a cathode, a signal input electrode, an output electrode, a gain control electrode, and at least two auxiliary positive cold electrodes, the said gain control electrode and one of said positive cold electrodes being disposed between the signal input electrode and the cathode, a signal input network connected to the signal input electrode, an automatic gain control arrangement comprising a rectifier adapted to produce a negative direct current potential from signal energy, and a direct current connection between said rectifier and said gain control electrode for impressing said negative potential upon the latter.

11. In a signal transmission system a tube having input and output circuits, said tube having at least a cathode, anode, a positive screen grid, a signal grid between the screen grid and anode, and a gain control grid between the cathode and screen grid, means for varying the negative bias of the gain control grid over a range of values, and a source of signals connected to the signal grid.

12. An amplifier including a tube having input and output circuits, said tube having at least a cathode, anode, a positive screen grid, a signal grid between the screen grid and anode, and a gain control grid between the cathode and screen grid, means for varying the negative bias of the gain control grid over a range of values, a source of signals connected to the signal grid, and an additional positive screen grid between the signal grid and anode.

13. An amplifier including a tube having input and output circuits, said tube having at least a cathode, anode, a positive screen grid, a signal grid between the screen grid and anode, and a gain control grid between the cathode and screen grid, means for varying the negative bias of the gain control grid over a range of values, and a source of signals connected to the signal grid, said signal source being of a radio frequency, and said bias varying means including a device adapted to produce from said signals a direct current potential component proportional in value to the signal carrier amplitude.

14. In an amplifier stage having a vacuum tube provided with a signal grid located between a cathode and an anode, the method of controlling the stage gain which comprises establishing a positive field between said cathode and signal grid, and controlling the electron flow from said cathode to said positive field by a negative field between said cathode and the positive field.

15. In the operation of an amplifier stage including a tube having a cathode cooperating with a signal grid and anode, the method of reducing the transconductance of the tube from signal grid to anode without increasing the distortion introduced into the amplified output of the tube, which method comprises establishing a positive or accelerating field between the signal grid and cathode, and controlling the electron flow from said cathode to the region of the positive field and signal grid by a negative field adjacent said cathode.

16. An audion amplifier stage comprising a tube having a cathode cooperating with a signal grid and an anode to form an amplifier, an input circuit connected between said signal grid and cathode, an output circuit between said anode and cathode, and means for controlling the gain of the stage; said means comprising a pair of oppositely polarized electrodes located between said cathode and signal grid, and means for adjusting the potential between one of said electrodes and the cathode.

17. An audion amplifier stage comprising a vacuum tube having a cathode, a positively polarized anode and at least three grid electrodes between said cathode and said anode, means impressing a negative bias on the outermost and innermost of said three grids, means polarizing the intervening grid positive with respect to said cathode, circuit connections impressing a signal voltage between the outer negative grid and cathode, an output circuit between said anode and said cathode, and means for adjusting the negative bias on the inner negative grid, thereby to control the gain of said stage.

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