Oct. 8, 1935. P. O. FARNHAM 2,016,366

AUTOMATIC VOLUME CONTROL

Filed Oct. 23, 1931 2 Sheets-Sheet 1

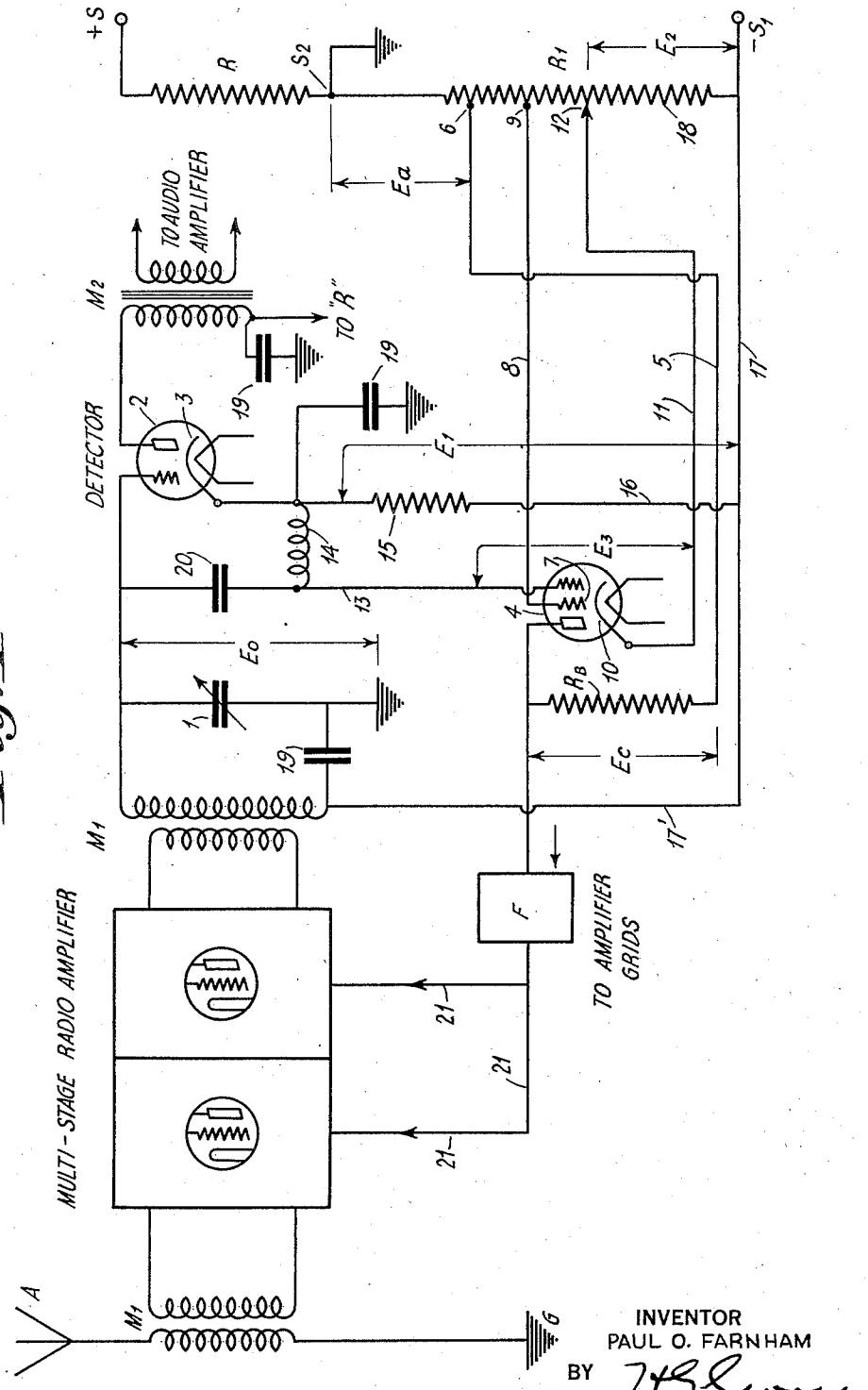

Fig. 1

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Fig. 2

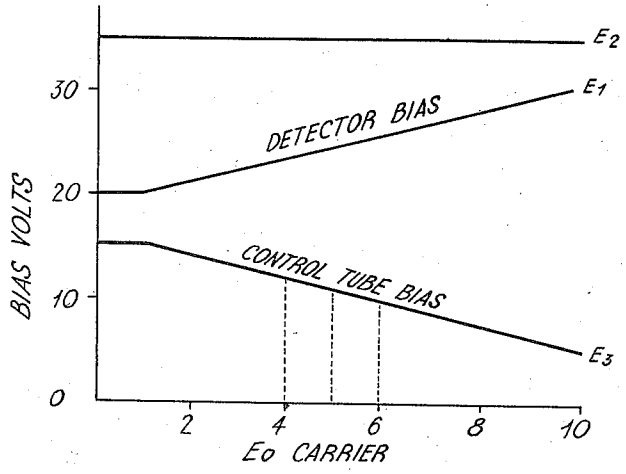
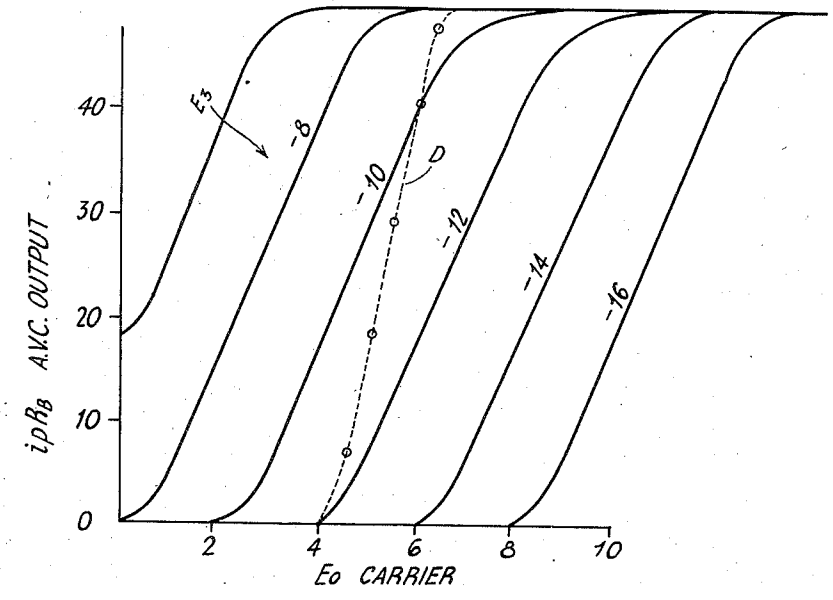


Fig. 3



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AUTOMATIC VOLUME CONTROL

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13 Claims. (Cl. 250—20)

My present invention relates to automatic gain control arrangements, and more particularly to an improved method of, and means for, controlling the gain of a high frequency amplifier, especially where such amplifiers are utilized in radio receivers.

Automatic gain control for the radio frequency amplifiers of radio receivers has been employed to a great extent in the past. Such gain control systems of the prior art usually employ the direct current component of the detector output for automatically controlling the gain of the radio frequency amplifier. In some systems a direct current amplifier is disposed between the controlled amplifier and the detector circuit. In still other systems a special automatic volume control tube has been employed as a rectifier operating from the carrier voltage at the output of the radio frequency amplifier and providing a direct current component to be utilized for controlling the gain of the radio frequency amplifier. In all these systems, however, the control of the radio frequency amplifier has not been ideally sharp.

Now, I have devised an arrangement for automatically controlling the gain of a radio frequency amplifier which combines the essential features of both the aforementioned systems of the prior art, and yet increases the sharpness of gain control. That is to say, according to the present invention a special tube is utilized in conjunction with the usual detector tube of the radio receiver for simultaneously acting as a direct current amplifier for the direct current component of the detected output, and, additionally, as a rectifier adapted to produce a direct current component for controlling the gain of the radio frequency amplifier, this simultaneous use of the automatic gain control tube resulting in an increased sharpness of control action.

It may therefore be stated that it is one of the main objects of my present invention to provide a method of, and means for automatically controlling the gain of a radio frequency amplifier, which consists in disposing a control tube in such relation to the detector and radio frequency amplifier that the control grid of the control tube has a bias established through a path wherein there flows the anode to cathode current of the detector tube, deviation in signal carrier intensity above or below predetermined limits resulting in changes in the flow of current through said path whereby the control tube is adapted automatically to vary the gain of the radio frequency amplifier in that direction which will compensate for a deviation from one of said predetermined limits.

Another important object of the present invention is to provide a radio receiver including a multi-stage radio frequency amplifier, a detector, and an automatic gain control tube, the control grid of said gain control tube being connected through a capacity to the radio frequency output of said amplifier whereby said radio frequency output is rectified by said control tube to provide an additional direct current component of voltage in the anode circuit of said control tube which direct current voltage is adapted to control the gain of said radio frequency amplifier.

Still other objects of the invention are to improve generally the efficiency of automatic gain control circuits, and to particularly provide a gain control arrangement which is not only reliable in operation, but increases the sharpness of control action.

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 drawings in which I have indicated diagrammatically one circuit arrangement for carrying my invention into effect.

In the drawings,

Fig. 1 diagrammatically shows a receiving circuit embodying the invention,

Fig. 2 graphically illustrates the relation between signal carrier intensity and bias voltage variation on the detector and on the control tube,

Fig. 3 is a graphic comparison between the operation of the present invention and one of the systems known in the prior art.

Referring to the accompanying drawings there is shown in Fig. 1, in diagrammatic manner, a receiving circuit which embodies the usual grounded antenna circuit A, G, the circuit being coupled, as at M, to the input of a multi-stage radio frequency amplifier. The construction of such a radio frequency amplifier is so well known to those skilled in the art that it is not believed necessary to show such an amplifier in more than conventional representation. It is, also, to be clearly understood that the amplifier can be of the tuned type well known to the prior art. The amplified output of the radio frequency amplifier is impressed upon the input circuit of a detector tube, as at M_1, the variable condenser *f* being provided for tuning the detector input. It is to be understood that the condenser *f* may be arranged for uni-control, in any well known man-

ner, with the tuning condensers of the radio frequency amplifier. The detector tube 2, shown as a triode for the sake of simplicity, may be an electron discharge tube of any type well known in the art, and is preferably shown as embodying a cathode 2 of the indirect heated type.

An audio frequency transformer M_2 couples the output of the detector to any conventional audio frequency amplifier, of one or more stages, in the usual manner. The amplifier may then be followed by any type of utilization means, such as head phones, loud speaker and the like. The aforementioned general features of the receiver are so well known to those skilled in the art that they need not be described in any further details, except to point out that they may be replaced by any other elements adapted to perform the same functions.

In order to provide automatic control of the gain of the radio frequency amplifier a control tube 4 is provided, the tube preferably being a tetrode of the screen grid type and employing a cathode which is indirectly heated. The various electrodes of the detector tube and control tube 4 are energized from a power supply source S. It is to be understood that the source S, S_1 is adapted to receive filtered, rectified alternating current, or where direct current is available from a power line, it may be directly connected to such a direct current power line. It will be noted that the terminal S is the positive side of the power source, while the terminal S_1 is designated as the negative side of the source, an intermediate point S_2 of the source being grounded.

A resistor R is disposed between the terminal S and the grounded intermediate point S_2, and functions as a voltage divider for the various electrodes of the receiver requiring positive bias. For example, the anode of the detector tube 2 would be connected for the application of a positive potential thereto through a path including the primary coil of the coupling transformer M_2 and a lead which would be connected to a desired point on the resistor R, the latter lead not being shown to preserve simplicity of description.

A resistor R_1 is connected in series with the resistor R, and between the points S_2 and S_1. The anode of the control tube 4 is connected through a fixed resistor R_B and a lead 5 to a point on the resistor R_1 which is positive with respect to the terminal S_1. The difference of potential between the point S_2 and the point 6, to which the anode of tube 4 is connected, has been designated by the letters E_a and represents the initial bias on the grids of the radio frequency amplifier. The screen grid electrode 7 of the control tube is connected by a lead 8 to a point 9 on the resistor R_1 which is less positive than the point 6, whereby the screen grid electrode is maintained at a less positive potential than the anode of the control tube.

The cathode 10 of the latter is connected by a lead 11 for adjustable connection to a point 12 on the resistor R_1, the latter being a point of less positive potential than the point 9, and of more positive potential than the terminal S_1. The control grid of the control tube is connected to the terminal S_1 through a path which includes the lead 13, the choke coil 14, the resistor 15, the lead 16 and the lead 17. The portion 18 of the resistor R_1 between the point 12 and the terminal S_1 is connected in series with the lead 17, and the drop of potential across the portion 18 has been designated by the reference character E_2.

The drop of potential across the resistor 15 has been designated by the reference character E_1, while the potential of the control grid of the tube 4 with respect to its cathode 10 has been represented by the reference character E_3. It will now be seen that the effective negative bias E_3 on the control grid of tube 4 is equal to E_2-E_1, since the control grid of tube 4 is connected through the choke coil 14 to a direct current potential E_1 volts above S_1 and the cathode of tube 4 is connected to a direct current potential E_2 volts above S_1 and E_2 is greater than E_1. It will be seen that since E_1 is determined by the flow of anode-cathode current in the detector, E_3 will be decreased by a carrier voltage input to the detector.

The grounded, fixed condensers 19 are employed to provide a path of low impedance to radio frequency and audio frequency currents between the output and input circuits of the detector tube 2. The function of the fixed condenser 20, in series with the lead 13 and the choke coil 14 is to apply to the control grid of the control tube a carrier voltage input which by rectification in the control tube will cause a control bias for the radio amplifier to be developed in resistor R_B. Thus, tube 4 develops a rectified output due to this carrier voltage, in addition to its use as a direct current amplifier.

The control grid of the detector tube 2 is maintained at a negative bais through a path which includes the secondary of the coupling transformer M_1 in series with the lead 17' and 17 and cathode biasing resistor 15, it being, therefore, seen that the bias of the grid of tube 2 is equal to the direct current voltage furnished by the anode to cathode current of tube 2 flowing through resistor 15.

The anode of the control tube 4 is connected by means of the leads 21 to the grid circuits of the radio frequency amplifier stages. The particular manner of connection between these grid circuits and the leads 21 need not be shown since they are too well known to those skilled in the prior art to require any further explanation. The voltage produced by the potential drop across the resistor R_B has been designated by the reference character E_c, and represents the gain control bias which is developed during operation of the receiver.

The operation of the present gain control arrangement will now be clear from the aforegoing description and the drawings. If the signal carrier intensity, represented by the reference character E_0, increases, there will be produced both by rectification and by the decrease in E_3 due to increasing E_1 an increased flow of current in the plate circuit of the control tube 4. This increased flow of plate current results in an increased drop of potential across the resistor R_B with the result that the value of E_c becomes greater, and necessarily increases the bias on the grids of the amplifier tubes thereby reducing the radio frequency amplification and compensating for the increase of carrier voltage above the predetermined upper limit.

The increase of plate current flow in the gain control tube results because of two factors. One of these factors involves a rectification of the signal voltage E_0 applied to the control tube through condenser 20, and the other factor involves the decreasing bias E_3 on the grid of the gain control tube. It will be readily seen that with increased values of E_0 there will occur a greater flow of direct current through the path between the anode and cathode of the detector tube, which path includes the resistors R, R_1 and

15. In other words, when E_0 increases, the value of E_1 increases, and hence, since E_3 is equal to E_2-E_1, the value of E_3 is diminished with the result that a greater value of current is produced in the plate circuit of the tube 4.

By means of the present arrangement a more rapid increase of plate current flow in the gain control tube with E_0 increase is produced than either the direct current amplifier or rectifier system of gain control used alone, hence increasing the sharpness of control. By sharpness of control I refer to the shape of the control characteristic, that is the shape of the curve connecting audio output versus modulated carrier voltage impressed upon the radio frequency amplifier in a receiver system embodying this arrangement. This control characteristic is said to be sharp when the range of input carrier voltage required to go from a point at which the control action starts to a point beyond which the control characteristic is substantially flat is small. In order to distinguish between modulation effects and fading effects a filter system F usually made up of resistors and capacities in a manner well known to those skilled in the art, is used on the line feeding bias from the control tube back to the amplifier tubes. Such a filter is quite necessary whatever the sharpness of control, and is able to distinguish between modulation and fading only upon the basis of the speed of these effects.

The sharpness and completeness of an automatic volume control characteristic depends upon at least three factors: (1) The rate of increase of direct current bias furnished by the control tube as a function of carrier voltage operating on the control tube, (2) the rate of decrease in amplification of a radio frequency stage as a function of bias furnished by the control tube, and (3) the number of stages being controlled. The present arrangement provides a means of increasing the first of these factors.

In Fig. 2 there is graphically shown the relation between the potentials E_2, E_1 and E_3 as the carrier input E_0 is increased. E_3, the negative bias voltage of the control tube is thus seen to decrease with increasing carrier input since $E_3=E_2-E_1$. The control tube will, therefore, operate as a direct current amplifier, its input being derived from changes in the direct current bias of the detector tube, and its output being a direct current voltage across R_B. In addition it will operate as a rectifier as shown in Fig. 3.

In Fig. 3 there is shown a graphic comparison between the operation of the present arrangement and the rectifier arrangement of the prior art. Carrier voltages "E_0 carrier" are plotted against "i_pR_B A. V. C. output" for different values of control grid bias E_3 on the control tube. Thus, the dotted line D shows the variation, according to my present invention of voltage E_c with carrier voltage E_0. Without the variation of E_3 bias on the control tube 4, the A. V. C. voltage E_c would vary as the "—12" curve with the carrier. There will be observed from Fig. 3 that the present arrangement provides for a sharpness of control not possible without the utilization of variation of E_3 bias on the control tube.

While I have indicated and described one arrangement 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 organization 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. In combination, a radio frequency amplifier, a detector tube, a control tube, means connecting the anode of the control tube to an amplifier grid, means connecting the control grid of the control tube to a biasing path connected between the cathode and anode of the detector tube whereby the direct current potential difference between the control grid and cathode of said control tube is determined by the direct current potential drop across said biasing path, and means impressing the output of said radio frequency amplifier upon the control grid circuit of said control tube.

2. In combination, a radio frequency amplifier, a detector tube, a control tube, means for connecting the anode of the control tube to an amplifier grid, and means for connecting the control grid of the control tube to a biasing path connected between the cathode and anode of the detector tube, said path including a high radio frequency impedance connected between the said control grid and the cathode of said detector tube, and a capacity for impressing the radio frequency input to the detector upon said control grid connected between the detector grid and said impedance.

3. In combination, a radio frequency amplifier, a detector tube, a control tube, means for connecting the anode of the control tube to an amplifier grid, means for connecting the control grid of the control tube to a biasing path connected between the cathode and anode of the detector tube whereby the direct current potential difference between the control grid and cathode of said control tube is determined by the direct current potential drop across said biasing path, the cathode of the control tube being connected to a point on said path which is more positive than the point to which said control grid is connected, and means impressing the output of said radio frequency amplifier upon the control grid circuit of said control tube.

4. In combination, a radio frequency amplifier, a detector tube, a control tube, means for connecting the anode of the control tube to an amplifier grid, and means for connecting the control grid and cathode of the control tube to a biasing path connected between the cathode and anode of the detector tube whereby the direct current potential difference between the control grid and cathode of said control tube is determined by the direct current potential drop across said biasing path, said path including a resistor connected between the anode and cathode of the detector tube, and means impressing upon the control grid of said control tube the carrier voltage output of said radio frequency amplifier.

5. In combination, a radio frequency amplifier, detector tube, and control tube, means adapting the flow of direct current in the anode circuit of said control tube for providing a bias to control the gain of said radio frequency amplifier, means in the anode-cathode circuit of said detector providing modulation frequency output, means in the anode-cathode circuit of said detector tube providing a direct current potential that is a function of the output of said radio frequency amplifier, means impressing said direct current potential as a bias in the control grid circuit of said control tube, and means impressing the output of the radio frequency amplifier upon the control grid of said control tube, whereby said ocntrol tube functions simultaneously as a direct

current amplifier and as a rectifier, to maintain the carrier voltage output of said radio amplifier within narrow limits over a wide range of carrier voltage input to said amplifier.

6. An automatic volume control arrangement for a radio receiver, which receiver includes at least a super-audible frequency amplifier and a detector, said arrangement comprising a volume control tube having at least one output electrode and at least one input electrode, a direct current connection between the output electrode and the amplifier such that a bias is provided to control the amplifier gain, a direct current connection between the said input electrode and a point in the cathode-anode circuit of said detector, the said last circuit including an impedance for providing a bias for said input electrode which is a function of the carrier voltage output of said amplifier, and a connection, of high impedance to direct current, between said input electrode and a point between the amplifier and detector to impress said carrier voltage on said input electrode for rectification.

7. An automatic volume control arrangement for a radio receiver, which receiver includes at least a super-audible frequency amplifier and a detector, said arrangement comprising a volume control tube having at least one output electrode and at least one input electrode, a direct current connection between the output electrode and the amplifier such that a bias is provided to control the amplifier gain, a direct current connection between the said input electrode and a point in the cathode-anode circuit of said detector, the said last circuit including an impedance for providing a bias for said input electrode which is a function of the carrier voltage output of said amplifier, and a connection, of high impedance to direct current, between said input electrode and a point between the amplifier and detector to impress said carrier voltage on said input electrode for rectification, said carrier voltage output being maintained within narrow limits over a wide range of carrier voltage input to said amplifier.

8. A method which consists in collecting modulated carrier frequency energy, amplifying the collected energy, detecting the amplified energy, amplifying the direct current component of the detected energy, rectifying a portion of the amplified carrier energy simultaneously with the amplification of said direct current component, and varying the amplification of the collected carrier energy with the said amplified direct current component and said rectified carrier energy in a direction such that the amplified carrier frequency voltage is maintained within narrow limits over a wide range of collected carrier frequency voltage.

9. An automatic volume control arrangement for a receiver, which receiver includes a high frequency amplifier and detector, comprising a control tube, a condenser connecting the control grids of the detector and control tube, a detector grid biasing resistor in the space current path of the detector, a radio frequency choke connected between one side of the resistor and a point intermediate the condenser and the control tube grid, a voltage supply resistor, the other side of said biasing resistor being connected to a negative point of the supply resistor, the control tube cathode being connected to a more positive point on the supply resistor, the control tube anode being connected to a point on the supply resistor more positive than said last two points, and a conductive gain control connection between the control tube anode and said amplifier.

10. In the operation of a receiver of the type including a radio frequency amplifier, a detector, and means including a rectifier for automatically biasing said amplifier to control the gain thereof in accordance with the strength of received radio waves, the method which comprises initially biasing said amplifier for maximum gain, initially biasing said rectifier to render the same inoperative, and reducing the rectifier bias to render the same operative when the received radio waves reach that value which, with maximum amplifier gain, produces a predetermined value of radio input on the detector.

11. In a receiving system, a signal amplifier, a detector tube provided with a signal grid, cathode and anode, an impedance in the space current path of the detector tube, the signal grid of the detector being connected to a point of said impedance which is negative with respect to the cathode potential, an amplifier gain control tube provided with at least a grid, cathode and anode, means for connecting the control tube grid to the said detector cathode, a connection from the control tube cathode to said point on the said impedance, an adjustable source of voltage for said control tube whereby the initial point of operation thereof with respect to signal amplitude may be predetermined, a gain control connection between the control tube anode and said signal amplifier, and a signal path connected between the detector signal grid and the control tube grid.

12. In a receiving system, a signal amplifier, a detector tube provided with a signal grid, cathode and anode, an impedance in the space current path of the detector tube, the signal grid of the detector being connected to a point of said impedance which is negative with respect to the cathode potential, an amplifier gain control tube provided with at least a grid, cathode and anode, means for connecting the control tube grid to the said detector cathode through a signal frequency choke coil, a connection from the control tube cathode to said point on the said impedance, a signal path connected between the detector signal grid and the control tube grid, and a gain control connection between the control tube anode and said signal amplifier.

13. In a receiving system, a signal amplifier, a detector tube provided with a signal grid, cathode and anode, an impedance in the space current path of the detector tube, the signal grid of the detector being connected to a point of said impedance which is negative with respect to the cathode potential, an amplifier gain control tube provided with at least a grid, cathode and anode, means for connecting the control tube grid to the said detector cathode, a connection from the control tube cathode to said point on the said impedance, a signal path connected between the detector signal grid and the control tube grid, an impedance connected between the control tube anode and cathode, and a gain control connection between the control tube anode and said signal amplifier.

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