Feb. 21, 1939. M. A. McLENNAN 2,148,030

AUTOMATIC TONE CONTROL SYSTEM

Filed July 25, 1936

Fig. 1

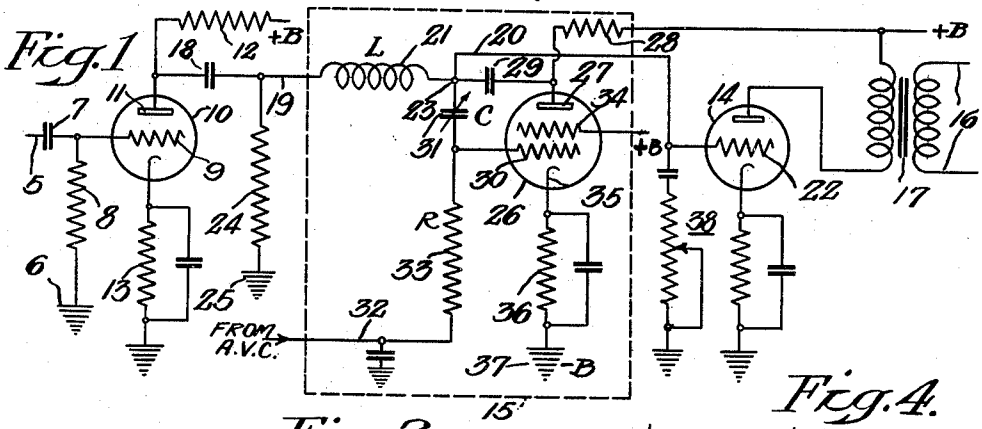


Fig. 2.

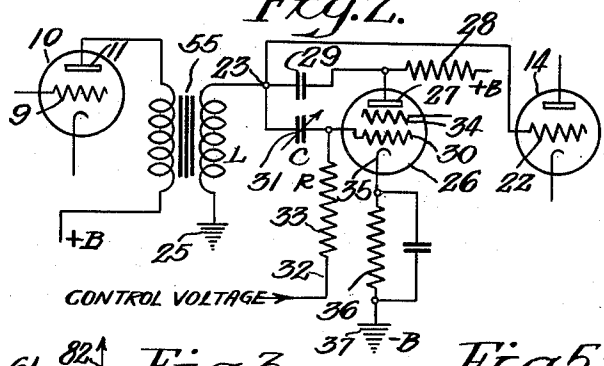


Fig. 3.

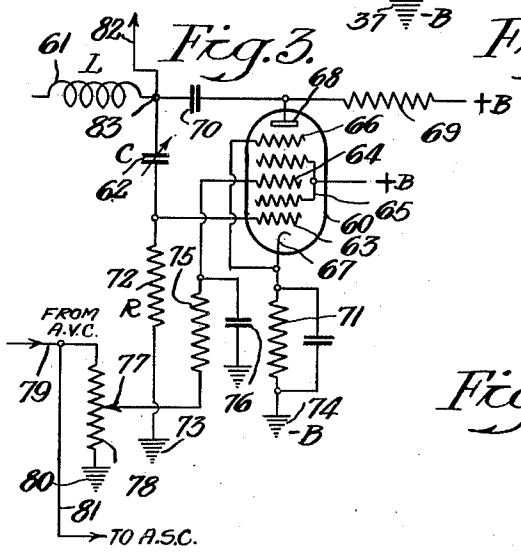


Fig. 4.

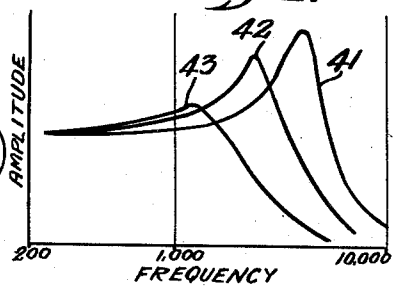


Fig. 5.

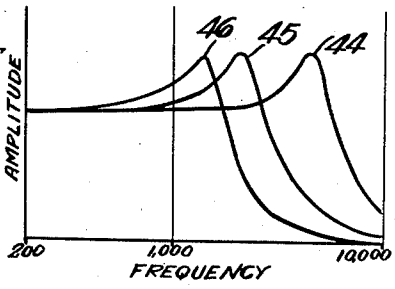
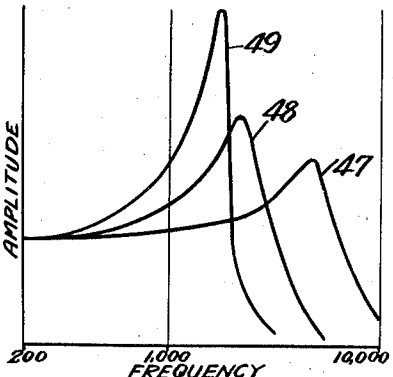


Fig. 6.



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Patented Feb. 21, 1939 2,148,030

UNITED STATES PATENT OFFICE

2,148,030

AUTOMATIC TONE CONTROL SYSTEM

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Application July 25, 1936, Serial No. 92,560

11 Claims. (Cl. 179—1)

The present invention relates to an automatic tone control system for radio receiving apparatus, and has for its object to provide an automatic tone control system which is responsive to automatic volume control potentials available in a receiving system, to control an audio frequency amplifier circuit in a predetermined manner, and to impart thereto a predetermined tone control characteristic.

In a practical application of the invention to a radio receiving system, a capacity amplifier comprising the anode circuit of an amplifier tube is provided with a series inductor and a capacitor to form a variable low pass filter of the type shown and described in the copending application of Poul F. G. Holst, Serial No. 57,121, filed January 2, 1936, now Patent No. 2,078,762, issued April 27, 1937, for "Automatic tone control system" and assigned to the same assignee as this application.

In the said application of Poul F. G. Holst the capacity element of the low pass variable filter is controlled by a voltage-variable-gain amplifier which operates to provide a wide range of tone control with a relatively small control voltage and low distortion in the audio frequency amplifier circuit with which it is employed.

In the present application, a loading capacitor for the filter, between the anode and grid of an amplifier tube, is effectively varied in connection with the inductance element with which it operates as a filter. The capacity of the coupling capacitor is adjusted to provide a predetermined audio frequency response characteristic for a predetermined range of control potentials for the amplifier device. Such control potentials may be provided by any suitable source such as an automatic volume control means.

It is a further object of the present invention to secure an improved variable cut-off in a low pass filter suitable for use as an automatic tone control means, the audio frequency characteristic of which is such that tone compensation may be obtained in accordance with variations in the strength of a received modulated carrier wave, or the audio frequency fidelity may be improved in a similar manner.

It is also a further object of the present invention, to provide manual control means for a tone control system responsive to automatic volume control means, which is effective to control the audio frequency tone characteristic of a radio receiving system without changing the control effected by the automatic volume control means.

It is also an object of the present invention to provide in an audio frequency amplifier, a variable cut-off filter including a capacity loading tube, the cut-off of the filter being controllable by controlling the gain of said tube and the frequency characteristic of the filter being controllable by means of a variable capacity element connected between the anode and the control grid of said tube.

In connection with high fidelity or automatic selectivity control receiving systems which operate to provide a broader frequency response and a lower degree of selectivity in the presence of strong modulated carrier waves, the system of the present invention operates to provide audio frequency compensation which may be adjusted to compensate high audio frequency losses with increased selectivity, or to provide simultaneous increase in high audio frequency response in the presence of relatively strong carrier waves.

The invention, therefore, has for its further object to provide an automatic tone control system operable to provide high audio frequency compensation to accentuate certain portions of the high audio frequency response range, in response to variations in selectivity adjustment of variable selectivity control receiving systems.

The invention will, however, be better understood from the following description when considered in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is a schematic circuit diagram of an audio frequency amplifier forming part of the signal transmission channel of a radio receiving system embodying the invention;

Figs. 2 and 3 are similar schematic circuit diagrams of modifications of the invention shown in Fig 1, and

Figs. 4, 5 and 6 are graphs or response curves illustrating the operation of an automatic tone control system embodying the invention as in Fig. 1 for example.

Referring to Fig. 1, the radio receiving system may include a detector output circuit represented by the lead 5 and ground connection or chassis 6, which is coupled through a coupling capacitor 7 and grid resistor 8 with the control grid 9 of an audio frequency amplifier tube 10. The anode 11 of the tube receives anode potential through an anode coupling resistor 12 and is provided with biasing potential from a self bias resistor 13.

The amplifier 10 is coupled to a succeeding amplifier stage comprising the amplifier tube 14, through a coupling and control unit indicated within the dotted outline 15. The stage 14 may

be of any suitable type and may be coupled to an audio frequency output circuit 16 through a suitable coupling transformer 17.

Audio frequency signals received from the detector output circuit 5—6 and amplified in the device 10 are applied to the amplifier stage 14 through a coupling capacitor 18 in the output anode circuit and output leads 10 and 20 between which is connected at 21 a series inductance element L. The control grid 22 of the second stage amplifier 14 is connected through the lead 20 with a tone control point 23 at the output end of the inductance element. At the input end of the inductance a shunt output resistor 24 may be connected to chassis or ground as shown, to provide a grid leak for the tube 14.

The tone control unit comprises a capacity amplifier tube 26, the anode 27 of which is supplied with anode potential through a coupling impedance or resistor 28 and which is coupled to the control point 23 through a capacitor 29 which may be of a fixed value, for example, substantially 200 micro-microfarads.

The control grid 30 of the tube is coupled at 31 through a variable capacitor C with the tone control point 23 on the audio frequency circuit and is also connected with a bias potential supply lead 32 through a resistor R at 33 which may be, for example, one megohm. In the system shown, the variable capacitor 31 may have a capacity variable between 50 and 1500 micro-microfarads.

The tube may be of any suitable high gain type and is preferably of the variable mu type having a screen grid indicated at 34 between the control grid and the anode 27. The cathode 35 is provided with an initial fixed biasing potential source such as a self bias resistor 36 connected with ground 37 which is also the negative anode potential supply source as indicated by —B.

Control potentials are applied between ground and the control lead 32 from any suitable source such as automatic volume control means, as indicated, whereby the tube 26 is placed under control of the automatic volume control means, and, as is well understood, may thus receive through the lead 32 with respect to cathode and ground, an increasing negative biasing potential in response to an increase in the amplitude of a received carrier wave, thereby operating to reduce the gain of the tube.

The series inductance L and the capacitor 29 which is substantially in shunt relation to the audio frequency circuit through the tube 26, provide a variable cut-off filter, the cut-off point of which is controllable by controlling the gain of the capacity loading tube 26, the gain being controlled by the control voltage applied thereto through the lead 32.

Because of a shift in phase of the voltage through the network LCR, and of the voltage applied to the grid 30, the signal output current from the plate 27 through the feedback path provided by the capacitor 29 will be nearly 90° out of phase with the voltage at the correction point 23 on the network. The capacitor 31 is relatively low in capacity value with respect to the capacitor 29.

The tube 26 operates to vary the reactance between the point 23 and ground for the reason that the feedback current is substantially 90° out of phase with the voltage at 23 and, therefore, the effect is the same as if a reactance were connected between the point 23 and ground.

Varying the biasing potential on the grid 30 changes the amount of reactive current fed back through the capacitor 29, and this reactive current flows from the point 23 through the capacitor 31 and resistor R and the by-pass to ground. Thus, the tube operates to provide a condition which would exist if a variable reactance were connected between the point 23 and ground since, like a variable reactance, it causes a change in the flow of signal current.

Since the capacitor 31 offers a relatively high impedance to low frequency currents, the flow of reactive feedback current from the tube 26 is limited to the higher frequency portion of the audio frequency signal band.

The capacitor 29 should be of such capacity value that it offers a relatively low impedance in the frequency range in which feedback currents are to be utilized for correction purposes. The L—C network includes the inductance 21 and the capacitor 31, together with the resistance element 33 through which the variable biasing potential is applied to the grid 30. The total effective capacity C in the network is that at 31 which controls the flow of the reactive current from the point 23.

Stated in other words, the variable reactance such as the capacitor 31 connected across the signal circuit at the point 23 would establish an out-of-phase relation between the current and the voltage at the point 23, and variation in the reactance would cause a change in the flow of reactive current. This same effect is provided by tube 26 since the voltage applied to the grid 30 through the capacitor 31 from the point 23 is shifted in phase. The feedback current from the tube is out of phase with the voltage at the point 23, and varying the bias changes the amount of reactive current, thereby producing, in effect, a variable reactance across the circuit at the point 23.

The effect of this control system may better be understood with reference to the response curves shown in Figs. 4, 5 and 6 to which attention is now directed. The curves are plotted between frequency, covering the higher frequency end of the audio frequency response range of the audio frequency amplifier shown in Fig. 1, and the voltage or signal amplitude available between the control point 23 and the low potential side of the audio frequency system which, in the present example, is the chassis or ground 37.

The curves shown in Fig. 4 and represented at 41, 42 and 43 represent the audio frequency response characteristic and operating range of the tone control unit 15 with the filter capacitor 31, which is the element C of the filter, relatively large, for example, substantially 1400 micro-microfarads in value, with an inductance L at 21 of 1.7 henries, and with a resistance at R or 33 of substantially one megohm.

The curves 41, 42 and 43 represent the audio frequency response when the grid bias applied through the control lead 32 is reduced in three successive steps for the curves 41, 42 and 43.

With this arrangement, it will be seen that with an increase in the strength of a received carrier wave resulting in an increased negative biasing potential from the automatic volume control lead, the audio frequency response or tone characteristic of the amplifier is extended and peaked in the high frequency direction, giving an improved high frequency and greater fidelity response in the presence of strong carrier waves.

It will also be seen that as the signal strength decreases the high frequency end of the audio

frequency response range is attenuated appreciably thereby resulting in a reduction of interference and noise in response to signals of lower amplitude.

The audio frequency response is preferably raised or accentuated at the high frequency end to compensate for losses in the audio frequency response because of side band cutting in other portions of the amplifying system (not shown). However, the response may be maintained substantially at constant level or may be peaked in a reverse direction in response to carrier wave variations, depending upon the capacity of the loading capacitor 31. The cut off range of operation for a given adjustment of the capacitor 31, is dependent upon the bias potential applied to the control lead 32.

In Fig. 5, curves 44, 45 and 46 represent the response characteristic of the audio frequency amplifier when operating the tone control means with the capacity C adjusted to 400 micro-microfarads and for corresponding changes in grid bias as in Fig. 4, the negative bias being reduced in value for the curves 45 and 46, from that applied to obtain the curve 44. From these curves it will be seen that the audio frequency response characteristic or tone control may operate to cut off the high frequency end of the operating range as the signal strength and negative grid bias is reduced, without appreciably accentuating the high frequency response characteristic.

In Fig. 6, three curves 47, 48 and 49 are shown which result when the negative grid bias on the control lead 32 is reduced in the same successive steps as in Figs. 4 and 5, and with the capacitor 31 adjusted to a relatively small value, such as 50 micro-microfarads, for example. In this case it will be seen that as the grid bias is reduced, the audio frequency response at the high frequency end of the audio frequency range is gradually reduced to a sharp cut off with a compensating high frequency peak in response to reduced signal strength and the grid bias.

A response characteristic of this character is desirable in connection with a receiving system in which a high degree of selectivity is obtained when the signal strength is low since the high frequency losses with selectivity are greatest, thereby requiring compensation by "peaking" or accentuating the high frequency response preceding the cut off point. The peaks may be reduced by additional high frequency tone control means, variably controllable in the usual manner as indicated at 38 in connection with the grid circuit of the amplifier stage 14.

From the foregoing description it will be seen, that a capacity amplifier in connection with the capacitor element of a low pass filter for an audio frequency circuit, may be varied to control the audio frequency response of an audio frequency signal circuit a predetermined frequency response characteristic, and that this characteristic may be varied as the cut off point of the filter is varied. By this means the amplifier may be compensated to correct for variation in selectivity, for example, in an automatic selectivity control system, as shown by the curves of Fig. 6, or, as shown by the curves of Fig. 4, the characteristic may be such that with an increase of signal strength, (the audio frequency characteristic may not only be extended, but may be accentuated in the high frequency end of the range.

The variable cut off filter may be provided in connection with any suitable inductance element in the audio frequency circuit. For example, as shown in Fig. 2, the amplifier tubes 10 and 14 may be coupled through an audio frequency transformer 55, the leakage reactance of which forms the inductance element of the low pass filter of which the capacity element is indicated at 31 and in which circuit the remainder of the elements are the same and bear the same reference numerals as in Fig. 1.

The control voltage available on the lead 32 serves to vary the effect of the capacitor 31 as described in connection with the circuit of Fig. 1 and Figs. 4, 5 and 6.

It will be noted that the secondary of the coupling transformer 55 is connected to the control point 23 and to ground 25, thereby being substituted for the coupling impedance 24 of Fig. 1, and rendering unnecessary the series inductance element 21. If a transformer of suitable frequency characteristic is employed at 55, the audio frequency characteristic of the amplifier may be substantially the same as the amplifier of Fig. 1.

Referring now to Fig. 3, a capacity loading tube 60 is provided for controlling an audio frequency amplifier circuit as a tone control means in conjunction with a series inductance element 61 and a loading capacitor 62 forming, with the inductance element, a variable low pass filter.

The device 60 may be of the type known commercially as an RCA6L7 tube, which is provided with two separate control grids 63 and 64. The grids are provided with a screen 65 and with a suppressor grid 66 connected to the cathode 67. The output anode 68 receives potential through a coupling resistor 69 and is coupled to the inner control grid 63 through a coupling capacitor 70 and the control capacitor 62. The inner control grid also receives biasing potential from a self bias resistor 71 through a grid resistor 72 which is connected in common with the resistor 71 to ground 73 and the negative anode potential supply 74.

The bias supply connection for the outer control grid 64 is provided with a series filter resistor 75 and filter capacitor 76, and is further provided with a manually operable control element 77 in connection with a potential supply resistor 78 in the automatic volume control circuit 79—80. Control potentials for other purposes such as automatic selectivity control may be derived from the lead 79 as indicated by the output lead 81. As automatic selectivity control means are well known and understood and per se do not concern the invention, the same are not illustrated.

An audio frequency output lead 82 is provided in connection with the tone control point or terminal 83 between the inductance element 61 and the controlling capacitor 62 as in the preceding circuits, and the system operates in substantially the same manner to control the tone characteristic or frequency response, except that the capacity variation is effected in connection with the inner control grid while the cutoff range is controlled by potentials applied to the outer control grid in response to the automatic volume control means, and simultaneously with the application of control potentials to the automatic selectivity control lead.

In this system, furthermore, the manual control means 77 may be adjusted for any given signal strength with respect to that established by the automatic volume control means. For example, referring to Fig. 4, the adjustment of the

contact 77 by manual operation serves to provide tone control variation without effecting the automatic volume control operation, and serves to move the operating peak with respect to the established characteristic resulting from a predetermined signal strength being received at any time.

In other words, the biasing potential adjustment causes the cutoff characteristic to be varied independently of the characteristic established by the signal. This is a desirable feature in connection with selective receiving systems and serves to provide manual tone adjustment without the addition of further tone control means.

From the foregoing description it will be seen that a variable low pass filter may be controlled by a variable gain amplifier tube connected to the output of a series inductance element in an audio frequency amplifier circuit, the tube operating to vary the effect of a shunt tuning capacitor in accordance with the mu of the tube, and that the cutoff characteristic of the filter provided by the capacitor and the series inductance element may be varied continuously through a wide range by variation of the grid bias on the tube.

Furthermore, it will be seen that the variation in grid bias may be effective in a receiving system to control the tone or audio frequency characteristic of the audio frequency amplifier in accordance with variations in signal strength, thereby to compensate for attenuation of the high frequency end of the audio frequency response range because of variations in selectivity.

It will also be seen that the gain of the capacity amplifier may be controlled so that the cutoff point of the variation low pass filter may be adjusted to suit local reception conditions by variable control means which may be adjusted to regulate the value of automatic control potential acting upon the capacity amplifier and that this control may be utilized as a manual tone control means without effecting the operation of the automatic volume control.

I claim as my invention:

1. In a radio receiving system, the combination with an audio frequency amplifier circuit, of an automatic tone control circuit comprising a low pass filter having a series inductance element and a shunt capacity element, a resistor in series with said capacity element, and an amplifier tube having a control grid connected between the junction of the capacity element and the resistor element and having an anode electrode capacitively coupled to the junction between said inductance element and said capacity element through an audio frequency path exclusive of said capacity element, means for deriving a controlled signal from said last named junction, and means for applying a controlled potential to the control grid through said resistor element.

2. In a radio receiving system the combination as defined in claim 1, further characterized by the fact that the capacity element is variable between predetermined limits, thereby to vary the frequency response characteristic of the tone control circuit independently of the control potential applied to the control grid.

3. In a radio receiving system, the combination as defined in claim 1, further characterized by the fact that automatic volume control means is provided for applying a controlling potential to said grid in accordance with said signal strength variations.

4. In an audio frequency amplifier, the combination of a variable low pass filter comprising a series inductance element and a shunt variable capacitor element, and a potential responsive controlling amplifier therefor having a control electrode and an anode electrode coupled to the junction between said series inductance element and the variable capacitor element through an audio frequency feedback path exclusive of said variable capacitor element, and having said variable capacitor element connected between said junction point and said control electrode, and means for applying a variable negative control potential to said control electrode with respect to the cathode.

5. In an audio frequency amplifier, tone control amplifier means comprising in combination, a variable low pass filter including a series inductance element and a shunt variable capacitor element, and a potential responsive controlling amplifier device therefor having a control electrode and an anode electrode, a feedback capacitor coupling said anode electrode to the junction between said series inductance element and the variable capacitor element, said variable capacitor element being connected between said junction point and said control electrode, and means for applying a variable potential to said control electrode, said last named means including an automatic volume control circuit and manually adjustable means for controlling the automatic volume control potential applied to said control grid.

6. Automatic tone control system for an audio frequency amplifier, comprising in combination, a variable cut-off low pass filter having a series inductance element, an electric discharge amplifier tube having a control grid and an anode, a feedback capacitor connected between the anode and the output terminal of said low pass filter inductance element, a variable capacity providing coupling with the control grid of said tube for the output terminal of said filter inductance element, means for varying the cut-off characteristic of the filter comprising a biasing potential source connected with said grid, and means for varying the potential applied by said source.

7. In an audio frequency amplifier, the combination with an audio frequency signal transmission circuit, of a series filter inductance element in said circuit, means for deriving audio frequency signals from the output end of said inductance element, an electric discharge amplifier device having an anode and a control grid each capacitively coupled to said output end of the inductance element through separate audio frequency paths, the capacity coupling element between the control grid and said point being variable to provide a high frequency peak in the audio frequency response of said amplifier, and means for applying automatic volume control potentials to said control grid, said last named means including a series resistor providing a coupling element with said grid for said capacitive coupling circuit.

8. An automatic tone control system for radio receiving apparatus and the like comprising, in combination, an audio frequency amplifier having a control grid and an anode electrode, an interstage coupling network for said amplifier including a control tube, a series inductance element and variable shunt capacity means providing a low pass filter in said network, said last named means including a feedback capacitor and a variable capacitor in series between the anode and the control grid of said amplifier and with the

inductance element of said filter having an output terminal connected to a point between said series connected capacitors, and means for variably biasing the control grid in response to signal strength variations.

9. A radio receiving system in accordance with claim 8, further characterized by the fact that the gain of said tube is additionally controllable by manual gain control means associated with said automatic volume control means.

10. In an audio frequency amplifier, automatic tone control means comprising, in combination, a variable low pass filter through which audio frequency signals flow, including a series inductance element and a shunt reactance element comprising a capacitor having a capacity value such that it offers a relatively high reactance in the lower portion of the audio frequency response range of the amplifier, the series inductance element and the said capacitor being connected together to provide a controlling terminal for said tone control means, an electric discharge amplifier having a control grid coupled to said terminal through said capacitor and having an anode coupled to said control terminal to supply feedback current thereto in an out-of-phase relation to the signal voltage, and means for applying a variable biasing potential to said control grid to vary the feedback current through said tube, whereby the effect of a variable reactance at said control terminal is provided by said tube.

11. In an audio frequency amplifier, automatic tone control means comprising, in combination, a variable low pass filter through which audio frequency signals flow, including a series inductance element and a shunt reactance element comprising a capacitor having a capacity value such that it offers a relatively high reactance in the lower portion of the audio frequency response range of the amplifier, the series inductance element and the said capacitor being connected together to provide a controlling terminal for said tone control means, an electric discharge amplifier having a control grid coupled to said terminal through said capacitor and having an anode coupled to said control terminal to supply feedback current thereto in an out-of-phase relation to the signal voltage, and means for applying a variable biasing potential to said control grid to vary the feedback current through said tube, whereby the effect of a variable reactance at said control terminal is provided by said tube, said last named means including an automatic volume control circuit and manually adjustable means for controlling the automatic volume control potential applied to said control grid.

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