

Nov. 8, 1932.

O. H. SCHADE

1,887,329

AMPLIFICATION CONTROL SYSTEM

Filed March 22, 1928 3 Sheets-Sheet 1

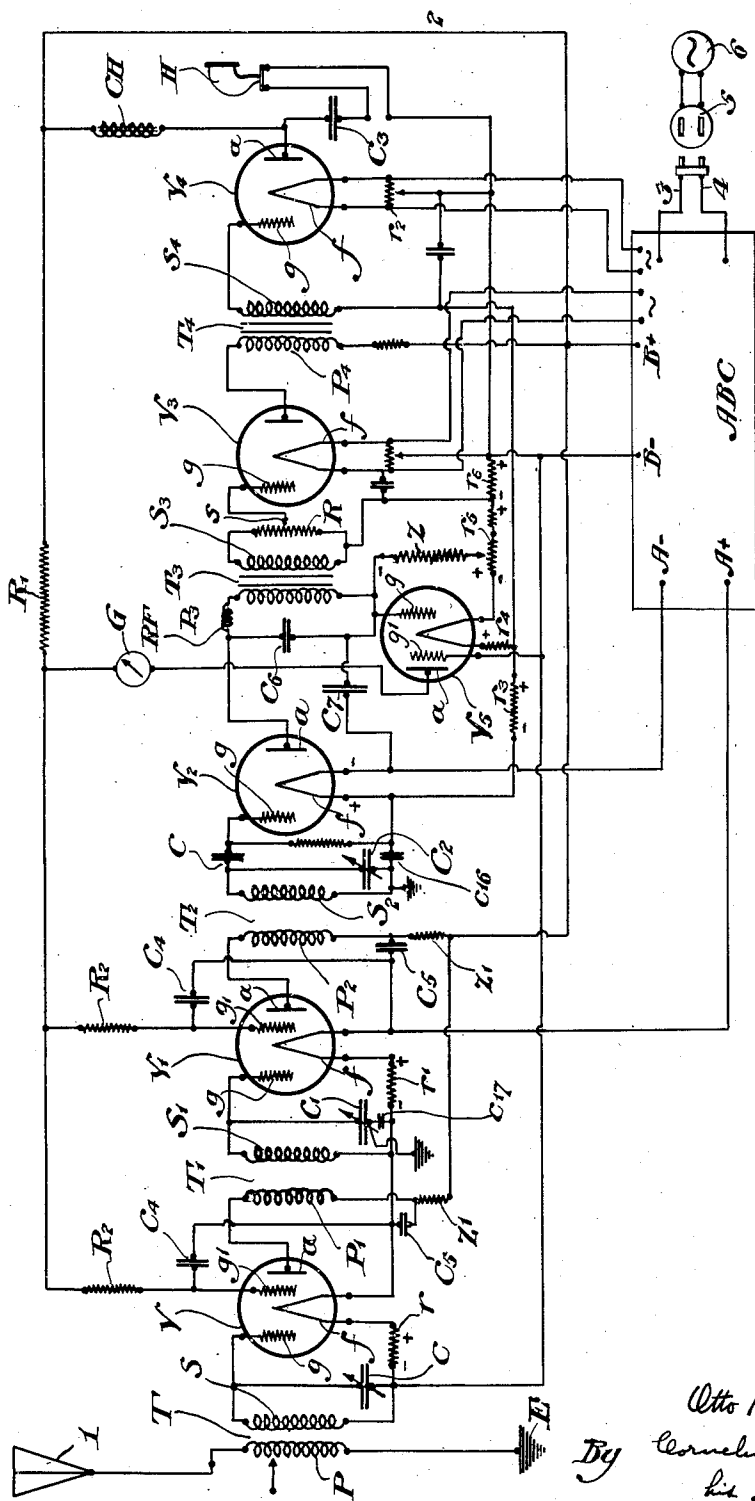


Fig. 1.

Inventor
Otto H. Schade
By *Cornelius L. Ebert*
his Attorney

Nov. 8, 1932.

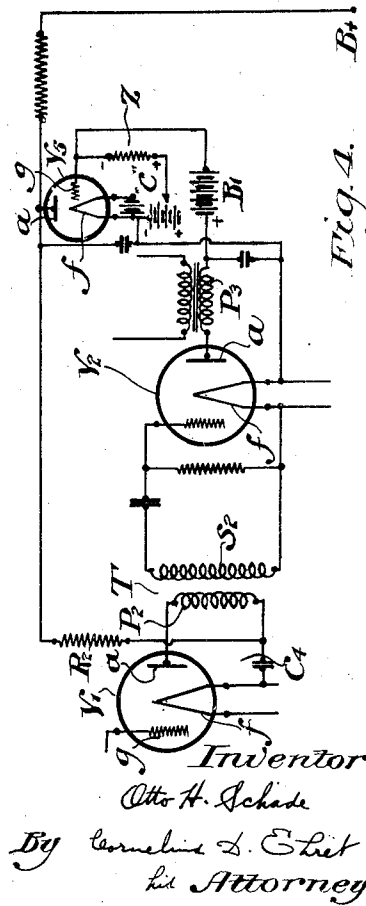
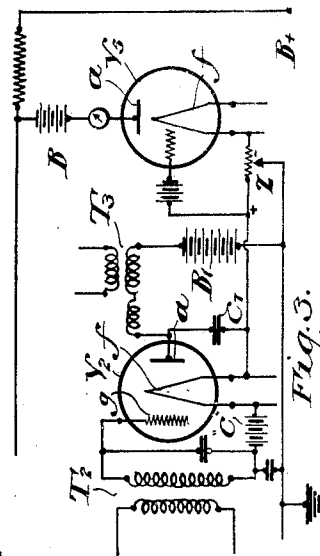
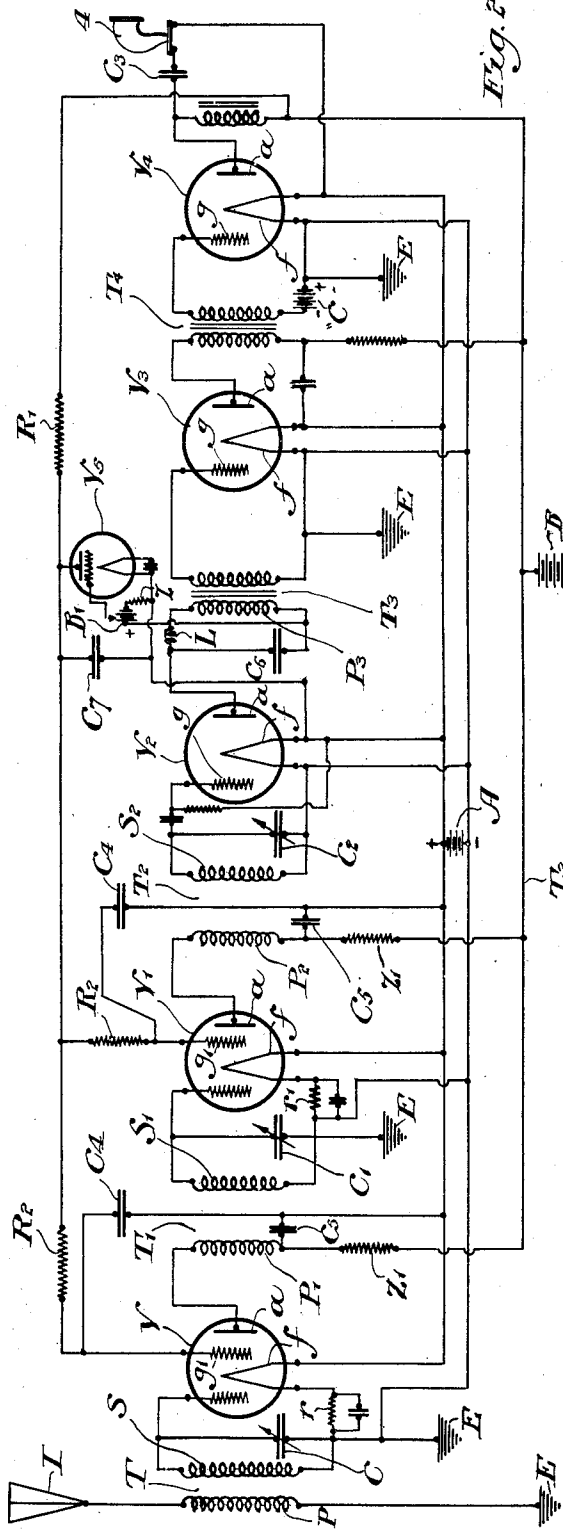
O. H. SCHADE

1,887,329

AMPLIFICATION CONTROL SYSTEM

Filed March 22, 1928

3 Sheets-Sheet 2



Inventor
Otto H. Schade
By *Carmelita L. Glick*
his Attorney

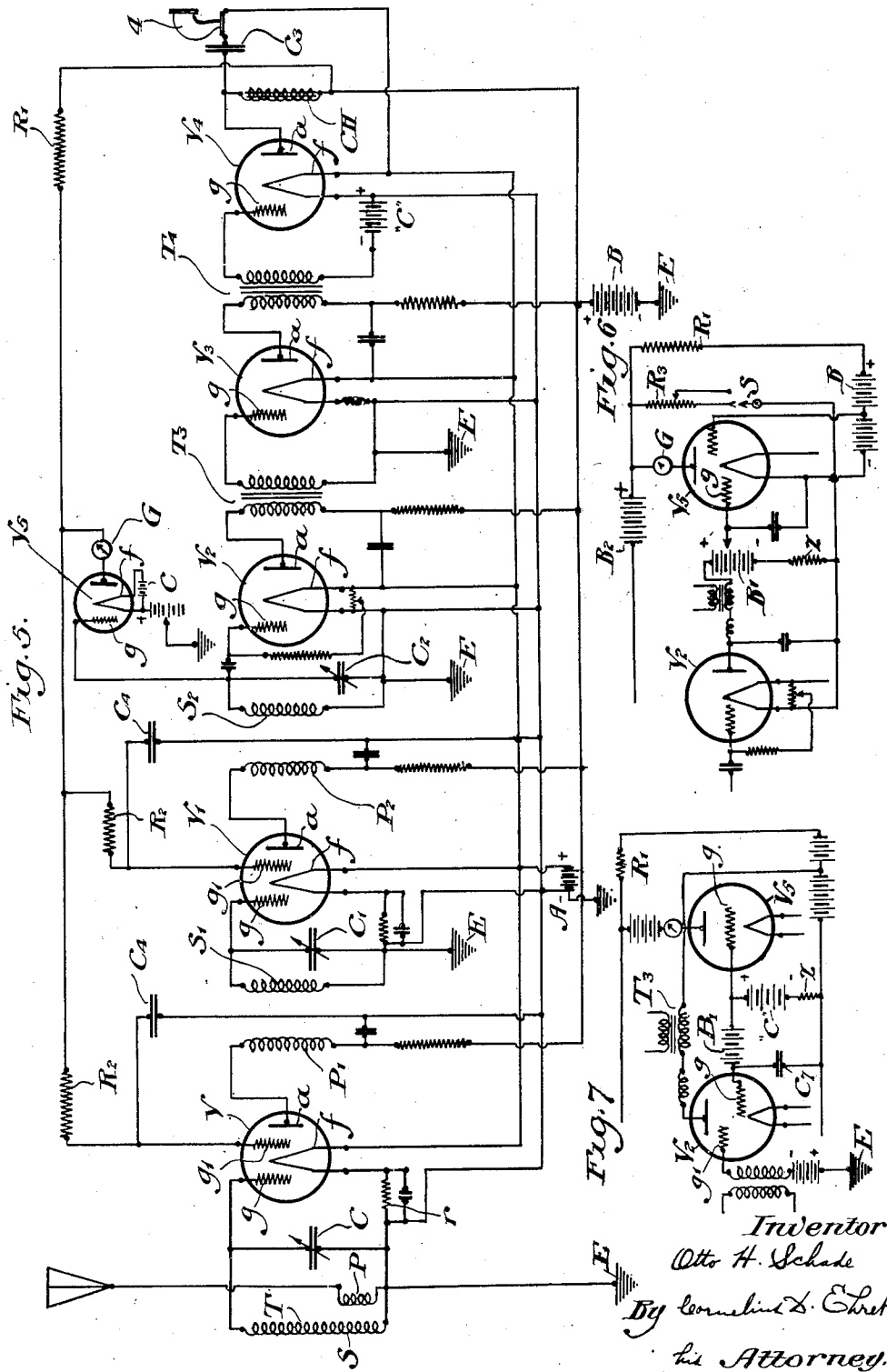
Nov. 8, 1932.

O. H. SCHADE

1,887,329

AMPLIFICATION CONTROL SYSTEM

Filed March 22, 1928 3 Sheets-Sheet 3



Inventor
Otto H. Schade
By Cornelius S. Ebert
his Attorney.

UNITED STATES PATENT OFFICE

OTTO H. SCHADE, OF PHILADELPHIA, PENNSYLVANIA, ASSIGNOR TO ATWATER KENT MANUFACTURING COMPANY, OF PHILADELPHIA, PENNSYLVANIA, A CORPORATION OF PENNSYLVANIA

AMPLIFICATION CONTROL SYSTEM

Application filed March 22, 1928. Serial No. 263,643.

My invention relates to the control of thermionic amplifiers, particularly as utilized in radio receiving apparatus to effect a desired intensity or amplitude of signals, music or speech, reproduced thereby.

In accordance with my invention, the effective direct-current voltage of the anode of one or more amplifier tubes, is caused to assume values related to the amplitudes of alternating energy, as of carrier waves of incoming radiant energy, particularly those in excess of a predetermined value, as a predetermined minimum, the effective voltage varying in a sense opposite to the sense of change in amplitude of an energy or between amplitudes of different energies and to an extent to maintain substantially constant the intensity of reproduced signals, music or speech which may be represented by input energies of different magnitudes, more specifically and preferably, the amplifier tubes are of the type having anode, cathode, control grid, and a screen-grid or shielding anode.

Furthermore and more particularly in accordance with my invention, there is associated with the anode circuit of a demodulator tube, a volume or amplification control tube or thermionic device, the potential between the input elements of which varies in accord with changes in the average of the direct-current component of the plate current of the demodulating tube, which average changes by an amount dependent upon the magnitude of rectified signal energy, which potential varies the shunting effect of the internal plate-filament resistance of the control tube to cause the effective direct-current plate voltage of one or more amplifier tubes preceding the demodulator tube to assume a value which causes the input signal energy of the demodulator tube to be substantially the same for widely different magnitudes of received signal energy.

My invention further resides in features of arrangement and combination hereinafter described and claimed.

For an illustration of some of the forms of my invention, reference is to be had to the accompanying drawings in which:

Fig. 1 is a diagrammatic representation of a circuit arrangement of a radio receiving apparatus utilizing my invention.

Figs. 2 and 3 are diagrams of radio receiving apparatus utilizing modified forms of my invention.

Figs. 4, 5, 6 and 7 are additional modified forms of my invention.

Referring to Fig. 1, signal energy impressed upon the antenna 1, or equivalent absorption structure as a loop, is transferred to the input circuit of a thermionic device V, such as a radio frequency amplifier, by a transformer T having its primary P connected between the antenna 1 and the earth E, or its equivalent, as a counterpoise, and its secondary S across whose terminals is connected the tuning condenser C whose terminals are connected respectively to the control grid *g* and to the filament or cathode *f* through a grid biasing resistance *r*. The amplified signal energy in the anode circuit of the amplifier V is impressed upon the input electrodes of a second thermionic amplifier tube V1 by a radio frequency transformer T1 having its primary P1 connected in circuit between anode or plate *a* and the cathode *f* of the first amplifier tube V and its secondary S1 whose terminals are connected respectively to the grid *g* and through a blocking condenser *c*17 to the filament *f* of the second amplifier tube V1, the connection to the filament including a grid biasing resistance *r*1. The secondary S1 is tuned by a variable condenser C1 and comprising therewith a closed circuit tunable to the same frequencies as the closed circuit comprising the secondary S and condenser C associated with the input electrodes of the first amplifier tube.

In amplified form, the signal energy is transferred to the input circuit of a demodulating tube V2 by a radio frequency transformer T2 having its primary P2 in circuit between the anode *a* and the cathode *f* of the second radio frequency amplifier tube V1, and its secondary S2 in the input circuit of the detecting or demodulating tube V2 with one of its terminals connected to a terminal of a grid condenser *c*, the other of whose terminals is connected to the grid *g* of the tube

V2, the other terminal of the secondary being connected through a stopping condenser C16 to the cathode f of the same tube. The condenser C2 is variable to tune the input circuit of the detector tube V2 to the same frequency of wave length as the input circuits of the preceding radio frequency amplifiers.

The provision of stopping or blocking condensers c16 and c17 having low impedance to currents of radio frequency but substantially infinite resistance to direct current permits, in the series-filament system herein-after more fully described, the grounding of the rotors of tuning condensers C, C1 and C2 which is of advantage when the rotors are mechanically coupled for single dial operation, for example when utilizing coupling bands and drums of the character disclosed in Kent Patent 1,668,156, granted May 1, 1928.

The rectified signal energy varying at audio or speech frequency is impressed upon the input circuit of an audio frequency amplifier tube V3 between whose grid g and filament f is connected the secondary S3 of an audio frequency transformer T3 whose primary P3 is connected in the anode circuit of the demodulator tube V2. The potential impressed upon the grid g and therefore the degree of audio amplification or amplitude of signal may be varied by adjusting the contact slider s along a resistance R connected directly across the terminals of the secondary S3.

The energy is further amplified at audio frequency by being impressed upon the input circuit of the second audio frequency amplifier tube V4 which includes the secondary S4 of an audio frequency transformer T4 having its primary P4 in the anode circuit of the preceding amplifier tube V3.

The audio frequency variations of the anode or plate current of the audio amplifier tube V4 traverse the condenser C3 having low impedance to currents of audio frequency, and the windings of a loud speaking device H connected in series therewith between the anode a and the midpoint of a resistance $r2$ connected directly across the terminals of the filament f of the tube V4. The choke coil C H in the anode circuit offers high impedance to currents of audio frequency and suitably small resistance to direct current.

In the anode circuit of the demodulating tube V2 is included a resistance Z, preferably inductive and offering substantial impedance to currents of low frequency as of voice frequency including that of any current ripple due to use of rectified alternating current, forming with C7 a filter section.

Upon increase in amplitude of signal energy impressed upon the input circuit of the rectifier V2 the average plate current of the tube decreases, decreasing the drop in po-

tential across the impedance Z and therefore across the input electrodes of the control tube V5, whereupon the plate current of the control tube increases. Conversely upon decrease in amplitude of signal energy impressed upon the input circuit of the detector tube V2 the average plate current increases, increasing the drop in potential across the terminals of the impedance Z and therefore the potential between the grid g and cathode f of the control tube to effect decrease of the plate current thereof.

Current is supplied to the anode a of the control tube V5 and to the auxiliary or shielding anodes $g1$ of the radio frequency amplifier tubes V and V1 through a resistance R1 of suitably high magnitude connected to the positive terminal of a suitable source of direct current by conductor 2. The current may be supplied for example by an arrangement comprising a rectifier, not shown, connected to the conductors 3, 4 of a power outlet plug and a filter, not shown, to supply current to the terminals B-, B+ of a battery eliminating device ABC.

Upon increase of current in the anode circuit of the control tube V5 as indicated, for example by a suitable device, as a milliammeter G, the drop of potential in the resistance R1 increases whereupon the difference in potential between the shielding anodes $g1$ and associated cathodes f decreases, decreasing the effective direct current voltage between the anodes a and filaments f , and thereby reducing the amplification effected by the radio frequency amplifier tubes V and V1. Conversely decrease of current through the control tube effects an increase of potential between the shielding anodes $g1$ and cathodes f , to increase the effective plate voltage and amplification of the radio frequency amplifiers. The effect of the presence of the control tube V5 in the relation above described is to maintain substantially constant the amplitude of energy transferred to the input circuit of the detector tube V2, irrespective of the amplitude of energy in the antenna or absorption circuit. In adjustment of condensers C, C1 and C2 to a desired frequency, maximum reading of the milliammeter G indicates resonance with incoming signal frequency.

To provide a suitable time lag in the operation of the automatic control, in series with each of the control grids $g1$ there is included a resistance R2 of suitably high magnitude, as for example, about 400,000 ohms, and between the shielding anode and the filament or cathode f there is connected a condenser C4 of suitably high capacity, as for example about 1 microfarad, to give a time constant preventing distortion of the modulation as well as preventing low frequency disturbances known as "motor-boat-ing".

The filaments of the amplifier tubes V and V1, the demodulator V2, and the control tube V5 may be connected in series across the terminals A- and A+ of a source of rectified and filtered alternating current of suitably high voltage. For example the current may be supplied from an arrangement comprising a suitable rectifier connected to the conductors 3, 4 leading to the plug of a power output socket, and a filter suitably designed to supply substantially direct current. The series circuit includes the resistances r and $r1$ which as above stated provide a proper bias for the control grids g of the radio frequency amplifier tubes, the resistance $r6$ which provides a suitable difference of potential between the grid g and the filament f of the first audio frequency amplifier tube V3 and the resistances $r4$, $r5$ and $r6$ in series to effect a desired difference of potential between the grid g and filament f of the second audio frequency tube V4.

Preferably the end of resistance Z more remote from the anode a of the rectifier tube V2 is connected to a contact adjustable along the resistance $r5$ to vary the biasing voltage upon grid g of the control tube to effect adjustment of the range of control with a given detector tube, or to permit the use of detector tubes having different operating characteristics.

The contact may be adjusted along resistance $r5$ to a position slightly beyond that at which the milliammeter reading is zero, adjusting the grid bias to an extent that the tube V5 does not effect any control until the amplitude of incoming signal energy is in excess of a desired minimum. The biasing voltage upon the control grid g of the volume control tube V5 determines the lower limit of amplitude at which the controlling action occurs. The effective plate voltage of the rectifier tube is determined by the fall of potential through the resistances $r3$, $r4$ and that portion of the resistance $r5$ between the contact slider connected to the impedance Z and resistance $r4$.

As the filaments of the radio frequency tubes V and V1 are positive with respect to the filament of the volume control tube V5, after the difference of potential between the shielding anodes and their associated cathodes has been reduced to zero, there still exists a substantial difference of potential between the anode a and filament f of the volume control tube which permits further operation of the control to render the shielding anodes $g1$ negative with respect to the cathodes. While theoretically, it should be sufficient to reduce the relative difference of potential to zero to destroy the repeating property of a shielding-anode tube, actually it is necessary as in the arrangement described, to insure that the filament is positive with respect to the auxiliary anode. Further

as in the series-filament arrangement described, the filaments or cathodes of the radio frequency amplifier tubes are at different positive potential with respect to the control tube filament, the potentials of the respective auxiliary anodes with respect to their associated cathodes are different.

The filaments or cathodes of the thermionic tubes V3 and V4 may be heated by alternating current energy supplied, for example from a step-down transformer having its primary connected to the above mentioned terminals 3, 4 of a plug device adapted to be inserted in the socket receptacle 5, and having secondaries delivering current at suitable voltage to the respective filaments.

Preferably in the direct current connection to the primaries P1 and P2 there is included the resistances Z1 offering substantial impedance to currents of radio frequency, and between the associated cathode and the connection between the primary and associated impedance Z1 is connected a condenser C5 having low impedance to currents of radio frequency. Connected in series between the anode a and filament f of the demodulator tube V2 are the condensers C6 having low impedance to currents of radio frequency, and condensers C7 having low impedance to frequencies of audio and higher frequency. The conductor joining the condensers is connected to the control grid of the volume control tube V5. The condenser C6 by-passes current of radio frequency about the primary P3 and a choke coil RF of the audio frequency transformer T3 and the condenser C7 prevents the potential of the control grid g of the volume control tube V5 from varying at audio frequency.

It will be understood that my invention is not limited to apparatus employing the above arrangement in which the filaments of a number of tubes are connected in series or in which one or more circuits of the thermionic tubes are supplied from an ultimate alternating current source. Referring to Fig. 2 the filaments or cathodes f of the radio frequency amplifier tubes V and V1, the detector V2 and the audio frequency amplifier tubes V3 and V4 are connected in shunt and rendered electron emissive by a battery A, and the anode circuits of the amplifier tubes and of the control tube V5 are energized by a battery B which also produces the voltage impressed upon the shielding anodes $g1$ of the radio frequency amplifier tubes. In this arrangement the plate circuit of the detector tube V2 is energized by a separate battery B1 connected in series with the primary P3 and the impedance Z between the anode a and the cathode f of the detector tube. Furthermore the volume control tube V5 may be of the three-electrode type, particularly one having a high amplification constant, instead

of the four-electrode, auxiliary electrode type as in Fig. 1.

In Fig. 3, there is associated with input circuit of the demodulating tube V2, a "C" battery having its negative terminal presented to the control grid *g* thereof, the potential being adjusted so that upon increase of grid potential as by an incoming carrier wave, the average direct current in the plate circuit increases. Under these circumstances the input electrodes of the control tube are relatively reversed, the cathode thereof being connected to the anode of the detector tube V2, and the control grid thereof being connected to the filament or cathode of the detector. The anode current of the control tube increases as the average value of the anode current of the detector tube increases, to effect decrease of voltage of the shielding anodes of the amplifier tubes. Upon decrease in amplitude of incoming energy and decrease of detector anode current, the converse operation is effected as in the modification previously discussed.

While it is preferable that amplifier tubes of the screen-grid type be utilized, it is possible to employ three-electrode tubes particularly of the type in which the anode current is relatively small. Referring to Fig. 4, change in the difference of potential between the grid *g* and filament *f* of the control tube V5 directly effects a change in the potential of the anode *a* of a three-electrode tube V1 having its output electrodes connected across the terminals of a primary P2 of a transformer having its secondary S2 in the grid circuit of a demodulating tube, the anode *a* of which is connected to the positive terminal of a suitable source of direct current energy B1 through the primary P3.

Referring to Fig. 5, in this modification of my invention, the control grid *g* of the volume control tube is connected to one terminal of the tunable circuit comprising the secondary S2 and condenser C2 and the other input electrode or cathode *f* is connected to the other terminal of the closed loop. In circuit between the control grid and the cathode there is included an adjustable portion of a biasing battery C to determine the minimum signal amplitude at which control action is effected. In this arrangement as the amplitude of signal energy impressed upon the input circuit of the detector tube V2 increases, the plate or anode current of the volume control tube increases to effect decrease of potential of the control grids *g*1 and conversely upon decrease in amplitude of energy, the potential of shielding anode *g*1 increases to increase the effective anode potential and the amplification property of the tube.

In the modification of my invention shown in Fig. 6, the battery B1 supplying direct current to the anode circuit of the demodulating tube V2 is utilized to supply suitable biasing

potential to shielding anode *g* of the volume control tube V5. The maximum amplification of the apparatus may be determined by adjusting the maximum effective voltage which can be applied to the anodes of the amplifier tubes. As shown the contact S may be adjusted to include a desired portion of the resistance R3 in a shunt path between the low potential ends of the resistance R1 and the battery B supplying direct current for example to the shielding anodes of four electrode amplifier tubes. The battery B2 having a voltage less than the maximum effective voltage between the anode and filament of the volume control tube is connected in opposition to the battery B between the anode of the control tube and the amplifier auxiliary anodes. Upon continued decrease of the effective voltage produced by the battery B between the anode and filament of the control tube, the potentials of the shielding anodes with respect to the associated cathodes are eventually reduced to zero and upon further decrease of the effective voltage across the output electrodes of the volume control tube, the shielding anodes become negative with respect to associated filaments effectively to prevent the tube from functioning as a repeater.

In the modification of my invention disclosed in Fig. 7, the demodulator tube V2 is of the same type as tubes V and V1, the input electrodes however comprising in this use of the tube, the electrode *g*1 as the control grid. The grid *g*, termed in this use of the four-electrode tube, the "space charge" grid is connected through battery B1 to the control grid of the control tube V5, and through a biasing battery "C" and resistance Z to the cathode of the tube V2 completing the direct-current path. The anode circuit of the detector tube is not modified and may be as described in Fig. 5. Although demodulation is effected by plate rectification, the input electrodes of the volume control tube are not reversed as in Fig. 3, since the average current in the space-charge grid circuit varies in a sense opposite to the sense of change of incoming signal energy.

It will be understood that my invention is not limited to control of amplification of currents of radio frequency but may be applied to audio amplifying systems. When utilized with a radio frequency amplifier, as of radio receiving apparatus, the intensity of signals reproduced thereby will be independent, when in excess of a predetermined value, of the amplitude of the carrier wave and for different signals the intensities will be equal for carrier waves equally modulated. When utilized with an audio frequency amplifier, the intensity is independent of the percent modulation. Both the radio and audio amplifiers may be controlled, each by a combination of a rectifier and control tube with time constant impedances of proper values,

to produce signals of definite intensity from an apparatus irrespective of the amplitude or per cent. modulation of the incoming carrier wave.

What I claim is:

1. The method of controlling the amplification of one or more thermionic tubes of the shielding anode type which comprises rectifying amplified alternating signal energy, and effecting variation of the voltage applied to the shielding anode electrodes thereof by the rectified, amplified energy.

2. In a system comprising one or more thermionic amplifier tubes of the shielding anode type, a demodulator device and a thermionic control tube, the method of controlling the amplification of said amplifier tubes which comprises rectifying alternating signal energy by said demodulator device, varying the potential of the control grid of said control tube by the rectified energy, and producing thereby a change in magnitude of the voltage applied to the shielding anode electrodes of said amplifier tubes.

3. A radio receiving system comprising at least one radio frequency amplifier tube having an electrode whose biasing potential determines the amplification, a conductive impedance in circuit with said electrode, a detector tube, a conductive impedance in the anode circuit of said detector tube, a control tube, a source of direct current for supplying current to said tube, a resistance traversed by direct current from said source for negatively biasing the grid of said control tube, an input circuit for said control tube including said second conductive impedance and said resistance in series whereby the normal grid-biasing negative potential derived from said resistance is reduced to an extent determined by the amplitude of received signal, and an output circuit for said control tube including said first conductive impedance whereby the biasing potential of said amplifier electrode is varied to maintain constant volume of reproduction.

4. A radio receiving system comprising at least one radio frequency amplifier tube having an electrode whose biasing potential determines the amplification, a conductive impedance in circuit with said electrode, a detector tube, a conductive impedance in the anode circuit of said detector tube, a control tube, a source of direct current for supplying current to said tubes, a resistance traversed by direct current from said source for negatively biasing the grid of said control tube, an input circuit for said control tube including said second conductive impedance and said resistance in series whereby the normal grid-biasing negative potential derived from said resistance is reduced to an extent determined by the amplitude of received signal, an output circuit for said control tube including said first conductive impedance

whereby the biasing potential of said amplifier electrode is varied to maintain constant volume of reproduction, and means for manually varying the magnitude of said resistance in series with said second conductive impedance within said input circuit of said control tube for predetermining its range of control.

5. A radio receiving system comprising a control tube, a conductive impedance connected between the input electrodes thereof, a detector tube operating as a plate circuit rectifier, a source of anode current, connections for including said impedance in the detector anode circuit between the cathode of the detector tube and the negative terminal of said source, one of said connections connecting the grid of the control tube to the cathode of the detector tube, an amplifier tube in advance of said detector tube and having an electrode whose biasing potential determines the amplification, a second conductive impedance in series with said electrode, and connections for including said second conductive impedance in the anode circuit of said control tube whereby the magnitude of current flowing through said second impedance and determining the biasing potential of said electrode is regulated by the control tube by and in accordance with the amplitude of received signal energy.

6. A radio receiving system comprising a radio-frequency amplifier tube of the screen-grid type, a control tube, a detector tube, a source of current for supplying direct current to said tubes, serially connected resistances traversed by direct current from said source, connections from electrodes of said tubes to said resistances whereby one of the grids of said amplifier and the grid of said control tube are biased with respect to their cathodes, a conductive impedance traversed by the detector anode current and included in circuit with the grid of said control tube for automatically modifying its bias in accordance with the amplitude of a received signal, a second conductive impedance in the anode circuit of said control tube, and a connection from said second impedance to the other grid of said amplifier for impressing thereon a biasing potential automatically varied by action of said control tube to maintain constant volume of reproduction.

7. A radio receiving system comprising a radio-frequency amplifier tube of the screen grid type, a control tube of the screen grid type, a detector tube, a source of current for supplying direct current to said tubes, serially connected resistances traversed by direct current from said source, connections to said resistances whereby at least one grid of the amplifier and control tubes are biased with respect to their cathodes, a conductive impedance traversed by the detector anode current and included in circuit with the other

grid of said control tube for automatically varying its bias in accordance with the amplitude of a received signal, a second conductive impedance in the anode circuit of said control tube, and a connection from said
5 second impedance to the other grid of said amplifier for impressing thereon a biasing potential automatically varied by action of said control tube.

10 8. A radio receiving system comprising a control tube, a radio-frequency amplifier tube, a source for supplying direct current to said tubes, serially connected resistances traversed by current from said source, and
15 connections thereto whereby the cathode of said amplifier tube is positive with respect to the cathode of said control tube and whereby grid structures of said tubes are biased, a detector tube, a conductive imped-
20 ance traversed by the detector anode current and included in circuit with grid structure of said control tube to provide a biasing potential automatically varying in accordance with the amplitude of a received signal, a
25 second conductive impedance traversed by anode current of said control tube, and a connection therefrom to grid structure of said amplifier tube for impressing thereon a biasing potential automatically varied by action
30 of said control tube.

OTTO H. SCHADE.

35

40

45

50

55

60

65