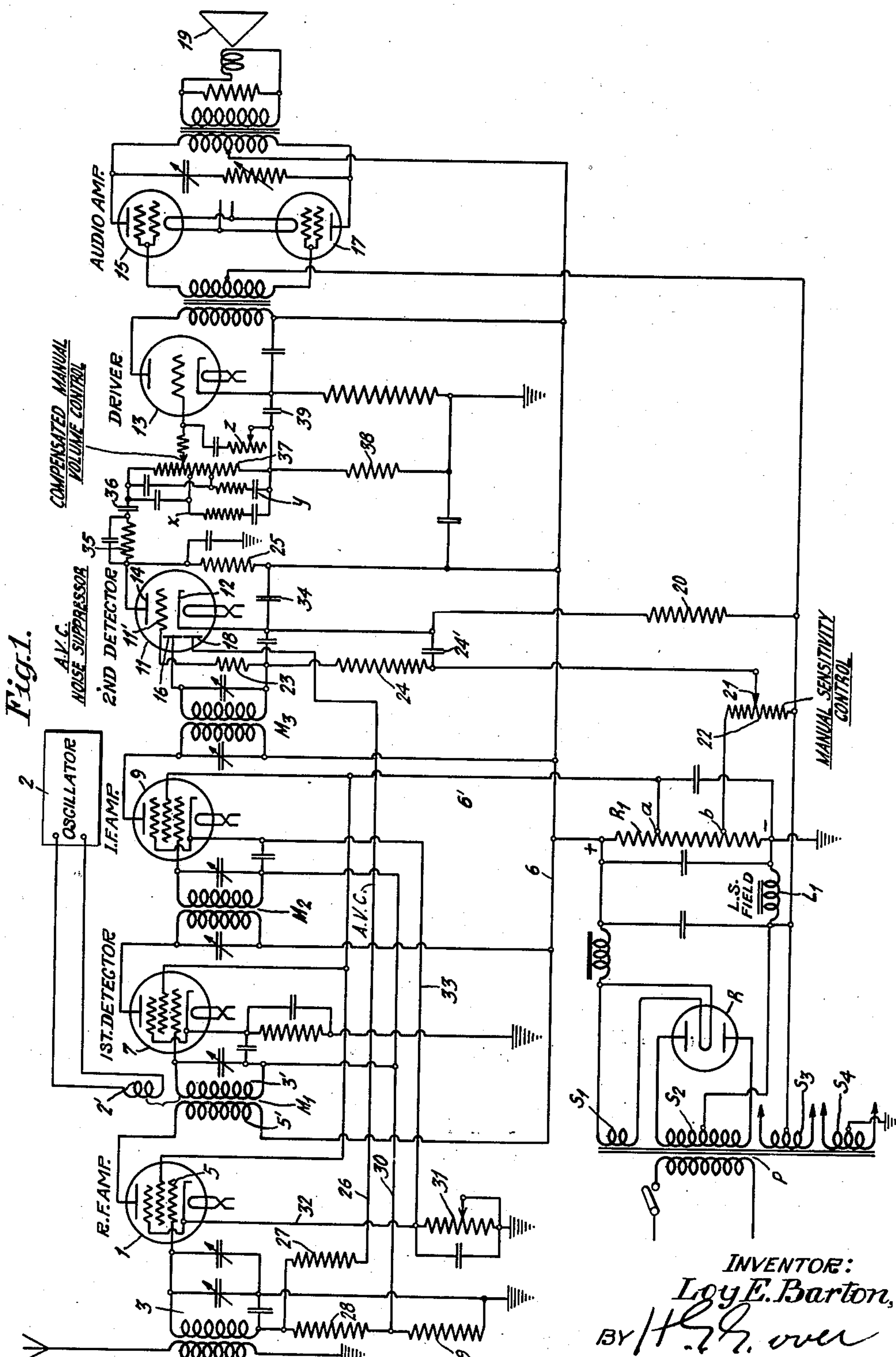
Oct. 1, 1940. L. E. BARTON 2,216,582

AUTOMATIC VOLUME CONTROL WITH NOISE SUPPRESSION

Filed Nov. 3, 1932 3 Sheets-Sheet 1



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AUTOMATIC VOLUME CONTROL WITH NOISE SUPPRESSION

Filed Nov. 3, 1932 3 Sheets-Sheet 2

Fig. 4.

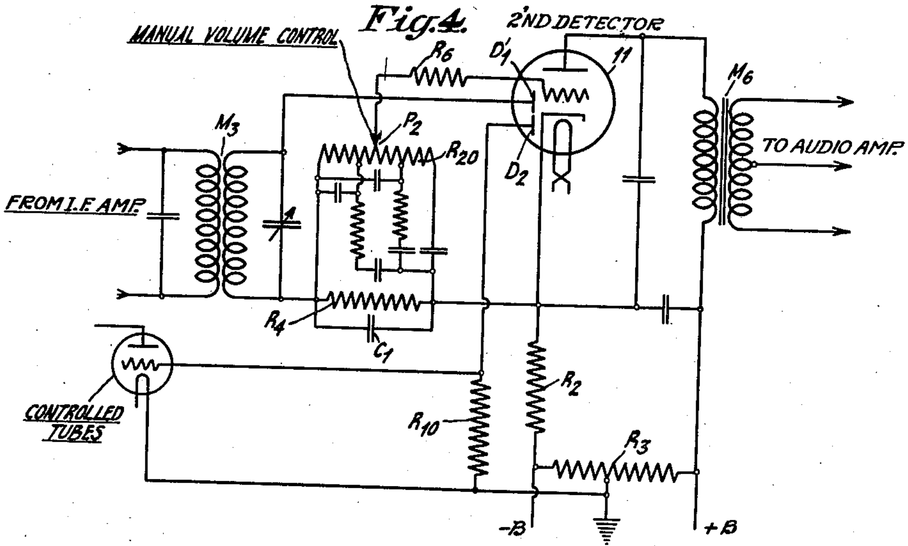
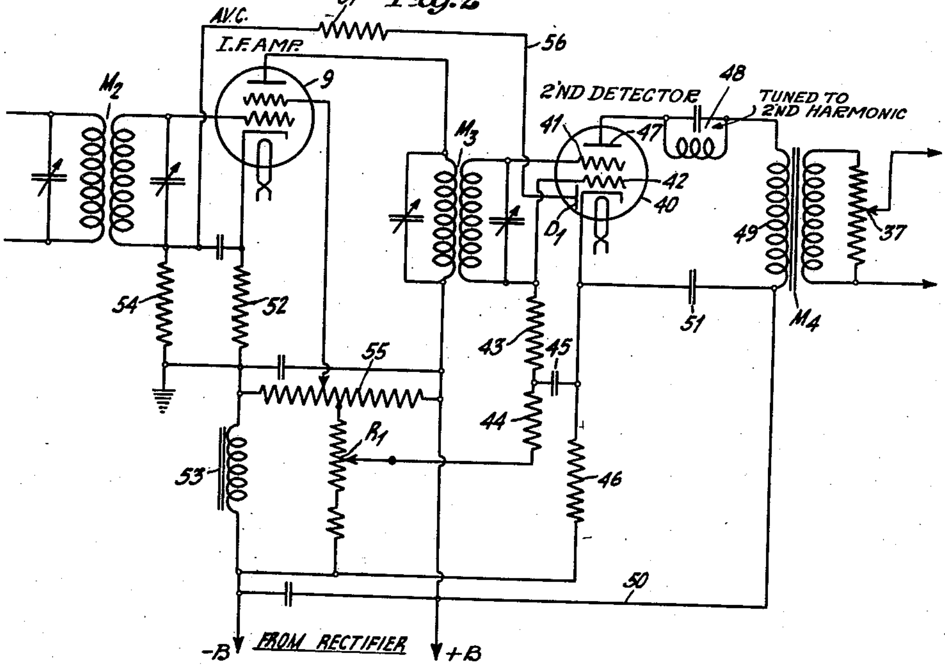


Fig. 2



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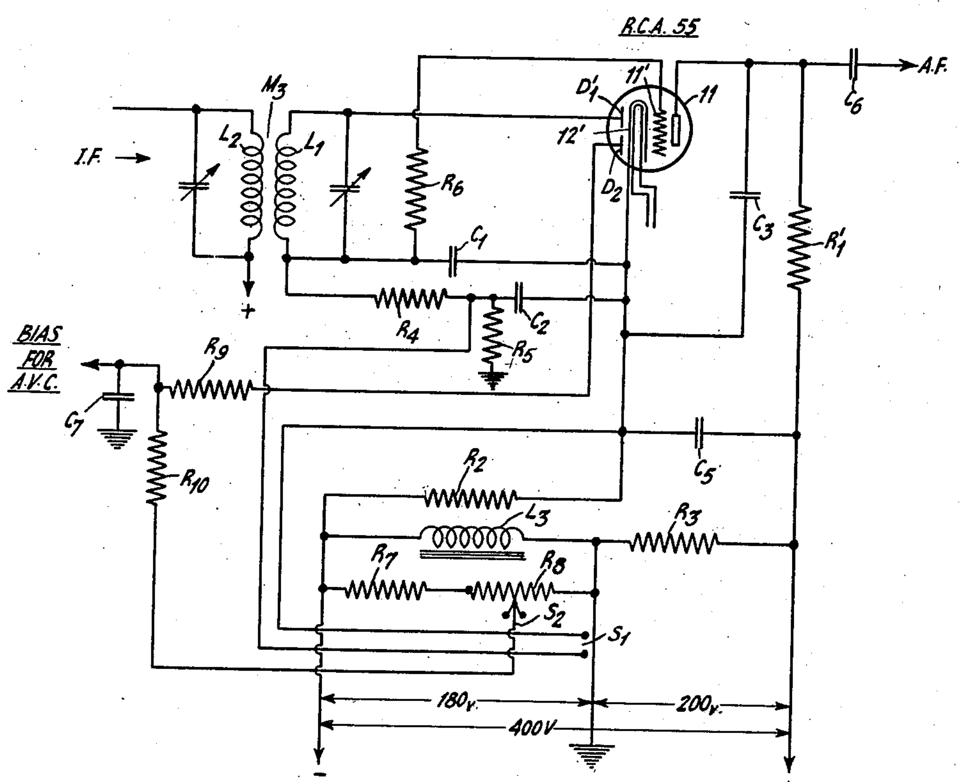
Filed Nov. 3, 1932 3 Sheets-Sheet 3

Fig. 3



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Patented Oct. 1, 1940

2,216,582

UNITED STATES PATENT OFFICE

2,216,582

AUTOMATIC VOLUME CONTROL WITH NOISE SUPPRESSION

Loy E. Barton, Collingswood, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application November 3, 1932, Serial No. 640,946

34 Claims. (Cl. 250—20)

My invention relates to signal receiving apparatus, and it has particular relation to devices for preventing the response of such apparatus to signals of amplitude less than a predetermined value.

It has previously been proposed to provide signal receiving apparatus with automatic volume control devices whereby the ultimate sound output is rendered substantially independent of fading and other phenomena which tend to cause the amplitude of an incoming signal to greatly vary. In the operation of receivers equipped with automatic volume control devices, however, some dissatisfaction has been experienced by reason of the fact that, during the operation of manually or automatically tuning the system from one desired station setting to another, intervening stations are received. Furthermore, during the tuning operation, there is always present, from a wide variety of sources, objectionable interference of the type generally designated as "background noise."

It is, accordingly, an object of my present invention to provide means whereby a portion of a radio receiver is rendered inoperative during the tuning operation.

Another object of my invention is to provide means whereby background noise shall be eliminated during the operation of tuning a signal receiving system from one desired station to another station.

Another object of my invention is to provide, in a system of the type described, means whereby automatic volume, or gain, control, as well as "silent tuning," may be had without the necessity of using an extra thermionic tube.

A still further and more specific object of my invention is to provide a novel thermionic tube, through the use of which the foregoing enumerated functions may be had.

The aforementioned objects and other objects appurtenant thereto, I prefer to accomplish through the use of a new and improved thermionic tube wherein, in addition to the usual triode structure, is disposed one, or more, diode plates providing, with the cathode of the tube, additional space current paths. I also provide a system of resistors and potential sources whereby the current traversing one, or more, of the additional space current paths in the aforementioned tube gives rise to a potential, or potentials, proportional to the amplitude of an incoming carrier wave, and, in addition, I provide circuit connections whereby the said potential, or potentials, may be utilized for both volume control purposes and for the purpose of rendering the system unresponsive to background noise or signals below a predetermined amplitude during the operation of tuning from one desired station to another.

My invention lends itself readily to a wide variety of specific embodiments, certain of which have been chosen for purposes of illustration, but it will hereinafter be noted that, irrespective of the specific nature of the triode portion of my improved thermionic tube, one of the diode elements is utilized for automatic volume control.

The novel features that I consider characteristic of my invention are set forth in particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages, will best be understood from the following description of a specific embodiment and certain variants thereof, when read in connection with the accompanying drawings wherein:

Fig. 1 is a diagrammatic view of a radio receiver of the superheterodyne type including a preferred embodiment of my invention,

Fig. 2 is a fragmentary diagrammatic view illustrating a modification of my invention,

Fig. 3 is a further fragmentary view of a radio receiver illustrating yet another modification of my invention,

Fig. 4 shows a modification of the circuit shown in Fig. 3.

Although, as will be obvious to those skilled in the art, my invention is applicable to radio receivers of many different types, I have found it convenient to exemplify it in connection with a superheterodyne receiver. Referring specifically to Fig. 1 of the drawings, a superheterodyne radio receiver is shown including a preferred embodiment of my invention and comprises a radio frequency amplifier tube 1 of the radio frequency pentode type having a tunable input circuit 3 connected to the control grid 5 thereof. A first detector tube 7, of the same type, has its tunable input circuit 3′ coupled to the output tunable circuit 5′ of tube 1.

An intermediate frequency amplifier tube 9, also of the pentode type, follows the first detector; a combined second detector, automatic gain control, noise suppressor and audio frequency amplifier tube 11, constructed according to my invention, follows the tube 9. A driver tube 13 is coupled to the output of tube 11, and is followed by a plurality of audio frequency amplifier tubes 15 and 17 connected in push pull, the output circuit of which may be coupled in any desired manner to a loudspeaker 19 or other indicating device.

A local oscillator is included in the system, and is conventionally indicated in the drawings by a rectangle 2. The oscillator is shown as having an output circuit 2′ coupled to the input circuit 3′ of the first detector tube 7. Naturally, the oscillator in an actual receiver includes a thermionic tube having a tunable resonant circuit which is simultaneously tunable with the tunable resonant circuits of the radio amplifier and first detector stages of the receiver. In order to simplify the drawing the specific connections of the said oscillator tube have been omitted; the unicontrol tuning mechanism also being omitted for the same reason.

As is usual in receivers of the superheterodyne type, the couplings between the radio freqeuncy amplifier 1 and the first detector 7, between the first detector and the intermediate frequency amplifier 9, as well as between the intermediate frequency amplifier and the second detector 11, are of the band pass type. Such couplings are constituted by radio frequency transformer M_1 and intermediate frequency transformers M_2, and M_3, respectively, each of the latter two having a tunable primary and a tunable secondary winding. The transformers M_2 and M_3 are resonant to the operating intermediate frequency; the latter is kept constant in any desired manner throughout the tuning range of the receiver.

The second detector tube may be coupled to the driver tube 13 in any desired manner; I find it expedient to utilize a coupling network so designed as to permit of compensated volume control. The network will hereinafter be referred to in more detail. As is customary in radio receivers of the so-called "all electric" type, the cathode heating, grid biasing and anode potentials of the receiver tubes are supplied from a commercial alternating current supply line.

Specifically, the potential supply system I have found satisfactory includes a power transformer P having a plurality of secondary windings S_1, S_2, S_3, and S_4. The windings S_2, and S_1, respectively, supply cathode and plate potential to a full wave rectifying device R, while the last mentioned windings S_3 and S_4 supply cathode heating potential to the several tubes in the system. The rectifier R is provided with an output resistor, or potential dividing device R_1, and in the negative connection thereof I find it expedient to dispose the field winding L_1 of the loud speaker of a sound producing device for a purpose which will later be referred to.

Plate potential to all of the amplifying tubes in the system is supplied from the positive end (+) of the output resistor R_1 over a common conductor 6. Screen grid potential is supplied to the radio frequency amplifier 1, the first detector 7, and the intermediate frequency amplifier 9 from an intermediate point *a* on the output resistor R_1 over a common conductor 6′. The multiple duty tube 11 comprises a cathode 12, a control grid 11′, an anode 14, and a plurality of diode anode elements 16 and 18.

As hereinbefore pointed out, it is one of the objects of my invention to provide a receiver wherein tuning is silent. In order that this may be accomplished, I utilize one of the diode elements as a detector, and supply the said element with a controllable bias potential of such magnitude that incoming signals supplied thereto from the intermediate frequency amplifier are not rectified unless the said signals exceed a definite predetermined amplitude. The manner in which the controllable bias is supplied to the diode element is as follows: The cathode 12 of the tube 11 is connected to the most negative portion of the potential supply system through a cathode resistor 20.

The grid 11′ of the said tube is connected through an adjustable contact device 21 to a point on a resistor 22 which, in turn, is shunted across between the said most negative portion of the potential supply system and a point *b* on the output resistor R_1 at a positive potential with respect to ground. The path to the device 21 also includes the resistors 23, 24. Adjusting the movable contact element 21 permits the grid 11′ of the tube 11 to be supplied with a potential which is either positive or negative with respect to the grounded point of the said output resistor.

In the operation of the system, and assuming that no signals are being impressed upon the diode element 16 of the tube 11, the movable contact device 21 is adjusted along the resistor 22 until the fall in potential along the self-bias resistor 20 is substantially balanced by the rise in potential across the loud speaker field winding L_1, whereby the grid 11′ of the tube 11 and the diode element 16 are maintained at zero potential with respect to the cathode, or at a potential which is slightly negative. The amount of the negative potential is, of course, determined by the position of the contact element 21, and adjustment of this element may be so made that the diode element does not function until the said negative potential is overcome by an incoming signal having a definite predetermined amplitude. This feature enables the system to be adjusted for silent tuning.

Assuming now that the incoming signal exceeds the predetermined minimum amplitude, it is applied between the diode element 16 and the cathode 12 of tube 11 through grid leak resistor 24 and condenser 24′. The control grid 11′ of the tube is connected to the high potential side of the grid leak 24 through resistor 23. It will be noted that the intermediate frequency voltage applied to the control grid will be very small, and that the resistor 23 is inserted to further reduce the signal at the intermediate frequency. It should also be apparent that the bias for the control grid is obtained from the direct current voltage across the grid leak 24 which, in turn, is proportional to the carrier of the signal.

The plate current of the triode portion of the tube is limited by a resistance 25, (or a series combination of plate, reactor and resistance) in series with the plate supply conductor 6, and by the cathode resistor 20 so that the voltage across the said cathode resistance is a maximum at zero signal and decreases as the signal increases.

It will also be apparent that the voltage across the cathode resistance 20 and the loud speaker field L_1 are in the same direction, and that normally the voltage across the said resistor 20 is larger than the voltage across the field in the absence of signals. In this condition, therefore, the diode plate 16 may be negative with respect to the cathode of the tube depending upon the adjustment of resistance 22. The second diode plate 18 is negative in the last named condition, and is connected over a conductor **26** and a plurality of resistors **27**, **28**, **29** to ground.

In the no signal condition the potential drop across the cathode resistor **20** is greater than the rise in potential across the loud speaker field L_1 and, accordingly, a negative potential is supplied to the said second diode element **18**. For automatic volume control purposes, the grids of the radio frequency amplifier **1**, the first detector **7** and the intermediate frequency amplifier **9** are connected to appropriate points on the aforesaid resistors included between the second diode plate **18** and ground. Thus, the grid of tube **1** is connected to one side of resistor **28**; the grids of tubes **7**, **11** are connected through lead **30** to a point intermediate resistors **28**, **29**. This permits the bias applied to the grid of tube **1** to be greater than that applied to tubes **7** and **9** to prevent overloading on the side of a strong carrier. Obviously, therefore, during the no signal condition the negative bias applied to the said tubes is a minimum, and is determined solely by the potential drop across the self-bias resistor **31** connected into the cathode return circuit of tubes **1** and **9**.

As a signal is applied to the diode plate **16** its rectification causes a negative potential to be developed across the grid leak **24**, and, since the control grid **11'** of the tube is connected to the said grid leak as hereinbefore explained, it becomes more negative, thus causing the plate current of the triode section of the tube **11** to decrease. The decrease in current through the cathode resistor **20** permits the second diode element **18** to become more positive with respect to cathode **12** by the amount of change in the difference of the voltage across the loudspeaker field and the cathode resistor **20**. If the input signal is sufficiently large, the decreased voltage across resistor **20** causes the diode anode **18** to become positive with respect to cathode **12** by virtue of the fact that cathode **12** becomes negative with respect to ground. Therefore, current flows from ground to the diode anode **18** through resistors **29**, **28** and **27**, the voltage across these resistors being essentially equal to ground and the potential of cathode **12** because the resistance of the diode anode **18** is relatively small. The direction of this current is from ground up through the resistors **29**, **28**, **27**, included between ground and the diode plate, causing a potential drop in the proper direction to supply bias to the radio frequency amplifier **1**, the first detector **7**, and the intermediate frequency amplifier **9** for automatic volume control purposes. Obviously, the amount of current taken by the second diode element **18** increases as the signal increases in amplitude, and thus the increased signal is caused to be met by tubes the gain in which has been decreased.

In general, the voltage across the cathode resistor **20** during the no signal condition should be about 30 to 50 volts higher than the voltage across the loud speaker winding. This voltage determines the extent to which the automatic volume control action is delayed. The signal applied to the first diode element **16** may cause a reduction in voltage in the said cathode resistor **20** to approximately 60% of the initial voltage without serious distortion of the audio signal. In this connection, attention is called to the fact that there will be no automatic volume control until the voltage across the cathode resistor **20** is approximately equal to the voltage across the loud speaker field, so that a voltage for automatic volume control of 60 to 75 volts may be obtained without overloading the detector **11**, if the voltage across the loud speaker field is about 170 volts and the plate supply for the receiver is about 230 volts.

The maximum voltage available for automatic volume control depends upon the available voltage across the speaker and resistor **20**. Referring again to the action of the second detector tube **11**, it should be noted that the audio voltage, due to the rectification of the signal by the first diode element **16**, is applied to the control grid **11'**, whereby the said tube functions not only as a detector, but also as an audio frequency amplifier. The noise suppression, or silent tuning, is obtained by adjustment of the contact device **21** associated with the resistor **22** which shunts a portion of the rectifier output resistor R_1 and the loud speaker field winding. Naturally, if the contact element is moved downward toward the negative end of the shunting resistor, a signal of greater amplitude or noise of greater amplitude is required to overcome the negative bias applied to the first diode element **16**. In locations where interstation noise is not objectionable, the diode plate **16** may be maintained at substantially zero potential by proper adjustment of the contact element. It should be noted that if the diode anode **16** is made negative with respect to the cathode by the adjustable tap **21**, a signal slightly larger than this value is required to overcome the bias to cause some detection. The negative potential to grid **11'** increases due to detection which automatically reduces the cathode potential with respect to the point **21**, thereby removing the negative potential on the diode anode **16** and thus permitting normal detection.

In order that a further control of the sensitivity of the system may be had, I prefer to supply normal bias to the radio frequency amplifier and the intermediate frequency amplifier through a variable self-bias resistor **31** which is connected by leads **32**, **33** between the cathodes of the said tubes and ground. Through proper adjusting of the said variable resistor, since in the no signal condition no bias is supplied from the circuit of the second diode plate **18**, the normal bias on the said tubes may be adjusted to the desired point.

The resistor **25** is by-passed with the condenser **34**, and the audio voltage is obtained from the resistor **25** (and/or choke) in the plate circuit of tube **11** through resistor **35** and condenser **36** to the potentiometer **37**. The network, including the series condenser-resistor paths X, Y, Z, associated with the potentiometer **37**, or the audio volume control, are used to obtain the desired compensation for varying volume levels and also tone control. The resistor **38** and condenser **39** are used as a hum filter, if such is necessary. The network between tubes **11** and **13** need not be described in any further detail, since it is not a part of the present invention. The amplifier tubes **15** and **17** are arranged in push-pull, and need only be described as furnishing an amplifier of the class B push-pull type operating with zero grid bias. This arrangement has been described and claimed by me in a co-pending application Serial No. 586,874, filed January 15, 1932, granted June 15, 1937 as U. S. Pat. 2,084,180, and is also described in the I. R. E. for July, 1932.

The tube **11** is of the type known as an RCA-55, or a duplex-diode triode. The diode elements **16**, **18** are disposed around an extreme portion of the cathode sleeve. The cathode is common for the diode elements and the triode grid and plate. However, the diode anodes 16, 18 function independently of the triode elements. That is, the diode anodes 16 and 18 are outside the electron system between cathode 12, grid 11′ and anode 14. Further details of the construction of this tube will be found in a co-pending application of T. M. Shrader application Serial No. 622,140, filed July 12, 1932, granted Oct. 27, 1936 as U. S. Pat. 2,058,834.

In Fig. 2 there is shown a modified form of the automatic volume control and noise suppressor arrangement of Fig 1. The combined second detector, automatic volume control, noise suppressor tube is designated by the numeral 40. This tube is of the co-planar grid type with a diode anode, indicated as D_1.

The grid 41 is connected to the one side of the tuned secondary winding of the transformer M_3, in the same manner as the diode element 16 in the case of tube 11 of Fig. 1. The grid 41 is connected to the other grid 41, and to the potentiometer R_1 through a path which includes resistor 43 having a value of about 2 megohms, and a resistor 44 having a magnitude of about 20,000 ohms, a condenser 45 being connected between the junction of resistors 43 and 44 and the cathode of tube 40. It should be noted that the resistor 43 may be connected to the center of the secondary of coupling transformer M_3 without altering the operation of the grids.

The cathode of tube 40 is connected to the −B side of a power supply system through a resistor 46 which functions in the same manner as resistor 20 in Fig. 1. The main anode 47 of tube 40 is connected to the +B side of a power supply system through a network 48, tuned to the second harmonic, the primary winding 49 of the audio frequency coupling transformer M_4, and lead 50. The condenser 51 connects the low potential side of the winding 49 to the cathode of tube 40. The tuned circuit 48 increases the sensitivity of the tube 40 slightly but may be omitted.

The preceding intermediate frequency amplifier tube 9 has its cathode connected to the −B side of the power supply system through a path which includes the resistor 52, and the loud speaker field winding 53, the junction of resistor 52 and field winding 53 being connected to the low potential side of the tuned input circuit of tube 9 through a grounded resistor 54 having a value of about 0.5 megohm. The resistor 55 is connected between the junction of resistor 52 and the winding 53 and the anode lead to tube 9, one side of the potentiometer resistor R_1 being connected to an intermediate point of the resistor 55. The diode anode D_1 of tube 40 is connected to the low potential side of the grid circuit of tube 9 through a path, which includes lead 56 and resistor 57 in order to cause resistor 54 to feed automatic volume control voltage to tube 9.

The co-planar grid tube 40 is a tube wherein the grids 41 and 42 are concentrically wound in the same cylindrical surface. The diode anode D_1 is disposed outside the main electron stream from the cathode to the anode 47, and therefore provides a diode independent of the co-planar grid triode. The circuit of diode anode D_1 provides delayed automatic volume control action. Potentiometer R_1 is so adjusted that in the absence of signals the grid-cathode bias is zero. The voltage across the resistor 46 decreases with signal because of the negative potential across 43 which is proportional to the signal and, until this voltage decreases to a certain predetermined value, say 160 volts from 190 volts, the bias for the intermediate frequency tube 9 will be normal. When such predetermined voltage has been reached, current begins to flow through the resistor 54 due to the potential across resistor 46 having become less than that across field winding 53 so that anode D_1 has become positive relative to the cathode of tube 40. Further increase in signal causes a decrease in voltage at resistor 46, and this increases the bias on tube 9. The arrangement shown in Fig. 2, also, includes noise suppression so that most, or all, noise when tuning between stations is automatically suppressed. The potentiometer R_1 can be so adjusted that the tube 40 will have a negative bias on the grids 41 and 42, thereby preventing detection until a carrier of a predetermined amplitude is received. Signal detection causes the voltage across 46 to decrease, to say 160 volts, which removes the negative bias so that the grids 41 and 42 may detect in a normal manner. Further decrease in voltage across 46 automatically controls the sensitivity of the receiver by applying the further decrease as bias to the tube 9 through circuit 54, 57, 56 and the diode D_1. The grids 41 and 42 will become positive but the actual positive potential will be very small because of the high resistance 43. The slight positive potential will not interfere with detection.

In Fig. 3 there is shown a modification of the automatic volume control, delay and noise suppressor circuits of tube 11 in Fig. 1. The 55 type tube 11 is used for the second detector, automatic volume control and noise suppression functions, as in the case of Fig. 1. Referring to Fig. 3, the input intermediate frequency signal is applied to the diode anode D'_1 with the condenser and leak arrangement C_1—R_4. Contacts S_1 are insulated from the contact arm S_2 but are so mechanically connected that the contacts are closed when S_2 is at extreme right. It will be noted that when the sensitivity control S_2 is at the extreme right hand position, the sensitivity is maximum, and the switch contacts S_1 are caused to be connected together by the movable arm S_2, so that the diode element D_1 returns directly to the indirectly heated cathode sleeve. The tube 11 in Fig. 3 has been shown in greater constructional detail than in the case of Fig. 1 so as to show the positioning of the control grid and main anode, as well as the positioning of the auxiliary anodes D'_1 and D_2 with respect to the common cathode sleeve 12′.

When the arm S_2 is in the extreme right the controlling shaft will also cause the switch contacts S_1 to be closed as described above, and the bias on the element D_1 is zero as well as on the grid 11′ if the input signal is zero. The plate current for the tube 11 flows through resistor R'_1, and returns to the negative plate potential through resistor R_2 which is in the cathode lead of tube 11. The voltage drop across resistor R_2 is somewhat higher than the voltage across the loud speaker coil L_3. The resistor R'_1 is used as a plate coupling resistor for the audio signal, and the condenser C_5 by-passes the audio signal around resistor R_2, and also filters out any hum that may exist in the plate supply to tube 11.

Under no signal conditons, and with the arm S_2 in extreme right position so that the two contacts S_1 are closed, there is a negative potential on the diode element D_2 through the biasing resistor R_{10}. Therefore, there is no current flowing through the resistor R_{10}, so that the bias on the radio frequency and intermediate frequency systems is the minimum or fixed value. As a signal is applied to the element D'_1, the rectification causes a negative potential to be generated across resistor R_4, and this in turn causes the plate current of the triode section of tube 11 to decrease. This decrease in current through resistor R_2 results in a lower voltage drop across the latter, so that as the signal increases, the voltage across resistor R_2 will become less than the voltage across the speaker field winding L_3. Under these conditions, the diode element D_2 will become positive by the amount of the difference in voltage across resistor R_2 and the field winding L_3, and this causes a voltage across resistor R_{10} equal to approximately the last named difference.

The voltage across resistor R_{10} is in the proper direction to supply bias for automatic volume control, and it will be recognized that the diode element D_2 cooperates with the cathode resistor R_2 to provide a delay action for the automatic volume control system. In other words, there is provided here, with regard to the delay action, a rectifier system for producing audio and direct current components from the signal energy, a triode amplifier for amplifying both components, and an additional device of asymmetric conductivity for utilizing the amplified direct current component for delaying the automatic volume control action until the signal energy rises above a predetermined threshold value.

In general, the voltage across resistor R_2, with no signal, should be about 30 to 50 volts higher than the voltage across the winding L_3. The signal applied to the diode element D'_1 may cause a reduction in the voltage across resistor R_2 to approximately 60% of the initial voltage without serious distortion of the audio signal. It will be noted that there will be no automatic volume control action until the voltage across resistor R_2 is approximately the voltage across the winding L_3 so that a net voltage for automatic volume control of 60 to 75 volts should be obtained without overloading the detector tube 11. The audio voltage due to modulation will be applied to the grid 11' through the resistor R_6, and will be transmitted to the audio system through the plate resistor R'_1 and the coupling capacitor C_6. The resistor R_6 is used to reduce the intermediate frequency energy to the grid 11', but will not affect the audio frequencies appreciably.

The effective circuit which results when the arm S_2 is in contact with contacts S_1 may be had by referring to Fig. 4. This circuit will be the same as Fig. 3, except that the switch contacts S_1, the leads connecting S_1, the resistor R_5, and the condenser C_2 should be omitted from the circuit. The low potential end of R_4 will connect to the cathode of tube 11 to complete the changed circuit.

The noise suppression function is obtained by adjusting the potentiometer R_8 slightly to the left, which opens the switch S_1. In other words, when the arm S_2 is moved to the left along the potentiometer resistor R_8, the two contacts of switch S_1 are open, or disconnected, and the noise suppression function is restored. With this setting, that is the arm S_2 moved slightly to the left, the sensitivity of the receiver is maximum, but there is a negative potential applied to the detector diode D'_1 because the diode is connected to ground through resistor R_5. This negative potential amounts to approximately 8 volts, so that an incoming signal below this value will not be detected. Therefore, no noise will appear at the loud speaker.

If the noise level is such as to over-ride the suppressor, or negative diode, potential, then sensitivity may be reduced (by moving the arm S_2 still further to the left) by increasing the normal negative bias on the grids of the control tubes thus making the overall amplification less so that the noise will not over-ride the negative potential on the diode element D'_1. If this procedure is carried far enough it is obvious that no station can be received, so that the range of the sensitivity control should be limited to such a value that stations with high field strength can be received at the minimum sensitivity. This latter minimum point of sensitivity will then represent the extreme left position of the arm S_2 on the potentiometer resistor R_8.

The principal advantages of the system shown in Fig. 3, as well as that shown in Fig. 1, reside in the fact that the detector, delayed automatic volume control and noise control functions are performed by only one tube. The audio output of the detector is approximately 50 volts for 100% modulation before it overloads if the necessary intermediate frequency voltage is applied to the detector. This relatively high audio voltage permits the use of a compensated volume control. The voltage for the automatic volume control is also more dependable because it depends upon a change in plate current of the detector and does not depend directly upon power from the intermediate frequency system.

The noise control feature provides a means for using a sensitivity control with a negative potential on the diode detector. The negative potential on the diode eliminates the noise applied to the detector below a definite voltage, and the sensitivity control permits an adjustment of noise level to the detector. An ordinary, sensitivity control in some receivers can be used as a volume control, but in the above system an adjustment of the sensitivity control either causes the signal to disappear or to be received normally with a very limited range in which the signal is badly distorted. The result is that the user would not attempt to use the noise level or sensitivity control as a volume control.

The circuit shown in Fig. 3 normally supplies audio voltage through the coupling capacitor C_6 to a high resistance potentiometer arrangement for compensated volume control, which potentiometer may be connected directly to the grid of an audio frequency driver tube. This latter volume control arrangement is shown in Fig. 1 between the tubes 11 and 13. This is a satisfactory arrangement when the load in the plate circuit of the tube 11 is very light, or has a high resistance. However, it is desirable at times to connect a transformer M_6 to the plate circuit of the detector tube 11 so that a push-pull output system, of the type shown in Fig. 1 by tubes 15 and 17, can be driven directly. In general, the latter arrangement means a relatively low resistance in the plate circuit of tube 11 so that it is not desirable to use the resistance-condenser coupling network shown in Fig. 3.

The circuit arrangement shown in Fig. 4 is designed to eliminate the plate load difficulty referred to in the preceding paragraph, and yet retain most of the desirable features of the circuit shown in Fig. 3. The principal feature of the modification in Fig. 4 is the relatively low leak resistance R_4, having a value of 0.1 megohm, with the high resistance audio volume control P_2, the resistor R_{20} of the manual volume control P_2 having a value of about 1 megohm. The function of the manual volume control is similar to the compensated volume control in Fig. 1. It will be noted that the bias for the triode action of tube 11 is the voltage across the resistor R_4 so that the system for automatic volume control, detection and noise control as used in Fig. 3 may be employed here also. The resistor R_6 may be omitted if desired.

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. In combination, with a high frequency amplifier whose gain is to be controlled in such a manner that the output of the amplifier is maintained at a substantially uniform level, a rectifier including a source of electrons and a cold electrode coupled to the amplifier output, means connected to the cold electrode of the rectifier for maintaining the cold electrode negative with respect to the source of electrons when signals to be amplified are impressed upon the controlled amplifier input, an amplifier including a source of electrons and at least two cold electrodes, one of the two cold electrodes being connected to a point on said means, and the other cold electrode being connected to the source of electrons of the amplifier, a delay space discharge device electrically connected to the source of electrons of said amplifier, and an automatic volume control resistor connected between a cold electrode of the delay device and the high frequency amplifier.

2. In combination, an amplifier to be controlled as to the gain thereof, a rectifier, a second amplifier, means for impressing the rectifier output upon the second amplifier input, a device of asymmetric conductivity, means for impressing the second amplifier ouput on said device whereby the output of the second amplifier produces negligible effect in the output of said device until a desired threshold value is attained, and a direct current voltage connection between the output of said device and said controlled amplifier, the gain of said controlled amplifier being controlled from said device only after said threshold value is reached.

3. In combination, an amplifier to be controlled as to the gain thereof, a rectifier, a second amplifier, means for impressing the rectifier output upon the second amplifier input, a diode device, means for impressing the second amplifier output on said device whereby the output of the second amplifier produces negligible effect in the output of said device until a desired threshold value is attained, and a direct current voltage connection between the output of said device and said controlled amplifier, the gain of said controlled amplifier being controlled from said device only after said threshold value is reached.

4. In combination, an amplifier to be controlled as to the gain thereof, a rectifier, a second amplifier, means for impressing the rectifier output upon the second amplifier input, a device of asymmetric conductivity, means for impressing the second amplifier output on said device whereby the output of the second amplifier produces negligible effect in the output of said device until a desired threshold value is attained, and a direct current voltage connection between the output of said device and said controlled amplifier, the gain of said controlled amplifier being controlled from said device only after said threshold value is reached, said second amplifier comprising an electron discharge tube including a cathode, control grid and anode, and said device consisting of an auxiliary anode disposed adjacent said cathode outside the electron stream between the cathode and the first said anode.

5. In combination, an amplifier to be controlled as to the gain thereof, a rectifier, a second amplifier, means for impressing the rectifier output upon the second amplifier input, a device of asymmetric conductivity, means for impressing the second amplifier output on said device whereby the output of the second amplifier produces negligible effect in the output of said device until a desired threshold value is attained, and a direct current voltage connection between the output of said device and said controlled amplifier, the gain of said controlled amplifier being controlled from said device only after said threshold value is reached, said second amplifier comprising an electron discharge tube including a cathode, control grid and anode, and said device consisting of an auxiliary anode disposed adjacent said cathode outside the electron stream between the cathode and the first said anode and said rectifier comprising an additional auxiliary anode disposed adjacent said cathode outside said electron stream.

6. An automatic volume control arrangement for a radio receiver, which receiver includes a high frequency amplifier and a detector, said detector including an electron discharge tube provided with a cathode, at least one control grid and at least one anode, a resistor in the cathode circuit of said detector tube, at least one auxiliary cold electrode in said detector tube, a direct current voltage connection between said auxiliary electrode and said amplifier for controlling the gain of the latter, the voltage across said cathode resistor being of a magnitude exceeding the bias requirement for the detector.

7. An automatic volume control arrangement for a radio receiver, which receiver includes a high frequency amplifier and a detector, said detector including an electron discharge tube provided with a cathode, at least one control grid and at least one anode, a resistor in the cathode circuit of said detector tube, at least one auxiliary cold electrode in said detector tube, a direct current voltage connection between said auxiliary electrode and said amplifier for controlling the gain of the latter, the voltage across said cathode resistor being of a magnitude exceeding the bias requirement for the detector, a second auxiliary cold electrode within said detector tube, said second auxiliary electrode being connected to the output of said amplifier whereby it cooperates with a portion of said detector tube cathode to rectify signals supplied to the detector, means for connecting said control grid to a point on the detector input circuit whereby a wide range of voltage variation across said cathode resistor is secured.

8. An automatic volume control arrangement for a radio receiver, which receiver includes a high frequency amplifier and a detector, said detector including an electron discharge tube provided with a cathode, at least one control grid

and at least one anode, a resistor in the cathode circuit of said detector tube, at least one auxiliary cold electrode in said detector tube, a direct current voltage connection between said auxiliary electrode and said amplifier for controlling the gain of the latter, the voltage across said cathode resistor being of a magnitude exceeding the bias requirement for the detector and an additional control grid coplanarly arranged with respect to the first control grid connected to a signal potential point on the detector input circuit which is out of phase with the point on the said input circuit to which the said first grid is connected.

9. In combination with a high frequency amplifier stage whose gain is to be controlled, a tube provided with at least a cathode, control grid, and anode, and a pair of auxiliary anodes positioned outside the electron stream between the cathode and said anode, a signal input circuit coupled between one of said auxiliary electrodes and the cathode, said signal input circuit being additionally coupled to the output of said amplifier, means for coupling said tube anode to a low frequency amplifier, a direct current voltage connection between said control grid and said one auxiliary electrode, a direct current voltage connection between the other auxiliary electrode and said first amplifier, a resistive path in the cathode circuit of said tube, and an adjustable connection between said direct current voltage connection to said second auxiliary electrode and said resistive path.

10. In a superheterodyne radio receiver including an intermediate frequency amplifier, a second detector tube including a triode section and at least one independent diode section, an audio amplifier network connected to the output electrodes of the triode section, a signal input circuit connected to the diode section to provide a rectification network, and a biasing impedance in the cathode circuit of the triode section connected to the said diode section for rendering the latter inoperative when signals of less than a predetermined amplitude are impressed on said input circuit, an auxiliary electrode in said tube providing a second independent diode section, and a direct current voltage connection between the auxiliary electrode and a gain control electrode of the intermediate frequency amplifier.

11. In a superheterodyne radio receiver including an intermediate frequency amplifier, a second detector tube including a triode section and at least one independent diode section, an audio amplifier network connected to the output electrodes of the triode section, a signal input circuit connected to the diode section to provide a rectification network, and a biasing impedance in the cathode circuit of the triode section connected to the said diode section for rendering the latter inoperative when signals of less than a predetermined amplitude are impressed on said input circuit, an adjustable audio volume connection between the grid of said triode section and a point on said rectification network, and additional means for frequency compensating the said connection for different volume levels.

12. In a receiver of the type including at least one high frequency amplifier having a resonant input circuit, a detector stage including a tube provided with a cathode, a grid, an anode, and at least two cold electrodes adjacent said cathode but substantially unaffected by said grid, a signal circuit coupled to one of the cold electrodes and the cathode to produce rectified signal current, an impedance which is high for both direct and audio currents connected between said one electrode and cathode to be traversed by said rectified signal current, means to impress between the grid and cathode voltage derived from said rectified current flowing through said impedance whereby the direct current component is decreased in proportion to increasing signals, a direct connection from the other cold electrode to the amplifier, a connection from the cathode to a point more negative than ground, and a resistance in said connection which is traversed by the anode current whereby the potential of cathode with respect to ground is positive in the absence of signals but becomes negative in the presence of strong signals.

13. In a receiver of the type including at least one high frequency amplifier having a resonant input circuit, a detector stage including a tube provided with a cathode, a grid, an anode, and at least two cold electrodes adjacent said cathode but substantially unaffected by said grid, a signal circuit coupled to one of the cold electrodes and the cathode to produce rectified signal current, an impedance which is high for both direct and audio currents connected between said one electrode and cathode to be traversed by said rectified signal current, means to impress between the grid and cathode voltage derived from said rectified current flowing through said impedance whereby the direct current component is decreased in proportion to increasing signals, a direct connection from the other cold electrode to the amplifier, a connection from the cathode to a point more negative than ground, and a resistance in said connection which is traversed by the anode current whereby the potential of cathode with respect to ground is positive in the absence of signals but becomes negative in the presence of strong signals, means for selecting at will a desired potential difference between the rectifier cold electrode and the cathode.

14. In combination with an amplifier, rectifier means for deriving a direct current proportional to an incoming signal, a space current device including an anode and a cathode, means for normally maintaining said anode negative with respect to said cathode, and means whereby the said direct current is utilized to cause a reversal of the polarity of said electrodes, with consequent flow of space current.

15. In a receiver of the type including at least one high frequency amplifier having a resonant input circuit, a detector stage including a tube provided with a cathode, a grid, an anode, and at least two cold electrodes adjacent said cathode but substantially unaffected by said grid, a signal circuit coupled to one of the cold electrodes and the cathode to produce rectified signal current, an impedance which is high for both direct and audio currents connected between said one electrode and cathode to be traversed by said rectified signal current, means to impress between the grid and cathode voltage derived from said rectified current flowing through said impedance whereby the direct current component is decreased in porportion to increasing signals, a direct connection from the other cold electrode to the amplifier, a connection from the cathode to a point more negative than ground, and a resistance in said connection which is traversed by the anode current whereby the potential of cathode with respect to ground is positive in the absence of signals but becomes negative in the presence of strong signals and means for bias-

ing the second cold electrode more negative than ground by an adjustable amount whereby current will not flow from the cathode to the second electrode until the cathode is more negative.

16. In a radio receiver, a radio frequency amplifier, a multiple function tube including a diode signal rectifier and an amplifier, circuit elements connecting said rectifier between said radio amplifier and said second amplifier, means including a second diode for controlling the gain of said radio amplifier, and means for automatically suppressing the transmission of rectified signals by said tube when the radio frequency voltage impressed on said rectifier falls below a predetermined value.

17. In a radio receiver, a radio frequency amplifier, a multiple function tube including a diode signal rectifier and an amplifier, circuit elements connecting said rectifier between said radio amplifier and said second amplifier, means including a second diode disposed in said tube for controlling the gain of said radio amplifier, and means for automatically suppressing the transmission of rectified signals by said tube when the radio frequency voltage impressed on said rectifier falls below a predetermined value.

18. A multiple duty tube including an evacuated envelope, a cathode, a main anode, and a pair of co-planarly wound grids disposed within the envelope, said grids being arranged within the electron stream between the cathode and anode, and an auxiliary anode, of a relatively smaller area than said main anode, disposed adjacent said cathode outside said stream, the electron stream between said cathode and auxiliary anode being unobstructed by any electrode and independent of the said first stream, means for connecting the auxiliary anode and cathode to provide a diode rectifier circuit, and additional means for connecting the said grids to opposite sides of a signal input circuit.

19. In a radio receiver provided with a tube having a diode section and an electronic section including at least two cold electrodes and the cathode of said diode section, a signal input circuit connected to said diode section and providing a rectification network, a source of signal energy, means for connecting one of said cold electrodes to a point of alternating current potential in said network, and an auxiliary cold electrode disposed adjacent said cathode providing a second diode section, and a gain control connection between the auxiliary electrode and said signal source.

20. In a radio receiver, the combination with a tube having an anode, a control grid, plate and cathode, of a radio frequency amplifier, means cooperating with said anode and cathode to form a diode detector working out of said amplifier, means for automatically controlling the gain of said radio frequency amplifier, circuit elements for impressing upon said control grid an audio frequency voltage developed by said diode detector, an audio frequency load in the plate circuit of said tube, means establishing a bias voltage between cathode and another tube element to suppress the transmission of audio frequency currents by said tube, and means operable automatically when the received radio frequency voltage rises above a critical level to reduce the bias voltage to permit normal transmission by said tube.

21. The invention as set forth in claim 20, wherein said means for automatically controlling the gain of said amplifier includes a second anode within said tube and cooperating with said cathode to form a diode rectifier.

22. In combination with an amplifier of modulated high frequency carrier energy, a detector system comprising an electron discharge tube provided with a cathode, a plate and at least one control grid disposed in the electron stream between the cathode and plate, a resonant input circuit connected between the grid and cathode, at least two resistors connected in series with each other and connecting the grid and cathode, one of said resistors nearest the cathode being disposed in the space current path of the tube for developing a detection suppression bias for said grid in the absence of carrier energy above a predetermined intensity level, the said grid having impressed thereon direct current voltage developed across said other resistor when said energy increases above said level whereby the space current flow through the said one resistor is reduced.

23. A radio receiver comprising an amplifier with potentially operated gain control means, a detector-amplifier-governor comprising a cathode, an anode, a grid and two auxiliary anodes arranged to receive electrons from the cathode without interaction with electrons flowing to the other electrodes, a signal rectifier circuit comprising the cathode and an auxiliary anode coupled to an output circuit of the amplifier and to the grid, and an automatic gain control circuit comprising a potential source, the cathode, the second auxiliary anode and a connection to the gain control means and a manually operated sensitivity control for said first named amplifier.

24. In combination, a source of potential, a radio frequency amplifier with potentially operative gain control means, an electron tube having a hot cathode and a plurality of cold electrodes arranged to receive electrons from the cathode without interaction with electrons flowing to the other electrodes, a rectifier circuit comprising the cathode and a cold electrode electronically related to the cathode only coupled to an output point in the amplifier, an amplifier circuit comprising the source of potential, the cathode and cold electrodes coupled to the rectifier circuit and an automatic gain control circuit comprising the source of potential, an impedance, the cathode, a cold electrode electronically related to the cathode only and the gain control means.

25. In combination in carrier wave receiving apparatus, a source of electrical energy with potential taps, a carrier frequency amplifier with manual and automatic gain control means, an electron tube having an amplifier section and two diode sections, a rectifier circuit including one diode section coupled to the output of the carrier frequency amplifier, an amplifier circuit including the amplifier section coupled to the rectifier circuit and energized from taps on the source of energy, and an auttomatic volume control circuit including the other diode section, a connection including an impedance from said diode to an intermediate tap on the source of potential, and a connection from the diode to the automatic gain control means in the carrier frequency amplifier.

26. The method of carrier wave reception which comprises the successive operations of amplifying the carrier, rectifying the amplified carrier, re-amplifying the rectified carrier, balancing a direct current component of the re-amplified rectified carrier against a fixed direct current and permitting current to flow for con-

trolling amplification when the relative levels and polarities of the balanced currents satisfy predetermined conditions.

27. The method of governing the gain of an amplifier which comprises rectifying the output of the amplifier, amplifying the rectified output, balancing the amplified rectified output against a steady current, and passing governing current to control the gain of the amplifier when the amplified rectified output reaches a predetermined level relative to the steady current.

28. In combination with a diode rectifier circuit having a tuned input circuit, a load resistor in circuit with said tuned circuit between the diode anode and cathode, an electron discharge tube having at least a cathode, plate and control grid, connections from the control grid and cathode of the tube to points of different direct current potentials on said resistor, the grid connection point being negative with respect to the cathode connection, a network in shunt with said load resistor comprising a resistor and an audio by-pass condenser in series, and said control grid connection including an adjustable tap in sliding contact with said series resistor whereby the impression on the grid of the audio component of the voltage developed across the load resistor may be varied without changing the said direct current potential difference between said grid and cathode.

29. In a radio receiver, the combination with a radio amplifier, a detector, a direct current amplifier working out of said detector, and having a plate-cathode resistance by-passed for radio frequencies, a diode having said resistance connected between the cathode thereof and the anode through a serially connected resistor and a direct current source, said source impressing a positive potential upon said anode, and a circuit connection for impressing the direct current potential of one of said diode elements upon said radio amplifier as a gain control bias.

30. A radio receiver as set forth in the above claim 29 wherein said destroyer, direct current amplifier and diode comprise elements within a single vacuum tube.

31. In the operation of a radio receiver including a radio amplifier working into a rectifying system which produces a direct current voltage that varies inversely with the radio input to the receiver, a device of uni-lateral conductivity having an output resistance included in a gain control circuit of said amplifier, and a source of direct current potential, the method of maintaining normal gain of said amplifier for all radio input below a critical value and then varying the gain with changes in receiver input above that critical value which comprises impressing the output voltage of said rectifying system on said device in a sense opposing conduction therethrough, and impressing upon said device from said source a direct current voltage tending to produce conduction and of a magnitude neutralizing the blocking effect of said first impressed voltage when the latter falls to the value corresponding to the said critical radio input to the receiver.

32. A radio receiver comprising an amplifier with amplification control means, an electron tube having a cathode, anode, control grid and at least two auxiliary anodes arranged to receive electrons from the cathode without influencing or being influenced by other electrodes, a rectifier circuit embodying the cathode and an auxiliary anode for rectifying signals and a uni-laterally conducting circuit embodying the cathode, a potential source and an auxiliary anode for automatically controlling amplification for signals above a determined level.

33. In combination, a detector-governor comprising a cathode, an amplifier section and two auxiliary anodes, a rectifier circuit comprising the cathode and one auxiliary anode, a governor circuit comprising the cathode and second auxiliary anode and an amplifier circuit comprising the cathode and amplifier section.

34. In a modulated carrier-current signaling system employing a carrier-current amplifier and rectifier, which rectifier produces a modulated uni-directional voltage, a direct current voltage connection from said rectifier to an element of said amplifier whereby the amplification is automatically regulated, said connection including a space discharge device of unidirectional conductivity, and a connection from said rectifier to a modulation current amplifier whereby the signal is further amplified, and an additional connection from the output of the modulation current amplifier to the output electrode of said rectifier for varying the potential of said rectifier output electrode in dependence on the intensity of received carrier current.

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