Dec. 10, 1935. J. S. STARRETT 2,023,449

MUTED AUTOMATIC VOLUME CONTROL CIRCUITS

Original Filed Nov. 25, 1932 2 Sheets-Sheet 1

Fig. 1

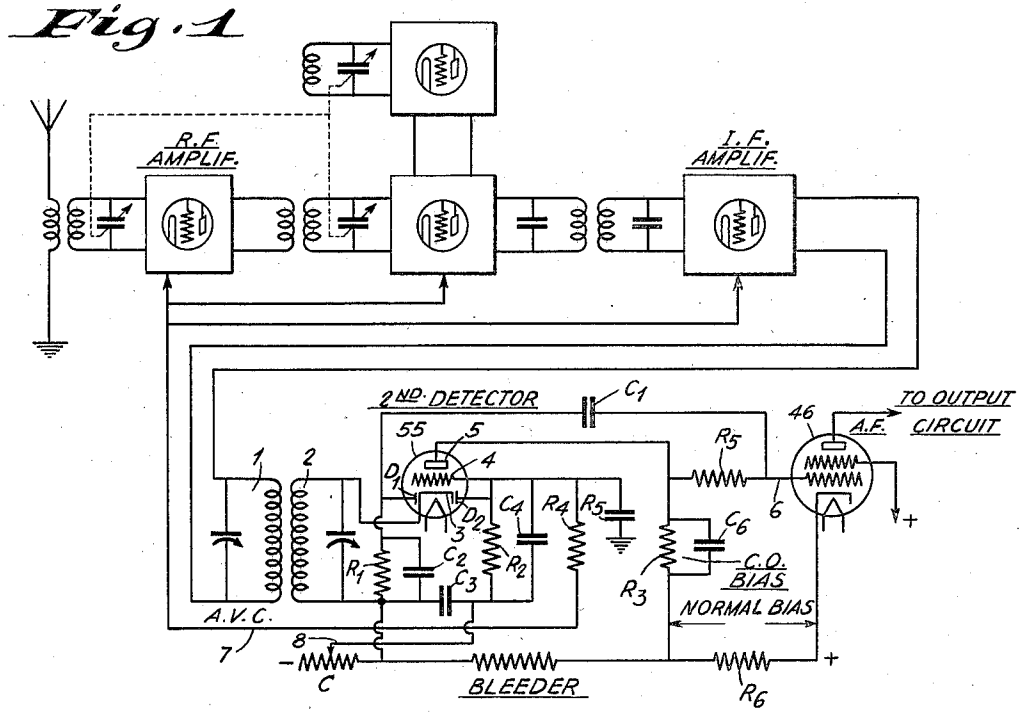
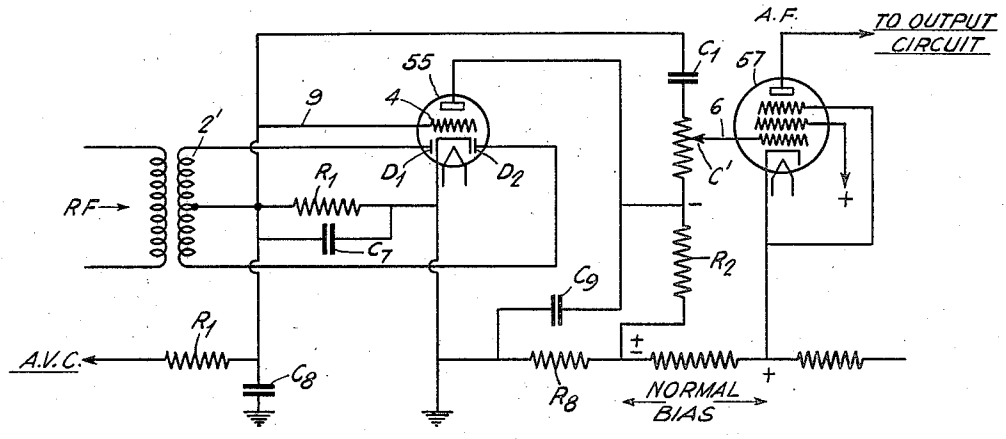


Fig. 2



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Fig. 3

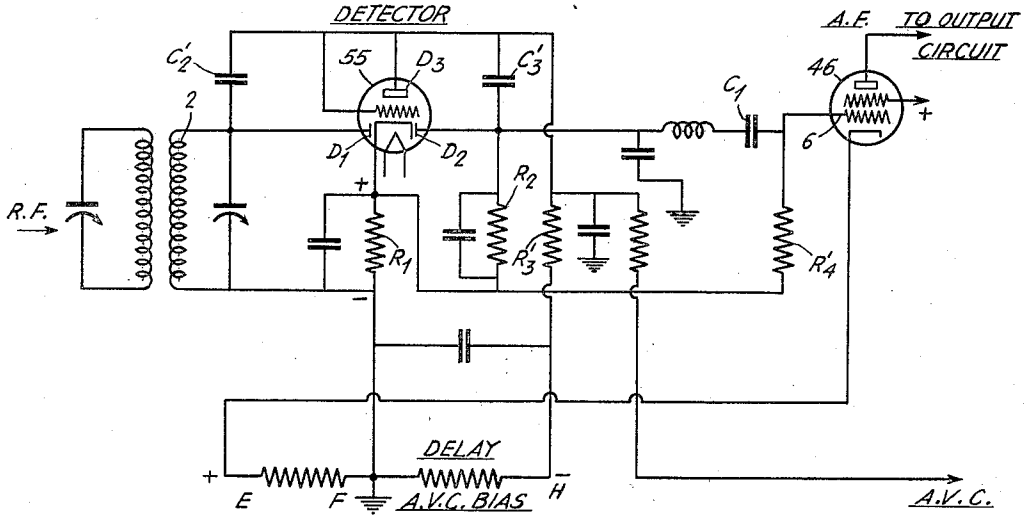
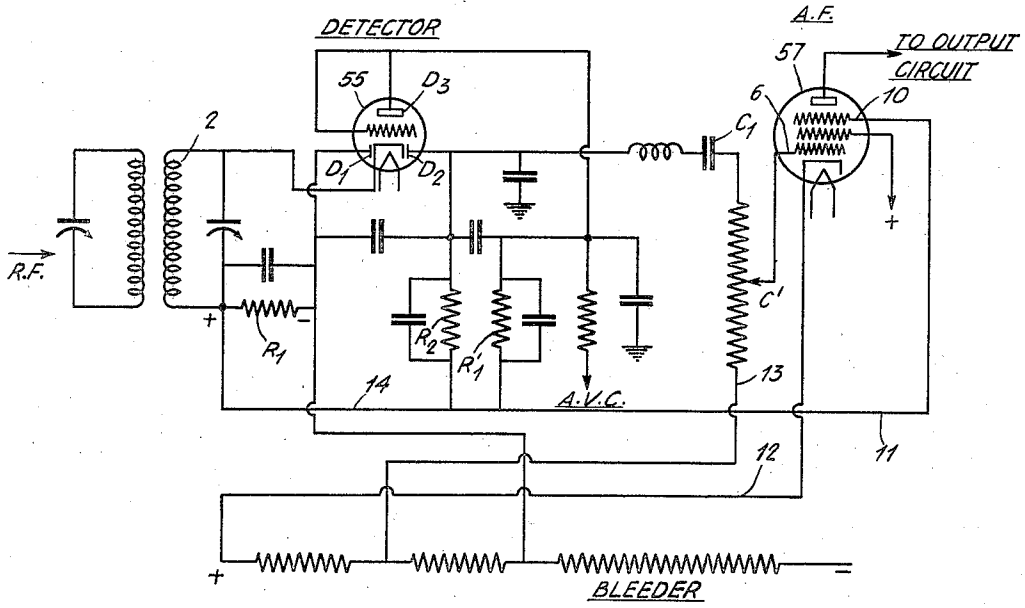


Fig. 4



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UNITED STATES PATENT OFFICE

2,023,449

MUTED AUTOMATIC VOLUME CONTROL CIRCUITS

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Original application November 25, 1932, Serial No. 644,160. Divided and this application July 31, 1934, Serial No. 737,713

11 Claims. (Cl. 250—20)

My present invention is a division of application serial No. 644,160, filed November 25, 1932, and relates to automatic volume control circuits for radio receivers, and more particularly to improved circuits for the accomplishment of detection, automatic volume control and automatic suppression, or muting of, interchannel noise.

There has been disclosed by D. G. Burnside in application serial No. 644,149, filed November 25, 1932, various circuits for securing detection and delayed automatic volume control functions from a single stage. It has also been shown by D. G. Burnside that receiver noises present when no carrier is tuned in could be prevented from appearing in the reproducer by a system of so-called delayed detection, in which system a detector diode anode is biased negatively by an amount just greater than the noise potential. It was pointed out that this biasing prevented the diode anode from becoming positive, and therefore, prevented detection; consequently, the noise voltages are not able to pass the detector.

Furthermore, it has also been shown in the aforementioned Burnside docket that the three functions of detection, delayed automatic volume control and inter-channel noise suppression could be accomplished with a single tube of the duplex diode-triode type, a tube of the latter type having been disclosed by T. M. Shrader in application serial No. 622,140, filed July 12, 1932. While the inter-channel noise suppressor arrangement for an automatic volume control circuit shown by Burnside is entirely satisfactory for many purposes, at times, due to the different delay voltages which may be used for biasing the detector and volume control anodes, interaction of an undesirable kind between the two circuits may be experienced. If the aforedescribed detector bias is more than a small fraction of the signal voltage, it may cause distortion due to a deeply modulated carrier wave.

Accordingly, it may be stated that it is one of the main objects of the present invention to provide a method of eliminating, or suppressing, inter-channel noises in a receiver equipped with automatic volume control, and wherein the detection and automatic volume control functions are performed by a single tube, the method consisting in utilizing the said single tube, in the absence of a signal, to suppress the inter-channel noises by the application of a cut-off voltage to the grid of an audio frequency amplifier stage, such a method of noise suppression being adapted to function without distortion, and the presence or absence of a signal voltage greater than a noise voltage determining whether the bias on the grid of the first audio frequency amplifier stage is such as to repeat, or such as to reject the audio frequency voltage reaching the said stage; it being possible, in addition, to so design the time constant of the cut-off action so that no change in the bias of the said audio stages takes place sufficiently quickly to produce distortion.

Another important object of the present invention is to provide in a radio receiver a single stage capable of performing diode detection, delayed automatic volume control and inter-channel noise suppression functions, the noise suppression function being such that the grid of the first audio frequency amplifier tube is, in the absence of a signal biased to cut-off, but is automatically removed from cut-off when a signal is received.

Still another object of the invention is to provide a radio receiver equipped with a duplex diode-triode tube capable of accomplishing detection, automatic suppression of inter-channel noises, and delayed automatic volume control, the duplex-diode triode tube embodying at least three independent anodes with a common cathode, one of the anodes being used for detection, a second for automatic volume control, and a third anode as a source of direct current potential for biasing a grid of a tube subsequent to the triple anode tube.

Another object of the present invention is to provide a radio receiver wherein a single tube functions to perform detection, automatic volume control and muting, the tube including a triode section independent of at least two diode sections, the muting being accomplished by controlling the bias on a grid other than the signal grid of a multi-grid tube following the aforementioned multiple duty tube.

Fundamentally, the present invention contemplates the use of a duplex diode-triode tube as a detector, source of automatic volume control voltages, and additionally, as a special means for suppressing circuit noises. The tube is arranged in such a manner that when zero or very small signal is present at the detector, the grid of the first tube following the detector shall be biased to cut-off; that is, shall pass no plate current. The circuits contemplate that when a signal is received, provided it is above a certain minimum and predetermined voltage, the tube following the detector (that is, the first audio tube) shall be removed from cut-off, and the

signal passed in the usual manner. The removal of the grid from cut-off is arranged to be accomplished by the supply of a reversed voltage from the rectified current through an impedance in series with one of the sets of diode elements in the duplex diode-triode tube.

The coupling for the audio or signal voltage from the detector to the first audio tube is made by means of a coupling condenser arranged in any suitable manner. Ordinary automatic volume control, or delayed automatic volume control, may be used, and half wave or full wave diode detection and rectification may also be employed. Again, detection and rectification may be from different sets of diode elements, or may be from the same ones. The audio tube control may be of any type ordinarily suitable for audio amplification. If the audio tube is a triode the cut-off control should ordinarily be on the control grid. However, if the audio tube is of the multi-grid type, this control may be on the signal control grid, or on the suppressor grid, if the tube is of the pentode audio output type.

Finally, it may be stated that other objects of the present invention are not only to improve generally the simplicity and efficiency of automatic volume control circuits for radio receivers, but to also provide receivers of this type which not only include the aforedescribed features, but are durable and reliable in operation, and economically manufactured and assembled.

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

In the drawings,

Fig. 1 diagrammatically shows a superheterodyne type of receiver embodying the present invention,

Fig. 2 shows a modification of the invention of Fig. 1,

Fig. 3 shows still another modification,

Fig. 4 shows an arrangement similar to the modification in Fig. 3, a modified form of noise suppression function being shown.

Referring now to the accompanying drawings wherein like reference characters designate the same circuit elements in the different figures, there is shown in Fig. 1, in schematic fashion, a superheterodyne receiver embodying the present invention. As is well known to those skilled in the art, such a receiver usually embodies an antenna circuit, a tuned radio frequency amplifier, a local oscillator, a first detector stage, an intermediate frequency amplifier, a second detector stage, and one or more audio frequency amplifier stages followed by a reproducer. A unicontrol means is shown for simultaneously tuning the radio frequency amplifier, first detector and local oscillator stages, it being understood that various expedients are known for tuning the receiver throughout the broadcast range while supplying a substantially constant intermediate frequency from the output of the intermediate frequency amplifier.

The output of the intermediate frequency amplifier includes a resonant network 1 which is fixedly tuned to the aforesaid intermediate frequency, the resonant circuit 1 being magnetically coupled to the resonant input circuit 2 of the second detector, this input circuit also being fixedly tuned to the operating intermediate frequency.

The second detector stage includes a tube 55, which is of the so-called duplex diode-triode type, and is adapted to cooperate with its circuits to function as a combined second detector, automatic volume control, and inter-channel noise suppressor device. The first audio frequency amplifier stage includes a tube 46 having its anode arranged for connection to an output load circuit which may include additional power amplifier stages and a reproducer (not shown).

Of course, it is to be clearly understood that the present invention is not limited in any manner to a superheterodyne receiver, but may be employed with equal facility in connection with a radio frequency amplifier preceding the tube 55 and an audio frequency amplifier following the latter. Hence, in Figs. 2, 3 and 4 the symbol "R. F." is to be understood as designating a source of radio frequency energy, whether, it be of intermediate frequency, or a frequency usually employed prior to a detector in a tuned radio frequency amplifier receiver.

Considering, now, the specific nature of the network connected between the input circuit 2 and the tube 46, it is believed sufficient for the purposes of this application to conventionally represent the tube 55. As shown, the tube comprises a triode section including a cathode 3 (of the indirectly heated type), a grid 4, and a main anode 5; a diode section consisting of a diode anode D_1 and a portion of the cathode 3 not emitting electrons for the main anode 5; and an additional diode section consisting of the diode anode D_2 also disposed adjacent the cathode 3 out of the electron stream to the main anode 5. Such a tube has been specifically described and claimed in the aforesaid Shrader application, and the construction shown therein may be employed in designing tube 55.

Briefly, in actual construction the tube 55 is provided with a cathode sleeve, within which is mounted the heater element, a grid and main anode being concentrically positioned about the sleeve. The pair of diode anodes D_1 and D_2 are placed around an end of the sleeve projecting beyond the triode grid and anode. In operation, the two diodes and the triode are independent of each other except for the common cathode sleeve which has one emission surface for the diode anodes D_1 and D_2, and another for the triode grid and anode.

The circuits associated with the electrodes of tube 55 may now be considered. Fig. 1 shows half-wave diode detection, and separate half-wave diode rectification for delayed automatic volume control, together with coupling from the detector diode through a condenser to the grid of the first audio stage tube. The circuit is so arranged that when no signal is applied, the plate current of the triode element is used to bias the control grid of the first audio amplifier tube to cut-off, and prevent any relay action by the latter tube.

The incoming signal is applied between the cathode and the diode anode D_1, and the potential developed across resistor R_1 by the audio component of diode current is coupled by means of the condenser C_1 to the grid 6 of the first audio tube. This grid, however, in the absence of a signal above a predetermined threshold, is biased to cut-off by means of the plate current of the

tube 55 flowing through the resistor R_3. When a signal is received on diode anode D_2 by means of the coupling condenser C_3, the voltage drop through resistor R_2 is such as will bias the grid of the tube 55 to cut-off. This eliminates the potential drop across resistor R_3, and removes the audio frequency tube from cut-off.

In other words, when no signal is received, the triode section of tube 55 passes plate current which is used to develop a voltage for biasing the second tube 46 to cut-off. When a signal is received the first tube biases its own triode grid element 4 to cut-off, and thus removes the cut-off bias of the second tube. By the proper choice of values for the various resistances and condensers the circuit can be made to operate in a very satisfactory manner. It will be noticed that the diode D_2, together with the grid 4 of the first tube, is given a negative bias controlled by the potentiometer C which enables a suitable adjustment of operation to be made. It is, of course, desirable that the audio tube be one which exhibits a sharp cut-off of plate current with change of grid voltage.

The automatic volume control function is accomplished through the path 7 (designated AVC) connected between the grid circuits of the radio frequency amplifier, first detector, intermediate amplifier stages and one side of the resistor R_4. The opposite side of the latter is connected to the diode anode D_2. The diode rectifier including anode D_2, then, functions to control the bias of the grid 4 for the muting action, and also furnishes rectified current for securing a volume control voltage by the drop across resistor R_4. The direct current connections to the controlled pre-detector stages are too well known to require further description. The condensers C_4, C_5, C_6 are radio frequency by-pass condensers. The bleeder resistor provides the electrodes D_1, D_2, 5, 4 of tube 55 with the required potentials; the grid 6 of tube 46 is given a normal bias, relative to the cathode, in virtue of the drop across resistors R_6, R_3, R_5. The adjustable connection 8, between the resistor R_2 and the potentiometer resistor C, furnishes a means for adjusting the sensitivity of the receiver at which muting occurs.

Recapitulating the operation of the tube 55, and its associated circuits, the rectified voltage across the resistor R_2 occurs when a peak signal greater than the negative bias at the potentiometric resistor C is impressed upon the signal input circuit 2. Automatic volume control action then occurs, and the grid 4 is biased to cut-off by the additional voltage across the resistor R_2. The voltage drop across resistor R_3 is then zero, or very small, and the audio amplifier tube 46 is working with normal bias which passes the audio signal. With no signal delivered to the diode anode D_2, the grid of the tube 55 is removed from cut-off, and the increased potential drop across the resistor R_3 biases the tube 46 to cut-off. As pointed out heretofore the audio signal voltage is fed to the amplifier tube 46 from the path including resistor R_1.

Fig. 2 shows full-wave diode detection with diode bias, and automatic volume control so arranged that when no signal is received the plate current of the triode section flowing through a resistance biases the control grid of the first audio tube to cut-off, and thus prevents noise from being passed. When a signal is received the grid of the triode section of the tube 55 is biased at, or near, cut-off, and the signal applied through the coupling condenser from the grid of the tube 55 to the control grid of the first audio tube is relayed by that tube.

More specifically Fig. 2 is similar to Fig. 1, except that there is provided full-wave diode detection and automatic volume control rectification from the same elements, and a slightly different method of connections to the first audio tube is given. As before, the rectified current is led off in the usual manner, for automatic volume control, and the audio component is coupled to the succeeding tube by means of the condenser C_1. When no signal is received, the grid 6 of the first audio tube 57 is biased to cut-off by means of the normal bias and the voltage due to the plate current of the tube 55 flowing through the resistance R_2.

When a signal is received the direct current drop across resistor R_1 biases the grid 4 to cut-off, reduces, or eliminates, the current flowing through resistor R_2, and removes the grid of the audio tube from cut-off, thus passing the signal. This arrangement provides for suppression of noise in that a signal of a predetermined value is required to bring the tube 55 to cut-off, and to remove the audio tube from cut-off. Adjustment of volume may be had by means of a potentiometer C' in that the signal voltage applied to the grid of the audio tube may be varied at will. The circuit shows ordinary automatic volume control; that is, without delayed action.

Briefly, then, in Fig. 2 the rectified voltage across the resistor R_1 brings the grid 4 to cut-off, and removes the audio stage from cut-off, functioning in the same manner as in Fig. 1. Full wave rectification occurs between the two diode plates D_1 and D_2, these two diode plates being connected to opposite sides of the input circuit coil 2'. The resistor R_1 is connected between the grounded leg of the cathode of tube 55 and the midpoint of coil 2', the condenser C_7 functioning as a radio frequency by-pass condenser connected between one side of resistor R_1 and the lead 9 between the grid 4 and the automatic volume control path. The resistor R_7 and the condenser C_8 provide a filter network for the automatic volume control path.

The condenser C_9 provides a radio frequency by-pass around the resistors R_2 and R_8. The potentiometer at C' provides a manually operable audio volume control, and it will be observed that the tube 57 is of the pentode type including a suppressor grid, disposed between the anode and screen grid, at cathode potential. In the modification shown in Fig. 2 the automatic volume control is obtained from the voltage drop across the resistor R_1, and, as stated above, this resistor also provides the audio signal for the tube 57, as well as control of the muting bias.

Passing on to Fig. 3, the latter shows half-wave diode detection; separate diode rectification for delayed automatic volume control voltage; and the use of a third diode for the development of direct current for the cancellation of cut-off bias on the grid of the first audio tube when a signal is received. In the case of Fig. 3 a triple diode arrangement is shown; the grid and plate of the triode of the tube 55 are connected together to serve as a diode anode D_3. Detection is secured by means of diode anode D_2 which is coupled to the radio frequency input circuit 2 by means of condensers C'_2 and C'_3. The detected audio component is fed to the first audio tube by means of condenser C_1 in the usual manner.

When no signal is being received the voltage supplied from across the voltage bleeder points EF biases the grid 6 of the audio tube 46 to cut-off; hence, no circuit noises are passed. An incoming signal rectified by diode anode D_1, and flowing through the resistance R_1, produces a counter-bias which removes the audio tube from cut-off. Automatic volume control voltage is supplied by the rectified current flowing through the diode anode D_3 and the resistance R'_3. This may be delayed by the desired amount by means of the automatic volume control bias from across the bleeder points FH. It will be noted that the potential of the circuit D_2, R_2 and R'_4, varies as a unit with the voltage developed across R_1 so that this voltage supplies the bias for the audio tube.

Summarizing, the operation of the modification shown in Fig. 3, it will be observed that effectively the tube 55 includes within its envelope three independent diodes, two of which diodes include the anodes D_1 and D_2 while the grid and plate of the tube 55 are tied together to serve as the additional one. The circuit is arranged so that with no signal to the diodes, the bias on the amplifier tube 46 is at, or beyond, cut-off. With signal, the voltage across R_1 bucks out part of the applied bias, and removes the amplifier tube from cut-off; thus, passing the signal. Detection takes place in the diode having resistance R_2, while automatic volume control voltage is developed across R'_3 when the peak signal equals the delay bias on this diode.

The modification shown in Fig. 4 is substantially similar to that shown in Fig. 3, but with the cut-off bias of the first audio tube applied to the suppressor grid 10 of the audio tube 57. This tube 57 is of the pentode type including a signal grid 6, a positive screen grid, and the grid 10 disposed between the screen grid and the anode. The suppressor grid 10, a grid other than the signal grid, is connected by a lead 11 to the positive side of the resistor R_1, and the cut-off bias for the audio tube 57 is applied to the grid 10, rather than to the signal grid 6. This is arranged by means of a positive bias of approximately 45 volts, applied to the cathode from the resistance strip of the voltage supply.

In other words, the cathode of tube 57 is connected by a lead 12 to the positive side of the bleeder. The signal grid 6 of tube 57 is connected through the adjustable tap of the volume control C' and lead 13 to a point on the bleeder which is less positive than the point to which the lead 12 is connected. The negative side of the resistor R_1 is connected by a lead 14 to a point on the bleeder which is less positive than the point to which the lead 13 is connected.

When a signal is impressed on the resonant input circuit 2, the audio frequency tube 57 is removed from cut-off by means of the direct current drop across the resistor R_1. The audio voltage from the diode anode D_2 is supplied to the grid 6 of the audio tube by means of the condenser C_1. With no signal impressed on the input circuit 2, the suppressor grid 10 is 45 volts negative with respect to the cathode of tube 57. The rectified voltage developed across the resistor R_1, when a signal is present, bucks the applied voltage, and brings the suppressor grid 10 to zero potential, and passes the signal. Otherwise, the operation of the arrangement shown in Fig. 4 is substantially the same as that described in connection with Fig. 3.

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, a high frequency amplifier whose gain is to be controlled, a multi-grid audio frequency amplifier, three independent diodes, a resonant signal input circuit coupling the output of said high frequency amplifier to one of said diodes, means coupling a second of said diodes to said input circuit, a direct current connection between said high frequency amplifier and the cold electrode of said second diode, a path of low impedance to audio frequency signals connected between one of the grids of said audio frequency amplifier and the third diode, and a direct current connection between the cold electrode of the third diode and a predetermined point of the first diode, and a direct current connection between a grid of said audio frequency amplifier, other than the first mentioned grid, and said first and third diodes.

2. In an arrangement of the type disclosed in claim 1, a common tube envelope, said three diodes being disposed within said envelope and having a cathode common to all of the diodes.

3. In a radio receiving system, an electron discharge tube provided with a cathode and at least three cold electrodes, a signal input circuit connected between a cathode and one of the cold electrodes to provide a diode rectification network, means for impressing signal energy from said input circuit between the cathode and a second of said cold electrodes, said cathode and second cold electrode providing a diode detection network, circuit elements electrically associated with the cathode and third cold electrode to provide a second diode rectification network, an electron discharge tube having its input electrodes connected to said diode detection network, a transmission control electrode included within said second tube, a connection between said transmission control electrode and said first diode rectification network, and an automatic volume control connection to said second diode rectification network.

4. In a receiver as defined in claim 3, said second tube being an audio amplifier, and said transmission control electrode being a grid disposed between the plate of the audio amplifier and its signal input grid.

5. In a receiver as defined in claim 3, two of said cold electrodes being disposed outside the electron stream from said cathode to the third cold electrode.

6. In a receiver as defined in claim 3, a load resistor included in said first diode rectification network, a connection to said transmission control electrode being to a point of positive potential on said resistor, and the cathode of said second tube being at a positive potential with respect to the negative side of said load resistor.

7. In a radio receiver of the type provided with a signal amplifier, a diode detection network, and an audio frequency amplifier, connections between the detection network and the input electrodes of said audio amplifier, a diode rectification network coupled to the signal input circuit of said detection network, said diode rectification network including a load impedance for developing a direct current voltage depending

upon the amplitude of received signals, connections between at least one electrode of said audio amplifier and a point on said load impedance whereby the transmission efficiency of the audio amplifier is decreased when the received signal amplitude is less than a predetermined minimum value, and a second diode rectification network coupled to said input circuit of the diode detector for providing a gain control voltage for the signal amplifier.

8. In a receiver as defined in claim 7, a common tube envelope housing the diode electrodes of said diode detector and said two diode rectification networks.

9. In combination, a high frequency signal transmission tube whose gain is to be controlled, three diode devices, an audio electron discharge tube whose operation is to be controlled, a resonant signal input circuit coupling the first tube output to one of the diode devices, means coupling a second of the diode devices to said input circuit, a gain control direct current connection connected between a gain control electrode of the said first tube and the cold electrode of said second diode, means in circuit with the third diode device for developing an audio voltage from signals impressed thereon from the said input circuit, means for impressing the audio voltage upon said audio tube for utilization thereof, means establishing a cold electrode of the audio tube at an abnormally high negative bias with respect to the cathode thereof, and means in circuit with said first diode device for reducing the abnormal bias to a desired normal bias when signals are impressed on said input circuit.

10. In combination, a high frequency signal transmission tube whose gain is to be controlled, three diode devices, an audio electron discharge tube whose operation is to be controlled, a resonant signal input circuit coupling the first tube output to one of the diode devices, means coupling a second of the diode devices, to said input circuit, a gain control direct current connection connected between a gain control electrode of the said first tube and the cold electrode of said second diode, means in circuit with the third diode device for developing an audio voltage from signals impressed thereon from the said input circuit, means for impressing the audio voltage upon said audio tube for utilization thereof, means establishing a cold electrode of the audio tube at an abnormally high negative bias with respect to the cathode thereof, and means in circuit with said first diode device for reducing the abnormal bias to a desired normal bias when signals are impressed on said input circuit, said three diode devices comprising a common cathode and three independent anodes, said electrodes being disposed in a common tube envelope.

11. In combination, a high frequency signal transmission tube whose gain is to be controlled, three diode devices, an audio electron discharge tube whose operation is to be controlled, a resonant signal input circuit coupling the first tube output to one of the diode devices, means coupling a second of the diode devices to said input circuit, a gain control direct current connection connected between a gain control electrode of the said first tube and the cold electrode of said second diode, means in circuit with the third diode device for developing an audio voltage from signals impressed thereon from the said input circuit, means for impressing the audio voltage upon said audio tube for utilization thereof, means establishing a cold electrode of the audio tube at an abnormally high negative bias with respect to the cathode thereof, and means in circuit with said first diode device for reducing the abnormal bias to a desired normal bias when signals are impressed on said input circuit, said audio voltage being impressed between the input grid and cathode of the audio tube, and said cold electrode of the audio tube being said input grid.

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