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C. TRAVIS

2,034,497

AMPLIFICATION CONTROL CIRCUITS

Filed Nov. 22, 1933

2 Sheets-Sheet 1

Fig. 1

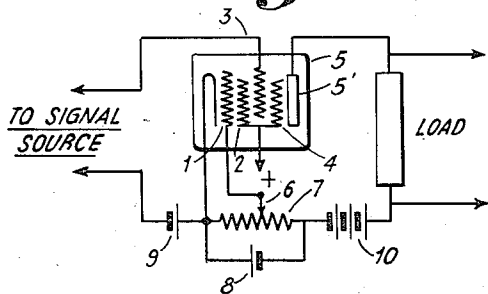


Fig. 2

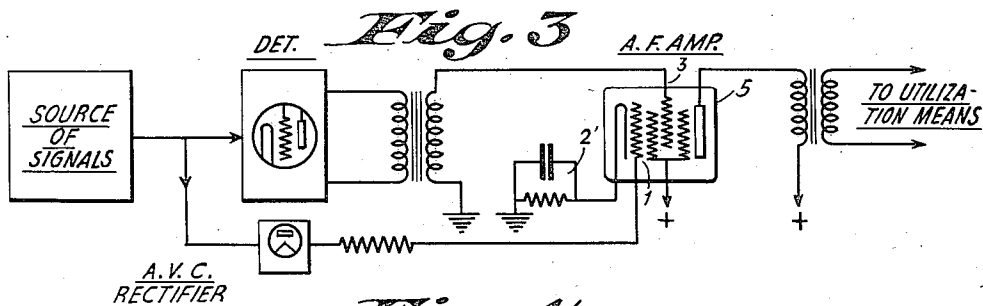
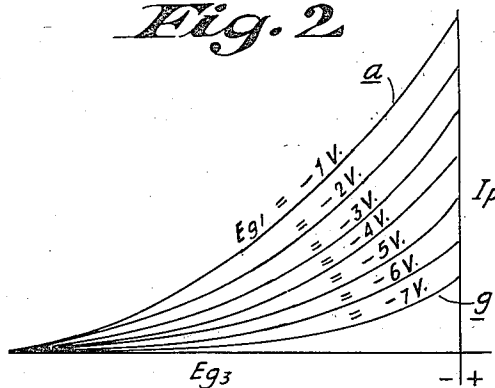


Fig. 4

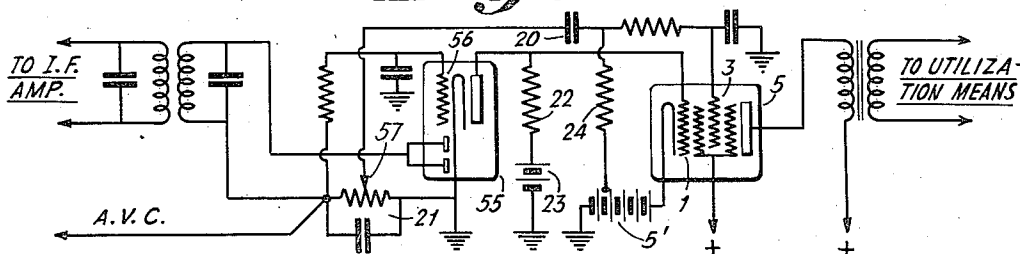
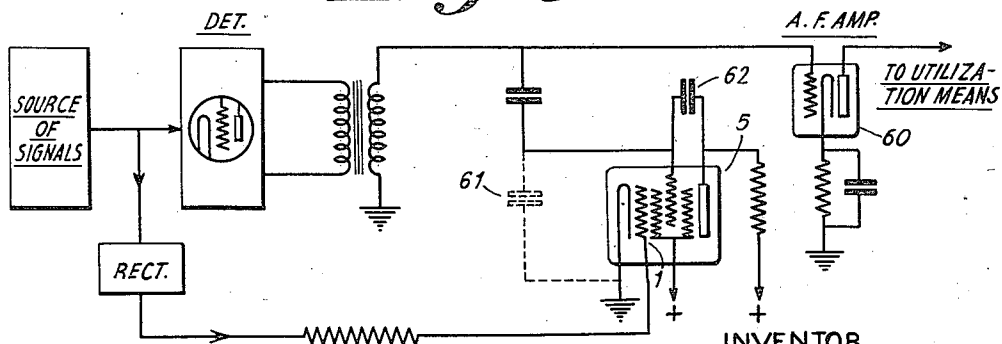


Fig. 5



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The diagram illustrates the internal circuitry of a radio receiver. It begins with a 'SOURCE OF SIGNALS' block connected to a 'DET.' (Detector) stage, which contains a vacuum tube and a variable capacitor. The output of the detector is connected to a 'RECTIFIER' stage, also featuring a vacuum tube and a variable capacitor. The rectifier's output is connected to a transformer with multiple secondary windings. One winding is connected to a 'TO A.F. AMPLIFIER' block. Another winding is connected to a variable capacitor (41) and a variable inductor (42). A third winding is connected to a variable capacitor (43) and a variable inductor (43'). The output of the rectifier is also connected to a variable capacitor (44) and a variable inductor (45). The output of the rectifier is connected to a transformer with multiple secondary windings. One winding is connected to a 'TO A.F. AMPLIFIER' block. Another winding is connected to a variable capacitor (41) and a variable inductor (42). A third winding is connected to a variable capacitor (43) and a variable inductor (43'). The output of the rectifier is also connected to a variable capacitor (44) and a variable inductor (45).

The diagram illustrates the internal circuitry of a radio receiver, divided into three main functional blocks:

- SOURCE OF I.F. SIGNALS:** This block on the left provides the initial intermediate frequency signal. It is connected to a tuned circuit consisting of an inductor and a capacitor.
- I. F. AMPLIFIER:** The central section contains a vacuum tube (labeled 1) with three internal windings (labeled 3 and 5). The primary winding (3) is connected to the input from the source. The secondary winding (5) is connected to a second tuned circuit (inductor and capacitor). The tube's filament is connected to a power source (battery) through a variable resistor (labeled 1').
- 2ND DET. (2nd Detector):** This section follows the I.F. amplifier. It receives the signal from the second tuned circuit and is connected to a third tuned circuit (inductor and capacitor). The output of this stage is sent to the A.V.C. Rectifier.
- A.V.C. RECTIFIER:** This block contains a vacuum tube (labeled 1) and a variable resistor (labeled 1'). It receives the signal from the 2nd detector and provides feedback to the I.F. amplifier to control its gain.
- TO I.F. AMP.:** An output line from the A.V.C. Rectifier section, labeled "TO I.F. AMP.", indicates the feedback signal path.

The diagram illustrates a two-channel audio system. The left channel, labeled 'AUDIO SOURCE № 1', features a transformer with primary windings 84 and 82, and a secondary winding 80. The secondary is connected to a network of resistors and capacitors, including components 86 and 85, which is grounded. The right channel, labeled 'AUDIO SOURCE № 2', features a transformer with primary windings 87 and 83, and a secondary winding 81. Its secondary is connected to a similar network of resistors and capacitors, including components 88 and 89, which is grounded. A dashed line labeled '90°' connects the output of the first channel to the input of the second, indicating a phase shift. The output of the second channel is directed 'TO UTILIZATION MEANS'.

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UNITED STATES PATENT OFFICE

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AMPLIFICATION CONTROL CIRCUITS

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Application November 22, 1933, Serial No. 699,187

9 Claims. (Cl. 250—20)

My present invention relates to control circuits for high frequency systems, and especially to amplification control circuits of novel and improved types.

Various problems in audio and radio frequency amplification control can be solved by employing as an amplifier for such frequencies a type of electron discharge tube provided with a cathode, anode and at least three interposed grid electrodes, the intermediate grid electrode functioning as a positive screen grid, one of the other grids acting as a signal grid, and the remaining grid having gain control bias potential applied to it. It can be shown that utilization of such a tube in an amplifier, be it audio or radio, permits substantially distortionless regulation of the amplifier gain over a relatively wide range without the need of the extremely high control bias potentials heretofore used in amplifier gain regulation, and it is one of the main objects of this invention to provide amplifier networks embodying the aforesaid type of tube whereby increased efficiency may be secured in radio receivers, as well as other high frequency systems.

Another important object of the invention is to provide an amplifier using a multi-grid tube, one of the grids having signal waves impressed thereon and being completely surrounded by a positive screening field, another grid functioning solely as a gain control element and having a variable negative bias applied thereto, the gain control grid being positioned between the cathode of the tube and the positive screening field, the amplifier being particularly characterized by the fact that the slope of the anode current-signal grid potential curve is dependent upon the potential of the gain control grid, but the potential range of the signal grid available for signal reception being substantially independent of the gain control grid potential.

Another object of the invention is to provide an amplifier whose effective plate current-signal grid voltage characteristic is dependent upon the bias of a special gain control grid but whose signal grid potential range is independent of the said bias, and to embody such an amplifier in various amplifier circuits subject to automatic gain control, automatic tone control, manual volume control, manual fading, the amplifier being capable of such operation at audio or higher frequencies without distortion or the need for high control bias values.

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, both as to its organization and method of operation, will best be understood by reference to the following description, taken in connection with the drawings, in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:—

Fig. 1 shows a conventional amplifier circuit embodying the invention,

Fig. 2 is a graphic representation of the operating characteristic of the tube in Fig. 1,

Fig. 3 diagrammatically shows the invention applied to AVC of an audio amplifier,

Fig. 4 shows the application of the invention to interstation muting,

Fig. 5 shows an automatic tone control circuit embodying the invention,

Fig. 6 illustrates a modified form of the circuit of Fig. 5,

Fig. 7 shows AVC of a high frequency amplifier while employing the present invention,

Fig. 8 shows an audio amplifier fader system utilizing the invention.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, there is shown in Fig. 1 in purely diagrammatic fashion a network which embodies the present invention. In this figure the reference numeral 5 designates an electron discharge tube which is provided with a cathode, an anode, and four grids interposed between the cathode and anode. The grid 1 nearest the cathode is connected by an adjustable tap 6 to a resistor 7 connected in shunt across a control potential source 8. The signal grid 3 of the tube is interposed between grid 2 and grid 4, grids 2, 3 and 4 being disposed between grid 1 and the anode 5'. The source of signal energy, which source is omitted for the sake of simplicity, is connected between the grid 3 and one side of resistor 7, the potential source 9 providing a fixed normal operating negative bias for the signal grid 3. In the circuit connected to the anode 5' there is included the resistor 7, the positive potential source 10 and the utilizing load.

In actual construction the tube 5 may follow the constructional details of the type of tube known as a 2A7. Such a tube has been shown in Haines application Serial No. 663,171, filed March 28th, 1933. It will be noted, however, that in the present application there is no grid employed between grid 1 and grid 2. This is the only respect in which tube 5 differs from the tube 55

shown in the Haines application. As a matter of fact it would be perfectly permissible to employ a tube of the 2A7 type, the rod grid employed in the latter between grids 1 and 2 being tied directly to the cathode. Hence, it is to be understood that the representation of four intermediate grids in the present application does not preclude the use of other grids in the tube if it is desired to utilize an already existing tube which can be made to perform the functions to be hereinafter described. Further the tube 5 can employ three grids, the positive screen grid being disposed in that case between the gain control grid and the signal grid, the gain control grid being adjacent the cathode.

Considering the electrical reactions taking place in the arrangement shown in Fig. 1, for the purpose of explaining the general principle underlying the present invention it may be assumed that the signal source connected to tube 5 is of radio frequency, intermediate frequency, or audio frequency. It is found that in a tube of the type shown in Fig. 1, where the signal grid is interposed between a pair of grids at a positive potential, and wherein the negative control potential is varied on an independent grid interposed between the cathode and one of the positive shielding grids, the G_m from grid 3 to anode 5' is controlled by the bias on grid 1. Furthermore, it is found that the G_m is not only controlled by variation of the bias on grid 1, but that this is accomplished without particularly changing the range available for signals and the cut-off point on grid 3. With increasing negative bias on grid 1 the I_p-E_{g3} characteristic is brought nearer to the zero axis over its whole length, and not merely shifted horizontally.

In Fig. 2 there is illustrated in graphic manner the electrical operation explained above. In this figure there is plotted values of I_p , that is, the plate current flow in the circuit of anode 5', as ordinates against values of E_{g3} as abscissæ. A family of characteristic curves is shown in Fig. 2, each curve representing a different value of E_{g1} . Thus, it will be noted that adjustment of tap 6 along resistor 7 results in operation along a different characteristic curve of the family of curves shown. It is pointed out that the curves shown in Fig. 2 are merely illustrative in nature, and are provided to graphically show the basic principle of operation. The seven curves represent the different operating characteristic curves which would be encountered in a variation of the bias of grid 1 from a value of -1 volt to a value of -7 volts.

Considering a particular case for Fig. 1, a positive voltage of 250 volts was applied to the anode 5', 100 volts positive was impressed on the grids 2 and 4, and potentials were applied to grid 3 chosen from a range of approximately -1 to -8 or 10 volts. It was found that the effective, or resultant, I_p-E_{g1} curve was very nearly linear for the signal voltage range on grid 3, but that the slope of this curve, and hence the gain, could be reduced to practically zero by increasing the negative bias on grid 1 without cutting down the available range and without introducing distortion. In other words, with the aforementioned potential relations, and initially applying a negative bias of -1 volt to grid 1, operation along curve *a* in Fig. 2 resulted. As the negative bias on grid 1 was increased there was substituted for the characteristic curve *a* characteristic curves corresponding to the negative bias of grid 1.

When a negative bias of -7 volts was applied to grid 1, curve *g* of Fig. 2 illustrates the characteristic curve which was being utilized with that negative bias. It will, therefore, be seen that it is possible with the arrangement shown in Fig. 1, and from the graphic illustration of Fig. 2, that the gain of the tube 5 may be reduced to practically zero without particularly changing the range available for signal and the cut-off point on grid 3. This offers a convenient and highly reliable method for controlling the gain without introducing distortion, and without cutting down the available signal range on the signal grid. In other words, the amplifier in Fig. 1 may be characterized by describing it as having an effective plate current-signal grid voltage characteristic whose slope depends upon the potential of the gain control grid but whose available signal grid potential range is substantially independent of the gain control grid bias.

In embodying the basic principle of the present invention in high frequency circuits, it is first pointed out that the signal energy applied to the grid 3 may be of an audio, intermediate or radio frequency. Furthermore, the variation of the negative grid bias on grid 1 may be accomplished automatically and in response to a variation in received signal carrier amplitude, as well as manually. Additionally, the tube 5 and its associated circuits may be utilized in various circuit arrangements, and there will now be disclosed various circuit arrangements to show the wide applicability of the present invention.

One of the circuit arrangements for using the network 5 is in the case of an audio frequency amplifier. In that case, the signal source feeding the grid 3 is any well known source of audio frequency energy, and the movable tap 6 functions as the manual volume control device of the amplifier. The load connected to the anode 5' is another stage of audio frequency amplification, or a reproducer. In such a case it will be seen that a wide range of audio frequency amplification adjustment is provided without the introduction of distortion due to operation along a single characteristic near the cut-off point of the characteristic.

In Fig. 3 there is shown the utilization of tube 5 as an audio frequency amplifier between the detector of a radio receiver and a succeeding utilization means, such as an additional audio amplifier and/or reproducer. The grid 3 is the signal grid, while the grid 1 functions as the control potential grid, and in this case the variation of negative bias is accomplished automatically and in response to variations in received signal carrier amplitude. The control potential is obtained in any conventional and well known manner, and is exemplified as being derived from the input to the detector of the receiver by a rectifier designated as "AVC rectifier". Those skilled in the art are well acquainted with the fact that the volume control rectifier furnishes the D. C. component of the received signal carrier, and this component varies in the same manner as the variation in the carrier amplitude.

Thus, there is supplied a range of negative potentials for varying the bias of grid 1. In this way there is secured an automatic volume control action in a radio receiver by adjusting automatically the gain of an audio frequency amplifier. Heretofore, such an automatic volume control arrangement has been undesirable because of the distortion introduced into the controlled

audio amplifier. However, reference to Fig. 2 will show that such audio distortion does not occur in a system of the type shown in Fig. 3 because variation of the negative bias of grid 1 results only in a change in operation along a different characteristic curve of a family of curves, and not in operation along a single characteristic curve, as in the prior art.

The invention is not limited to the automatic gain control of an audio frequency amplifier in a radio receiver, and in Fig. 7 there is shown a receiver arrangement wherein the tube 5 is operated as a radio frequency amplifier. Specifically, the stage is the intermediate frequency amplifier stage of a superheterodyne receiver, and only those details are shown which are essential to a proper understanding of this invention. The receiver embodies the usual source of intermediate frequency signals and the second detector, the latter feeding the audio frequency amplifier. The control bias for the grid 1 is supplied by the "AVC rectifier", and the control rectifier is connected to the input circuit of the second detector for its signal energy. This type of automatic volume control arrangement is well known in the art, and for the purpose of illustration reference is made to application Serial No. 642,544, filed November 14th, 1932 of Chittick, et al., which shows an automatic volume control network which can be employed both in the case of Figs. 3 and 7.

Of course, the tube 5 can also be employed in the radio frequency amplifier stage of the receiver shown in Fig. 7. The self-biasing network 1' in the cathode circuit of tube 5 provides a normal negative bias of 4 to 5 volts on the signal grid 3. In the case of the arrangement shown in Fig. 3 the self-biasing network 2' may also be used to furnish a normal bias on the signal grid of -4 to -5 volts. When used as a high frequency amplifier as shown in Fig. 7, the grid 1 can be made to have a very sharp cut off to give a more sensitive control. Since grid 3, the signal grid, does not have its available signal range reduced by the volume control potential adjustment, this grid need not be made of the remote cut-off type. By making the grid 3, as a matter of fact, of the close cut-off type modulation distortion is eliminated, and a higher R_p for the tube is obtainable with less plate current drain. The tube 5 controls as well with 18 or 20 volts minus on grid 1 as a 58 type tube, a variable mu tube, requiring say—45 to 50 volts to cut-off. It is also pointed out that there may be added in the tube, in the circuits shown in Figs. 3 and 7 as well as other circuits to be hereinafter described, a suppressor grid between grid 4 and the anode 5', this suppressor grid being connected to the cathode within the tube; this construction being well known to those skilled in the art.

In Fig. 4 there is shown another circuit arrangement employing the present invention, the tube 5 in this case being utilized as an audio frequency amplifier whose signal grid 3 is connected through an audio frequency coupling condenser 20 and adjustable tap to a point on resistor 21 arranged in the second detector circuit of the receiver. The receiving arrangement shown in Fig. 4 is of the superheterodyne type, and the tube 55 is of a type known as a duplex diode triode tube provided with a diode section and a triode section.

The resistor 21 is included in a half wave diode rectifier circuit which functions as the second detector network, the "AVC" lead being con-

nected to a point of negative direct current potential on resistor 21, while the grid 56 of the triode section of tube 55 is connected to the negative side of resistor 21. In the anode circuit of the triode section of tube 55 there is arranged a resistor 22, one side of the resistor being connected to the anode of tube 55 and to the grid 1 of tube 5, the opposite end of the resistor being connected to the positive potential source 23. The cathode of tube 5 is elevated in potential by potential source 5' above ground, and the cathode is kept above ground by a little more than the amount of the plate battery of tube 55 so that when the latter is drawing no plate current, grid 1 of tube 5 will be negative. Finally, grid 3 of tube 5 receives its bias through the path including resistor 24.

The arrangement shown in Fig. 4 is used in a receiver utilizing automatic volume control and inter-channel noise suppression. When no signals are impressed on the diode rectifier circuit of tube 55 the grid 56 is at its most positive potential, with the result that the flow of plate current through resistor 22 is at a maximum. This means that the control grid 1 of tube 5 is biased to its most negative potential, and the circuit constants are so chosen that the normal transmission of signals through tube 5 is substantially prevented when little or no signal energy is impressed on the second detector diode rectifier network. As the signals increase the plate current flow through resistor 22 decreases and the negative bias on grid 1 decreases, with the result that the tube 5 becomes capable of normally transmitting audio signal energy.

The audio frequency component of the rectified signal energy is impressed on the signal grid 3 by connecting this grid to an appropriate point on resistor 21 through the path which includes the coupling condenser 20 and the tap 57. The automatic volume control potential developed across resistor 21 may be utilized in any well known manner to vary the gain of the preceding high frequency amplifiers. The advantage of utilizing the present invention in an inter-channel noise suppression network of the type shown in Fig. 4 resides in the fact that it is possible to vary the gain of tube 5 over a relatively wide range without introducing audio distortion into the audio amplifier system.

In previous arrangements of the muter AVC type, wherein the muting action is performed on an audio amplifier, cut-off of the audio amplifier for muting results in an introduction of audio distortion. In the present case this is substantially prevented because increase of negative bias on the grid 1, as shown in Fig. 2, while resulting in a decrease in the flow of plate current, does not bring the signal grid 3 to cut-off. The flow of plate current with the muting control potential applied is insufficient to permit normal transmission of signals to the reproducer, but the signal grid 3 is not biased so that the tube is in the cut-off condition. In other words, the tube 5 functions in Fig. 4 as a noise gate tube. At present bad distortion occurs when the noise gate tube is biased at or near cut-off. With tube 5 this cannot occur and the signal will go in and out smoothly as the resonant point is tuned over. Of course, the arrangement in Fig. 4 is merely illustrative, and the tube 5 may be used in muter arrangements well known to those skilled in the art at the present time, and wherein the tube 5 is a signal transmission tube whose action is rendered highly inefficient when little or no signal

energy is impressed on the signal collector of the receiver.

In Figs. 5 and 6 there are disclosed two alternative circuit arrangements for employing the tube 5 in automatic tone control systems. It is very often desired to automatically render the transmission of the higher audio frequencies highly inefficient when receiving weak signals such as distant signals, and the reverse when receiving strong signals such as local signals. In Fig. 5 there is disclosed an automatic tone control arrangement of the type described and claimed by J. Yolles in application Serial No. 638,514, filed October 19th, 1932 patented October 15, 1935 as U. S. P. 2,017,270. In this arrangement the tube 5 is employed as a voltage operated capacity, the inherent capacity between the grid 3 and cathode being effectively connected in series between ground and the grid circuit of the audio frequency amplifier tube 60. The aforesaid inherent capacity is denoted in dotted lines, and represented by the numeral 61.

As explained in the Yolles application, a condenser 62 is connected between the signal grid and the anode to augment the action of the condenser 61. The effective negative bias of the control grid 1 is varied in response to variations in the received signal carrier amplitude, and this may be accomplished by an arrangement of the type described in connection with Fig. 3 for example. The essential feature of the control arrangement between the input of the detector and the control grid 1 is that it should utilize a rectifier for providing a direct current component which varies in the same direction as the variations in received signal carrier amplitude.

When strong signals are received the negative bias on the control grid 1 of tube 5 is at a maximum, and the magnitude of the inherent capacity 61 is a minimum, whereby the higher audio frequencies are transmitted to the grid of tube 60 substantially unaffected. When weak signals are received the negative bias on grid 1 is at a minimum and the magnitude of capacity 61 is sufficiently great to by-pass the higher audio frequencies, and, since undesired background noises lie in the higher audio frequency range, such noises are substantially suppressed.

In other words, the tone control action of Fig. 5 depends on reflected capacity across the audio transmission line from the input of a tube whose gain is varied, this tube having an appropriate capacity between the signal grid and the plate. At present bad distortion may be introduced when the automatic tone control tube is biased near cut-off owing to the variation in tone control over the audio cycle due to the variation in gain. With the tube 5 employed as described in the present invention this audio distortion is not introduced for reasons already explained.

The automatic tone control arrangement shown in Fig. 6 differs from that shown in Fig. 5 in that the tube 5 is employed as a variable resistor instead of as a variable capacity. In this case, the automatic tone control arrangement is of a type described and claimed by W. S. Barden in application Serial No. 530,268, filed April 15th, 1931 patented February 20, 1934 as U. S. P. 1,947,822. Between the detector and the audio frequency amplifier, the latter not being shown, there is disposed a choke coil 40 connected between the cathode of tube 5 and the negative terminal of the detector positive plate potential source 41. A fixed condenser 42 is connected between the cathode side of choke 40 and the high

potential side of the detector output circuit. The control grid 1 of tube 5 is connected by a lead 43 including 43' to the output of the automatic volume control rectifier which functions in this case to control both the tone and volume of the receiver.

The circuit shown in Fig. 6 is particularly adapted for low impedance circuits. The impedance of the cathode circuit (internal) of tube 5 as looked into from the two terminals of the audio choke 40 can be shown equal to $R_k = 1/(G_m + G_p)$ or approximately $1/G_m$. This tube impedance is in series with condenser 42 across the transmission line. Variations in the direct current bias on the control grid change the value of G_m , and hence change the value of the internal R_k and the attenuation of the high audio frequencies for the reason that this resistance is in series with the above condenser.

In the circuit shown in Fig. 6 the variation of G_m is brought about not by changing the bias on grid 3, but on grid 1 which latter is by-passed back to cathode so that only the direct current is effective. The full signal range of grid 3 is thus left effective to take care of the variations in potential at audio frequency that occur between grid 3 and cathode, these variations necessarily taking place when the device is functioning.

Still another use for the present invention is shown in connection with fading systems for audio amplifier circuits. In Fig. 8 the tubes 80 and 81 represent a pair of tubes constructed in accordance with the present invention. One source of audio frequency energy is connected between the signal grid 82 and the cathode of tube 80, while a different source of audio frequency energy is connected between the signal grid 83 and the cathode of tube 81. The anodes of tubes 80 and 81 are connected to a common output circuit. The control grid 84 of tube 80 is connected by a variable tap 85 to a negative bias resistor 86. The control grid 87 of tube 81 is connected through a variable tap 88 to the resistor 89 connected across a second negative biasing source.

The dotted line 90 represents a mechanical coupling between taps 85 and 88, and the mechanical coupling is constructed in such a manner that the tap 85, for example, is adjusted to bias the control grid 84 to its most negative potential for the cutting out of tube 80 from the circuit, when the tap 88 will be simultaneously connected to a point on resistor 89 such that the grid 87 will be biased to a point such that tube 81 is transmitting signals from its audio source to the common output circuit. The advantage of a fader arrangement of the type shown in Fig. 8 resides in the fact that audio distortion is substantially prevented while connecting any one of the audio tubes and cutting out the other tube. It is believed that the reason for the prevention of this audio distortion which occurs in present systems will be clear from the explanation which has heretofore been given in connection with Fig. 2.

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. An amplifier circuit including a source of signal waves, a multi-element tube with an anode, 75

a cathode, a positive screen, a signal grid disposed between the screen and anode and an additional auxiliary control grid adjacent the cathode, and means for varying the direct current potential of said auxiliary grid over a potential range such that the slope of the anode current-signal grid potential curve is dependent upon the potential of the auxiliary control grid, but the point at which this curve intersects the axis of zero anode current, or cut-off point, and hence the potential range upon the signal grid available for the reception of signals, is substantially independent of the potential of this auxiliary control grid.

2. An audio amplifier including a tube having input and output circuits, said tube having at least a cathode, anode, a positive screen grid, a signal grid between the screen grid and anode, and a gain control grid between the cathode and screen grid, means for varying the negative bias of the gain control grid over a range of values to regulate the gain of the amplifier over a wide range without audio distortion, and a source of signals connected to the signal grid.

3. In combination with a source of audio signals, an amplifier having a plate, a cathode and at least three grids, one of the grids being a positive screen, the other grid being a gain control grid, and the remaining grid being coupled to the said signal source, said signal grid being disposed between the positive screen and the plate, said tube having an effective plate current-signal grid voltage characteristic whose slope depends on the bias of said gain control grid, the potential range of the signal grid available for signals being substantially independent of the gain control grid bias, and means for varying the bias of the gain control grid over a range of negative values to regulate the flow of current in the plate circuit of said tube.

4. In combination with a source of audio signals, an amplifier having a plate, a cathode and at least three grids, one of the grids being a positive screen, the other grid being a gain control grid, and the remaining grid being coupled to the said signal source, said signal grid being disposed between the positive screen and the plate, said tube having an effective plate current-signal grid voltage characteristic whose slope depends on the bias of said gain control grid, the potential range of the signal grid available for signals being substantially independent of the gain control grid bias, and means for varying the bias of the gain control grid over a range of negative values in response to variations in the signal amplitude to regulate the flow of current in the plate circuit of said tube.

5. In the operation of an audio frequency amplifier stage including a tube having a pair of grids serially arranged between the cathode and the signal grid, the method of controlling the gain of the stage without increasing the distortion introduced into the amplified audio output

of the tube, which method comprises positively polarizing the outer of said pair of grids, impressing a negative bias on the inner of said pair of grids, and adjusting the magnitude of the negative bias so impressed upon the inner grid, thereby to control the density of the electron stream reaching the signal grid.

6. In a radio receiver, the combination with a radio amplifier of the automatic gain control type and a detector, of an audio frequency amplifier stage, said stage comprising a tube having a cathode cooperating with a signal grid and an anode, a stage input circuit connected between the signal grid and cathode, an output circuit between said anode and cathode, and means for controlling the gain of the stage; said means including a pair of grids between said signal grid and cathode, means polarizing the outer of said pair of grids positively with respect to the cathode, means impressing on the inner grid a bias potential which is negative with respect to said cathode, and means for adjusting said bias potential on the inner grid.

7. In an amplifier stage for transmitting audio signals falling within an extended range of frequencies, the combination with a vacuum tube including a cathode, a signal grid, an anode and at least two additional grids serially arranged between said cathode and signal grid, of an audio frequency input circuit between said signal grid and cathode, an audio frequency load circuit between said anode and cathode, means impressing a negative bias on said signal grid, means polarizing positively that additional grid which is adjacent said signal grid, means for impressing a negative bias upon another of said additional grids, and means for adjusting the magnitude of the bias impressed upon the said additional grid, thereby to control the gain of the stage.

8. In a radio receiver, the combination with a radio frequency amplifier, means for adjusting the gain of said amplifier, a detector, and a reproducer, of an audio amplifier between said detector and reproducer; said audio amplifier comprising a tube having a signal grid and anode cooperating with cathode means, the said cathode means comprising a cathode element and two grids serially positioned between said cathode element and said signal grid, means impressing a negative bias on the grid adjacent said cathode element, means impressing upon the grid adjacent said signal grid a direct current potential which is positive with respect to said cathode element, and gain-adjusting means for controlling the magnitude of the negative bias impressed on the grid adjacent the cathode element, thereby to adjust the gain of said audio amplifier.

9. A receiver as claimed in claim 8, wherein the means for adjusting the gain of one of said amplifiers includes means for automatically adjusting the said gain as a function of the strength of a received signal.

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