Jan. 17, 1939. W. R. KOCH 2,144,224

AUTOMATIC VOLUME CONTROL CIRCUITS

Filed June 30, 1937 3 Sheets-Sheet 1

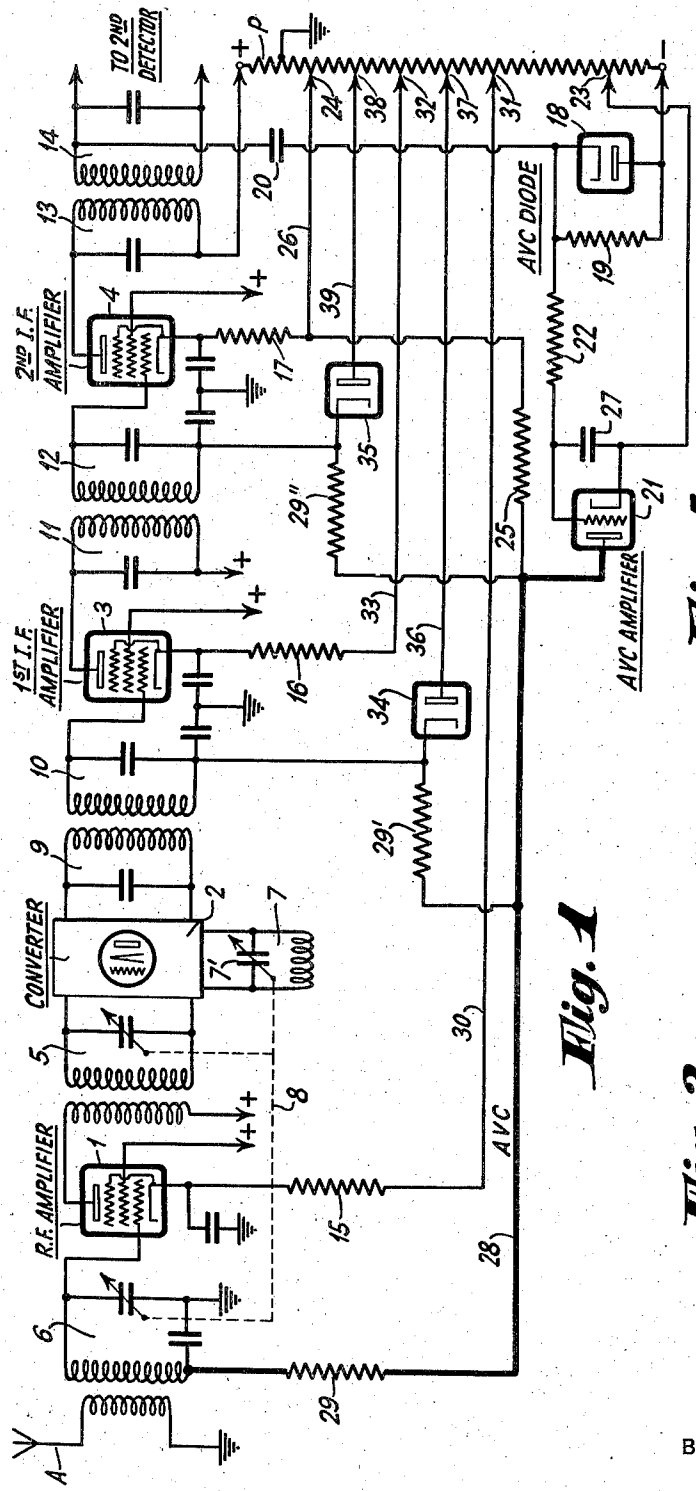


Fig. 1

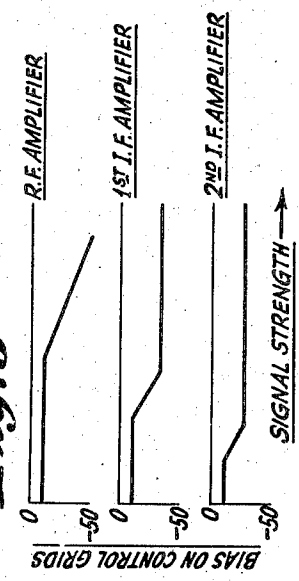


Fig. 5

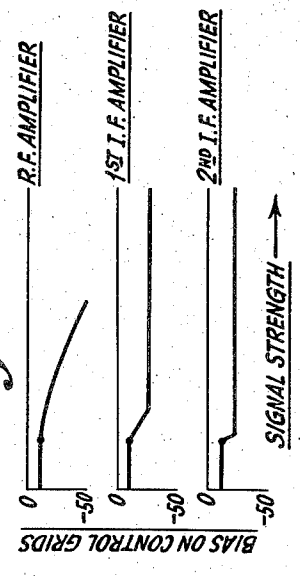


Fig. 3

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AUTOMATIC VOLUME CONTROL CIRCUITS

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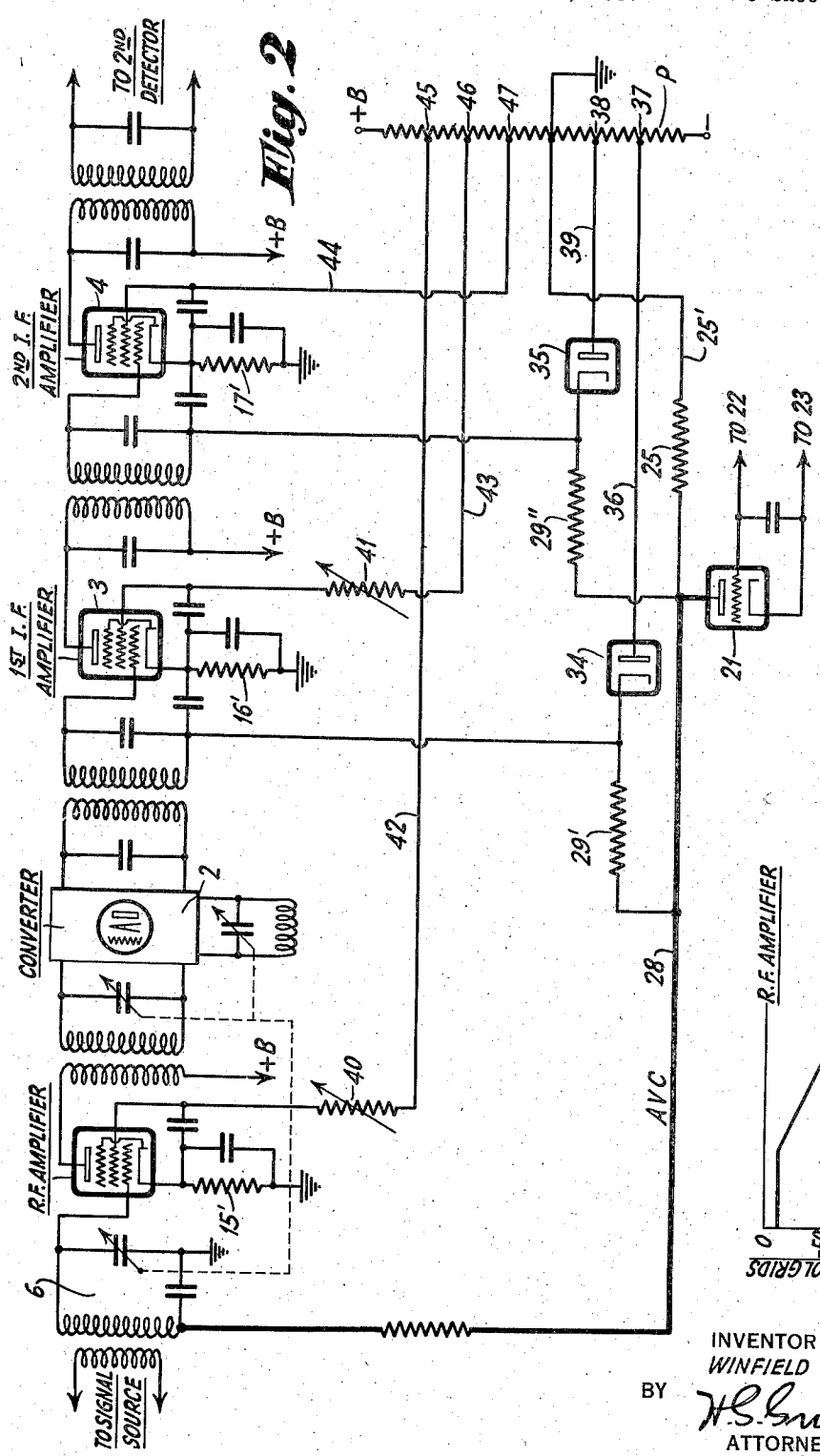


Fig. 2

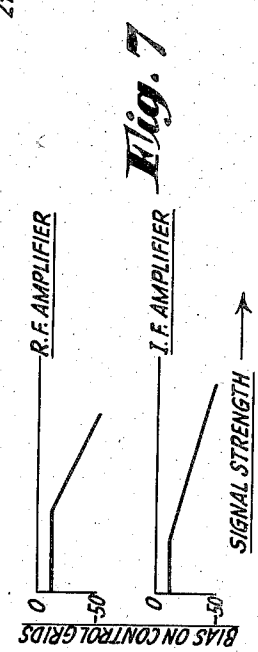


Fig. 7

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AUTOMATIC VOLUME CONTROL CIRCUITS

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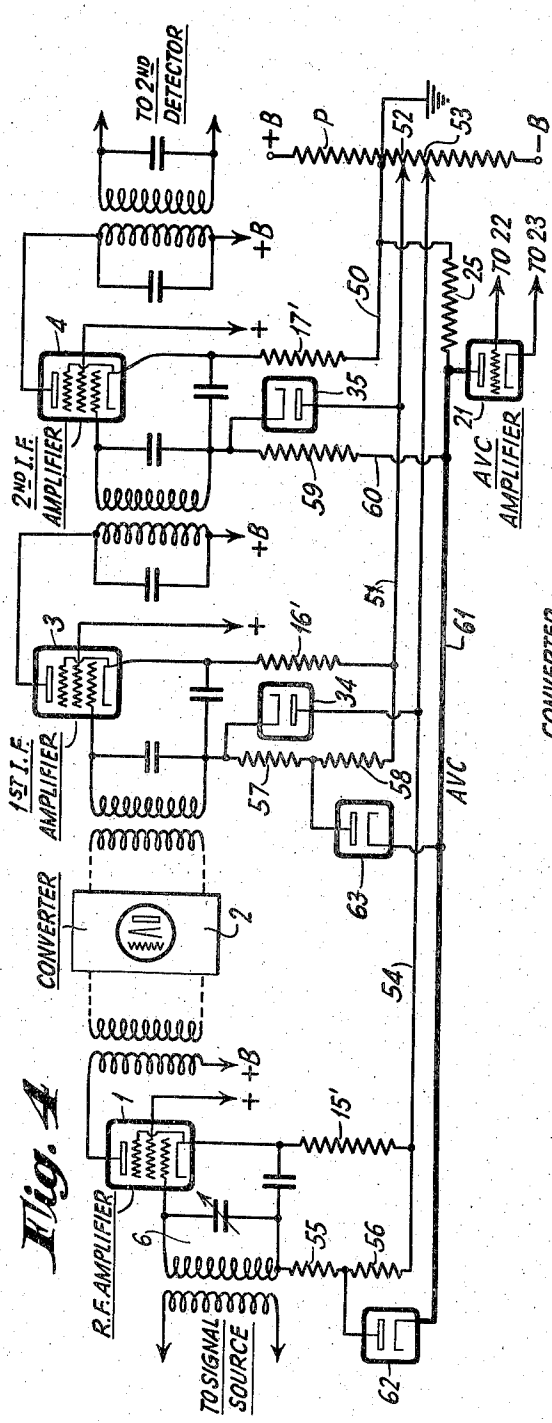


Fig. 4

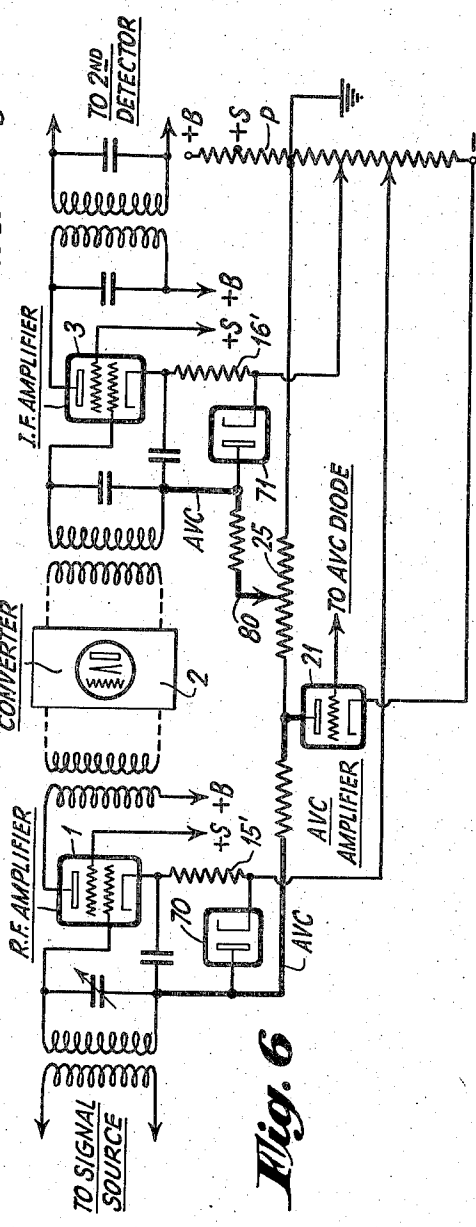


Fig. 6

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AUTOMATIC VOLUME CONTROL CIRCUITS

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Application June 30, 1937, Serial No. 151,102

10 Claims. (Cl. 250—20)

My present invention relates to automatic volume control circuits for radio receivers, and more particularly to improved volume control circuits adapted to regulate the gain of cascaded signal transmission tubes in a graduated manner.

Automatic gain control has been applied, in the past, to the cascaded signal transmission tubes of a radio receiver; the control being graduated in such a manner that the tubes handling the most signal energy have had the least control bias applied to them. The purpose of such progressively decreasing control action is to prevent distortion by overloading on strong signals of the transmission tubes following the first radio frequency amplifier tube. However, such control action results in a poor signal-hiss noise ratio when receiving weak signals. Since the subsequent high frequency transmission tubes have very little AVC bias applied during weak signal reception, hiss and noise originating in the output circuit of the first transmission tube are greatly amplified.

Accordingly, it may be stated that it is one of the main objects of my present invention to provide a novel method of, and means for, automatically controlling the gain of a plurality of cascaded signal transmission tubes, wherein the gain control of the tubes increases sequentially for weak signal reception, while the gain control decreases sequentially for strong signal reception, thereby effectively preventing the reproduction of hiss and noise when weak signals are received and preventing overloading when strong signals are received.

Another important object of my invention is to provide in a radio receiver of the type employing a graduated automatic volume control arrangement which acts to apply control bias to the cascaded receiver tubes in progressively decreasing amounts, an arrangement for permitting such decreasing control action only when the received signals are above a desired amplitude; the gain control of the receiver tubes being graduated in a reverse sense for the reception of signals below a desired amplitude.

Another object of the invention may be stated to reside in the provision of a superheterodyne receiver employing an automatic volume control circuit (AVC) which acts sequentially to bias in a progressively increasing sense at least two signal transmission tubes prior to the second detector during weak signal reception, whereas the same tubes are controlled in the reverse sense for strong signal reception.

Another object of my invention is to provide an AVC network for a superheterodyne receiver, which network biases the second I. F. amplifier, first I. F. amplifier and radio frequency amplifier in succession for reception of weak signals, whereas these stages are biased in the reverse order upon the received signals exceeding a desired intensity.

Still other objects of my invention are to improve generally the operating efficiency of radio receivers of the AVC type, and more especially to provide novel graduated AVC circuits which are reliable in operation, and economically manufactured and assembled in receivers.

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 drawings in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:

Fig. 1 is a circuit diagram of a superheterodyne receiver employing the invention,

Fig. 2 illustrates a modification of the AVC circuit of Fig. 1,

Fig. 3 graphically shows the operation of the AVC circuits of Figs. 1 and 2,

Fig. 4 shows a receiver employing still a different form of AVC circuit,

Fig. 5 is a graphic analysis, similar to Fig. 3, of the operation of the AVC circuit in Fig. 4,

Fig. 6 is a circuit diagram of still another modification,

Fig. 7 is a graphic analysis of the AVC operation in the circuit of Fig. 6.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, there is shown in Fig. 1 a superheterodyne receiver of conventional construction; a signal collector A feeding a tunable radio frequency amplifier 1, a converter 2, first and second I. F. amplifiers 3 and 4 and a second detector (not shown) all in cascade. The second detector will, of course, feed audio signals to an audio amplifier network which is followed by a reproducer. Each of the cascaded stages is of well known and familiar construction; each amplifier tube has a tuned input circuit which is coupled to the output circuit of a preceding tube. Thus, converter 2 has the

tunable input circuit 5 thereof coupled to the output circuit of radio frequency amplier 1.

The amplifier 1 has a tunable signal input circuit 6 coupled to the collector A. The oscillation tank circuit 7 has its variable tuning condenser 7' arranged for unicontrol adjustment with the variable condensers of the signal input circuits 5 and 6. The dotted line 8 represents the unicontrol tuner which varies the position of the condenser rotors. The frequency range of circuits 6 and 5 (which may be, for example, 500 to 1500 k. c.) differs from the frequency range of the tank circuit 7 by the value of the I. F. (75 to 450 k. c. may be the range from which the I. F. value is selected). The converter output circuit 9 is coupled to the input circuit 10 of the first I. F. amplifier 3; the output circuit 11 of the latter is coupled to the input circuit 12 of the second I. F. amplifier 4. Circuits 13—14 couple the plate circuit of amplifier 4 to the second detector. Each of the resonant circuits 9—10; 11—12; 13—14 is tuned to the operating I. F.; hence, the tuning thereof is fixed to the desired I. F. value.

The converter 2 may be of the combined local oscillator-first detector type using a 6A7 tube if desired; however, separate local oscillator and first detector tubes may be utilized. Each of amplifiers 1, 3 and 4 includes a self-bias resistor in its cathode circuit; thus numerals 15, 16, 17 denote the grid bias resistors disposed in the space current paths of tubes 1, 3 and 4 respectively. These bias resistors are of progressively decreasing magntudes; the reason for such design will be given at a later point. The tubes 1, 2, 3, 4 are energized from a direct current source P; the latter is illustrated as a bleeder resistor whose terminals are connected across the filter output of the usual rectified 60 cycle current source. The screen and plate electrodes of the signal transmission tubes are to be understood as being connected to points of appropriate positive potential on the bleeder P; an intermediate point of the latter is established as ground potential reference point.

The AVC circuit for the receiver comprises a diode 18 having a load resistor 19 connected between its electrodes. Signal energy is impressed on the diode by the connection, through condenser 20, from the I. F. circuit 14 to the cathode side of resistor 19. The direct current voltage component of rectified I. F. energy is impressed on the amplifier 21, the latter being normally biased beyond cut-off. The cut-off bias is secured by connecting the control grid of tube 21 to the negative terminal of resistor P through a path including resistors 22 and 19. The cathode of tube 21 is connected to a less negative potential point 23 on resistor P; the voltage between point 23 and the negative terminal of resistor P is more than sufficient, in the absence of signals to cut off the plate current flow through amplifier 21. Since the grid of tube 21 is connected to the cathode side of load resistor 19, the impression of I. F. energy on the diode 18 causes the cathode side of resistor 19 to become increasingly positive until the positive potential overcomes the normal cut-off bias.

The plate of AVC amplifier 21 is connected to point 24 on resistor P through a path including resistor 25 and lead 26; an audio bypass condenser 27 being connected between the grid and cathode of tube 21. The plate side of resistor 25 is connected by AVC leads to the control grids of tubes 1, 3 and 4. Thus, lead 28 is connected to the aforesaid control grids by filter resistors 29, 29' and 29''. Of course, the AVC lead may be connected to the signal grid of the converter, if desired. The normal bias on the controlled tubes is provided by connecting the bias resistors 15, 16 and 17 to points of respectively different negative potentials on bleeder P. Resistor 15 is connected to point 31 on the bleeder by lead 30; resistor 16 is connected to point 32 by lead 33; lead 26 connects resistor 17 to point 24. When no signals are impressed on the receiver the normal positive potential of the cathode of tube 1 will be equal to the voltage drop across resistor 15 less the voltage between points 31 and 24 on resistor P.

The drop across resistor 16 less the potential difference between points 32 and 24 determines the normal cathode potential of tube 3; while the drop across resistor 17 provides the bias for tube 4. The voltage relations are so chosen that the effective negative biases on the control grids of the controlled tubes are the same; that is, the tubes 1, 3 and 4 have equal transconductance for signals of less than a desired amplitude. This initial equality is secured, despite the non-uniform magnitudes of the self-bias resistors 15, 16, 17, by the tap adjustments of the cathode leads on bleeder P.

A pair of diodes 34 and 35 are employed to reverse the sequence of gain control action when signals of a relatively strong intensity are received. Diode 34 has its cathode connected to the grid side of resistor 29'; its anode being connected by lead 36 to point 37 on the bleeder P. Thus, the diode 34 is normally biased to be non-conductive; point 37 being at a negative potential with respect to point 24 to which the diode cathode is connected. Diode 35 is similarly biased by connecting its cathode to the grid side of resistor 29'' and connecting the diode anode to the point 38 through lead 39; point 38 being at a negative potential with respect to point 24. These two diodes 34 and 35 are rendered conductive only when the AVC bias developed across resistor 25 overcomes the biases on the diodes. Since the biases are progressively less on diodes 34 and 35, it follows that diode 35 will be rendered conductive prior to diode 34.

In the circuit of Fig. 1, the AVC action does not commence on any of the transmission tubes 1, 3 and 4 until the cut-off bias on the AVC amplifier 21 is exceeded by the signal amplitude; that is, by the drop across resistor 19. This explains why, in the three curves of Fig. 3, the initial portions of the curves have the same effective bias before the control action commences. The progressively decreasing delay for the AVC action is secured by means of the cathode resistors of decreasing size. Considering the second I. F. amplifier 4, its cathode resistor 17 is of a relatively low value, and, therefore, the potential drop thereacross is relatively small. This potential drop supplies the initial bias for the control grid of the amplifier. As the AVC bias on the control grid of the second I. F. amplifier 4 increases when weak signals are received, the drop across the cathode resistor 17 is varied by a small amount since the resistor is relatively small in magnitude. This means that the effective control grid bias applied to the amplifier 4, for gain control, increases at a fast rate, because the opposing potential drop across the cathode bias resistor changes by such a small amount that it does not prevent the I. F. amplifier 4 from using practically the entire developed AVC bias.

However, when the signals have attained an intensity of a predetermined amount above the weak signal intensity, the diode 35 will be ren-

dered conductive, the cathode of the diode being connected through the AVC filter resistor 29'' to the plate of the AVC amplifier 21. When the diode 35 is rendered conductive, current flows through the filter resistor 29'', and the resulting potential opposes the AVC bias to an extent sufficient to prevent further appreciable increase of negative bias on the control grid of tube 4.

In the case of the first I. F. amplifier 3, it will be seen that the sloping middle portion of the second curve in Fig. 3 signifies a less rapid increase of control grid bias. This follows because the cathode resistor 16 has a larger magnitude than the cathode resistor 17 of the second I. F. amplifier. In turn, this means that the increasing AVC bias for weak signal reception is opposed by a larger potential variation across cathode bias resistor 16. The diode 34 in this case produces the flattening effect of the characteristic curve, because the diode becomes conductive when the AVC bias becomes sufficiently strong to overcome the initial cut-off bias of the diode. Hence, in Fig. 3 the middle curve shows the control grid bias for tube 3 increasing at a less rapid rate than in the case of tube 4; and eventually becoming constant in value.

In the case of the amplifier 1, the cathode resistor 15 is larger in magnitude than the following two cathode resistors, and, therefore, there will be a larger variation in voltage drop thereacross to oppose the increasing AVC bias. In this case it is not desired to use a limiting diode, because it is necessary to have the AVC action on the first signal transmission tube greater than the AVC on the following tubes for strong signal reception. The top curve in Fig. 3 shows the control grid bias increasing at a slower rate, but maintaining the increase even after the control biases on the tubes 3 and 4 have become constant.

The circuit in Fig. 2 is similar in action to that of Fig. 1. Instead of using cathode bias resistors of different magnitudes, the cathode resistors 15'—16'—17' remain equal in value. However, to secure the sequentially increasing AVC rates for the cascaded stages, there are disposed resistors 40 and 41 of progressively decreasing magnitudes in the screen grid leads of tubes 1 and 3. It is to be noted that the screen grid lead of the second I. F. amplifier 4 actually has zero added resistance. The screen grid leads 42, 43 and 44 are connected to points of progressively lower positive potential on the bleeder resistor. For example, the screen resistor 40 of the amplifier 1 is connected to the most positive point 45 on the bleeder; the first I. F. amplifier screen resistor 41 is connected to a point 46 which is of less positive potential; and lead 44 is connected to point 47 of still less potential. The points 47, 46 and 45 are so chosen that the effective screen potential of each amplifier is the same in the absence of AVC bias being developed across resistor 25. When the voltage across load resistor 19 (not shown in Fig. 2) exceeds the cut-off bias on tube 21, then the AVC bias across resistor 25 acts on the control grids of the amplifiers 1—3—4 to reduce the space current flow thereof.

Since the screen grid leads progressively decrease in resistance value, the variation in potential across resistor 40 will be greater than that across resistor 41 and still greater than that in lead 44. Hence, the gain of the amplifiers 1, 3, 4 will vary at progressively faster rates; the gain of tube 4 will decrease much more quickly than that of tube 3, and the gain of the latter will decrease at a faster rate than that of tube 1. However, when the signals get sufficiently strong to cause diodes 35 and 34 to become successively conductive, then the gain reduction order will be reversed. As explained previously, the diode 35 will become conductive when its cathode is negative with respect to its anode. Since point 38 is less negative than point 37 it follows that the cut-off bias on diode 35 is less than that applied to diode 34. It will be noted that resistor 25 is connected to the intermediate ground potential point on bleeder P by lead 25'. Also, resistors 40 and 41 may be made variable in magnitude to permit a control over the rate of gain variation in tubes 1 and 3. The curves of Fig. 3 represent the operation of the circuit in Fig. 2, it being understood that the ordinates in the latter case would represent the gain of each amplifier. When weak signals are received the gains of the amplifiers are sequentially reduced, whereas for strong signal reception the gain reduction order is reversed.

In Figs. 1 and 2 the controlled tubes have been shown as having the same initial gains; the order of gain variation being dependent upon the use of resistors (either in the cathode circuit or screen circuit) of different magnitudes. In Fig. 4 there is shown a modification wherein the order of gain variation for weak signals is dependent upon a sequentially decreasing delay of the AVC bias applied to the control grids of amplifiers 1, 3 and 4. For strong signals, however, the diodes 35 and 34 are employed to reverse the gain reduction sequence. The bias resistors 15', 16' and 17' are of equal magnitude; the resistor 17' is connected by lead 50 to the intermediate ground potential point of the bleeder resistor P. A lead 51 connects resistor 16' to a more negative potential point 52 on the bleeder, while lead 54 connects resistor 15' to a point 53 on the bleeder which is more negative than point 52.

In the absence of received signals the normal gain of each of the controlled tubes is determined by the voltage drops across the bias resistors. It will be seen that the control grid of amplifier 1 is connected to the negative side of resistor 15' through a resistor tapped at an intermediate point, and divided into a pair of series sections 55 and 56. The control grid of amplifier 3 is connected to the negative side of bias resistor 16' through resistor sections 57 and 58; while the control grid of amplifier 4 is connected to the grounded lead 59 through a path which includes the AVC filter resistor 59, lead 60, AVC lead 61, resistor 25. There is associated with each of resistor sections 56 and 58, diodes 62 and 63 respectively. The anode of diode 62 is connected to the junction of resistors 55 and 56, while the cathode thereof is connected to the AVC lead 61. The diode 63 has its anode connected to the junction of resistors 57 and 58, while its cathode is connected to the lead 61.

It will be observed that the diode 62 normally has its anode negatively biased with respect to its cathode, because its anode is connected to the point 53 on the bleeder P and the diode cathode is connected to the ground potential point. The diode 63 similarly has a normal cut-off bias, but this cut-off bias is less than that applied to diode 62, because the anode of diode 63 is connected to point 52 on the bleeder which is less negative than point 53. The diodes 35 and 34 are connected in circuit with amplifiers 4 and 3 respectively in the manner previously described. The anode of diode 35 has a cut-off bias

applied to it, in the absence of signals which is equal to the potential between the ground point on bleeder P and point 52. The diode 34 has a cut-off bias applied to it which is equal to the potential difference between points 53 and 52 on the bleeder. The AVC bias developed across resistor 25 determines the conductivity of each of diodes 62, 63, 34 and 35.

The progressively decreasing delay of the AVC action is secured in this case by the following means: Considering the second I. F. amplifier 4, when the AVC bias is produced, the gain of the amplifier 4 is reduced until the limiting diode 35 becomes conductive; the lowest characteristic in Fig. 5 flattens out. In the case of the first I. F. amplifier 3, the AVC bias does not begin to cut the grain down until a greater predetermined AVC bias intensity is attained. The AVC bias begins to affect the amplifier 3 when the auxiliary diode 63 connected to the resistor 58 becomes conductive. This will occur when the AVC bias becomes greater than the voltage between point 52 and ground. The diode 34 comes into play when the anode side of the resistor 58 in the auxiliary diode circuit becomes sufficiently negative to render the limiting diode 34 conductive which will occur when the AVC voltage becomes greater than the voltage from point 53 to ground thereby flattening the AVC voltage characteristic in Fig. 5. In the case of the amplifier 1, there is no limiting diode, but the auxiliary diode 62 acts to produce AVC bias when it is rendered conductive by an AVC voltage greater than the voltage between point 53 and ground. It is to be noted that the cut-off bias of the auxiliary diode 62 is chosen so that the AVC action for the amplifier 1 is delayed to a greater extent than in the case of the amplifier 3 and the second I. F. amplifier 4. Fig. 5 shows the control grid bias changes as signal strength varies; the AVC bias on amplifier 3 is not effective until the diode 34 has become conductive.

Comparing Figs. 3 and 5, it will be seen that the circuit arrangements of Figs. 1 and 2 in reality provide a progressively decreasing rate of change of the AVC bias, whereas the circuit in Fig. 4 sequentially delays the AVC bias from being applied to the controlled tubes. From a generic viewpoint, in both cases there is a progressively increasing gain reduction action on the controlled tubes for weak signals, whereas for stronger signals the gain reduction action is progressively decreased.

In Fig. 6 there is shown a modification wherein the amplifier 1 has the control grid thereof connected to the cathode bias resistor 15' through a normally conductive diode 70. This means that the AVC bias will not affect the control grid of amplifier 1 until the diode 70 is rendered nonconductive. The amplifier 3 has a normally conductive diode 71 connected between the control grid thereof and the negative side of the cathode bias resistor 16'. The cut-off bias on this diode 71 is less than the cut-off bias on the diode 70. With proper circuit design the diode 71 will become non-conductive at a smaller AVC bias value than that required to make diode 70 nonconductive. It will be noted that the AVC bias is progressively smaller for stronger signals, because of the intermediate tap of the I. F. amplifier control grid on the AVC bias resistor 25.

Fig. 7 shows that, as in the case of the other arrangements, for weak signals the AVC bias progressively increases on the cascaded transmission tubes, whereas for stronger signals the AVC bias progressively decreases. Specifically, of course, the diodes 70 and 71 function as devices for blocking the AVC action on amplifiers 1 and 3; the blocking being released sequentially from the I. F. amplifier to the amplifier 1. However, the tap 80 on the bias resistor 25 assures less AVC bias on the amplifier 3. Hence, the curves in Fig. 7 are shown as having different slopes, the slope for the amplifier 1 being, of course, steeper.

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. A method of operating a radio receiver of the type including a plurality of cascaded signal transmission tubes, which includes sequentially decreasing the gain of said tubes from the last of the tubes to the first one, and sequentially decreasing the gain of said tubes from the first of said tubes to the last one as the signal strength increases.

2. A method of operating a radio receiver of the type comprising a plurality of cascaded tubes which includes transmitting signal energy through said tubes, deriving a control bias from received signal energy, applying the control bias to said tubes from the first to the last tube in a progressively increasing sense for weak signal reception, and reversing the sense of application of the control bias for strong signal reception.

3. A method of automatically controlling the gain of at least two cascaded signal transmission tubes which includes automatically controlling the gain of the tubes in a sense such that the gain of the tubes is reduced in a sequential manner from the second tube to the first tube, and reversing the gain reduction sequence as the signal strength increases.

4. In a superheterodyne receiver including a plurality of cascaded signal transmission tubes, and an automatic control circuit for progressively reducing the gain of the transmission tubes as the signal strength increases, additional means responsive to the automatic volume control means for reversing the gain reduction sequence when weak signals are received.

5. In a radio receiver of the superheterodyne type including a radio frequency amplifier and an intermediate frequency amplifier, an automatic gain control, means responsive to said gain control which reduces the gain of the intermediate frequency amplifier to a greater degree than that of the radio frequency amplifier for a predetermined range of weak signal intensities, and additional means responsive to said gain control which reduces the gain of the radio frequency amplifier to a greater degree than that of the intermediate frequency amplifier for signal intensities greater than a predetermined value.

6. In a multi-stage amplifier of the type comprising a plurality of cascaded tubes, an automatic volume control circuit for said tubes providing progressively decreasing gain control from the last to the first of the tubes in response to weak signal reception, and means operatively associated with said control circuit for reversing the order of said gain control in response to reception of signals above a predetermined amplitude.

7. In a radio receiver, at least two carrier wave amplifiers arranged in cascade, an auto-

matic gain control arrangement for said amplifiers, said arrangement predominantly reducing the gain of the second amplifier in response to carrier amplitudes below a desired intensity level, and predominantly reducing the gain of the first amplifier in response to carrier amplitudes above said level.

8. In a superheterodyne receiver of a type comprising at least a radio frequency amplifier and at least two intermediate frequency amplifiers all arranged in cascade, means establishing each of the amplifiers at the same normal gain, means for reducing the gain of said amplifiers in a progressively decreasing manner from the last to the first amplifier during weak signal reception, and means for further reducing the gain of at least the first of the amplifiers and to a greater extent than the following amplifiers during strong signal reception.

9. In a wave transmission system including at least three cascaded amplifiers, an automatic gain control circuit for said amplifiers, means for delaying gain reduction of said amplifiers by said control circuit in a progressively increasing order from the last to the first of said amplifiers in response to weak signal reception, and means preventing further gain reduction by said control circuit of the last two amplifiers, while gain reduction of said first amplifier continues, in response to strong signal reception.

10. In a wave transmission system comprising at least two cascaded amplifiers, an automatic gain control circuit for said amplifiers, means delaying gain reduction of said amplifiers by said control circuit in a progressively increasing order from the second to the first amplifier in response to wave amplitude increase up to a predetermined amplitude, and additional means causing gain reduction of said amplifiers by said control circuit in a progressively decreasing order from the first to the second amplifier for wave amplitudes above said predetermined amplitude.

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