Feb. 12, 1935. C. B. AIKEN 1,990,512

RADIORECEIVER

Filed Dec. 18, 1931 3 Sheets-Sheet 1

FIG. 1

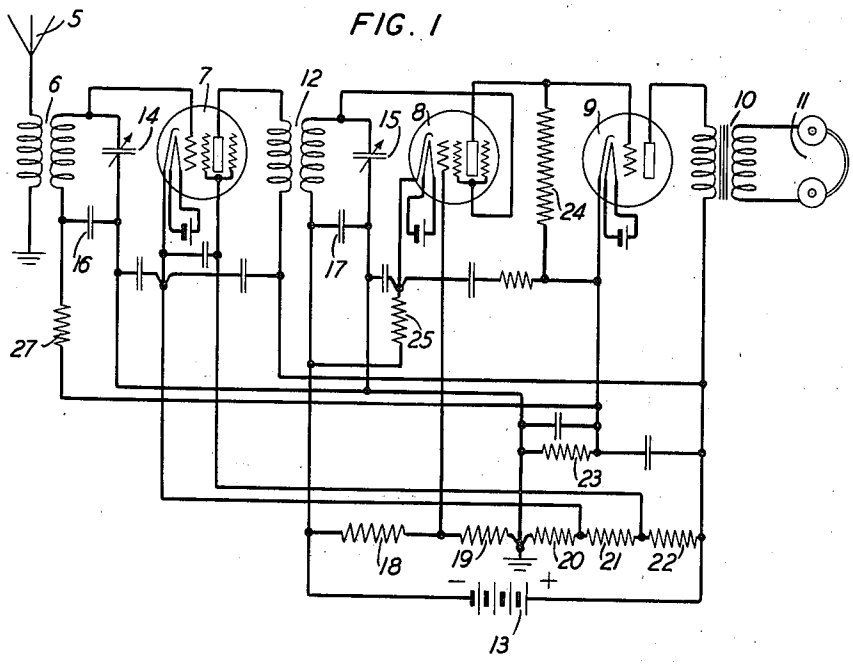
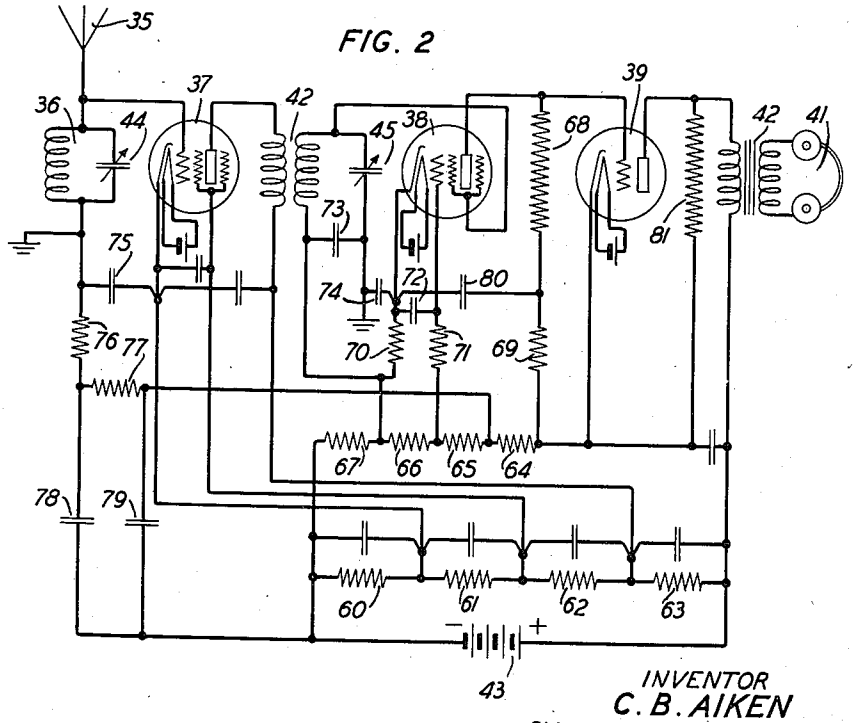


FIG. 2



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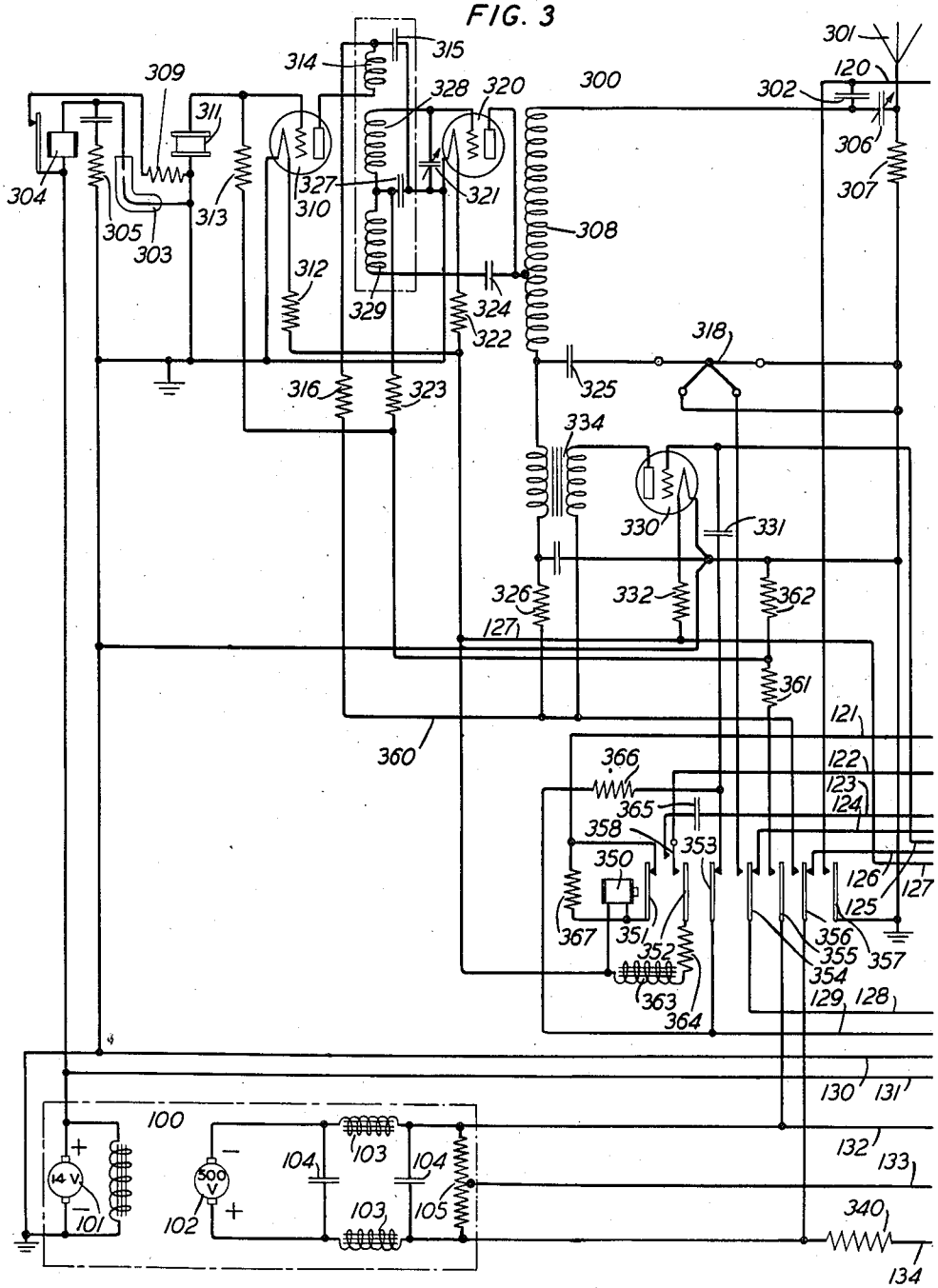
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Feb. 12, 1935. C. B. AIKEN 1,990,512

RADIORECEIVER

Filed Dec. 18, 1931 3 Sheets-Sheet 2

FIG. 3



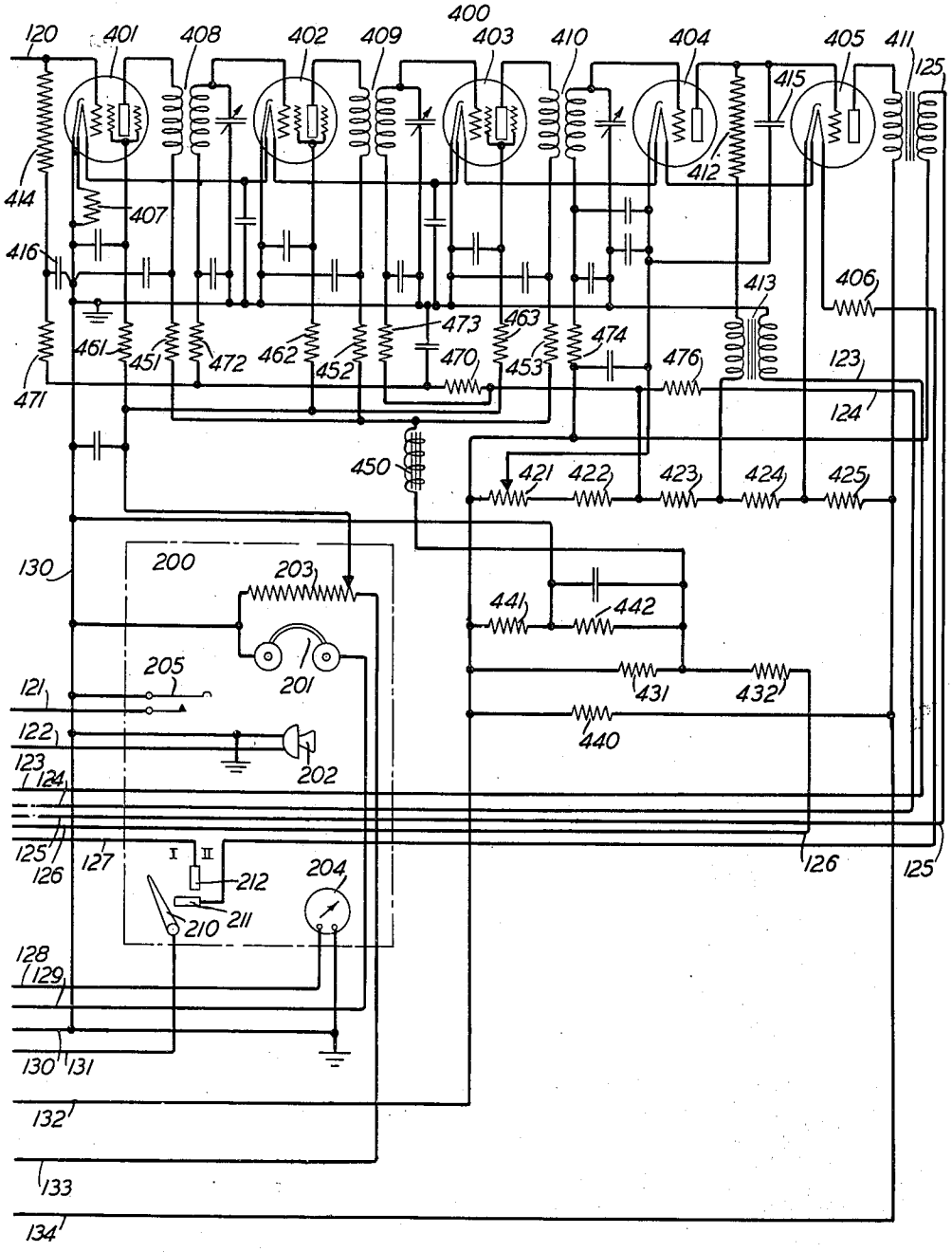
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Feb. 12, 1935. C. B. AIKEN 1,990,512

RADIORECEIVER

Filed Dec. 18, 1931 3 Sheets-Sheet 3

FIG. 4



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UNITED STATES PATENT OFFICE

1,990,512

RADIORECEIVER

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Application December 18, 1931, Serial No. 581,875

2 Claims. (Cl. 250—20)

This invention relates to systems for automatically controlling the gain of circuits employing electron discharge devices and particularly to such systems for use in radio receivers.

One object of the invention is to provide an efficient automatic gain control employing a minimum of equipment.

A general method of automatic gain control used in radio receivers and the like, is to rectify the amplified radio waves and employ the resultant electromotive force as a bias to control the gain of one or more of the amplifying tubes. For this purpose the direct current component of the rectified electromotive force appearing in the plate circuit of the detector may be used. Obviously, this rectified electromotive force must not be less than a certain minimum value in order to effect the desired control.

In many types of radio receivers, particularly those designed to operate into head telephone receivers, it is not desirable to make the signal level at the input of the detector sufficiently high to give a rectified electromotive force of the amplitude required to effect the gain control. Consequently it has heretofore been necessary either to amplify and rectify the signal waves in a separate path to provide the control electromotive force, or to separately amplify the direct current output of the detector. Both of these methods require the use of special additional apparatus. This is at best undesirable and in many cases may not be permissible, particularly where the space and weight requirements are controlling, as in aircraft apparatus, for example.

In accordance with a feature of this invention, such difficulties are overcome by the use of an amplifier which will operate to amplify both the detected signal and the direct current components of the detector output.

In a specific preferred embodiment of the present invention, the output circuit of the detector of a radio receiver is conductively coupled through a coupling resistance to an electron discharge tube which, as a result of the conductive coupling, acts to amplify both the detected signal waves and the direct current component of the detector output current. Both this device and the detector receive space current from the same source through a potentiometer. The voltage drop across a portion of this potentiometer which carries the space current of the amplifier tube is applied to the grid of one or more of the radio frequency amplifier tubes in opposition to a substantially constant negative bias. Since the detector is operated with a negative grid bias, any increase in the amplitude of the radio frequency signal wave supplied to its grid causes an increase in the space current and consequently in the D. C. electromotive force across the coupling resistance. This, in turn, causes an increase in the negative potential on the grid of the audio-frequency tube reducing its plate current and consequently the opposing electromotive force applied to the radio frequency amplifier grid. The final result is such a decrease in the gain of the radio frequency amplifier as to maintain the detector output substantially constant irrespective of ordinary variations in the amplitude of the received radio waves.

The circuit constants are preferably so adjusted that in the absence of a received radio wave, the net bias on the radio frequency amplifier is such as to give a maximum gain, consequently as the strength of received radio waves increases the bias becomes more negative reducing the gain of the radio frequency amplifier.

The invention can be more readily understood by reference to the following detailed description in connection with the drawings in which:

Fig. 1 shows one embodiment of the invention in a radio receiver;

Fig. 2 shows a second embodiment of the invention in a radio receiver; and

Figs. 3 and 4 placed side by side show a third embodiment of the invention in a combined radio receiver and transmitter.

Fig. 1 shows a radio receiver in which the waves received from the antenna 5 are impressed through the transformer 6 on the input on grid circuit of the tube 7 which operates as a radio frequency amplifier. The waves thus amplified are impressed on the tube 8 where they are detected and the detected waves amplified in the tube 9 and impressed through the transformer 10 on the telephone receiver 11. The plate circuit of the tube 7 is coupled to the grid circuit of the tube 8 through the radio frequency transformer 12. The plate of the detector 8 is directly connected to the grid of the tube 9 so that the latter tube operates not only to amplify the alternating current component of the plate current of the detector tube 8, but also the direct current component. This latter component is utilized to control the direct current potential on the grid of the tube 7 and consequently the degree of amplification obtained in that tube.

Tuning condensers 14 and 15 are provided for tuning the secondary of the transformers 6 and 12, respectively, to permit the selection of a desired incoming wave. The tuned circuits are com-

pleted through the blocking condensers 16 and 17, respectively, which are of large capacity to permit the free passage of alternating current while blocking the flow of direct current so as to separate the direct and alternating current portions of the input circuits of the tubes 7 and 8. Various by-pass condensers are employed for providing paths of low impedance for the alternating current components of the grid and plate circuit currents.

All of the tubes are of the uni-potential cathode type having a heater element physically separate from the active cathode element. Plate current and biasing potential for all of the tubes are supplied from the battery 13. The potentiometer comprising resistances 18, 19, 20, 21 and 22 is connected across the battery 13 to provide the correct voltages for the various tubes. The cathode circuit of the audio-frequency amplifier tube 9 contains, in addition to the resistances 18 and 19 of the potentiometer, a resistance 23.

The resistances 18 and 19 carry in addition to the plate current of the tube 9 the potentiometer current which acts as a ballasting current, plate and screen currents of the radio frequency tube 7, and in the case of resistance 19, the space charge grid current of detector tube 8. The total voltage across the resistances 18, 19 and 23 is the plate circuit voltage of the detector tube 8, the true plate voltage being this voltage less the drop in the coupling resistance 24 and the biasing resistance 25. The voltage drop in this latter resistance 25 furnishes biasing voltage for the control grid of the detector tube 8. The cathode of the radio frequency amplifier tube 7 is connected between the resistances 20 and 21 so that the plate circuit voltage of that tube is the drop across the resistances 21 and 22 and the screen grid voltage is the drop across the resistance 21. The space charge grid of the detector tube 8 is connected to the junction of resistances 18 and 19 so that the bias voltage applied thereto is the voltage across resistance 18 minus the voltage drop in the resistance 25.

The control grid of the radio frequency amplifier tube 7 is connected through the filter resistance 27 to the right-hand terminal of the resistance 23, the bias voltage applied thereto being the net voltage across the resistances 23 and 20, or the difference between the voltage drops across these resistances. The drop across resistance 20 is produced by the ballasting current flowing from the source 13, plus the direct current components of the plate and screen grid currents of the radio frequency tube 7. The circuit is so designed that the ballasting component of this current is so large compared with the other components that any variation in those currents will not adversely affect the operation of the automatic gain control. For the purpose of description of the automatic gain control, the drop across the resistance 20 may be considered to be substantially constant.

The voltage across the resistance 20 is of such a polarity as to bias the grid of tube 7 negatively and that across the resistance 23 is of the opposite polarity. The circuit elements are so adjusted that with no signal input on the transformer 16, the voltage drop in the resistance 23 predominates and the grid of the tube 7 will be given an initial bias which is positive with respect to the potential of the cathode. When a signal is impressed on the amplifier tube through the transformer 6, amplified and impressed on the control grid of detector tube 8, the plate current of the detector 8 increases causing an increase in current in the resistance 24. This results in an increase in the negative bias of the grid of the audio-frequency amplifier tube 9 and a corresponding decrease in its plate current flowing through resistance 23. This in turn results in a decrease in the voltage across the resistance 23 and consequently a decrease in the positive potential supplied to the grid of tube 7 in opposition to substantially constant negative potential supplied by the resistance 20, resulting in a net negative bias on the grid of the tube 7. This negative bias increases with increased signal strength and is made of such a value by the proper design of the circuit elements that the output of the audio-frequency amplifier tube 9 is maintained substantially constant over a relative wide range of variations in the amplitude of the received waves. Of course, inasmuch as the automatic gain control depends for its action upon a change in the radio frequency input to the detector, it is impossible to maintain an absolutely constant audio-frequency output with changing signal strength. However, it has been found possible to maintain the change in gain of the radio frequency amplifier sufficiently great for small changes in the detector input voltage so that the change in the audio-frequency output voltage will be very small over a wide variation in signal strength within the normal operating range.

The secondary effect on the detector plate voltage and plate and screen voltages of the radio frequency tube 7 produced by variations in the current through the resistances may be kept within such limits as not to alter the relative voltages of the system which affect the automatic gain control.

Fig. 2 shows a radio receiver of the same general type as that shown in Fig. 1, but employing a somewhat different type of resistance network for obtaining the automatic gain control. This receiver has an antenna 35 which is tuned by means of an anti-resonant circuit 36, the voltage across which is impressed upon the input circuit of a radio frequency amplifier tube 37. The output of the radio frequency amplifier tube is coupled through the transformer 42 to the input of a detector tube 38, the plate of which is directly connected to the grid of an audio-frequency amplifier tube 39. The audio-frequency output of the amplifier tube 39 is supplied to the telephone receiver 41 through the audio-frequency transformer 42. A tuning condenser 45 is connected across the secondary winding of the transformer 42 for tuning the circuit to select the desired radio frequency. For this purpose the condenser 45 is operated in conjunction with the condenser 44 of the antenna tuned circuit 36.

Plate current and biasing voltages for the control grids, screen grid and space charge grid of the tubes of the receiver are obtained from the battery 43. A main potentiometer comprising resistances 60, 61, 62 and 63 provide means for obtaining the proper voltages for the various elements of the radio frequency amplifier tube 37. For this purpose the plate of the tube 37 is connected at the junction of the resistances 62 and 63, the screen grid at the junction of resistances 61 and 62 and the cathode at the junction of the resistances 60 and 61. The condensers shown connected across the various resistances of the potentiometer provide low impedance by-pass circuits for the alternating current components.

The plate of the audio-frequency amplifier tube 39 is connected directly to the positive terminal

of the battery 43. The cathode circuit of this tube includes the resistances 64, 65, 66 and 67 which carry the plate current. The voltage across the resistances 64, 65 and 66 is the total plate circuit voltage of detector tube 38. Similarly, the voltage across the resistance 66 is the total space charge grid circuit voltage of that tube. Consequently the resistance 67 carries in addition to the space current of the tube 39 the plate and space charge grid currents of the detector tube 38. The true plate voltage of the detector tube 38 is the voltage across the resistances 64, 65 and 66 minus the sum of the drops in the coupling resistances 68 and 69 and the biasing resistance 70.

The control grid of detector tube 38 is connected at the junction of resistances 66 and 67 so that it is maintained at a negative potential with respect to the cathode by the voltage drop in the resistance 70. The by-pass condensers 73 and 74 are of large capacity offering substantially no impedance to alternating currents while blocking direct currents and operate to isolate the direct current and alternating current portions of the control grid circuit of the detector tube 38. The condenser 75 performs a similar function in the input circuit of the radio frequency amplifier tube 37.

The grid of the radio frequency amplifier tube 37 is connected through the filtering resistances 76 and 77 to the junction of the resistances 64 and 65. The condensers 78 and 79 cooperate with the resistances 76 and 77 in filtering the direct current biasing potential applied to the grid of the radio frequency amplifier.

As in the case of the circuit shown in Fig. 1, the biasing voltage on the grid of the radio frequency amplifier tube 37 is the difference in voltage drop across two resistance networks, in this case the difference between the drop across resistance 60 and the total drop across the resistances 65, 66 and 67. The voltage across resistance 60 is of such polarity as to maintain the grid of the tube 37 negative with respect to its cathode, while the voltage across the resistances 65, 66 and 67 is of the opposite polarity.

The circuit operates in the same manner as the circuit of Fig. 1 to maintain the audio-frequency output substantially constant irrespective of variations in the amplitude of the radio frequency signal input. The circuit elements are so adjusted that with no signal input the voltage drop across the resistances 65, 66 and 67 predominates over that across the resistance 60 so that the grid is maintained at a small positive bias (initial bias). When radio frequency waves are impressed through the amplifier on the control grid of the detector tube 38, they operate to increase the plate current of that tube causing an increase in the negative potential applied to the grid of the audio-frequency tube 29 and a consequent decrease in its plate current. This reduces the current through the resistances 65, 66 and 67 causing a decrease in the voltage drop therethrough and a consequent increase in the negative bias on the grid of the radio frequency amplifier tube.

When the circuit operates in response to radio frequency signals to increase the negative bias of the radio frequency tube 37, the plate and the screen grid currents are both reduced. As a result, the voltage drop across the resistance 60 tends to decrease. This effect would tend to counteract the gain control effect produce by the decrease in the current to the resistances 65, 66 and 67 since this would decrease the negative component of the grid bias potential of the tube 37 at the same time that the positive component was reduced. However, this effect is prevented by maintaining a fairly heavy ballast current through the resistance 60. It is found that very satisfactory results can be obtained when the ballast current is approximately three times the normal space current of the radio frequency amplifier, though it need not be so large in all cases.

One path for audio-frequency currents from the cathode of the audio-frequency tube 39 to the junction of the resistances 66 and 67 is through the resistance 69, by-pass condenser 80 and the resistance 70. The potential drop set up across the resistance 70 by this audio-frequency current derived from the output circuit of the tube 39 is of such a phase as to result in audio-frequency regeneration. This effect can be readily observed if the resistance 69 is short-circuited. However, such effects are made negligible by making the value of resistance 69 large, for example, of the order of 30,000 ohms. The resistance 71 performs a similar function in the space charge grid circuit although the effect in that circuit is not so noticeable.

The resistance 81 is preferably of very high value, for example, of the order of 100,000 ohms and is provided for protecting the audio-frequency tube 39. Without this resistance, the full voltage of the source 43 might at times be developed across the tube 39 when the filaments (heaters) of the tubes are cold. The effect of the resistance is to reduce the maximum possible potential which is developed across the cathode-anode space of the tube 39 and consequently prevent injury to the tube under such conditions. The resistance is made of such a high value that when the circuit is operating, the by-pass effect is negligibly small.

Figs. 3 and 4 placed side by side, show a combined radio transmitter and receiver embodying the invention. This system is of a type particularly adapted for use where weight and space requirements are controlling, for example, in aircraft.

The system comprises in main, a radio transmitter circuit 300, a radio receiver circuit 400, a power supply unit 100 and a control unit 200. A transmit-receive relay 350 controls the conditioning of the system for transmitting or receiving at the option of the operator. When this relay is in the release position, as shown in the drawings, the system is conditioned for operating the radio receiver 400.

Power for both the transmitter and receiver is obtained from the low voltage armature 101 and the high voltage armature 102 which may be separate generators, or separate armatures of a double voltage generator. The output of the high voltage armature 102 is filtered by means of a low-pass filter comprising series inductances 103 and shunt condensers 104. The potentiometer 105 connected across the output of the low-pass filter 103—104 provides means for obtaining the proper voltage for biasing the screen grids of the radio frequency amplifier tubes of the receiver 400. The switch 210 is provided for controlling the connection of the low voltage armature 101 to the cathode heaters of the tubes of the receiver 400 and to the filamentary cathodes of the tubes of the transmitter 300. When the switch is in the position I, the heater circuit for the tubes of the receiver 400 is closed through the connection from the positive terminal of the

armature 101, connection 131, armature and contact 211 of switch 210, resistance 406 and the cathode heaters of the tubes 405, 404, 403, 402, 401 in series, resistance 407 to the ground connection 130 in the negative terminal of the armature 101.

When the arm of the switch 210 moves to position II, the above connection is maintained and in addition the connections of the filamentary cathode heating circuit of the tubes of the transformer 300 are completed as is later described in detail.

The receiver proper comprises three radio frequency amplifier stages employing the vacuum tubes 401, 402, 403, respectively, a detector stage employing tube 404, and an audio-frequency amplifier stage employing the tube 405. Radio waves received in the antenna 301 are impressed on the grid circuit of the first tube 401 through the condenser 302 and connection 120. The antenna circuit which is common to the transmitter and the input circuit of this first stage of the receiver will be described later in connection with the description of the transmitter. A resistance 414 is connected across the input circuit of the tube 401, the connection being made from the grid of tube 401 through resistance 414 and blocking condenser 416 to the grounded cathode.

Transformers 408, 409 and 410 are provided for coupling together the radio frequency amplifier stages and for coupling the plate or output circuit of the last amplifier tube 403 to the grid or input circuit of the detector 404. The plate of detector 404 is directly connected to the grid of the audio-frequency amplifier 405. The plate circuit of the audio frequency amplifier 405 contains the primary winding of the audio-frequency transformer 411. One terminal of the secondary winding of transformer 411 is connected through the connection 125, blocking condenser 331, armature and contact 353 of the relay 350, connection 129 to one terminal of the telephone receiver 201. The other terminal of the secondary winding is connected through the resistance 441 to ground and the other terminal of the telephone receiver 201.

Like in the circuits of Figs. 1 and 2, the detector and audio-frequency amplifier tubes in addition to their usual functions, operate to provide automatic gain control of the radio frequency amplifiers 401 to 403 maintaining a substantially constant audio-frequency output over a wide range of variation in received signal strength. The detector tube 404 is operated with the bias adjusted to bring the plate current close to cut-off when no signal is impressed on the grid and operates to give plate rectification of the signal. In the process of detection, the plate current of the detector increases, the amount of increase being dependent upon the radio frequency signal voltage impressed upon the grid. The resistance 412 connected to the plate circuit of the detector is also connected in the grid circuit of the audio-frequency amplifier tube 405 and therefore furnishes part of the bias for that tube. This bias increases with the increase of detector plate current which results in a reduction in the audio-amplifier plate current. The detector tube 404 preferably has a high amplification constant and low input capacity.

Plate current at the proper voltage for the radio frequency amplifier tubes 401 to 403 is obtained from the high voltage armature 102 by means of the potentiometer comprising the resistances 431 and 432 which are connected in the following sequence: From the negative terminal of the armature 102, through the connection 132, resistance 431, resistance 432, connection 126, contact and armature 356 of the relay 350 to the positive terminal of the armature 102. The plates of the radio frequency tubes 401 to 403 are connected through the primary windings of the respective interstage transformers, the respective resistances 451, 452 and 453 and the retard coil 450 to the junction of the resistances 431 and 432.

The biasing potential screen grids of the tubes 401, 402 and 403 are obtained from the armature 102 by means of the potentiometer 105 and the gain adjusting potentiometer 203, which is connected across the upper half of the potentiometer 105. The connection can be traced from the midpoint of the potentiometer 105 through connection 133, gain adjusting potentiometer 203, ground connection 130, resistance 441 of the potentiometer 441—442, connection 132 to the negative terminal of the armature 102. The screen grids of the tubes 401, 402 and 403 are connected through the respective resistances 461, 462 and 463 to the variable tap on the potentiometer 203.

The audio-frequency amplifier tube 405 receives its plate current from the high voltage armature 102. For this purpose the voltage of the armature 102 is reduced by means of the potentiometer comprising the resistances 340 and 440 connected in series across the terminals of the armature from the positive terminal through resistance 340, connection 134, resistance 440, and connection 132 to the negative terminal. The plate of the tube 405 is connected through the primary winding of the output transformer 411 to the connection 134 constituting the junction between resistances 340 and 440. The cathode circuit of the audio-frequency amplifier tube 405 includes the series of resistances 424, 423, 422 and 421. These resistances carry, in addition to the plate current of the audio-frequency tube 405, the practically constant current flowing through resistance 425 and serves to furnish part of the grid bias voltage for the audio-frequency tube 405, plate and grid biasing voltages for the detector tube 404 and part of the grid bias voltage for the radio frequency amplifier tubes 401 to 403. The plate of the detector tube 404 is connected through the coupling resistance 412 and the primary winding of the transformer 413 to the junction of the resistances 423 and 424. The transformer 413 is used when the transmitter is operating to permit the use of the tube 405 as the first audio-frequency amplifier. When the receiver is operating, the circuit of the primary winding thereof is opened at the contact 358 of the relay 350 so that the presence of the secondary winding in the circuit can therefore be neglected in considering the operation of the receiver.

The voltage across the resistances 424 and 412 is the proper polarity for supplying a negative bias to the grid of the audio-frequency amplifier tube 405 as will be observed from a consideration of the flow of plate current of the tubes 405 and 404. The grid of the detector tube is connected through the secondary winding of the coupling transformer 410 and filter resistance 474 to the left-hand terminal of the resistance 421. The cathode of the detector tube 404 is connected to the variable tap on the resistance 421.

The total voltage across the resistances 423, 422 and the right-hand portion of the resistance 421 is the plate circuit voltage of the detector tube 404, the true plate voltage being this total voltage less the voltage drop in the resistance 412.

The grid bias voltage for the detector tube 404 is the voltage drop through the left-hand portion of the resistance 421 which is of such a polarity as to bias the grid negatively with respect to the cathode.

Condenser 415 is of such capacity as to give the plate circuit of the detector tube 404 a low impedance to radio frequencies.

The control grids of the radio frequency amplifier tubes 401 and 402 are connected through the respective filter resistances 471 and 472 through the left-hand terminal of the resistance 470. The control grid of the radio frequency amplifier tube 403 is connected through the filter resistance 473 to the right-hand terminal of the resistance 470 which in turn is connected to the junction of the resistances 422 and 423. Resistance 470 performs the function of somewhat reducing the biasing potential supplied to the grids of the tubes 401 and 402, which tubes are operating at a lower energy level than the tube 403. The cathodes of the radio frequency amplifier tubes 401 to 403 are connected together to ground which is the potential of the junction of resistances 441 and 442. Thus, the control grid bias for the radio frequency amplifier tubes 401 to 403 is the net voltage between ground (right-hand terminal of resistance 441) and the junction between resistances 422 and 423. This voltage is the difference between the sum of the drops across resistances 422 and 421 and the drop across resistance 441. The flow of the current is in such a direction that it makes the polarity of the voltage drop across resistance 441 of such a sign as to bias the grids of the radio frequency amplifier tubes negatively with respect to cathode, while the polarity of the drop across the resistances 421 and 422 is of the opposite polarity. Resistance 441 is part of the potentiometer or drain resistor connected across the radio frequency amplifier tube plate supply voltage and carries a substantially constant current made up of two components, one, the constant drain or ballast current through the resistance network and the other, the direct current component of the plate current of the radio frequency amplifier tubes. The constant component predominates. On the other hand, the current through the resistances 421 and 422 is predominatingly variable, the plate current of the audio-frequency amplifier 405 being the predominating component. The values of the resistance elements are so chosen that with no signal input on the receiver, the adjustable top to the resistance 421 may be adjusted to make the drop across the resistances 421 and 422 predominate giving a small positive bias to the grid of the radio frequency amplifier tube, which will be called the initial bias.

While this initial bias is positive, signal currents of small amplitude will operate to give a normal negative bias, the action being as follows: When the signal waves amplified in the radio frequency amplifier tubes 401 to 403 are impressed upon the grids of the detector, the plate current thereof increases, the amount of increase being dependent upon the voltage of the radio frequency signal impressed upon the grid. This increase in plate current causes an increase in the voltage drop across the coupling resistance 412, which being also included in the grid circuit of the audio-frequency amplifier tube 405 increases the negative potential of the grid of that tube and results in a reduction in the plate current of the audio-frequency amplifier tube 405. Since this current flows through the resistances 422 and 421, the voltages there-across will be reduced to a point at which it is less than the voltage across the resistance 441. This results in a net negative bias on the grids of the radio frequency amplifier tubes which negative bias tends to increase with the signal strength, thus reducing the gain of the radio frequency amplifier stages. Inasmuch as the automatic gain control depends for its action upon a change in the radio frequency input to the detector, it is impossible to maintain an absolutely constant audio-frequency output with changing signal strength. However, the change in the radio frequency gain is sufficiently great for small changes in the detector input voltage so that it has been found that the change in the audio-frequency output voltage may be made less than 2 to 1 for a 5000 fold increase in the signal strength within normal operating limits.

In detail, the sequence of operation of the automatic gain control as a signal is tuned in or as the signal increases in strength, is as follows:

1. The radio frequency signal voltage after amplification in the radio frequency amplifier stages is impressed upon the grid of the detector tube 404 causing an increase in the detector plate current flowing through resistance 412.

2. The resulting increase in voltage across resistance 412 supplements the voltage drop across resistance 424 to make the bias of the grid of the audio-frequency tube 405 more negative. This reduces the plate current of this tube and consequently the current through and the voltage drop across resistances 422 and 421.

3. The resulting difference in voltage between the drop across resistances 441 (which is substantially constant) and that across the resistances 422 and 421 will increase (except for weak signals), the voltage drop across resistance 441 predominating and biasing the grids of the radio frequency amplifiers negative. The amount of this bias and hence the reduction in radio frequency gain depends upon the signal strength.

There will be certain secondary effects which tend to oppose the operation of the automatic gain control, but which may be kept within such limits as not to adversely affect the proper operation. These are:

1. The change in current through the resistance 441 due to variations in the plate current of the radio frequency tubes.

2. Variations in the detector plate voltage due to changes in the current through resistances 423, 422 and the right-hand portion of resistance 421.

3. Variations in the grid bias of the audio-frequency tube due to variations in the current through resistance 424.

A reverse sequence of operation will take place when the signal strength is decreasing or tending to decrease. The effect of such reverse sequence will be such as to increase the gain of the radio frequency amplifier stages.

The effect of the automatic gain control is to maintain the audio-frequency output constant not only for such variations in the signal input as are produced by fading phenomena and the like, but also for variations in the signal voltage due to changes in the tuning of the circuit. Thus, when the receiver is not tuned in to a signal, the automatic gain control causes the radio frequency gain to rise to a high value and as the tuning approaches the frequency of the signal, the gain is reduced by the action of the auto-

matic gain control and is again caused to increase as the receiver is tuned away from the desired frequency on the opposite side of the signal. The result is to maintain a nearly constant audio-frequency output over a considerable tuning range at each side of the exact tuning point. The action of the automatic gain control is also apt to produce an effect which gives the impression of more interference than could be noticed with a receiver not so equipped. It is a fact that the maximum sensitivity of the receiver is always available when required. This makes an interfering signal sound louder with a given tuning away from the desired signal than it would in a receiver with manual gain control. However, this latter effect only depends upon the proper tuning of the set and the undesired signal will give no more interference when the set is properly tuned than with sets not having an automatic gain control. However, these effects make it very difficult to tune a set by ear as is done in the case of the usual type of radio receiver. The use of some type of tuning indicator is therefore desirable.

For this purpose there is provided a meter 204 which is so connected as to measure the grid bias voltage of the radio frequency tubes 401 to 403. The connection of this meter may be traced from the junction of the resistances 422 and 423 (the effective potential of the grids of the radio frequency amplifier tubes), through resistance 476, connection 124, right-hand contact and armature 354 of relay 350, connection 128 to the left-hand terminal of the meter 204; right-hand terminal of meter 204 to the cathodes of the radio frequency tubes at the grounded connection at the junction of resistances 441 and 442. Since this meter measures the negative bias of the grids of the radio frequency amplifier tubes, the needle will be against the stop under the condition in which no radio frequency signal is being received and will give a maximum deflection at the exact tuning point.

The connection of the meter through the armature 354 of the relay 350 permits the use of the meter for measuring the output of the radio transmitter 300 when it is being operated, as is described in detail below.

Under ordinary conditions of operation, the automatic gain control takes care of all variations in operating conditions. However, when extremely strong signals are being received, the tubes may become overloaded resulting in annoying disturbances in the telephone receivers. In order to permit operation under such conditions, the manual gain control potentiometer 203 is provided. This potentiometer controls the voltage supplied to the screen grids of the radio frequency amplifier tubes and may be operated to reduce this voltage and consequently the gain of the radio frequency amplifier stages, when extremely loud signals are being received.

Radio transmitter

The radio transmitter 300 comprises a crystal-control oscillator employing a tube 310, a modulating amplifier employing a tube 320 and an audio-frequency amplifier employing a tube 330. As indicated above and described in detail below, the audio-frequency amplifier tube 330 is a second stage of audio-frequency amplification and receives its audio-frequency current from the audio-frequency tube 405 of the receiver.

The transmitter is operated only when the cathode control switch 210 is in the position II and the push button 205 is operated to operate the transmit-receive relay 350. When the cathode control switch 210 is in the position II, cathode heating current is supplied to the tubes 310, 320 and 330 through the following circuit: From the positive terminal of the low voltage armature 101 through connection 131, arm and contact 212 of switch 210, connection 127, the cathodes of the tubes 310, 320 and 330 in parallel to the grounded negative terminal of the low voltage armature 101, resistances 312, 322 and 332 being connected in series between the positive leads of the cathodes of the tubes 310, 320 and 330 respectively.

Plate current for the tubes 310, 320 and 330 is supplied from the high voltage armature 102 through the following circuit: From the positive terminal of the armature 102, through armature 356 and left-hand contact to the positive bus 360 and from the negative terminal of the armature 102 through the armature 355 and resistance network 361, 362 to the grounded cathode circuit. In the operation of the transmitter the resistance network 361—362 is in parallel with resistance 441.

The oscillator employs a piezo-electric crystal 311 connected between the grid and cathode of the tube 310. The crystal is maintained at a constant temperature by means of a heater element 309 supplied with current from the low voltage armature 101 and controlled by means of a thermostat 303 and a relay 304. The heater circuit may be traced from the positive terminal of the armature 101 through the armature and contact of the relay 304, heater element 309 to the grounded negative terminal of the armature 101. When the temperature of the crystal reaches a certain predetermined value, the thermostat 303 operates to complete the circuit from the grounded negative terminal of the armature 101 through thermostat 303, winding of relay 304 to the positive terminal of the armature 101. The operation of the relay 304 opens the circuit through the heater element 309 permitting the crystal to cool down to a point at which the circuit through the thermostat is broken and the relay 304 released to again close the heater circuit. The resistance-condenser network 305 is provided to prevent damage to the thermostat 303 by inductive surges resulting from the opening of the relay circuit.

The grid of the tube 310 is connected through the grid leak resistance 313 to the junction of the resistances 361 and 362, the grid being maintained at a negative potential with respect to the cathode by the drop in the resistance 362. The radio frequency plate circuit of the oscillator tube 310 may be traced from the plate, through the plate circuit inductance 314, blocking condenser 315 to the grounded cathode circuit. The direct current plate circuit may be traced from the plate through the inductance 314, resistance 316 to the positive bus 360.

The grid circuit of the modulating amplifier tube 320 includes an inductance 328 coupled to the inductance 314. The alternating current grid circuit of the tube 320 may be traced from the grid of the tube through the inductance 328, blocking condenser 327 to the negative cathode terminal. The tuning condenser 321 is provided for tuning the grid circuit to select the second harmonic output of the oscillator tube 310. The direct current grid circuit of the tube 320 may be traced from the grid through the inductance

328 and grid leak resistance 323 to the juncture of the resistances 361 and 362, the grid being maintained negative with respect to the cathode by the voltage drop in resistance 362. Inductance 329 and condenser 324 provide a Rice type neutralizing circuit for preventing the tube from oscillating. The inductance 329 coupled to the inductance 328 has one terminal connected to the cathode through the blocking condenser 327 and the other terminal to the anode through the neutralizing condenser 324. The plate of the tube 320 is connected to a tap on the antenna tuning inductance 308. The alternating current plate circuit may be traced from the anode through the lower portion of the inductance 308, blocking condenser 325, thermocouple 318 to ground at the negative cathode terminal. The direct current anode circuit may be traced from the plate through the lower portion of inductance 305, secondary winding of the modulation transformer 334, resistance 326 to the positive bus 360.

The upper terminal of the antenna circuit conductor 308 is connected through the tuning condenser 306 in the antenna 301. A resistance 307 is connected between the antenna and ground.

Vacuum tube 330 supplies a second stage of audio-frequency amplification. This tube receives its plate current directly from the positive bus 360 through the primary winding of the modulating transformer 334. The grid is connected to the secondary winding of the audio-frequency transformer 411 through the connection 125 previously described. The grid circuit is completed from the other terminal of the transformer 411 through resistances 441 in parallel with resistance network 361—362 to the grounded cathode terminal. The grid biasing potential is furnished by the drop across the resistance network.

The audio-frequency tube 405 of the radio receiver is used to give the first stage of amplification for the transmitter. When the relay 350 is operated, the audio-frequency circuit of the microphone 202 may be traced from the grounded terminal of the microphone through primary of the audio-frequency input transformer 413, connection 123, blocking condenser 365, contact 358 and connection 122 to the microphone 202. The microphone 202 receives its direct current from the low voltage armature 101. This circuit may be traced from the grounded negative terminal of the armature 101 to the grounded terminal of the microphone, connection 122, contact 358, armature 352 of relay 350, resistance 364, choke coil 363, connection 127, filament switch 210, connection 131 to the positive terminal of the armature 101. The retard coil 363 prevents the flow of audio-frequency current in this direct current circuit while the blocking condenser 365 prevents the flow of direct current in the audio-frequency circuit of the microphone. Armature 352 and contact 358 of relay 350 are so arranged that the direct current circuit of the microphone is closed before the audio-frequency circuit is completed thus preventing microphone surges from reaching the amplifier.

When transmitting, the telephone receivers 201 are connected across the secondary winding of the audio-frequency transformer 411 in series with the resistance 366 thus giving side tone so that the operator may be assured that the transmitter is being properly modulated. When the relay 350 is in the unoperated position, resistance 366 is short-circuited through the armature 353 of the relay 350 so that the full output of the radio receiver is applied to the telephone receivers 201.

In transmitting, the connection to the potentiometer 431—432 for the plate current supply for the radio frequency tubes 401—403 is broken at the armature 356 and right-hand contact and the grid of tube 401 grounded through the connection 120 and armature 357.

In transmitting, the meter 204 is switched from the receiver circuit to the transmitter circuit through the operation of the armature 354 so that the output of the radio transmitter is indicated. Thus, when the relay 350 is operated the meter 204 is connected to the thermocouple 318 through connection 128, armature 354 and its left-hand contact.

The relay 350 is operated by the push button 205, operating current being supplied from the armature 101 through the circuit from the grounded terminal of the armature 101, connection 130, push button 205, connection 121, armature 351, winding of relay 350, connection 127, filament switch 210 to the positive terminal of the armature 101. Upon the operation of the relay, the contact at armature 351 is opened connecting the resistance 367 in series in the winding circuit of the relay 350 thus increasing the resistance of the winding circuit so that only sufficient current is drawn to hold the relay in the operating position. This reduces the current drain on the armature 101.

What is claimed is:

1. A radio receiver comprising an electron discharge device having control elements and being arranged to amplify the received radio wave, a second electron discharge device arranged to detect the radio wave amplified by the first device, a third electron discharge device having a control element conductively connected to the anode of said second device, a source of direct current, connections from a positive terminal of said source to the anode of the third device, a resistance network having one terminal connected to the cathode of said third device and a second terminal connected to the negative terminal of said source, a resistance element connected between the control element of said third device and a point on said resistance network, connections between the cathode of said second device and a point on said resistance network negative with respect to the last mentioned point thereon, connections from the control element of said first device to a point on said resistance network positive with respect to said second terminal thereof, connections from the anode of said first device to the positive terminal of said source and a resistance element connected between the cathode of said first device and the negative terminal of said source.

2. A radio receiver comprising an electron discharge device having control elements and being arranged to amplify the received radio wave, a second electron discharge device arranged to detect the radio wave amplified by the first device, a third electron discharge device having a control element conductively connected to the anode of said second device, a source of direct current, connections from a positive terminal of said source to the anode of the third device, a resistance network having one terminal connected to the cathode of said third device and

minal of said source, a resistance element connected between the control element of said third device and a point on said resistance network, connections between the cathode of said second device and a point on said resistance network negative with respect to the last mentioned point thereon, connections from the control element of said first device to a point on said resistance network positive with respect to said second terminal thereof, connections from the anode of said first device to the positive terminal of said source, a second resistance network having one terminal connected to the negative terminal of said source and another terminal connected to the positive terminal of said source, and connections from the cathode of said first device to an intermediate point on said second resistance network.

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