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G. R. EATON ET AL

2,050,291

RADIO RECEIVING SYSTEM

Filed Nov. 20, 1929

2 Sheets-Sheet 1

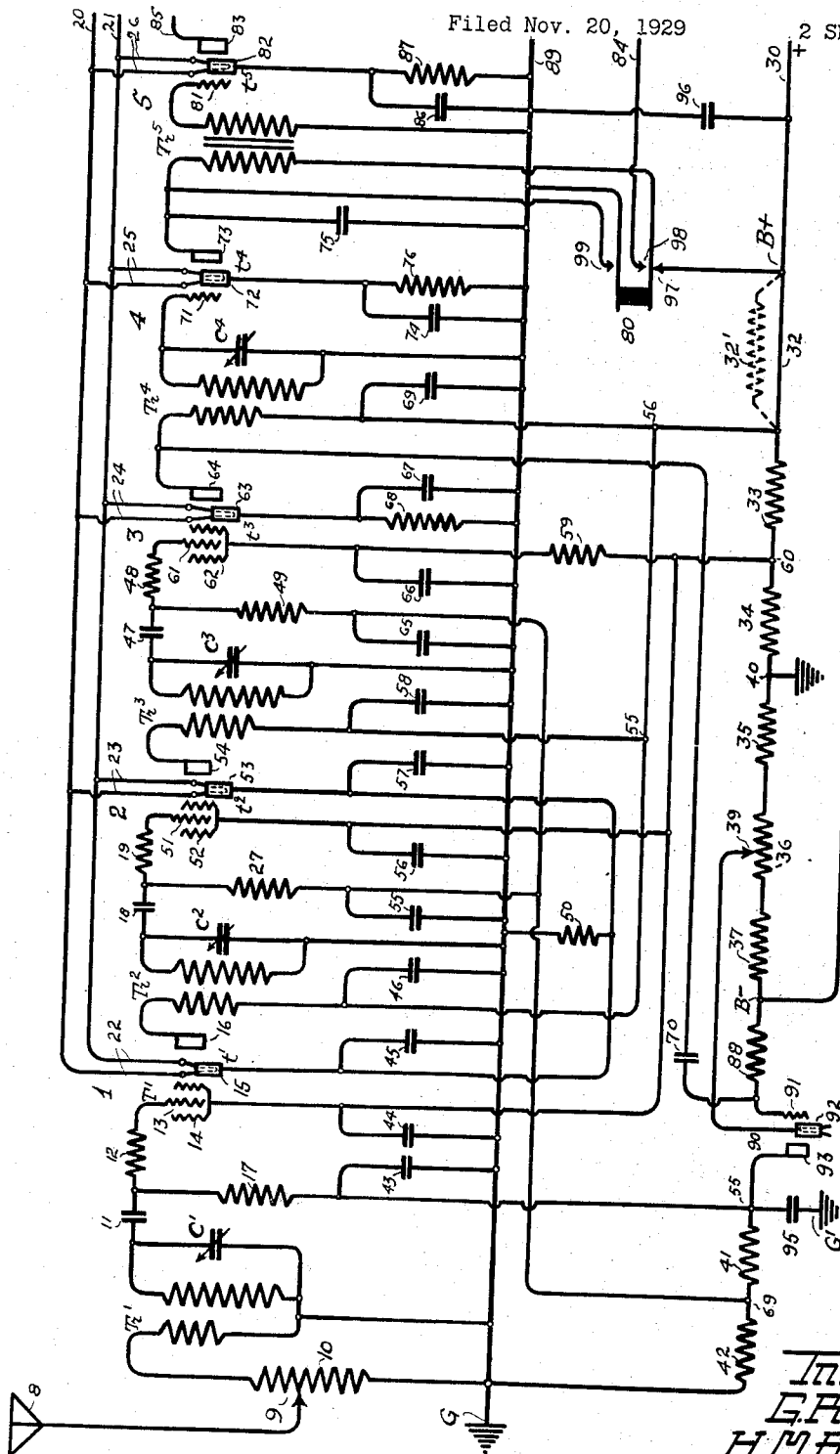


Fig. 1.

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2 Sheets-Sheet 2

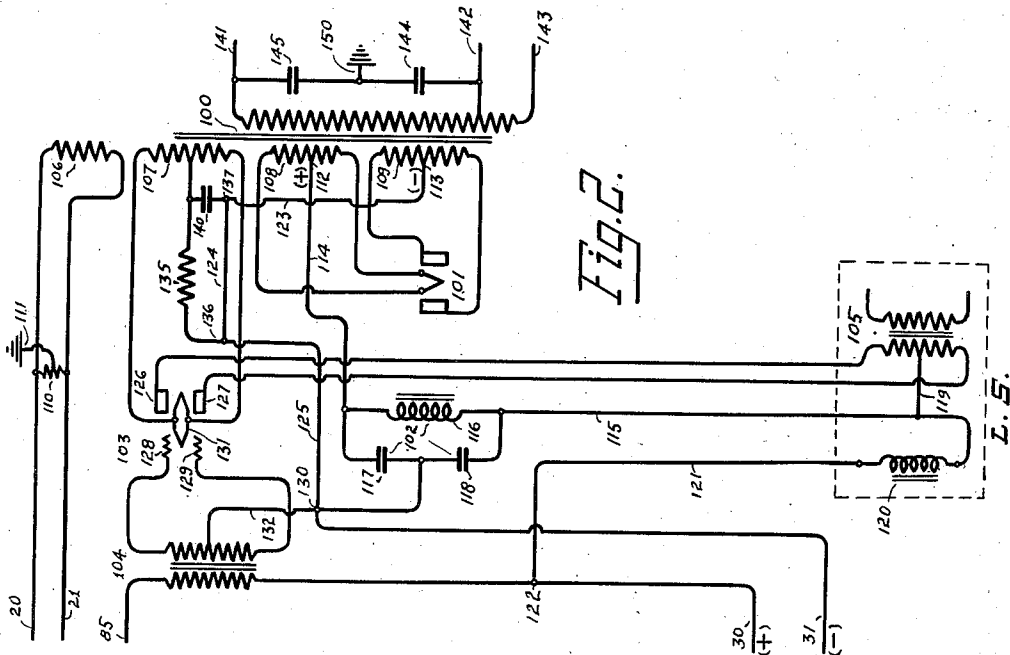


Fig. 2.

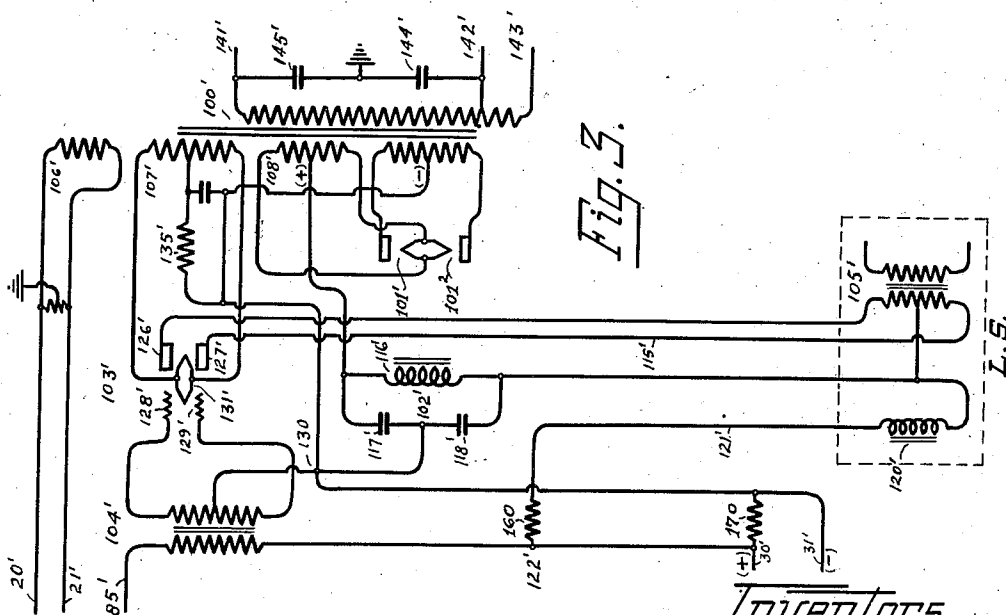


Fig. 5.

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UNITED STATES PATENT OFFICE

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RADIO RECEIVING SYSTEM

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1 Claim. (Cl. 179—171)

Our invention relates to radio receiving circuits, and more particularly to a radio signal amplification system in combination with a source of rectified alternating current, and the object of our invention is to provide an improved circuit arrangement for amplifying signal modulated electric waves.

A feature of our invention is the provision of a radio signal receiving system using in its high frequency amplification stages audion tubes of the tetrode type having an equi-potential cathode and a grid screen and deriving its operating power from a common transformer whose secondary winding furnishes unmodified alternating current for heating the filaments of the cathodes and, upon rectification, direct current potentials for polarizing the grids, the grid screens, the cathodes and for establishing a space discharge.

A further feature of our invention is the provision of an improved automatic volume control device adapted to maintain automatically the output strength of the received signals to a certain predetermined value regardless of the fact whether said signals arrive from a definite transmitting station, or from various transmitting stations in the course of the tuning operation.

Another feature of our invention is the provision of a volume control resistance associated on one side with the antenna, on the other side with the primary winding of the first coupling transformer and designed, while regulating the strength of the received signals, to maintain the impedance of the said primary winding constant.

Another feature of our invention resides in a manual volume control which is operative on the radio amplifier of our circuit in combination with an automatic volume control.

A further feature of our invention resides in the specific arrangement for operating the low frequency amplifier stages of our receiving set from a phonograph pick-up device.

Another feature of our invention has to do with the circuit arrangement of the push-pull amplifier which is used as a final audio amplification stage.

A still further feature of our invention is the provision of means for operating the power supply unit of our receiving set so that different power supply voltages may be connected thereto.

For a better understanding of our invention reference may be had to the following description in connection with the accompanying drawings in which:

Fig. 1 is a diagrammatic representation of the receiving set circuits;

Fig. 2 illustrates diagrammatically an alternating current rectifying and power supply unit together with a push-pull amplifier and a loud speaker circuit, all intended to be used in combination with the receiving set as illustrated in Fig. 1; and

Fig. 3 is similar to Fig. 2 except for minor modifications to be referred to subsequently.

Referring now more in detail to Fig. 1 it will be noted that we have illustrated a radio signal receiving system comprising three high frequency amplifying stages connected in cascade and designated respectively as 1, 2, and 3, one detector stage designated as 4, and one low frequency amplification stage designated as 5. The three thermionic tubes of the high frequency amplifier t^1 , t^2 and t^3 respectively are of the tetrode type having a shielded grid and an equi-potential alternating current indirectly heated cathode. The detector tube t^4 and the low frequency amplifier tube t^5 differ from the high frequency amplifier tubes only in so far as they have no grid screen. Alternating current for heating the cathodes of the tubes is supplied to the receiving set by the bus bars 20 and 21 originating in the power supply unit as illustrated in Figs. 2 and 3. From the bus bars 20 and 21 parallel circuits designated respectively as 22, 23, 24, 25, and 26 branch off to the heating filaments of the tubes. Direct current for the tube anodes and for the appropriate polarizing of the control electrodes, the grid screens and the cathodes of the tubes is supplied to the set by the bus bars 30 and 31 in a manner to be hereinafter described.

Each of the three high frequency amplifier stages 1, 2, and 3, and the detector stage 4 is provided with an individual air core coupling transformer designated respectively as Tr^1 , Tr^2 , Tr^3 and Tr^4 . The low frequency stage 5 is coupled to the detector by the iron core audio transformer Tr^5 . Each of the secondary windings of the transformers Tr^1 , Tr^2 , Tr^3 and Tr^4 have their one side grounded at G, each of these windings being moreover shunted by a corresponding variable condenser designated C^1 , C^2 , C^3 and C^4 respectively, and designed to form resonant circuits with said secondary windings. For the purpose of tuning to the various frequencies of the incoming signals, the said condensers C^1 , C^2 , C^3 and C^4 are multiple or gang controlled.

Coming now to the arrangement by virtue of which direct currents for the space discharge, and direct current polarity of the requisite potential gradients are supplied to the various electron tubes, it will be noted that the bus bars 30

and 31 of which the first is positive and the second is negative and which form the continuation of similarly marked bus bars in the power supply units of Figs. 2 and 3, are bridged between their respective terminals B+ and B- by a resistance strip consisting of resistances 33, 34, 35, 36, and 37 connected in series.

The fact that an intermediate point 40 between the resistances 34 and 35 is grounded, positions the polarity of the supply terminals B+ and B- with respect to ground so that the ground potential is positive relative to the negative side of the power supply. Resistance 36 on the negative side of the resistance strip is linked to ground also by a branch circuit comprising slide contact 39, the audion tube 90 and the resistances 41 and 42. The operation of the audion tube 90 as part of a volume control arrangement will be subsequently described more in detail.

It is obvious that from the resistance strip arrangement as described we may obtain various operating voltages for the tubes, as desired, on the potentiometer principle, depending upon which intermediate points between the supply terminals B+ and B- are tapped. The manner in which this has been accomplished in the case of each individual tube will become clear as we trace the travel and transformation of the modulated signal frequencies from the antenna to the last amplifier tube inclusive.

After being picked up by the antenna 8 the modulated high frequency oscillations are made to pass through resistance 10 which in combination with its slide contact 9 can be made use of as a volume control, as will be subsequently explained more in detail, and through the primary of transformer Tr' to ground. On the way they set up similar oscillations in the resonant circuit formed of the secondary winding of transformer Tr' and condenser C'. From the latter circuit the high frequency oscillations are transmitted in the well known manner across the coupling condenser 11 and resistance 12 to the grid 13 of the first amplifier tube t'. The input circuit of the first amplifier tube can be traced from grid 13, through resistance 12, coupling condenser 11, secondary of transformer Tr', condenser 45 to the cathode 15.

The biasing circuit of tube t' can be traced from grid 13, through resistances 12, 17, 41, and 42 to ground, and from ground across resistance 50 to the cathode. The last named resistance 50 traversed by the plate current is the biasing resistance. Resistances 41 and 42 serve to impart an additional bias to the grid in connection with the volume control arrangement, as will be subsequently explained. Resistance 17 serves as a grid leak and resistance 12, like the similarly connected resistances 19 and 48 in the second and third amplifier stages, serves as a stabilizer by acting to reduce the undesirable regenerative energy transfer from the plate to grid circuits due to stray capacities.

The output circuit can be traced from the anode 16 through the primary of transformer Tr², condensers 46 and 45, to the cathode 15. This is the path of the high frequency oscillations, the path of the direct current for the space discharge can be traced from the anode 16, through the primary of transformer Tr², resistances 33 and 34 on the positive side of the resistance strip to ground, biasing resistance 50, to the cathode 15. The grid screen 14 is connected to tap 60 on the positive side of the resistance strip, said tap 60 being chosen so as to

impart to the grid screen 14 a potential intermediate that of the cathode and the anode, with a view of minimum internal capacity of the tube. It will be noted that tap 60 is common to the grid screens of the other two high frequency amplifier tubes t² and t³ and that the three grid screens 14, 52 and 62 are linked to ground by individual condensers 44, 56, and 66 respectively. The function of these condensers is to offer a low impedance path to high frequency currents.

Condenser 43 serves to by-pass any stray frequencies which might otherwise be impressed upon the grid. Likewise, condenser 46 besides supplying a low impedance path in the output circuit serves to by-pass any stray frequencies which might otherwise, through the internal capacity of transformer Tr², become ingrafted upon the signal frequencies. Condenser 45 offers a low impedance path for both, the input and output circuits.

From the anode 16 of tube t' the magnified signal oscillations are transmitted to the grid 51 of tube t² through the instrumentality of coupling transformer Tr², the resonant circuit formed of its secondary winding and condenser C², the coupling condenser 18, and resistance 19. The input circuit of tube t² can be traced from grid 51, through resistance 19, coupling condenser 18, secondary of transformer Tr², condenser 57 to the cathode 53.

The biasing circuit of tube t² can be traced from grid 51, through the resistance 19, grid leak 27, resistances 42 and 50 to the cathode 53. The initial biasing resistance 50 is common to the first two high frequency amplifier tubes. Resistance 42 serves to impart an additional bias to the grid 51 in connection with the volume control arrangement.

The output circuit can be traced from the anode 54 through the primary winding of transformer Tr³, by-pass condensers 58 and 57 to the cathode 53. The direct current circuit for the space discharge can be traced from the anode 54, through the primary winding of transformer Tr³, resistances 33, 34 and 50 to the cathode 53. The grid screen 52, as has been indicated, is connected to tap 60 on the positive side of the resistance strip for the purpose of reducing the internal capacity of the tube.

Condenser 55 in addition serves to by-pass stray frequencies. Condenser 57 supplies a low impedance path for the signal frequencies in both the input and output circuits. Condenser 58 in addition to serving as a link in the output circuit, keeps stray frequencies from reaching the transformer Tr³.

From the anode 54 of tube t² the magnified signal oscillations are transmitted to the grid 61 of tube t³ in the usual manner across the coupling transformer Tr³ and the resonant circuit formed of its secondary winding and condenser C³. The input circuit of tube t³ can be traced from the grid 61, through resistance 48, coupling condenser 47, secondary of transformer Tr³, condenser 67 to the cathode 63. The initial biasing circuit can be traced from the grid 61, through resistance 48, grid leak 49, resistances 42 and 68 to the cathode 63. 68 serves as an initial or basic biasing resistance, while resistance 42 serves to impart to the grid an additional bias in connection with the volume control arrangement. The output circuit can be traced from the anode 64 through the primary winding of transformer Tr⁴, by-pass condensers 69 and 67 to the cathode 63.

The direct current circuit for the space discharge can be traced from the anode 64, primary winding of transformer Tr^4 , resistances 33, 34, and 68 to the cathode 63. The grid screen 62 is connected through resistance 59 to tap 60 on the positive side of the resistance bridge.

Condensers 65, 67, and 69 serve the same purposes as the similarly connected condensers in the preceding two amplifier stages. From the last high frequency amplifier tube the magnified signal oscillations are transmitted to the grid 71 of the detector tube t^4 in the usual manner across the coupling transformer Tr^4 and the resonant circuit formed by its secondary winding and condenser C^4 . The input circuit of the detector tube can be traced from the grid 71, through secondary winding of transformer Tr^4 , condenser 74 to the cathode 72. The output circuit can be traced from the anode 73, through primary winding of transformer Tr^5 , contact 97, condenser 96 and condenser 74, to the cathode 72. The direct current circuit for the space discharge can be traced from the anode 73, the primary winding of transformer Tr^5 , switch 80, whose purpose shall be indicated hereinafter, positive terminal B+, resistances 33, 34, and 76 to the cathode 72. The biasing circuit can be traced from the grid 71, through secondary of transformer Tr^4 , biasing resistance 76 to the cathode 72.

From the anode 73 of the detector tube the audio frequencies are transmitted to the grid 81 of the low frequency amplifier tube t^5 in the usual manner across the audio transformer Tr^5 . The input circuit of tube t^5 can be traced from the grid 81, through secondary winding of transformer Tr^5 , condenser 86, to the cathode 82. The output circuit can be traced from the anode 83, over conductor 85, continued in Fig. 2, through primary of transformer 104, to bus bar 30, common to Figs. 1 and 2, and condensers 96 and 86 to the cathode 82. The direct current circuit for the space discharge can be traced from the anode 83, over conductor 85, common to Figs. 1 and 2, through primary winding of transformer 104, bus bar 30, common to Figs. 2 and 1, resistances 33, 34, and 87 to the cathode 82. The biasing circuit can be traced from grid 81, through secondary winding of transformer Tr^5 , biasing resistance 87 to the cathode 82.

Coming now to the volume control arrangement, it has been set forth that resistance 36 on the negative side of the resistance strip is linked to ground by a branch circuit comprising the slide contact 39, the internal resistance of volume control tube 90 and the resistances 41 and 42, which, as has been indicated, are included in the additional biasing circuits of the three high frequency amplifier tubes. The grid 91 of the volume control tube 90 is linked on one side through resistance 88 to the negative supply terminal B-, on the other side through the small condenser 70 to the anode 64 of the last high frequency amplifier tube t^3 .

For the purpose of establishing the proper potential between the anode and cathode required for the space discharge in tube 90, it is to be noted that the anode 93 is connected to ground which is above negative potential, while the cathode derives its voltage from the negative side of the resistance strip. This circuit extends from the anode 93, through resistances 41, 42, 35 and part of resistance 39, to the cathode 92.

Since the resistances 41 and 42 form a part both of the biasing circuits of the high frequency

amplifier and of the volume control circuit, it is evident from the manner in which they are connected that an increase of the plate current of the volume control tube 90, would increase the voltage drop in these resistances and consequently increase also the negative bias of the amplifier tubes, which in turn operates to reduce the amplitude of the signal oscillations. A decrease of the plate current of tube 90 would in a similar manner operate to increase the volume of the signal. The plate current in our arrangement can be varied by varying the grid voltage. The grid to cathode circuit can be traced from the grid 91 through resistances 88 and 37, part of resistance 39 to the cathode. The resistances just referred to are proportioned in such a manner as to bring the operating point of the tube 90 to the lower bend of the static characteristic curve, which, as is well known, causes the tube to function as a rectifier.

There are two ways in which the plate current of tube 90 can be varied. One is by the operator varying the portion of resistance 39 included in the grid to cathode circuit, and since the resistances 37 and 39 form part of the resistance strip, it is obvious that moving the slide contact 39 to the right increases the voltage drop between B- and the slide contact 39, thus increasing the negative bias of the grid 91 and reducing the plate current. Moving the slide contact 39 to the left does in a similar manner effect an increase of the plate current of tube 90.

As to the second method in which the plate current of the volume control tube 90 is automatically varied, this is done in our arrangement through the instrumentality of condenser 70 linking the grid 91 to the anode of the last radio frequency tube. It is obvious that an increase in the radio frequency potential in the radio frequency amplifier tube t^3 would operate through condenser 70 to increase the amplitude of the grid potential oscillations of the volume control tube 90, and since tube 90 is adjusted to operate as a rectifier, the increased potential oscillations of the grid will operate in the well known manner to increase the plate current of the tube, which as has been previously explained, automatically increases the negative bias of the high frequency amplifier tubes and reduces the output volume of the signal by decreasing the amplifier gain.

The need for an automatic volume control arises most commonly in the course of the tuning operation, when the operator has once adjusted the volume control device to a certain desired volume output from a transmitting station A, and switches to some other station B which is either located nearer to the receiver, or is more powerful than A, then the volume output would increase if were not for the action of the automatic volume control device which holds down the volume output to the predetermined value. The automatic volume control device also operates to maintain the signal output from a certain station at the predetermined volume, if the signals from the station vary in strength.

We have indicated two different methods for manual control of the volume output of our receiving set, one is effected by resistance 36 and its slide contact 39, the other by resistance 10 and its slide contact 9 associated with the antenna 8. The first is to be used in preference by the operator for finer adjustment and for predetermining the automatic volume control; the other is to be employed when the signals from some powerful or nearby station are to be reduced

to a moderate volume. Resistance 10 has been proportioned in such a manner that the impedance of the primary winding of transformer Tr' remains constant irrespective of the location of slide contact 9, thus excluding the possibility of disturbing the simultaneous resonance of the three gang-controlled resonant circuits.

Condenser 95 linking the plate 93 of the volume control tube 90 to ground at G' operates in conjunction with condenser 43 of the first amplifier stage to supply a low impedance path to undesirable energy which may feed back into the first stage from the second and the third amplifier stages.

Condenser 96 linking the positive bus bar 30 to ground, in addition to its functions as previously indicated, operates to shunt undesirable ripples due to the alternating currents of the power supply unit.

Switch 80 is to be used for operating the receiving set, more exactly its low frequency amplifier stages, from a phonograph pick-up device. For this purpose the phonograph pick-up device is connected between lead 84 and ground at 89, and switch 80 is lifted so that it opens contact 97 and closes contacts 98 and 99.

Coming now to the power supply arrangement as illustrated diagrammatically in Fig. 2 it may be noted that it consists in the main of a power transformer 100 whose primary winding can be connected to a source of commercial alternating current: a full wave rectifier tube 101 fed from a secondary winding of said transformer 100; a filter 102 consisting of an inductance 116 and two condensers 117 and 118; a push-pull amplifier having tubes 103, an input transformer 104 and an output transformer 105, the latter being incorporated with the loud speaker LS, whose electrical connections are represented diagrammatically at the bottom of the drawings.

The secondary winding of transformer 100 is subdivided into four independent coils 106, 107, 108 and 109, respectively. 106 supplies alternating current for the heating filaments of the tubes through the bus bars 20 and 21, already referred to in a previous section of our description and to the heater of the automatic volume control tube. A resistance 110 connected between the bus bars 20 and 21 has its mid-point grounded at 111 for the purpose of eliminating ripples due to the alternating currents and high frequency currents.

Secondary coil 107 supplies the filaments of the push-pull amplifier tubes 103. Secondary coil 108 supplies the filament of the rectifier tube 101, its center tap 112 forming the positive terminal of the rectified voltage while the center tap 113 of coil 109 connected to the plates of the rectifier tube forms the negative terminal. The manner of operation of rectifier tube 101 is well known in the art.

The supply of positive voltage to the receiving set can be traced from the positive terminal 112, over lead 114, through filter 102, lead 115, field coil of loud speaker 120, lead 121 to tap 122, from where it is delivered on one side through the primary of the input transformer 104 to the anode of the audio frequency amplifier tube, and on the other side through the bus bar 30, already referred to in a previous section, to the resistance strip as shown in Fig. 1.

The supply of negative voltage to the receiving set can be traced from the negative terminal 113 of the rectifier over leads 123, 124, and 125 to tap 130, said tap 130 being common to the filter 102,

the input circuit of the push-pull amplifier tube and to bus bar 31 leading to the negative terminal of the resistance strip in Fig. 1.

The manner in which the filter 102 consisting of the inductance 116 incorporated in the positive supply line and condensers 117 and 118 linking each of its ends to the negative supply line, operates to reduce the direct current flowing in the said supply lines to uniformity, is well known in the art.

The purpose of the push-pull amplifier in our arrangement is two fold, first, to serve as a final audio-amplifying stage, and second, to eliminate undesirable even harmonics which might have become ingrafted upon the signal wave in the course of the previous amplification.

The input circuit of the push-pull amplifier tubes can be traced from either of the grids 128 and 129, through half of secondary winding of transformer 104, lead 132, to tap 130, over lead 125, through condenser 140, secondary coil 107 to the cathodes 131.

For the purpose of imparting the proper potential gradient to the anodes of the push-pull amplifier tubes with respect to the cathodes, it will be noted that the anodes 126 and 127 communicate, with the positive terminal 112 of the rectifier through the primary winding of the output transformer 105, lead 119, lead 115, filter 102 and lead 114. The average potential of the cathodes 131 on the other hand is brought down to the level of the negative terminal 113 of the rectifier by connecting the center tap of coil 107 supplying the cathodes to the said negative terminal 113 through resistance 135, tap 136, lead 124, tap 137, and lead 123. The elements just enumerated traced from cathode to anode form the output circuit of the push-pull amplifier tubes, except that condenser 140 should be substituted for resistance 135.

The audio frequency signal oscillations passing through the primary winding of the input transformer 104 induce similar oscillations in the secondary winding from whence these are communicated to the grids 128 and 129 and magnified in the output circuits as just traced. The magnified oscillations combine in the well known manner in the primary winding of the output transformer 105 eliminating even harmonics and inducing corresponding oscillations in the secondary winding from where the energy is transferred to the voice coil of a dynamic type of loud speaker, not shown in the figure, vibrating in a field generated by field coil 120.

The purpose of condenser 140 shunting the biasing resistance 135, has been indicated, namely, to supply a low impedance path in both the input and output circuits of the push-pull amplifier tubes.

The primary winding of transformer 100 is provided with three terminals 141, 142, and 143, of these 141 and 142 are designed to receive the commonly available alternating current voltage, while 141 and 143 can be used in localities where the voltage is slightly higher. The condenser bridge between the terminals 141 and 142 consisting of condensers 144 and 145 intermediately grounded at 150 is designed to offer a low impedance path to any undesirable stray high frequencies which might have become introduced into the alternating current supply lines.

Referring now to Fig. 3 it will be noted it consists essentially of the same elements as Fig. 2 except that instead of a double wave rectifier tube 101 (Fig. 2), two single wave rectifier tubes

101' and 101² are used. Since the voltage delivered by the rectifier in this case is considerably higher than in the case of the single tube rectifier, resistance 160 is inserted between the field coil of loud speaker 121' and tap 122' in order to bring the voltage supplied to the receiving set down to the desired value. For the same reason resistance 32' is substituted for strap 32 between the positive terminal B+ and tap 56 in Fig. 1. Resistance 170 in Fig. 3 connected between the bus bars 30' and 31' serves to stabilize the voltage supplied to the anodes of the radio frequency amplifier tubes. It also increases the current through the field coil of the loud speaker.

In general the operation of the system consists in tuning in the desired signal by rotating the gang condenser and then setting the automatic control device to the desired volume output. If the volume input was to vary now, the automatic control tube increases or decreases the bias on the radio amplifier tubes to maintain the volume output constant. If the tuning device is now rotated to tune in another station the automatic volume control mechanism operates to control the radio amplifier to maintain the volume output constant. The manual volume control 9 is

used if the set is situated near a powerful broadcasting station and it is desired to further reduce the volume output.

While we have shown certain specific circuit arrangements it is obvious that changes and modifications may be made without departing from the spirit of our invention, therefore, the invention should only be limited by the scope of the appended claim.

Having described our invention, what we claim as new and desire to secure by United States Letters Patent is:

In an amplifier circuit provided with audion tubes and with coupling transformers included in the input and output circuits of said tubes, a volume control resistance connected immediately of the antenna and the primary winding of first coupling transformer and proportioned to maintain the total impedance of the circuit associated with said primary winding constant irrespective of the variations of the volume control resistance, and resistances in, certain of said input circuits for reducing undesirable regenerative energy.

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