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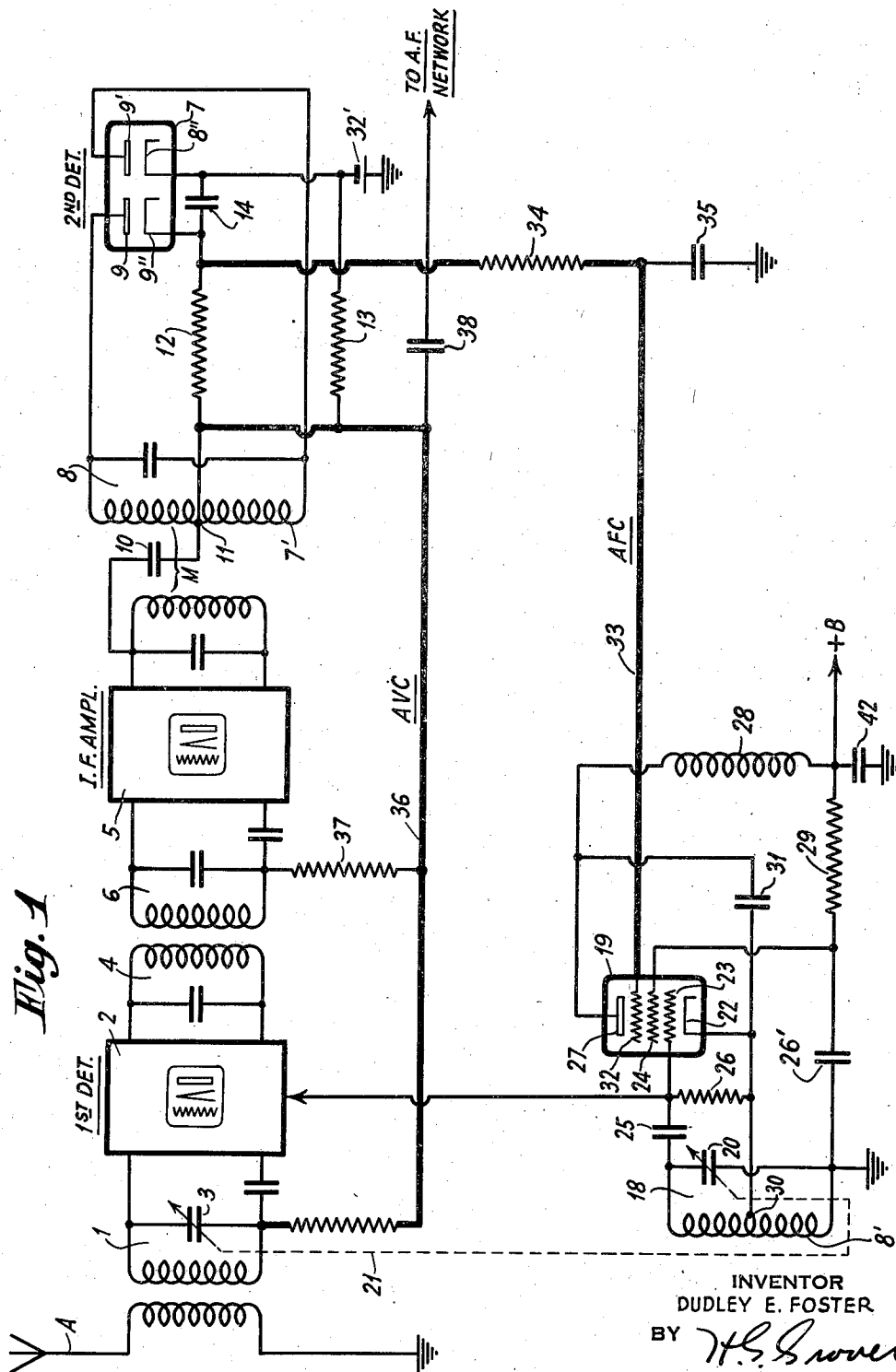
D. E. FOSTER

2,128,642

AUTOMATIC FREQUENCY CONTROL CIRCUIT

Filed June 27, 1936

2 Sheets-Sheet 1



INVENTOR
DUDLEY E. FOSTER
BY *H. B. Snow*
ATTORNEY

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D. E. FOSTER

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Fig. 2

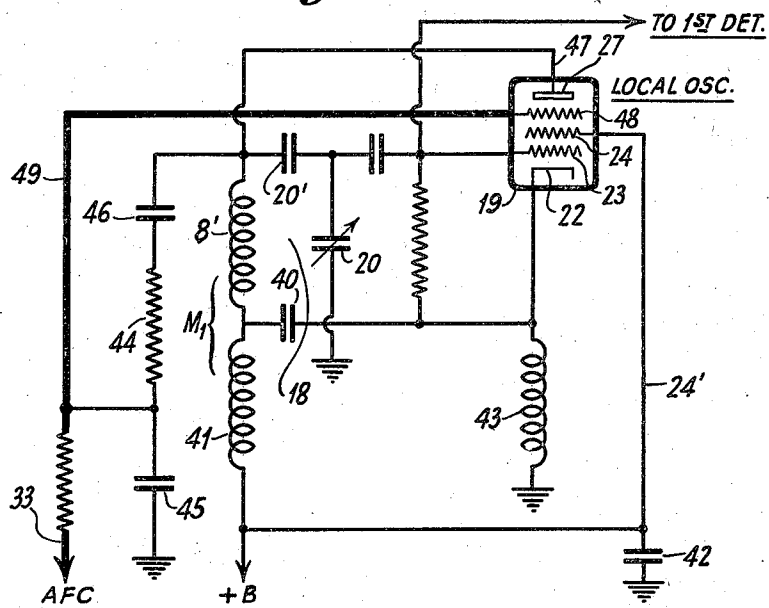
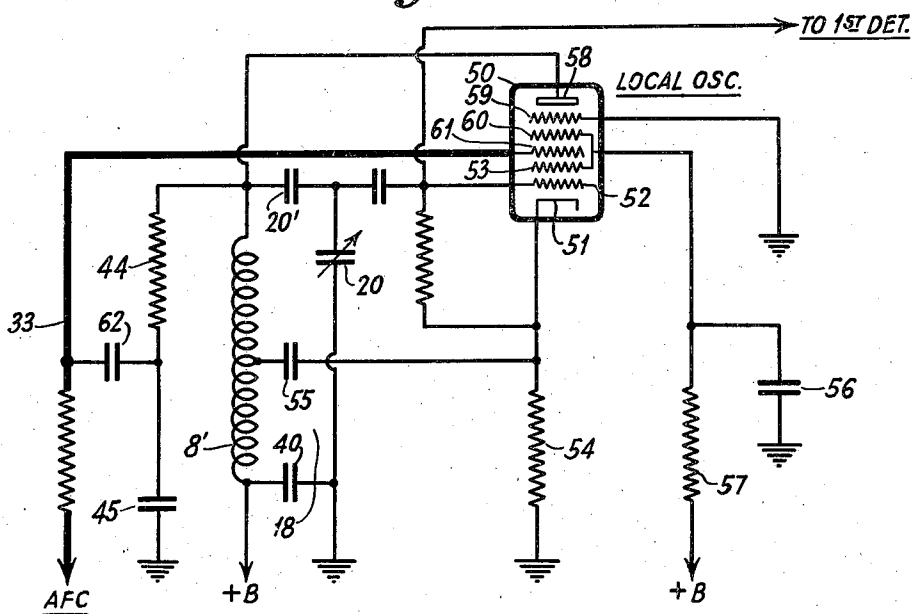


Fig. 3



INVENTOR
DUDLEY E. FOSTER
BY *H. S. Brown*
ATTORNEY

UNITED STATES PATENT OFFICE

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AUTOMATIC FREQUENCY CONTROL
CIRCUITSDudley E. Foster, Morristown, N. J., assignor to
Radio Corporation of America, a corporation
of Delaware

Application June 27, 1936, Serial No. 87,616

16 Claims. (Cl. 250—20)

My present invention relates to frequency control circuits for radio receivers, and more particularly to improved and efficient automatic frequency control arrangements for the local oscillator network of a superheterodyne receiver.

In my application Serial No. 55,749, filed December 23, 1935, there has been disclosed an automatic frequency control system of a practical and efficient type. Generally, this system comprises a discriminator network adapted to produce from the IF energy direct current voltage for automatic volume control (AVC) and automatic frequency control (AFC) purposes, as well as audio voltage for the audio network of the receiver. The AFC network in such a receiver comprises a frequency control tube, which is independent of the local oscillator tube, and the frequency control tube utilizes the direct current voltage produced by the discriminator network. In this way the frequency of the oscillator tank circuit is varied when the IF energy shifts in frequency from a predetermined frequency value.

It may be stated that it is one of the main objects of my present invention to provide an AFC system for a superheterodyne receiver wherein the frequency control on the oscillator tank circuit is performed by an electron discharge tube which not only houses the electrodes of the local oscillator, but also the electrodes of the frequency control device.

Another important object of the invention is to provide an AFC arrangement for a superheterodyne receiver, wherein the local oscillator tube is provided with at least two additional electrodes, responsive to a direct current voltage derived from the IF energy, which function to vary the oscillator tank circuit frequency in such a manner that a predetermined operating IF value is maintained.

Still other objects of my invention are to improve generally the efficiency and simplicity of AFC systems for superheterodyne receivers, and more especially to provide automatic frequency control systems in a manner such that they may be economically constructed, and readily embodied in commercial broadcast 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 organi-

zations whereby my invention may be carried into effect.

In the drawings,

Fig. 1 shows a circuit diagram of a superheterodyne receiver embodying a form of the invention,

Fig. 2 is a circuit diagram of the local oscillator network embodying another form of the invention, and

Fig. 3 is a modification of the arrangement shown in Fig. 2.

Referring now to the accompanying drawings, wherein like reference characters in the different figures designate similar circuit elements, attention is first directed to Fig. 1 which shows in a purely schematic manner a superheterodyne receiver embodying AFC. Since the function of the present invention is not dependent in any way upon the particular construction of the superheterodyne receiver, or the specific frequency discriminator network employed therewith, it is believed sufficient for the purposes of this disclosure to describe a typical superheterodyne receiver which can be utilized in conjunction with the novel frequency control network of my present invention. The receiving system shown in Fig. 1 is a conventional representation of a system shown in Fig. 1 of my aforesaid copending application. The usual signal energy collector A is coupled to the tunable input circuit 1 of the first detector 2 of the receiver. The tunable input circuit comprises a variable tuning condenser 3. It is to be clearly understood that one, or more, stages of tunable radio frequency amplification may precede the first detector tube, and in such case the rotors of the variable tuning condensers of the amplifiers would be uncontrolled with the rotors of the condenser 3.

The output circuit 4 of the first detector is resonated to the operating IF, and the latter may have a value chosen from a range of 75 to 465 kc. The IF amplifier 5 has its input circuit 6 resonated to the operating IF, and is coupled to the first detector output circuit 4. The IF amplifier 5 is followed by a double diode tube 7, and this tube may be of the 6H6 type. This type of tube is provided with independent diode electrodes, and the common resonant input circuit 8 thereof has one side connected to the diode anode 9, while the opposite side of the circuit is connected to the diode anode 9'. The high alternating potential side of the IF output circuit amplifier 5 is connected through condenser 10 to the mid-point of the secondary coil 7' of input circuit 8. The mid-point 11 is connected to

the junction of resistors 12 and 13; one side of resistor 12 being connected to the cathode 9'' of the diode 9-9'', and one side of resistor 13 being connected to the cathode 8'' of the diode 9'-8''.

The condenser 14 is connected between cathodes 9'' and 8'', and the cathode 8'' is grounded. The input circuit 8 is tuned to the operating IF, and is reactively coupled to the preceding tuned circuit as designated by the reference letter M. The AFC network involves the tunable tank circuit 18 of the local oscillator tube 19. As is well known to those skilled in the art, the variable tuning condenser 20 in the tank circuit 18 has its rotors mechanically uni-controlled with the rotors of the variable tuning condensers of the tunable signal selector circuits feeding the first detector 2. The dotted line 21 represents a mechanical uni-control device. The oscillator tube 19 is tuned at any setting of the tuning mechanism 21 to a frequency which differs from the frequency of the signal circuits by the operating IF. Those skilled in the art are fully aware of the manner of employing a padding condenser in the tank circuit 18 for maintaining the operating IF constant in value as the tuner 21 is varied through the operating frequency range; and the latter may be the broadcast range of 500 to 1500 kc. It may even be in the short wave bands, where the receiver is constructed to be of the multirange type.

The locally produced oscillations are impressed on the first detector 2 in any desired manner, as by impressing them on the cathode circuit of the first detector tube. The oscillator tube 19 has the cathode 22, the grid 23 and the positive screen grid 24 thereof functioning as the local oscillator electrodes. For this purpose the grid 23 is connected to the high alternating potential side of tank circuit 18 through the condenser 25, the leak resistor 26 being connected from the grid side of condenser 25 to the cathode 22. The condenser 25 and resistor 26 provide the usual leaky grid condenser network of the local oscillator circuit. The low alternating potential side of tank circuit 18 is grounded, and the oscillation feedback path to the tank circuit is provided by means of the condenser 25' connected between the screen electrode 24, which acts as the anode of the oscillator, and the grounded side of tank circuit 18; the cathode being connected to an intermediate point 30 on coil 8'.

The plate 27 of tube 19 is connected to a source of positive potential (+B) through a coil 28 having a magnitude of the order of 20 microhenrys. The electrode 24 may be connected to the positive potential source through a resistor 29, if it is desired to operate the electrode 24 at lower positive potential than the plate 27. The local oscillations may be taken off from the grid side of condenser 25, and impressed upon the input circuit of the first detector 2. Any other point of the local oscillator circuit may be used for the tapping point of the locally produced oscillations.

The plate side of coil 28 is connected to point 30 on oscillator tank coil 8' through a path which includes the condenser 31. It will be noted that the cathode 22 and leak resistor 26 are also connected to point 30 on coil 8'. The suppressor grid 32 of tube 19 is connected through a path, which includes the lead 33 and resistor 34, to the cathode side of resistor 12, the grid side of resistor 34 being connected to ground through condenser 35. The bias source 32' provides a normal negative bias for grid 32. As shown in Fig. 1 the lead 33 is the AFC lead, and the suppressor

grid 32 functions as the AFC electrode which varies in bias in dependence upon the direct current voltage of the cathode side of resistor 12. The network including resistor 34 and condenser 35 functions to suppress the pulsating components in the direct current voltage transmitted through lead 33. The lead 36, denoted as the AVC lead, is connected between the grid circuits of the signal transmission tubes whose gains are to be controlled and the junction of resistors 12 and 13. The AVC lead includes the proper pulsating component filter resistors 37.

In general, it may be stated that by including the coil 28 in the plate circuit of tube 19, and connecting the condenser 31 to point 30, there is produced an effective inductance in shunt across the tank circuit 18 between point 30 and ground. The magnitude of this effective inductance is a function of the space current flow to plate 27. This space current flow is dependent upon the bias of grid 32, and the bias value is in turn dependent upon the magnitude of the direct current voltage component of the differential rectified IF energy. In other words, the magnitude and polarity of the potential at the cathode side of resistor 12 determines the sense of magnitude variation of the effective inductance reflected across tank circuit 18.

It is not believed necessary to go into the detailed explanation of the construction and functioning of the discriminator network including tube 7, since such construction and functioning have been described in full in my aforesaid application. In general in the type of discriminator network shown in Fig. 1, the primary and secondary circuits coupled at M are so connected that two vector sum potentials of the primary and secondary voltages may be realized. The potentials on either end of coil 7', with respect to the center tap 11, are 180 degrees out of phase. Hence, if the center tap 11 is connected to the primary circuit, a potential is realized which maximizes above the resonant frequency of the coupled circuits, and a second potential is realized which maximizes below this common resonant frequency. When these two potentials are applied to the pair of diode rectifiers, and the resulting direct current voltages produced across resistors 12 and 13 are added in opposition, the sum will be equal to zero. The output load of the two diodes comprises the resistors 12 and 13, which are of like magnitude, and the resistors are connected in series between the cathodes 9'' and 8''.

The AFC action commences as soon as a little of the energy of a carrier wave is applied to the primary circuit. The polarity of the AFC voltage with respect to ground depends on the phase of the coupling M. By way of example, it is pointed out that in Fig. 1 the coupling M may be phased so that the AFC voltage becomes negative with respect to ground when the applied signal frequency is lower than the desired center frequency, the operating IF, of the coupled circuits. It will be observed that there is not only taken off AFC voltage from the resistors 12 and 13, but that AVC voltage is similarly taken off. The audio frequency component of rectified IF energy is transmitted through condenser 38 to one, or more, stages of audio frequency amplification, and the latter may be followed by any desired type of reproducer.

Coil 28 is connected, through condenser 31 and by-pass condenser 42, between tap 30 of coil 8' and ground. In the absence of oscillatory plate

current to anode 27 of tube 19, the total inductance between point 30 and ground is that resulting from the parallel combination of coil 28 and the portion of coil 8' below tap 30. Now when the potential of electrode 32 is such that current of oscillation frequency flows to anode 27, that plate current is in phase with the oscillatory voltage of the tank circuit 18. This in-phase current flowing through inductance 28 produces a quadrature voltage across the terminals of coil 28 which is impressed upon tap 30 of coil 8' through condenser 31. This quadrature voltage is thus seen to vary in magnitude in accordance with changes in potential of electrode 32. The quadrature voltage impressed from coil 28 on tap 30 varies the effective inductance between tap 30 and ground, and thus the oscillatory frequency. The amount of effective inductance change depends not only upon the operating characteristics of tube 19 and the magnitude of the inductance 28, but also on the point of coil 8' to which condenser 31 returns.

Fig. 1 shows condenser 31 returning to the same point on coil 8' as the cathode 22 of tube 19, as that mode of connection causes least change in oscillatory amplitude as the potential of electrode 32 is changed. Returning condenser 31 to a point on the coil 8' above tap 30 would increase the frequency control effect since inductance 28 would be across a larger proportion of coil 8'. However, the amplitude of oscillation would be affected more by changes in potential of electrode 32, than when condenser 31 is returned to the same point on coil 8' as the cathode 22. The choice of point 30 on coil 8' at which to return cathode 22 is such as to obtain optimum oscillation. In general, the number of turns from ground to the tap on coil 8' will be between 15% and 50% of the total number of turns, the proportion of turns below the tap being higher for the higher frequency ranges. In the broadcast band the tap is usually at about 25% of the turns from the bottom.

As stated before, the magnitude and the polarity of the direct current potential at the cathode side of resistor 12 determines the magnitude of the inductance reflected across tank coil 8' between ground and point 30. If the AFC voltage applied to grid 32 is positive, the space current flow to plate 27 increases. This in turn increases the space current flow through condenser 31, and causes the effective inductance of tank circuit 18 to increase, thereby causing the tuned frequency of tank circuit 18 to decrease since increase of space current causes an increase of a virtual negative inductance. It will now be seen that the frequency difference between the signal and the oscillator circuits is made automatically to shift towards the desired IF value as the receiver is tuned towards a desired station setting. The tube 19 is shown as a pentode, and this tube may be of the 6J7 type. The condenser 26' may have a value of 50 micro-microfarads.

In actual operation, the system shown in Fig. 1 is operative so that the AFC circuit automatically functions to adjust the tuning of tank circuit 18 in a direction such that the IF value which has been predetermined is produced, since the tuning means 21 is varied to a setting such that some of the modulated carrier energy of the desired frequency is received. As the potential of grid 32 becomes more positive, the frequency of tank circuit 18 is decreased due to the fact that additional negative inductance is reflected across a portion of tank circuit 18. On the other hand,

as the bias of grid 32 becomes increasingly negative, as is the case when the frequency value of the IF energy becomes lower than the operating value, then the reflected negative inductance across the tank circuit 18 decreases, and the tank circuit frequency increases. This results in an increase of the frequency of the IF energy towards the desired operating value. The same effect is produced if the receiver is adjusted to a desired signal frequency, and the tank circuit frequency should shift for some reason. It may be pointed out that with coil 28 having a value of approximately 20 microhenrys, a shift of 6 kc. can be secured with the impression of -16.5 volts on the suppressor grid 32. It will, therefore, be seen that efficient local oscillator frequency control is secured with this arrangement, and without using a separate frequency control tube; but, on the contrary, utilizing at least two additional electrodes in the local oscillator tube to accomplish this frequency control function.

In Fig. 2 there is shown a modification of the invention wherein the oscillator tube 19 is shown as a tube of the 6C6 type, or it may be a tube of the 6J7 type. The oscillator tank circuit 18 is shown as including the padder condenser 20' in series with the main tuning condenser 20. The plate 27 of tube 19 is connected to the coil 8' of the tank circuit, and a direct current blocking condenser 40 is inserted between the low alternating potential side of coil 8' and the coil 43. The cathode 22, control grid 23, and screen grid 24 cooperate to provide the local oscillator network, and the oscillator feedback path is provided by means of the coil 41 which is inserted in series with the screen grid 24, coils 41 and 8' being magnetically coupled as at M1, the lead 24' being connected to ground through by-pass condenser 42. The plate 27 is connected to the positive terminal of the potential source B through a path which includes the coils 8' and 41 in series, and the screen grid 24 is connected to the same positive potential source through the lead 24'. The radio frequency choke 43 is inserted between ground and the cathode 22 in order to maintain the cathode potential above ground.

The resistor 44 and condenser 45 are connected in series across the tank circuit, the direct current blocking condenser 46 connecting one side of the resistor 44 to the high potential side of coil 8'. The plate 27 is connected by lead 47 to the high potential side of coil 8', and the suppressor grid 48 is connected by lead 49 to the junction of resistor 44 and condenser 45. The AFC lead 33 is connected to lead 49 so that the bias of grid 48 may be varied in a manner depending upon the magnitude and polarity of the AFC voltage. If the resistance of resistor 44 is large compared to the reactance of condenser 45, currents through this series circuit will be substantially in phase with the voltage across tank circuit 18. The current passing through the condenser 45 produces a voltage across the condenser which lags the voltage across the tank circuit by substantially 90 degrees. This lagging voltage is applied to the grid 48. The plate current flowing through connection 47 of coil 8' will be substantially 90 degrees ahead of the voltage across the tank circuit 18. The current through the tuning condenser 20 lags the voltage across that circuit about 90 degrees. Thus, the plate current flowing through connection 47 to coil 8' acts as though the current flow-

ing in the variable tuning condenser 20 has been decreased.

In other words, by virtue of the connections of electrodes 48 and 27 to the tank circuit 18 there is produced an effective inductance across the tank circuit. The magnitude of this effective inductance is, of course, a function of the mutual conductance of tube 19 between cathode 22 and anode 27. The AFC connection 33 is made to the grid 48, and, therefore, the mutual conductance of tube 19 is varied in dependence upon the magnitude of the direct current component of the differential rectified IF energy. If the AFC voltage applied to grid 48 is positive, the mutual conductance of tube 17 is increased. The amount of leading current flowing in connection 47 is thereby increased, and this is the same as though the lagging current flowing through the variable tuning condenser 20 has been decreased. This, in turn, acts as though the tuning condenser 20 has been decreased in value thereby causing the tuned frequency of tank circuit 18 to increase.

Assuming that a signal impressed on primary circuit 6' is approaching the IF value of 465 kc., chosen by way of illustration, but is less than the latter, and also assuming that the cathode side of resistor 12 has a positive potential with respect to ground, the frequency departure may be due to a shift in oscillator frequency towards a lower frequency, or due to tuning the receiver towards the low end of the tuning range. The grid 48 becomes positive, and increases the gain of tube 19. This will result in an increase in the effective inductance reflected across tank circuit 18, and the frequency of the tank circuit will increase since in this case the virtual inductance is positive in sign. In this way the frequency difference between the signal and oscillator circuits automatically is made to increase towards the desired IF value. It will, further be seen that the method for reflecting the tuning adjustment inductance in Fig. 1 into the tank circuit 18 is different from that employed in connection with that of Fig. 2. However these arrangements have in common the fact that the local oscillator tube includes in its envelope at least two electrodes which are electrically associated with the tank circuit to provide a reflected reactance whose magnitude may be varied in a predetermined manner, and in dependence upon the AFC voltage. It will be appreciated that this is accomplished without materially affecting the amplitude of the locally produced oscillations, and this follows from the fact that the AFC electrode is disposed outside the oscillator anode electrode 24, and in Fig. 1 connection is made to a point where oscillation will not be affected, while in Fig. 2 the AFC current is in quadrature with oscillation current.

The modification in Fig. 3 differs from that shown in Fig. 2 in the nature of the tube employed. The tube 50 is of the 6L7 type, and the local oscillator electrodes comprise cathode 51, the control grid 52 and the grid 53. The grid 52 is connected to the high alternating potential side of the tank circuit 18, and in series with the padder condenser 20'. The resistive impedance 54 is inserted in the grounded cathode lead of the tube, and the cathode side of impedance 54 is connected to an intermediate point on coil 8' through condenser 55. The oscillation feedback path from electrode 53 is provided through condenser 56 and ground, the positive potential for electrode 53 being derived from the plus side of the B source through resistor 57. The 6L7 type

of tube has five grids disposed between the cathode 51 and the plate 58. The third, fourth and fifth grids are disposed between grid 53 and plate 58. The grid 59 is grounded; the fourth grid 60 is connected in common with grid 53 and is at the same positive direct current potential; and the third grid 61 is connected to the AFC lead 33, the grid 61 being disposed between the positive grids 53 and 60. The series path, including resistor 44 and condenser 45, is connected across the tank circuit, and the alternating current voltage developed across condenser 45 is impressed upon grid 61 through direct current blocking condenser 62.

The electrical relations in this circuit are substantially the same as those described in connection with Fig. 2. In other words, the phase relations between the current flow in the circuit connected to the plate 58, and the voltage across the tank circuit 18, as well as the current through the tuning condenser 20, are the same as those described in connection with Fig. 2. It may be pointed out that the grounding of grid 59 results in the maintenance of a high impedance in the plate circuit of tube 50.

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 is claimed is:

1. In a superheterodyne receiver of the type provided with at least a first detector adapted to produce intermediate frequency energy of a predetermined operating intermediate frequency, means for rectifying the intermediate frequency energy, a local oscillator network adapted to impress locally produced oscillations upon said first detector, adjustable tuning means electrically associated with said first detector and oscillator, and means responsive to a variation in frequency of said intermediate frequency energy from the operating frequency for adjusting the oscillator frequency in a sense to cause said intermediate frequency energy to approach said operating frequency, the improvement which is characterized by said oscillator network being provided with an electron discharge tube which includes at least a cathode, a control grid and an anode electrically connected to produce said oscillations, said tube including at least two additional electrodes electrically connected to the oscillator tank circuit to reflect a reactance of predetermined sign across the tank circuit, and an electrical connection between said oscillator frequency adjusting means and one of said two additional electrodes.

2. In a superheterodyne receiver of the type provided with at least a first detector adapted to produce intermediate frequency energy of a predetermined operating intermediate frequency, means for rectifying the intermediate frequency energy and producing a direct current voltage whose magnitude and polarity depends upon the direction and magnitude of frequency variation of the intermediate frequency energy from said operating frequency, and a local oscillator network provided with a tank circuit adapted to impress oscillations upon said first detector, the improvement which is characterized by said oscillator network including a tube which is provided with electrodes electrically connected to

produce said oscillations, at least two additional electrodes in the oscillator tube, one of the additional electrodes being electrically connected to said rectifying means so as to have said direct current voltage impressed thereon, electrical connections between the other additional electrode and the tank circuit of the oscillator network for providing a reflected reactance across the tank circuit.

3. In an oscillation generation system, an electron discharge tube provided with a cathode, a plate, and at least three grid electrodes therebetween, a resonant tank circuit connected between the cathode and one of the grid electrodes, a reactive feedback path connected between a second of the grid electrodes and the tank circuit whereby oscillations of a predetermined frequency are produced, electrical connections between at least the plate and the tank circuit for producing in the tank circuit a reflected reactance of a predetermined sign, and means for varying the direct current potential of the third grid electrode thereby to adjust the space current flow through the plate circuit whereby the magnitude of said reflected reactance is controlled.

4. In an oscillation generation system, an electron discharge tube provided with a cathode, a plate, and at least three grid electrodes therebetween, a resonant tank circuit connected between the cathode and one of the grid electrodes, a reactive feedback path connected between a second of the grid electrodes and the tank circuit whereby oscillations of a predetermined frequency are produced, electrical connections between at least the plate and the tank circuit for producing in the tank circuit a reflected reactance of a predetermined sign, means for varying the direct current potential of the third grid electrode thereby to adjust the space current flow through the plate circuit whereby the magnitude of said reflected reactance is controlled, a reactive path in shunt with said tank circuit, and means for impressing upon the third electrode voltage developed in said shunt reactive path.

5. In an oscillation generation system, an electron tube provided with a cathode, a plate, and at least three grid electrodes therebetween, a resonant tank circuit and feedback circuit connected to two of said grid electrodes and to the cathode whereby oscillations of a predetermined frequency are produced, a connection between the plate of said tube and the tank circuit, a circuit for impressing on the third grid a voltage of the oscillatory frequency but in quadrature with the tank circuit voltage, means for simultaneously impressing on the said third grid a direct current potential whereby the quadrature current in the plate circuit may be varied in accordance with the direct current potential of said third grid, the variations of quadrature plate current producing variations of the oscillation frequency.

6. In an oscillation generation system, an electron tube provided with a cathode, a plate, and at least three grid electrodes therebetween, means for impressing desired operating direct current potentials on the electrodes of said tube, a resonant tank circuit and feedback circuit connected to two of said grid electrodes and to the cathode whereby oscillations of a predetermined frequency are produced, a reactance connected in the plate circuit of said tube, a connection from the plate to the tank circuit, means for varying the operating direct current potential of the third

grid whereby the voltage of the oscillatory frequency developed across said reactance in the plate circuit is varied thereby producing variations of the oscillatory frequency.

7. In an automatic frequency control system for a superheterodyne receiver of the type provided with a local oscillator having a tuned tank circuit, the improvement which is characterized by said oscillator comprising a tube provided with at least a cathode, control grid and anode electrode, electrical connections between said three electrodes and tank circuit to produce local oscillations, at least two auxiliary electrodes being included in said tube, electrical connections between said tank circuit and auxiliary electrodes to reflect a reactance of predetermined sign across the tank circuit, and means for varying the direct current potential of one of the two auxiliary electrodes thereby to vary the magnitude of said reactance.

8. In a local oscillator network, adapted for use in a superheterodyne receiver, a tube provided with electrodes electrically connected to produce oscillations, at least two additional electrodes in the oscillator tube, a source of variable direct current voltage, electrical connections between one of the additional electrodes and the tank circuit of the oscillator network for providing a reflected reactance thereacross, and means connecting said source to the other of the additional electrodes.

9. In a local oscillator network, adapted for use in a superheterodyne receiver, a tube provided with electrodes electrically connected to produce oscillations, at least two additional electrodes in the oscillator tube, a source of variable direct current voltage comprising a signal frequency variation device, electrical connections between one of the additional electrodes and the tank circuit of the oscillator network for providing a reflected reactance thereacross, and means connecting said source to the other of the additional electrodes.

10. An automatic frequency control system for a superheterodyne receiver of the type provided with a local oscillator having a tuned tank circuit, the improvement which is characterized by said oscillator comprising a tube provided with at least a cathode, control grid and anode electrode, electrical connections between said three electrodes and tank circuit to produce local oscillations, at least two auxiliary electrodes being included in said tube, electrical connections between said tank circuit and auxiliary electrodes to reflect a reactance of predetermined sign across the tank circuit, and signal frequency departure responsive means for varying the direct current potential of one of the two auxiliary electrodes thereby to vary the magnitude of said reactance.

11. In combination, a tube provided with at least a cathode, a plate and at least three cold electrodes arranged therebetween, a tunable tank circuit connected between the cathode and one cold electrode, means reactively coupling a second cold electrode with the tank circuit to produce oscillations, an inductive reactance connected in the space current path of the tube, a capacitive reactance connected between the inductive reactance and a point of said tank circuit, and means for varying the potential of a third of the cold electrodes.

12. In combination, a tube provided with at least a cathode, a plate and at least three cold electrodes arranged therebetween, a tunable

tank circuit connected between the cathode and one cold electrode, means reactively coupling a second cold electrode with the tank circuit to produce oscillations, an inductive reactance connected to the plate in the space current path of the tube, a capacitative reactance connected between the inductive reactance and a point of said tank circuit, and a signal responsive means for varying the potential of a third of the cold electrodes.

13. In combination, a tube provided with at least a cathode, a plate and at least three cold electrodes arranged therebetween, a tunable tank circuit connected between the cathode and one cold electrode, means reactively coupling a second cold electrode with the tank circuit to produce oscillations, an inductive reactance connected in the space current path of the tube, a capacitative reactance connected between the inductive reactance and a point of said tank circuit, and means for varying the potential of a third of the cold electrodes, said tank circuit including a coil connected between ground and said one electrode, said cathode being connected to said tank circuit point, and the latter being located at an intermediate point of the coil.

14. In a local oscillator network, a tube provided with a cathode, a plate, and at least three grids therebetween, a tank circuit, including a tuning means, connected between one grid and the cathode, a second grid reactively coupled to

said tank circuit, an impedance connected across said tank circuit, a connection between the plate of the tube and said tank circuit, a connection between the third grid and said impedance, and means for varying the gain of said tube.

15. In a local oscillator network, a tube provided with a cathode, a plate, and at least three grids therebetween, a tank circuit, including a tuning means, connected between one grid and the cathode, a second grid reactively coupled to said tank circuit, an impedance connected across said tank circuit, a connection between the plate of the tube and said tank circuit, a connection between the third grid and said impedance, and means for varying the gain of said tube, an auxiliary grid disposed adjacent the plate, means for maintaining said auxiliary grid sufficiently negative to maintain a high impedance in the plate circuit of the tube.

16. In a local oscillator network, a tube having a cathode and a plurality of cold electrodes, a resonant tank circuit connected to the cathode and at least two cold electrodes to provide a source of local oscillations, means coupling a cold electrode of the tube to said tank circuit to provide a simulated reactance across the latter, and means for varying the space current flow to said last named cold electrode thereby to adjust the value of said reactance.

DUDLEY E. FOSTER.