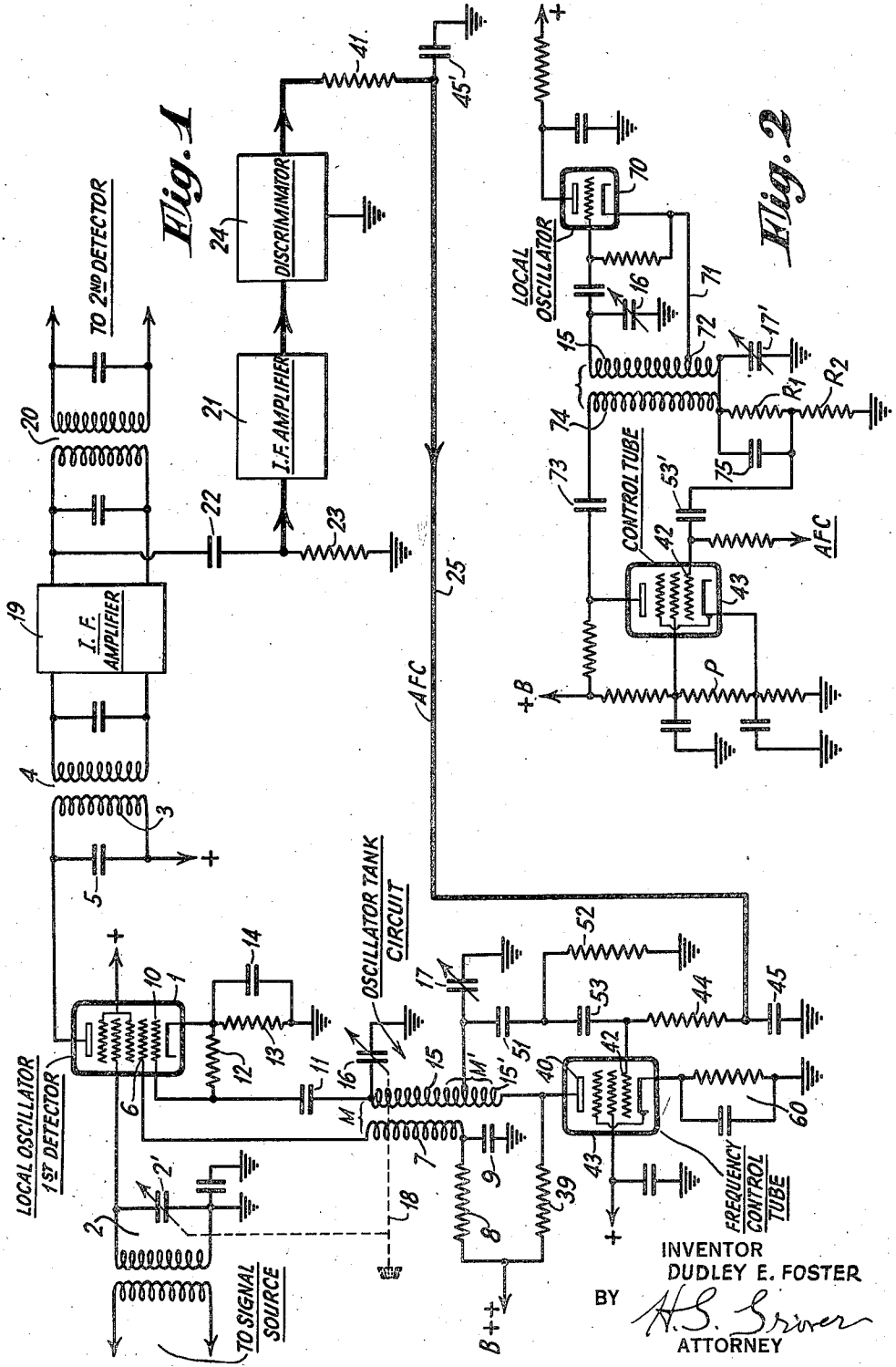
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AUTOMATIC FREQUENCY CONTROL CIRCUITS

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AUTOMATIC FREQUENCY CONTROL CIRCUITS

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My present invention relates to automatic frequency control circuits for superheterodyne receivers, and more particularly to an improved type of frequency control arrangement for the local oscillator tank circuit.

In application Serial No. 116,882, filed December 21, 1936 by D. E. Foster and G. Mountjoy, there has been disclosed an automatic frequency control circuit (AFC) which employs a discriminator network for deriving a direct current voltage from intermediate frequency (IF) energy, the voltage depending in magnitude and polarity upon the sign and amount of frequency departure of the IF energy from its assigned operating value. The derived direct current voltage is used to control the gain of a frequency control tube; and the input and output circuits of the control tube are connected to the oscillator tank circuit to produce an effective inductance across the latter. In addition, the input electrodes of the control tube are coupled through a resistor and condenser quadrature voltage network across the padder condenser of the tank circuit, with the alternating plate current of the control tube flowing through a primary coil coupled to the oscillator tank circuit and through the oscillator padder network in series. In this manner there is obtained a uniform frequency correction shift for the tank circuit at any setting of the tuning mechanism of the receiver; it being understood, of course, that variation of the gain of the frequency control tube, in response to discriminator output voltage, causes the frequency correction of the oscillator tank circuit.

It is one of the main objects of my present invention to provide an automatic frequency control network for a superheterodyne receiver, the network being of the type which responds to the direct current voltage output of a discriminator network; and the control network generally comprising an electron discharge tube which has its plate circuit coupled magnetically and electrostatically to the oscillator tank circuit, while its input electrode is connected to a point intermediate to a resistor and condenser which are in series; the series resistor-condenser network being, additionally, connected across the padder condenser of the local oscillator tank circuit whereby the alternating plate current of the control tube flows through a coil coupled to the tank circuit as well as through the oscillator padder network; the oscillator anode being reactively coupled to the oscillator tank circuit through a reactive coupling which is independent of the couplings between the control tube and the tank circuit.

Another important object of my invention may be stated to reside in the provision of an AFC superheterodyne receiver wherein there is employed magnetic coupling between the output circuit of the frequency control tube and the oscillator tank circuit, and additional capacity coupling being used between these two circuits through a network which includes the tank circuit padder condenser; additional flexibility of circuit arrangement and control action being secured by electrically separating the magnetic coupling producing the local oscillations and the magnetic coupling between the control tube output circuit and the tank circuit.

Still other objects of the invention are generally to improve the efficiency and reliability of AFC arrangements for superheterodyne receivers, and more specifically to provide frequency control circuits which can be economically manufactured and assembled in receivers of the superheterodyne type.

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

In the drawing:

Fig. 1 schematically shows a superheterodyne receiver of the AFC type embodying one form of the invention, and

Fig. 2 shows a modification of the frequency control tube circuit.

Referring now to the accompanying drawing, wherein like reference characters in the two figures designate similar circuit elements, there is shown in Fig. 1 only that portion of the superheterodyne receiver which is essential to a proper understanding of the present invention. The receiver is of the conventional type adapted to receive amplitude-modulated carrier waves; for example, those in the broadcast range of 550 to 1500 kc. In general, the receiver system is that disclosed in the aforesaid Foster and Mountjoy application; for this reason only such circuits of the present invention which are not found in the last named application will be shown here in detail. Generally, the receiver shown may comprise the usual signal collector followed by one,

or more, stages of tunable radio frequency amplification. The amplified radio frequency signals will be fed to a converter tube 1 which has a tunable input circuit 2.

The tube 1 is of the 6A7 type, and is well known to those skilled in the art as a pentagrid converter tube. In this type of tube the cathode and first two electrodes cooperate to provide a local oscillator section, when the tube 1 is to be used in a combined local oscillator-first detector network. The fourth grid of tube 1 is the signal grid, and is connected to the high alternating potential side of input circuit 2. The signal grid is disposed between a pair of positive screen grids. The plate of tube 1 is connected to a source of positive potential through the primary coil 3 of the IF transformer 4, and the condenser 5 fixedly tunes coil 3 to the operating IF; the latter having a value of 460 kc., for example, but it being understood that it may be chosen from a range of IF values of 75 to 480 kc.

The oscillator anode electrode 6 of tube 1 is connected to a source of positive potential B through a path which includes the feedback coil 7 and the resistor 8, the condenser 9 being connected to ground from the junction of coil 7 and resistor 8. The oscillator grid electrode 10 of tube 1 is connected to the high alternating potential side of the oscillator tank circuit through a path which includes the condenser 11, and the grid side of condenser 11 being connected to the cathode side of the bias resistor 13 through the resistor 12. It is pointed out that the bias resistor 13 is inserted in the cathode lead to ground, and the bypass condenser 14 is connected in shunt with resistor 13.

The oscillator tank circuit includes the coil 15, the high alternating potential side of which is connected to ground through the variable tuning condenser 16. The low alternating potential side of coil 15 is connected to ground through a padder condenser 17. The coils 7 and 15 are magnetically coupled, and the latter coupling is denoted by the letter M. The dotted lines 18 denote the mechanical uni-control device which is employed simultaneously to adjust the rotors of the variable condensers 2' and 16, which variable condensers control the tuning of the signal circuit 2 and the oscillator tank circuit respectively. The condenser 17 may have means for factory adjustment, and those skilled in the art are fully aware of the fact that the condenser is employed properly to "track" the tuning of tank circuit 15—16 with the tuning of the various signal circuits of the radio frequency amplifiers and the first detector input circuit.

The oscillator anode electrode 6 is magnetically coupled to the oscillator grid circuit by virtue of the reactive coupling M, and the local oscillations are produced by virtue of such coupling. The tank circuit 15—16 is adjusted in tuning through a frequency range which differs from the frequency range of the tunable signal circuits by the frequency of the IF energy. It is not believed necessary to explain the electrical mechanism which gives rise to the production of the IF energy in the IF output circuit 5—3. Those skilled in the art are fully aware of the fact that the IF energy output is provided by virtue of "electronic coupling" between the signal section of the converter tube 1 and its oscillator section. It is merely necessary to point out that at the different station settings of the tuning mechanism 18 the tank circuit 15—16 will constantly differ from the desired frequency value by the operating IF.

The IF energy output of the converter tube may be amplified in one or more stages of IF amplification 19. The numeral 20 denotes the IF transformer which couples the IF amplifier 19 to the second detector. It will be understood that the IF amplifiers are provided with resonant input and output circuits which are fixedly tuned to the assigned IF value. The detected IF energy may then be amplified by one or more stages of audio amplification, and finally will be reproduced by any desired type of reproducer, such as a loudspeaker. If desired, the second detector may be of the diode type; further, it may provide AVC (automatic volume control) bias for controlling the gain of the radio frequency amplifiers, the first detector and the IF amplifiers in a sense such that the signal amplitude at the second detector input circuit is substantially uniform regardless of wide variations at the signal collector.

The AFC circuit, which functions automatically to adjust the oscillator tank circuit to that frequency which will eventually produce the correct IF value in circuit 5—3, derives its signal energy from any desired point in the IF transmission network. For example, IF energy may be tapped off from the high alternating potential side of the primary circuit of IF transformer 20, and the IF energy may be impressed upon an IF amplifier 21. The amplifier 21 is conventionally represented, and it may be of the pentode type, if desired, and its input energy is shown derived from the series path including condenser 22 and resistor 23. The amplified IF energy is impressed upon the discriminator network 24, and it will be understood, that, although schematically denoted herein, the specific circuit details of the discriminator network may follow the details of the aforesaid Foster and Mountjoy application.

Briefly, the discriminator comprises a pair of diode rectifiers which have a common input circuit resonated to the operating IF, and the direct current voltage output circuits of the diodes being arranged in polarity opposition. A common load resistor is employed as the output circuit of the two diodes, and the AFC bias is taken off from the ungrounded side of the load resistor. In other words, in Fig. 1 it will be understood that the ground representation employed in connection with network 24 denotes the ground terminal of the discriminator load resistor, whereas the AFC lead 25 is connected to the ungrounded terminal of the load resistor. In the type of discriminator network shown in the aforesaid Foster and Mountjoy application, if the frequency of the IF waves applied to circuit 24 departs from resonance, the sum of the rectified outputs of the diode circuits combined in opposition will be some real value whose polarity will depend upon the sign of the frequency departure.

It is believed sufficient to explain that at the operating IF the differential voltage produced across the common load resistor of the discriminator is zero, whereas for frequencies differing from the IF the differential voltage (that is, the AFC bias) increases in magnitude and its polarity is dependent upon the sign of the frequency departure. The AFC bias is applied to the input electrode 42 of the frequency control tube 43. The AFC lead 25 includes the filter resistor 41, and the connection to the control grid 42 is made through a second resistor 44. The condensers 45 and 45', both connected to ground from their

respective resistors, cooperate with the resistors 44 and 41 respectively to suppress all pulsating components in the AFC bias. The tube 43 is a pentode of the 6J7 type, and its plate potential is derived from the same source which furnishes the positive potential for the oscillator anode electrode 6.

Thus, the plate 40 of control tube 43 is connected to the +B terminal of the positive potential supply source through a resistor 39, the plate 40, also, being connected to the junction of tank circuit coil 15 and padder condenser 17 through a coil 15' which may be an extension of coil 15. The screen grid electrode of tube 43 may derive its positive potential, of approximately 100 volts, from a proper potential reducing resistor connected to the source B. It will be understood that the voltage supply source may be a part of the common direct current voltage supply system of the receiver, but it is believed only necessary to show that portion of the supply source used in connection with the control tube 43 and the oscillation section of the converter tube 1.

There is connected in shunt with the padder condenser 17, a series path which includes a condenser 51 and a resistor 52. The control grid 42 of the control tube 43 is connected to the junction of condenser 51 and resistor 52 through a condenser 53, the filter resistor 44 being connected to the grid side of condenser 53. The condenser 51 is connected to the junction of coil 15 and condenser 17, and it will be noted that coils 15 and 15' are magnetically coupled, as denoted at M'. The desired amount of normal bias for the control grid 42 may be obtained by the usual grid bias network 60 disposed in the cathode lead of the control tube 43.

Considering, now, the operation of the AFC system shown in Fig. 1, it is first pointed out that the AFC bias need not be derived from a discriminator of the type shown in the aforesaid Foster and Mountjoy application. In general, any well known type of discriminator may be used; the essential requirement is that the discriminator derive from applied IF energy a direct current voltage whose magnitude will depend upon the amount of shift of the IF energy from the assigned IF value, and whose polarity will depend upon the sense of frequency shift. For example, the discriminator may employ a pair of diode rectifiers whose input circuits are oppositely detuned from the operating IF by equal amounts, but whose direct current voltage output circuits are combined in polarity opposition. Such a discriminator is shown by C. Travis in application Serial No. 4,793, filed Feb. 14, 1935.

The magnitude and the polarity of the AFC voltage determines the gain, or mutual conductance, of the control tube 43. The tube 43 is so connected with respect to the tank circuit 15—16 as to produce an effective capacity reactance across the padder condenser. The resistor 52 and condenser 51 are effectively in series across the padder condenser 17. The tank circuit current divides between the condenser 17 and the circuit comprising 51 and 52. Resistor 52 is small compared with the reactance of the tank circuit comprising coil 15 and padding condenser 17, so that the current passing through the resistor 52 produces a voltage thereacross which lags the voltage across the tank circuit by substantially 90 degrees. This voltage is applied to the control grid 42 of the frequency control tube 43. It will then be seen that the plate current flowing through the plate circuit of tube 43 is substantially 90 degrees ahead of the voltage across the tank circuit. The reactance of condenser 17 and condenser 51 in parallel act to decrease the reactance between the top of the tank circuit and ground. Thus, any plate current flowing in the plate circuit of tube 43 acts as though the current flowing through the inductance 15 had been changed in amount.

In other words, the tube 43 simulates a capacitive reactance across the padding condenser, and the magnitude of this simulated reactance is a function of the mutual conductance of the tube 43. If the AFC bias applied to grid 42 becomes positive the mutual conductance of tube 43 is increased, and the amount of current flowing in the plate circuit of the tube is increased. This acts as though the current flowing through the padder condenser 17 has been decreased. Consequently there is secured an effect equivalent to that if the padder condenser 17 had been increased in magnitude thereby causing the resonant frequency of the tank circuit 15—16 to decrease.

The combination of condenser 51 and resistor 52, connected in shunt to the padder condenser 17, is electrically equivalent to a fictitious resistor in series with condenser 17 in the tank circuit. The magnitude of this fictitious resistor varies with frequency, and in general decreasing with frequency. The manner in which this fictitious tank circuit resistor changes with frequency can be varied by adjustment of the relative values of condenser 51 and resistor 52. This follows from the fact that the proportion of tank circuit current which flows through the path 51—52 depends upon the impedance of that path relative to the reactance of the padder condenser.

If the plate of tube 43 were connected to the high potential side of padder 17 so that the virtual reactance of tube 43, due to the quadrature voltage impressed on its grid circuit, is across only the padder, insufficient frequency shift would be secured at the high frequency end of the tuning range. By connecting the plate 40 of the control tube to the winding 15', which is magnetically coupled to tank circuit coil 15, an increase in the frequency shift is secured at the high frequency end of the tuning range. By means of the connection shown in Fig. 1, the effect of the control tube on tank circuit frequency is chiefly through mutual inductance between coils 15' and 15 at higher frequencies, and by variation of the effective reactance across padder condenser 17 at low frequencies. The direction of winding of coils 15 and 15' is preferably such that the frequency shift due to the mutual inductance M', and that due to the padder condenser, will enhance each other.

In this type of circuit the frequency shift is due to a capacity effect across the padder, and a negative inductance in series in the tank circuit. Both effects change the frequency in the same direction with an increase in mutual conductance of the control tube, but one has more influence than the other at low tuning frequencies whereas the relative magnitudes of their influence on frequency shift is reversed at the opposite end of the tuning range. It is possible so to pole the mutual inductance M' that the frequency shift due to the latter opposes the shift due to the effect of the control tube across the padder if for any reason an extreme change in amount of shift with frequency were desired. With the winding direction as shown in the drawing, however, the effects are additive.

As stated heretofore, the values of condenser 51 and resistor 52 may be adjusted to change the manner in which quadrature voltage across resistor 52 varies with frequency. Therefore, these values can be so chosen that with a given value of mutual inductance M', and a given value of condenser 17 as may be required by the tank circuit for proper oscillation and tracking, the oscillator frequency shift brought about by variation of the AFC bias may be made substantially constant with frequency change of the tank circuit. Furthermore, by taking quadrature grid voltage from a path in shunt with the padder condenser instead of from a resistor directly in the tank circuit, there is less effect on the strength of oscillation.

Assume, now, that a signal impressed on the discriminator is approaching an IF value of 460 kc., but is greater than the latter; and let it further be assumed that the high potential side of the discriminator output resistor has a positive potential with respect to ground. If the positive polarity of AFC bias has been chosen to be positive when the IF energy is higher in frequency than the assigned value, the frequency departure causes the grid 42 to become positive and increase the gain of tube 43. This causes a change in the simulated capacity across padder condenser 17 such that the frequency of the tank circuit will decrease. Thus, the frequency difference between the signal and oscillator circuits will automatically be made to decrease and approach towards the desired IF value.

The reverse is true of the case where the IF energy applied to the discriminator is departing from the assigned IF value, and becoming lesser in magnitude. By virtue of the circuit arrangement employed between the control tube 43 and the tank circuit 15—16, frequency correction of the tank circuit will be substantially uniform no matter how the tuning control 18 is adjusted. This circuit solves the problem of a simple AFC circuit which will not only produce adequate frequency correction at each station setting of the tuner 18, but also produce a frequency correction which is substantially uniform over the tuning range, and which does not add appreciably to minimum circuit capacity.

The circuit arrangement disclosed herein in connection with control tube 43 is capable of being designed to produce different types of frequency shift-tuning dial frequency characteristics. Assuming that a uniform amount of frequency shift is desired at all points in the tuning range of the receiver, the circuit shown in Fig. 1 is capable of meeting this requirement. Generally speaking, the frequency control tube is magnetically coupled to the oscillator tank circuit coil, as at M', through an auxiliary coil 15' which may conveniently be a continuation of the coil 15. The oscillator feedback coil 7 is only coupled to coil 15, and there is no reactive coupling between the coil 7 and coil 15'. This method of control tube connection produces a frequency shift at the high frequency end of the tuning range and the coil 15' functions for this purpose. With coil 15' present there is some tendency for spurious high frequency oscillation of the control tube, but this is effectively prevented by the use of resistor 39.

It was found in actual usage that when the control tube network included a quadrature condenser 51 having a magnitude of 150 mmf., substantially flat "total frequency shift—tuning dial frequency" characteristics were obtained for different magnitudes of resistor 52 varying from 100 to 400 ohms. The oscillator network was stable for each of these values even when the control grid 42 had as much as 22 volts positive thereon. It was found, for example, that with a value of resistor 52 equal to 100 ohms, a substantially uniform total frequency shift of approximately 15 kc. could be secured over the entire tuning dial range of the receiver. With a resistor value of 400 ohms the characteristic was substantially flat with frequency shifts of approximately 35 kc. If it is desired to secure uniform shifts of greater magnitude than 35 kc., such increase may be obtained by using a larger value of quadrature condenser 51, while maintaining resistor 52 in the region of 400 ohms. Further, the frequency band coverage which was characteristic of the oscillator before the addition of the AFC components was only slightly decreased by the incorporation of AFC, the effective capacity added to the oscillator minimum being only 3 mmf.

The following specific illustration is given of circuit constants which may be employed in the receiving system, but it is to be clearly understood that these values are not given in any restrictive fashion, but are merely provided to enable those skilled in the art to readily practice the invention:

Coil 15	=120 microhenries
Coil 7	=27 microhenries
Coil 15'	=26 microhenries
M	=14 microhenries
M'	=43.5 microhenries
Condenser 51	=150 mmf.
Resistor 52	=100 to 400 ohms
Resistor 44	=0.5 megohm
Resistor 8	=10,000 ohms
Resistor 39	=15,000 ohms
Resistor 12	=50,000 ohms
Condenser 53	=100 mmf.
Condenser 9	=0.05 microfarad

An increased shift may be secured at the low frequency end of the tuning range by proper proportioning of the quadrature components 51 and 52. For example, a frequency shift of approximately 60 kc. at a dial setting of 600 kc., as against a frequency shift of approximately 35 kc. at a dial setting of 1500 kc., can be secured by employing a quadrature condenser 51 of 100 mmf. and a resistor 52 of approximately 800 ohms. With a resistor of 1600 ohms and a condenser value of 50 mmf., the frequency shift at 600 kc. is approximately 50 kc., while at 1500 kc. it would be somewhat less than 30 kc.

The frequency shift at the high frequency end of the tuning range may be accentuated by connecting the terminal of condenser 51, which in Fig. 1 is shown connected to condenser 17, to the junction of plate 40 and coil 15'. With this modification of the circuit the quadrature elements 51 and 52 are connected across the padder condenser 17 and the windings 15'. With such arrangement, and using for resistor 52 a value of 600 ohms, a value of 75 mmf. for condenser 51 gives a frequency shift of approximately 80 kc. at a dial setting of 1700 kc., as compared to a frequency shift of 50 kc. at a dial setting of 600 kc. When condenser 51 has a value of 50 mmf., the frequency shift at 1700 kc. is approximately 55 kc., as compared to a frequency shift of approximately 30 kc. at a dial setting of 600 kc. With a magnitude of 25 mmf. for condenser 51, the frequency shift is about 30 kc. at a dial setting

of 1700 kc., as compared to a frequency shift of approximately 17 kc. at a dial setting of 600 kc.

It will now be seen that the AFC arrangement described permits a wide range of choice of control shift, which may be made uniform over the frequency range or increased in amount at either end of the tuning range as desired. The initial bias on the control tube 43 should be so chosen that symmetry of shift with positive and negative discriminator potentials is secured. It will, also, be observed that the coupling M of the local oscillator is not electrically affected by or included in, the frequency correction circuit.

In Fig. 2 there is shown a modification of the frequency correction circuit wherein an oscillator tube 70 is employed independently of the first detector tube. The tank circuit in this case comprises the coil 15 shunted by the tuning condenser 16. Oscillation feedback is inductive by virtue of the tapping connection 71 between the grounded cathode of the oscillator tube and the tap point 72 on coil 15. The padder condenser 17' is connected to ground from the low potential side of coil 15, and the plate of the control tube 43 is connected through condenser 73 to a terminal of the coil 74; the latter being magnetically coupled to the coil 15. The AFC bias is applied to the control grid 42, and the quadrature voltage is applied to the control grid through a condenser 53'. The latter is connected to the junction of a pair of resistors R_1 and R_2 arranged in series between the opposite side of coil 74 and ground. The condenser 75 is connected in shunt across the resistor R_1, and the junction of resistor R_1 and coil 74 is connected to the junction of condenser 17' and the lower section of coil 15. A direct current voltage supply potentiometer P is connected to the plate screen grid and cathode electrodes of control tube 43 as shown in Fig. 2.

The locally produced oscillations may be impressed on the first detector in any well known manner, and it will be understood that the AFC bias is derived from a discriminator network of the type described in connection with network 24. The direct current return for the local oscillator cathode is through the path including resistors R_1 and R_2. The function of the condenser 75 is for obtaining radio frequency voltage from the oscillator circuit across resistor R_2 for the control grid 42. In other words, the elements 75 and R_2 are the quadrature components which are connected in shunt with the padder condenser 17'. There is magnetic coupling between the upper section of coil 15 and coil 74. In Fig. 2 it is immaterial whether or not there is coupling between coil 74 and the portion of coil 15 between tap 72 and condenser 17'. There will no doubt be some coupling since the coils are on the same form, but it can, and preferably should, be small, so that adjustment of feedback will not affect control and vice versa. As explained in connection with Fig. 1, the magnetic coupling between the plate circuit of control tube 43 and the tank circuit of the local oscillator enhances the control action produced by the capacity 17'.

While I have indicated and described a system 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 circuit organizations shown and described, but that many modifications may be made therein without departing from the scope of my invention as set forth in the appended claims.

What is claimed is:

1. In a superheterodyne receiver circuit adapted for automatic frequency control, a control tube, a local oscillator tank circuit including a padding condenser, a condenser and a resistive impedance in series with each other and both being connected across said padding condenser whereby part of the tank circuit current flows through the padding condenser and part through the series condenser and impedance, a connection for impressing on the control grid of the control tube alternating current voltage developed across said impedance, means magnetically coupling the output circuit of the control tube to the tank circuit, means other than said magnetic coupling means reactively coupled to said tank circuit for producing local oscillations, and means connecting the control tube output circuit to said padding condenser whereby currents flowing in the output circuit are impressed on the tank circuit partially through said magnetic coupling and partially across said padding condenser.

2. In a receiver as defined in claim 1, means responsive to a frequency shift in the intermediate frequency energy for varying the gain of said control tube, and said magnetic coupling and padding condenser magnitude being so related that the tank circuit frequency is substantially uniformly adjusted in magnitude at different station adjustments of the receiver.

3. In a receiver defined as in claim 1, the magnetic coupling means for the control tube and the reactive coupling means for producing oscillations being independent so that either may be adjusted without producing any substantial variation in the other.

4. In combination with an oscillator tube provided with a tank circuit comprising a coil and a variable condenser for adjusting the tank circuit frequency, a fixed second condenser in series with said coil and variable condenser, a resistor and third condenser in a series connection across said second condenser, means reactively coupling the oscillator tube output circuit with said tank circuit to produce oscillation, a network for supplementally adjusting the frequency of the tank circuit which comprises a tube having an input electrode and an output electrode, a radio frequency connection between the input electrode and the junction of said resistor and third condenser, a reactive coupling between the output electrode and said tank circuit, said reactive coupling being electrically independent of the first named reactive coupling means, and means for controlling the gain of said control tube.

5. In a system as defined in claim 4, said first named reactive coupling means comprising a coil magnetically coupled to said tank circuit coil, and said second reactive coupling comprising a second coil magnetically coupled solely to said tank circuit coil, and said second fixed condenser being in series with said second coil in the control tube output electrode circuit.

6. In combination with an oscillator network provided with a tank circuit including a padding condenser, said network including a radio frequency feedback path coupled to the tank circuit, a series path, of a condenser and an impedance, connected across said padding condenser whereby the tank circuit current divides between the padding condenser and the series path, an electron discharge tube having an input electrode connected to receive alternating voltage developed across the impedance, said tube having an output electrode, means electrically independent of said feedback path reactively coupling said output electrode to said tank circuit, an additional

connection between said output electrode and said padding condenser whereby currents flowing in the output electrode circuit of said tube divides between said reactive coupling means and said padding condenser.

7. In combination with an oscillator network provided with a tank circuit including a padding condenser, a series path, of a condenser and an impedance, connected across said padding condenser whereby the tank circuit current divides between the padding condenser and the series path, an electron discharge tube having an input electrode connected to receive alternating voltage developed across the impedance, said tube having an output electrode, means reactively coupling said output electrode to said tank circuit, an additional connection between said output electrode and said padding condenser whereby currents flowing in the output electrode circuit of said tube divides between said reactive coupling means and said padding condenser, said reactive coupling means comprising a magnetic coupling element, said impedance being a resistor, the impedance of said tube simulating a capacity effect across the padding condenser and simulating a negative inductance effect in series in the tank circuit, and means for varying the gain of said tube.

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