

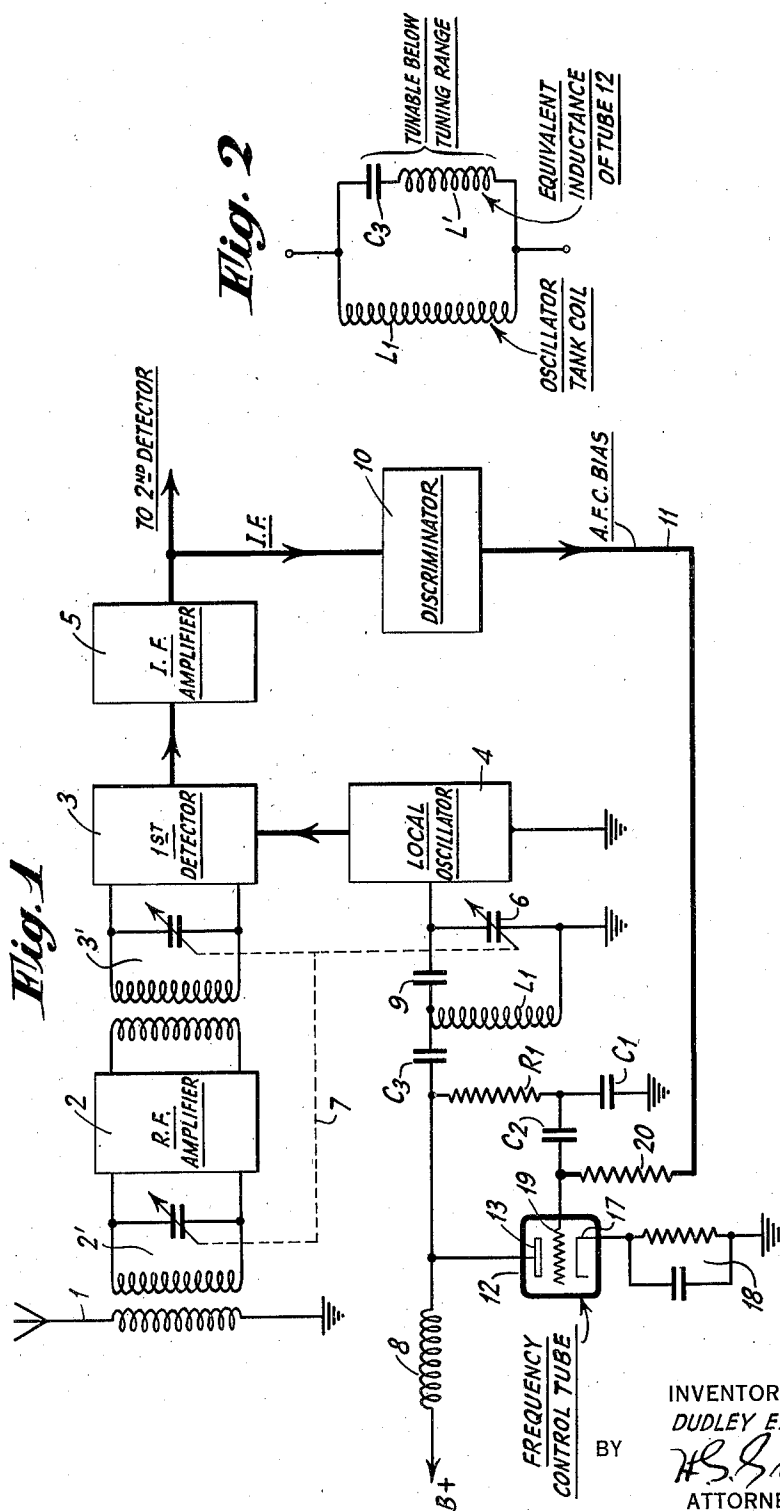
Sept. 6, 1938.

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2,128,997

AUTOMATIC FREQUENCY CONTROL CIRCUIT

Filed April 10, 1937



UNITED STATES PATENT OFFICE

2,128,997

AUTOMATIC FREQUENCY CONTROL
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Application April 10, 1937, Serial No. 136,064

7 Claims. (Cl. 250—40)

My present invention relates to automatic frequency control circuits for radio receivers of the superheterodyne type, and more particularly to a uniformly acting frequency control network for the local oscillator tank circuit of a superheterodyne receiver.

At the present time automatic frequency control circuits (AFC) for superheterodyne receivers generally comprise a discriminator unit for deriving a direct current voltage from the intermediate frequency (IF) energy when the latter shifts in frequency from the assigned IF value. In addition to the discriminator unit, there is utilized a frequency control tube network which is electrically associated with the local oscillator tank circuit in such a manner as to simulate across the tank circuit a reactance of a predetermined sign. The voltage output of the discriminator is employed to regulate the magnitude of the simulated reactance across the oscillator tank circuit, and the regulation is such that the oscillator frequency is shifted to a predetermined mean oscillator frequency at different settings of the receiver tuning device. It is, of course, desirable that the corrective oscillator frequency shift, at any setting of the tuning device, be substantially constant. In other words, an ideal AFC system would operate in such a manner that the amount of oscillator frequency correction would be substantially constant regardless of the positioning of the receiver tuning mechanism.

Accordingly it may be stated that it is one of the main objects of my present invention to provide a device for securing such substantially uniform oscillator frequency correction at different settings of the tuning device of a superheterodyne receiver employing an AFC circuit.

Another important object of the invention may be stated to reside in the provision of a superheterodyne receiver of the type utilizing an AFC arrangement, wherein a frequency control tube is electrically associated with the local oscillator tank circuit of the receiver in such a manner as to simulate across the tank circuit a reactance of a predetermined sign, and a reactance of a different sign being employed in conjunction with the simulated reactance in such a manner that the percentage oscillator frequency shift varies inversely with frequency whereby there is produced a more constant absolute frequency shift over the tuning range of the receiver.

Still other objects of the invention are generally to improve AFC arrangements for receivers of the superheterodyne type, and more especially to provide frequency control arrangements which

are not only efficient and reliable in operation, but are economically embodied in superheterodyne 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 drawing in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

Referring now to the accompanying drawing, wherein like reference characters in the two figures designate similar circuit elements, there is shown in schematic manner in Fig. 1 a superheterodyne receiver which employs an AFC arrangement embodying the present invention. In general, the receiver may be of any conventional superheterodyne type; it will usually embody a signal collector 1 which feeds a tunable radio frequency amplifier 2. The tunable first detector 3 is supplied with amplified signal energy, and oscillations from local oscillator 4 are also impressed on the detector, or mixer, 3. The IF energy output of the latter is amplified by an IF amplifier 5, and the output of the amplifier is demodulated by the usual second detector network. The latter, and the following audio network, are omitted, because they are well known to those skilled in the art. It is, also, pointed out that any type of automatic volume control arrangement may be used to maintain the signal intensity level at the demodulator input circuit substantially uniform. In this way a substantially uniform signal intensity level is maintained at the input circuit of the discriminator.

The signal circuits 2' and 3' have the rotors of the variable condensers thereof arranged for mechanical uni-control; the rotor of the variable condenser 5 is mechanically coupled to the tuning adjusting means, denoted by the dotted lines 7, for the rotors of the signal circuit condensers. The tank circuit of the local oscillator 4 includes the coil L₁ shunted by the grounded variable condenser 6. The fixed condenser 9 functions as a padder, and the latter acts to maintain the frequency of the oscillator tank circuit different from that of the signal circuits by a predetermined constant amount throughout the adjustment range of the tuning device 7. When the receiver is of the broadcast type and tunable through a range of from 500 to 1500 kc., then the IF may have a value chosen from a range of

from 75 to 480 kc. To secure accuracy in tuning, as well as to compensate for oscillator drift, there is employed an AFC arrangement. The AFC may be of the type shown by S. W. Seeley in his application Serial No. 45,413, filed Oct. 17, 1935.

The AFC generally comprises a discriminator 10 functioning to derive a direct current voltage (AFC bias) from the IF energy. The polarity and magnitude of the AFC bias is dependent on the sense and amount of frequency shift of the IF energy from the assigned frequency. The AFC bias is applied through lead 11 to an electrode of the frequency control tube 12. The latter functions to produce a predetermined reactive effect across tank circuit L_1 —6.

Since the specific construction of the discriminator network is of little importance in this case, it will be understood that the network can be of any desired type as long as it is capable of converting a frequency shift in IF energy into a direct current voltage change in polarity and magnitude. For example, the discriminator may comprise oppositely mistuned diode rectifiers, as shown by C. Travis in his application Serial No. 4,793, filed February 14, 1935. Again, the IF-tuned diode rectifiers of the aforesaid Seeley application may be employed in the discriminator network if desired. The circuit details of the frequency control tube and its connection to the oscillator tank circuit will now be described, since the present invention is embodied in that network.

The plate 13 of control tube 12 is connected to the positive terminal (+B) of a direct current source through a path which includes the radio frequency choke coil 8. The cathode 17 of control tube 12 is grounded through the usual self-bias resistor-shunt capacity network 18. The plate 13 40 is connected to the high potential side of oscillator tank circuit coil L_1 through a condenser C_3 . The plate side of condenser C_3 is connected to ground through a series path which includes resistor R_1 and the condenser C_1 . The control grid 45 19 of tube 12 is connected to the junction of resistor R_1 and condenser C_1 through a condenser C_2 .

There is impressed on the grid 19 alternating current voltage developed across the path R_1 — C_1 50 by oscillator tank current flowing through said path. The AFC lead 11 is connected to the grid side of condenser C_2 through a resistor 20, the function of the latter is to provide a D. C. path for AFC bias and act as an impedance to audio 55 frequency considerably higher than the impedance of condenser C_1 . By varying the bias of grid 19 the mutual inductance, or gain, of tube 12 is varied. This gain variation, in turn, changes the space current flow to the plate 13, and the 60 current flow through the coil L_1 .

The control action of tube 12 is produced in the following manner. The control circuit proper consists of tube 12, the resistors 20 and R_1 , and the condensers C_1 and C_2 . A certain alternating voltage, say E, exists between ground and the plate of control tube 12. The same voltage exists across resistor R_1 and condenser C_1 in series. If the resistor R_1 is a high resistance, the current 70 through it is nearly in phase with voltage E. The voltage across condenser C_1 , however, will lag nearly 90 degrees behind E. That is, the alternating voltage applied to grid 19 of tube 12 lags the plate voltage thereof, but the plate current 75 is in phase with the grid voltage. The plate cur-

rent, hence, lags behind the plate voltage nearly 90 degrees.

In an inductance of low resistance the current also lags 90 degrees behind the voltage. Hence, the frequency control tube 12, connected as shown, electrically simulates in shunt across coil L_1 an inductance with a small resistance and a condenser C_3 in series therewith. This shunt inductance capacity circuit acts to reduce the effective inductance of circuit L_1 —6; it increases the frequency of oscillation. The AFC bias applied to grid 19 acts to vary the gain of the control tube, and the magnitude of the simulated shunt inductance, so as to secure desired oscillator frequency correction in response to a frequency shift in IF energy from the assigned value. The mean bias of grid 19, which bias is developed by network 18, is so chosen that there will be approximately equal frequency changes on both sides of the mean oscillator frequency at any setting of the receiver tuning means. However, in actual operation in the past, such uniform oscillator frequency correction has not been secured as the variable condenser 6 is adjusted to change the operating frequency of the local oscillator from one end of the tuning range to the other end.

According to the present invention, the magnitude of the condenser C_3 is so chosen that this condenser resonates with the simulated shunt inductance to a frequency below the tuning range of the oscillator tank circuit. In Fig. 2 there is shown the equivalent network with respect to the oscillator tank circuit coil. It will be observed that the oscillator tank coil L_1 has connected in shunt therewith a series path which includes the condenser C_3 and a reactance designated as L' . The inductive reactance L' is the equivalent inductance of tube 12. In other words, the inductance L' represents the simulated inductive reactance which is developed across the tank circuit due to the action of the frequency control tube 12. The series path C_3 — L' is resonated to a frequency below the tuning range of the oscillator tank circuit in order to maintain substantial uniformity of frequency correction of the oscillator tank circuit throughout the tuning range thereof. The magnitude of resistor R_1 should be much larger than the reactance of condenser C_1 . The resonant frequency of C_3 — L' decreases with decreasing G_m of tube 12; hence AFC bias change causes no difficulty.

$$L' = \frac{R_1 C_1}{G_m}$$

In the above relationship G_m is that of the control tube 12. Merely by way of specific example, and not by way of limitation on the present invention, let it be assumed that R_1 =50,000 ohms, C_1 =20 mmf., and G_m =1,000 microhms. In that case L' will be equal to 1,000 microhenries. For this value of L' , the condenser C_3 should have a magnitude of 42.3 mmf. For these values C_3 resonates L' to approximately 770 kc. Of course, it is assumed for the last named illustration that the oscillator tank circuit L_1 —6 is tunable through a range of frequencies of approximately 1,000 to 2,200 kc., and that the IF is 460 kc.; the signal circuits tuning from 540 to 1740 kc.

If the percentage frequency shift were constant, say 10% of the oscillator frequency, the shift would be 100 kc. at a signal frequency of 540 kc. and 220 kc. at a signal frequency of 1740 kc.

With C_3 in series equal to 42.3 mmf. the following tabulation shows what happens:

Assume $L_1=120 \text{ h.}$

f	1,000 kc.	1,600 kc.	2,200 kc.
$X_{L'}$, ohms.....	6,280	10,000	13,800
X_{C_3} ohms.....	3,800	2,370	1,700
$X_{L'}-X_{C_3}$ ohms.....	2,480	7,630	12,100
L' , $\mu\text{h.}$	395	763	880
Percent L change.....	23.5	13.5	12
Percent f change.....	11	7	6
shift kc.....	110	112	130

The total shift varies 18% from one end of the range to the other, whereas without C_3 it varies 220%. L'' stands for the inductance at a given frequency which would be equal to the combination of L' and C_3 in series. This inductance changes with frequency being smaller at the low frequencies (nearer $L'-C_3$ resonance). It is this virtual inductance varying with frequency which produces the desired effect on shift with frequency, since a low inductance in shunt with another inductance has greater effect.

By resonating the path C_3-L' to a frequency below the tuning range of the local oscillator tank circuit several advantages are secured. The percentage frequency shift of the oscillator tank circuit varies inversely with oscillator frequency, and, therefore, produces a more constant absolute frequency shift. Furthermore, the condenser C_3 is in series with the static capacity of the control tube 12 thereby decreasing the total capacity shunting coil L_1 . Again, the effective frequency variation of the tank circuit is greater, and hence the AFC system is more sensitive than with the condenser C_3 large, or omitted.

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 organization 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 combination with a resonant circuit of the type which includes means for tuning it over a desired tuning range, a tube connected to said circuit to have the cathode to plate impedance of the tube simulate a reactance across the circuit, means for varying the gain of the tube to adjust the magnitude of said reactance, and a reactance of different sign from the first reactance in series with the impedance across said circuit, said two reactances being resonant to a frequency below said tuning range.

2. In combination with a resonant circuit of the type which includes means for tuning it over a desired tuning range, a tube connected to said circuit to have the cathode to plate impedance of the tube simulate a reactance across the circuit, means for varying the gain of the tube to adjust the magnitude of said reactance, a reactance of different sign from the first reactance in series with the impedance across said circuit, said two reactances being resonant to a frequency below said tuning range, said simulated reactance being inductive, and the second reactance being capacitive.

3. In combination with a resonant circuit of the type which includes means for tuning it over a desired tuning range, a tube connected to said circuit to have the cathode to plate impedance

of the tube simulate a reactance across the circuit, means for varying the gain of the tube to adjust the magnitude of said reactance, and a reactance of different sign from the first reactance in series with the impedance across said circuit, said two reactances being resonant to a frequency below said tuning range, said gain varying means adjusting said magnitude when the circuit frequency departs from predetermined frequency values of said range.

4. In combination with a coil tuned to a desired frequency, a tube having connections thereto to have the cathode to plate impedance of the tube produce an inductance effect across the coil, a condenser in series with said impedance across the coil, said condenser resonating said inductance to a frequency below said desired frequency.

5. In combination with a resonant circuit of the type including a coil and a condenser in shunt therewith, said circuit being tunable through a desired frequency range, an electron discharge tube including at least a cathode, control grid and an anode, means for impressing the output current of said tube on said resonant circuit, a circuit element connected to said resonant circuit whereby the voltage across said circuit element is substantially in quadrature with the voltage across said resonant circuit, means for applying said quadrature voltage to said control grid whereby the effective reactance of the coil of said resonant circuit is decreased by virtue of a simulated inductive reactance produced across said coil, and a condenser effectively connected in series with said simulated inductance across said coil, said condenser and simulated inductance being resonant to a frequency below the tuning range of said resonant circuit.

6. In a superheterodyne receiver of the type including an automatic frequency control circuit, said automatic frequency control circuit being of the type which includes a frequency control tube having input and output electrodes electrically coupled with the local oscillator tank circuit of the receiver to produce a simulated inductive reactance across the tank circuit, a condenser connected between the output electrode of said control tube and the high alternating potential side of said tank circuit whereby the condenser is effectively in series with said simulated reactance across the tank circuit, and said condenser and simulated reactance being resonant to a frequency below the lowest frequency of said tank circuit.

7. In a superheterodyne receiver of the type including a local oscillator network provided with a tank circuit tunable over a relatively wide frequency range, an intermediate frequency network, an electron discharge tube having input and output connections to the tank circuit such that the cathode to plate impedance of the tube acts as an inductance across the tank circuit, and a discriminator, responsive to shifts in the intermediate frequency energy from an assigned frequency, for controlling the gain of said tube in a sense to cause the inductance to correct the frequency of the tank circuit and maintain said assigned frequency value; the improvement which comprises a condenser in series with said cathode to plate impedance across said tank circuit, and said condenser resonating the said inductance to a frequency below said frequency range whereby said correction is substantially uniform over said range.

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