

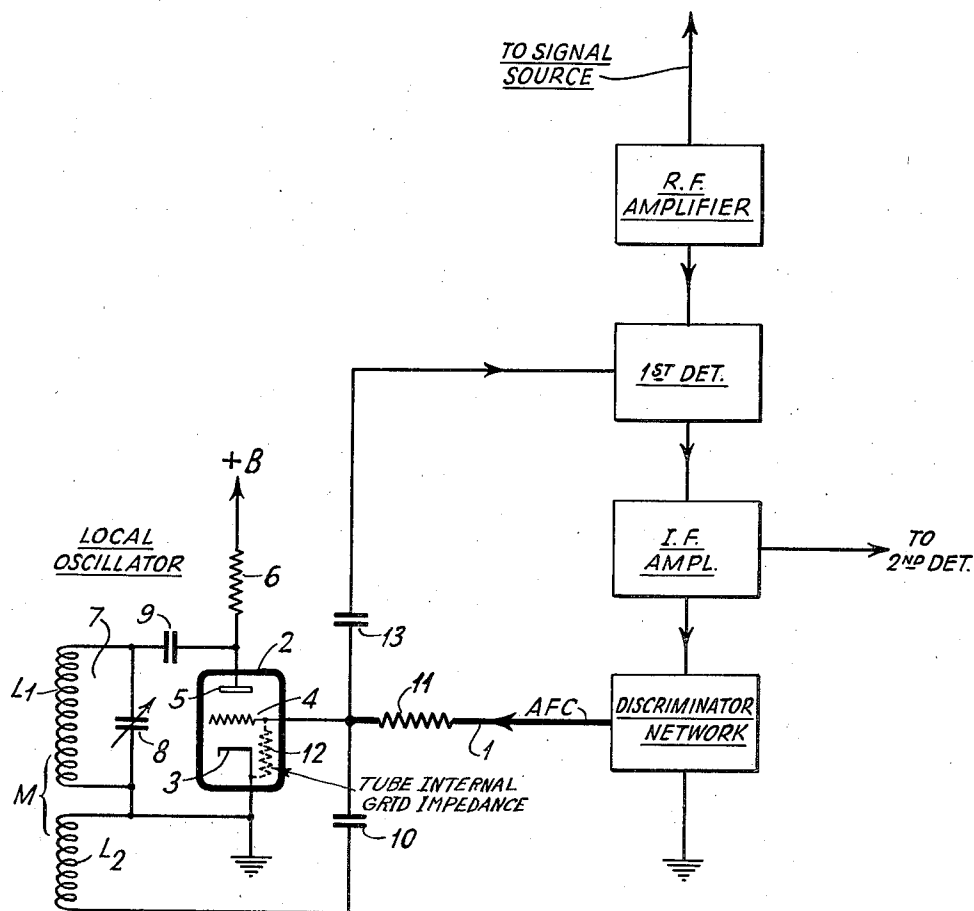
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AUTOMATIC FREQUENCY CONTROL CIRCUIT

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BY

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AUTOMATIC FREQUENCY CONTROL
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My present invention relates to automatic frequency control circuits, and more particularly to a superheterodyne receiver system employing a local oscillator network whose associated circuits are designed to provide automatic frequency control.

One of the main objects of my present invention is to provide a simplified type of automatic frequency control circuit for a superheterodyne receiver; the control circuit utilizing a frequency correction network which is provided for the local oscillator without the need for employing an auxiliary frequency control tube.

Another important object of this invention is to provide a tunable local oscillator which employs the existing circuit elements of the oscillator network for securing an automatic frequency correction upon regulation of the gain of the oscillator tube.

Another object of this invention may be stated to reside in the provision of an oscillator tube whose tunable tank circuit is provided between the plate and cathode of the tube, the control grid of the tube being regeneratively coupled to the tank circuit through a feedback coil; and the mutual inductance between the tank circuit and feedback coil, and the self-inductance of the feedback coil, being chosen to provide a reactive effect across the tank circuit which may be varied in magnitude by adjusting the gain of the oscillator tube.

Still another object of the invention is to provide a superheterodyne receiver wherein the intermediate frequency (I. F.) energy is utilized to provide a direct current voltage whose polarity and magnitude depend upon the sense and magnitude of frequency departure of the I. F. energy from an assigned I. F. value; and the discriminator output voltage being employed to regulate the bias of the control grid of a local oscillator which has the constants of the inductive components of its feedback circuit so selected as to provide a reactive effect across the tank circuit which is variable in magnitude in dependence upon the variation in bias of the oscillator grid.

Still other objects of my invention are generally to improve the simplicity of automatic frequency control circuits for superheterodyne receivers, and more especially to provide such a control circuit in an economical manner, and which is, furthermore, reliable and efficient in operation.

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, there is shown in schematic manner the various networks of a superheterodyne receiver of the type employing an automatic frequency control circuit. Since such receiving systems are well known at the present time, it is not believed necessary to show the details of any network other than the local oscillator circuit which embodies the present invention. For the purposes of the present application it is believed sufficient to make reference to the disclosure of S. W. Seeley in application Serial No. 45,413, filed Oct. 17, 1935, granted June 21, 1938, as U. S. Patent 2,121,103. In Fig. 4 of the latter patent there is disclosed a superheterodyne receiver employing an automatic frequency control circuit (AFC hereinafter). It may be stated that the present receiving system shown in the drawing may be considered similar to that shown in Fig. 4 of the aforesaid Seeley patent, except that the frequency control circuit disclosed herein in connection with the local oscillator circuit is different therefrom in the various details to be explained at a later point.

In general, it may be stated that the present system can be of the broadcast type, or of the "all-wave" type, and will comprise the usual signal collector which feeds one or more stages of radio frequency amplification. The first detector will be fed with amplified radio frequency signals, and will feed its I. F. energy output to one or more I. F. amplifiers. The I. F. value may be chosen between 75 to 450 kc., and the I. F. energy is impressed upon a discriminator network of the type disclosed in the Seeley patent. The audio voltage component of the discriminator output may be used for audio frequency amplification and then reproduced. However, for the sake of simplicity, the I. F. energy is shown in the present application as being fed to a second detector which is independent of the discriminator network. Of course, the discriminator network may also be of the type wherein opposed rectifiers are tuned above and below the assigned I. F. value by the same predetermined frequency amount. In any event the discriminator network will produce a direct current voltage whose polarity and magnitude depend respectively upon the sense and amount of frequency departure of the I. F.

energy from the assigned I. F. value. In other words, as the receiving system is tuned to a desired signal frequency, the discriminator network will produce a direct current voltage whose polarity and magnitude will depend upon which side of the incoming carrier frequency the receiver is being tuned to.

The AFC voltage is applied to the control grid of the local oscillator tube by means of a lead 1. The local oscillator tube 2 includes at least a cathode 3, a control grid 4 and plate 5. The plate is connected to a source of appropriate positive potential (not shown) through a voltage reduction resistor 6, and the cathode 3 may be considered to be at a fixed potential such as ground. The tank circuit 7 comprises the coil L_1 and the variable tuning condenser 8. The high alternating potential side of circuit 7 is connected to the plate 5 through a direct current blocking condenser 9, whereas the low potential side of the circuit 7 is established at ground potential. The control grid 4 is regeneratively coupled to the tank circuit 7 through a path which includes the direct current blocking condenser 10 and the feedback coil L_2 .

The symbol M denotes the magnetic coupling which provides reactive coupling between coils L_1 and L_2 , it being pointed out that one end of coil L_2 is at ground potential. The AFC lead 1 is connected to control grid 4 through a grid leak resistor 11, and the numeral 12 denotes the internal grid impedance (shown in dotted lines) of the oscillator tube 2. The local oscillations may be impressed upon the first detector through condenser 13. It will be understood that the variable condenser 8 will have its rotor plates adjusted simultaneously with the rotor plates of the tunable signal circuits of the receiving system. The frequency of the tank circuit 7 is maintained at a frequency different at all times with respect to the frequency of the signal circuits by a value which is equal to the assigned I. F. value. If, for example, when the receiver is employed in the broadcast band of 550 to 1500 kc., the variable condenser 8 will adjust the tank circuit 7 through a frequency range which is generally higher than the signal frequency range; and differs therefrom at all settings of the tuning device by the assigned I. F. value.

The AFC circuit functions to provide a frequency adjustment of tank circuit 7 over a small range on either side of predetermined station settings of the variable condenser 8. As explained previously when the variable condenser 8, and the variable condensers of the signal circuits, is adjusted to a setting such that the I. F. energy is close in frequency to the assigned I. F. value, the discriminator network will produce AFC voltage which will vary the bias of control grid 4 sufficiently to produce a frequency adjustment of tank circuit 7, which is independent of the frequency adjusting action of condenser 8, so as to maintain the I. F. energy at the assigned I. F. value. In the present case this is accomplished by proper choice of the constants of M and L_2 . That is to say, the magnetic coupling between the tank circuit and the feedback coil L_2 , and the self-inductance of coil L_2 , are chosen so as to provide a reactive effect in tank circuit 7 and which can be varied in magnitude upon variation of the gain of tube 2. This reactive effect is equivalent to a parallel negative inductance. In other words, the frequency correction of the oscillator tank circuit is secured without adding any auxiliary circuit elements for the

function. It will be appreciated that such a simplified AFC circuit is of advantage particularly in the case of receivers of the compact type such as are used in automobiles, airplanes and the like.

There will now be explained the nature of the electrical reactions which give rise to the production of the simulated reactive effect across the tank circuit 7. If the reactive magnitude of feedback coil L_2 is made large compared to the magnitude of the internal grid impedance 12, then it can be demonstrated that the voltage of the grid 4 will depend upon the product of the alternating voltage across tank circuit 7, the ratio of the magnitude of M to L_1 , and the ratio of the magnitude of impedance 12 to the reactive value of feedback coil L_2 . In effect this relationship means that there exists a quadrature component in the expression defining the value of the voltage of grid 4. Variation of the bias of grid 4 will then cause a frequency variation of tank circuit 7 by virtue of a variation of the reactive effect produced thereacross.

Voltage across tank circuit causes lagging current in coil L_1 . Polarity of M must be such as to make the circuit oscillate, so that induced voltage in L_2 is 180° out of phase with tank voltage. This voltage flows through L_2 and the internal grid resistance of tube 2. If the reactance of L_2 be made high compared with the internal grid resistance, current therein will lag induced voltage substantially 90°, i. e., lead tank voltage approximately 90°. This quadrature voltage applied to the grid 4 causes equivalent quadrature current flow in the plate circuit i. e., the tank circuit. Making grid 4 more positive increases mutual conductance of tube 2 which decreases the negative equivalent inductance across tank circuit and which in turn causes an increase in the oscillation frequency of the tank circuit. No added elements over the ordinary oscillator circuit are needed, but the proportion of reactance of L_2 and internal grid resistance must be such that reactance predominates in order to obtain frequency correction effect.

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 I claim is:

1. In an oscillator network, a tube provided with at least a cathode, control grid and plate, a tank circuit including means for tuning it over a wide range of frequencies, said tank circuit being connected between the plate and cathode, inductive means coupling the control grid to said tank circuit to provide feedback for the production of oscillations, the reactive magnitude of said inductive means being large compared to the magnitude of the internal grid to cathode impedance of said tube at the frequency of operation whereby there is provided a substantial reactive effect across the tank circuit, and means for varying the direct current voltage of said control grid of said tube sufficiently to vary the magnitude of said reactive effect thereby to adjust the frequency of said tank circuit at selected frequencies of said wide range.

2. In an oscillator network of the type employing a tube having its input and output electrodes reactively coupled to provide oscillations, said network including a tunable tank circuit

connected between the cathode and anode of the oscillator tube, a feedback coil magnetically coupling the control grid of the tube to the tank circuit, the value of the reactance of the feedback coil inductance being large compared to the magnitude of the internal grid to cathode impedance of said tube at the frequency of operation thereby to provide a pure reactance effect across the tank circuit, and means for varying the direct current voltage of the oscillator tube control grid thereby to adjust the magnitude of said pure reactance effect.

3. In a local oscillator for a superheterodyne receiver, an electron discharge tube having at least a cathode, a control electrode and an anode electrode, a tunable tank circuit including a coil and variable condenser connected between the cathode and anode, a second coil reactively coupling said tank coil and said control electrode, the value of said feedback coil reactance being large compared to the value of the internal control electrode to cathode resistance of said tube at the operating frequency thereby to provide a simulated reactance across said tank circuit, additional means for varying the gain of said tube thereby to vary the value of said simulated reactance.

4. In a local oscillator for a superheterodyne receiver, an electron discharge tube having at least a cathode, a control electrode and an anode electrode, a tunable tank circuit including a coil and variable condenser connected between the cathode and anode, a second coil reactively coupling said tank coil and said control electrode,

the value of the reactance of the feedback coil inductance being large compared to the magnitude of the tube internal control electrode to cathode impedance at the operating frequency thereby to provide a simulated negative inductive reactance across said tank circuit, additional means, responsive to received signal carrier frequency variations, for adjusting the gain of the tube in a sense to cause said simulated reactance to compensate for said frequency variations.

5. In a superheterodyne receiver of the type including an intermediate frequency energy circuit followed by a discriminator network adapted to produce direct current voltage whose magnitude is a function of frequency shift of the intermediate frequency carrier, a local oscillator circuit comprising an electron discharge device including at least a cathode, control electrode and anode electrode, a tunable tank circuit connected between the cathode and anode electrode, an inductive reactance coupling the tank circuit to the control electrode, the magnitude of the inductive reactance being large compared to the magnitude of the internal control electrode to cathode impedance of said oscillator discharge device at the operating frequency thereby to provide a predetermined reactive effect across the tank circuit, and means for applying said direct current voltage to the control electrode thereby to vary the value of the reactive effect sufficiently to adjust the frequency of the tank circuit.

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