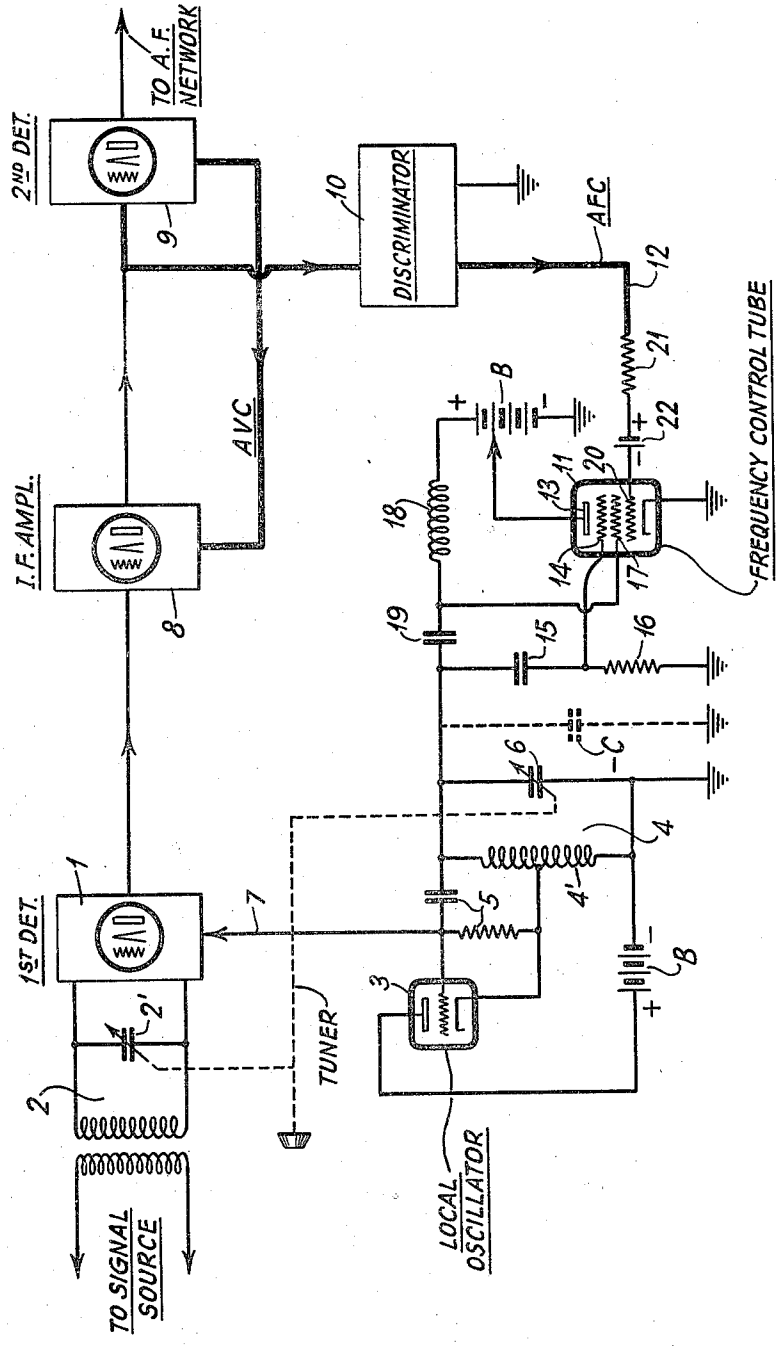
Feb. 11, 1941. G. MOUNTJOY 2,231,367

AUTOMATIC FREQUENCY CONTROL CIRCUIT

Filed Feb. 23, 1938



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Patented Feb. 11, 1941 2,231,367

UNITED STATES PATENT OFFICE

2,231,367

AUTOMATIC FREQUENCY CONTROL CIRCUIT

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Application February 23, 1938, Serial No. 191,885

4 Claims. (Cl. 250—40)

My present invention relates to frequency control circuits, and more particularly to electronic reactances of negative sign adapted to adjust the tuning of oscillator circuits.

It has been previously proposed to employ electronic reactances for tuning oscillator circuits. For example, an automatic frequency control (AFC) system at the present time uses electronic reactance, whether inductive or capacitative, as a supplemental tuning device in the oscillator tank circuit. There are advantages to be derived from employing an electronic reactance of negative sign for tuning an oscillator tank circuit. This is particularly true in the case of an electronic reactance comprising a negative capacitance. Such negative capacitance can be developed by either negative or positive mutual conductance tubes; hence, the use thereof is readily adapted to varying conditions.

It may, therefore, be stated to be one of the main objects of my present invention to provide a tuning device for a resonant circuit, wherein the tuning device comprises a negative reactance developed by an electron discharge tube which is connected to the resonant circuit in a predetermined fashion.

Another important object of the invention can be stated to reside in the provision of a tube having its plate and control grid circuits related to an oscillator tank circuit so as to simulate thereacross a negative capacitance; and the magnitude of the latter being adjustable by varying the gain of the tube thereby to control the tank circuit frequency.

Another object of the invention is to provide a negative mutual conductance tube having input and output circuits related to an oscillator tank circuit to develop across the latter a negative capacitance; the tube conductance being adjustable to vary the magnitude of said capacitance.

A more specific object of this invention is to provide an automatic frequency control system for a superheterodyne receiver; the control system utilizing a tube having a negative mutual conductance for providing a negative capacitance across the local oscillator tank circuit; and the frequency of the oscillator being adjustable, in addition to the action of the main tuning device, by varying the gain of the said tube in response to frequency changes in the intermediate frequency (I. F.) energy.

Still other objects of the invention are to improve generally the operation and efficiency of superheterodyne receivers of the A. F. C. type, and more especially to provide oscillator tank circuit control networks which are readily and economically manufactured and assembled.

Referring now to the accompanying drawing there is shown a frequency control network of the present invention applied to an AFC system of a superheterodyne receiver. The latter may be of any well known type; as, for example, that shown in application Serial No. 45,413, filed Oct. 17, 1935, by S. W. Seeley and granted June 21, 1938, as U. S. Patent 2,121,103. Generally, the receiver comprises a converter, or first detector, network 1 which is fed with signals and locally produced oscillations. The signals, after collection by any desired collector, may be amplified in a tunable radio frequency amplifier, and finally impressed on the tunable input circuit 2. The oscillator comprises a tube 3 having a tunable tank circuit 4. The plate of tube 3 is connected to the grounded end of the tank circuit by the source of positive d. c. potential B. The grid of tube 3 is connected to the high potential side of tank circuit 4; the cathode of tube 3 is connected to the midpoint of the coil 4'. The usual resistor-condenser network 5 is employed to maintain the oscillator grid negative. The oscillator connections are well known, and need not be described further.

The numeral 2' denotes the variable condenser used for tuning the circuit 2 over the signal range; the latter may be the broadcast range of 500 to 1500 K. C. The variable condenser 6 in the tank circuit 4 is varied over an oscillation range which differs from the signal range by an I. F. value which may be chosen from a range of 75 to 450 K. C. or greater. The dotted lines denoted "Tuner" represent the usual uni-control mechanism for adjusting the rotors of the tuning condensers. Of course, the receiver may be of the multi-wave type; in that case, well known wave band changing switches will be used in the signal and oscillator networks. The frequency control network to be described below is of particular advantage in the short wave band; although it is beneficial on all wave bands.

The local oscillations produced in the receiver are impressed, as at 7, upon the network 1. If desired, a combined local oscillator-first detector tube may be used; the latter may be a 2A7 or 6A7 tube. The I. F. energy output of network 1 is amplified by an I. F. amplifier 8; a second detector 9 detects the amplified energy. The detected energy may be amplified by one or more amplifier stages, and the final amplified audio

energy is reproduced by any desired loudspeaker. The direct current voltage component of detected I. F. energy is employed for AVC; for example, the AVC bias is used to decrease the gain of I. F. amplifier 8.

The AFC system employs a discriminator 10, upon whose input circuit is impressed I. F. energy. The discriminator may be constructed as described in said Seeley patent; in such case the input circuit is tuned to the I. F. The direct current voltage derived from the discriminator output depends in magnitude and polarity on the extent and sense of the frequency shift of the I. F. energy. The AFC voltage is employed to "correct" the tuning of the tank circuit in a sense to maintain the predetermined value of the I. F. This correction is accomplished by connecting tube 11 to the tank circuit, and AFC line 12 to tube 11, in the manner now to be described.

The plate 13 of tube 11 is connected to a desired positive potential point on current source B; the control grid 14 is connected to the junction of condenser 15 and resistor 16. The latter two elements are connected in series relation; they are arranged in shunt with the tank circuit 4. The grid 14 is disposed between the positive plate 13 and a grid 17 which is at a more positive potential than the plate. The grid 17 is connected to a point on source B through the radio frequency choke coil 18. The direct current blocking condenser 19 is connected between the high potential side of condenser 15 and the grid end of coil 18. The grid 17, if desired, may be at the same positive potential as the plate 13; the essential thing is that the tube 11 have a negative mutual conductance characteristic.

The gain of tube 11 is regulated by the grid 20; the latter being disposed between the grounded cathode and grid 17. The lead 12 is connected to grid 20 through a pulsating voltage filter resistor 21 and a negative bias source 22. With no bias applied to grid 20 from the discriminator 10, the gain of tube 11 is determined by the bias source 22. In the absence of AFC bias (that is, when the I. F. energy is of the correct frequency) the grid 20 will have a predetermined negative bias. In that state there will be simulated across the tank circuit 4 a negative capacitance —C; the latter is shown by dotted lines in the drawing to denote that the negative capacity effect is produced by the effect of tube 11 and its circuits.

The simulation of negative capacity is produced in the following fashion. The resistor-condenser network 15—16 acts as a phase-shifting device; the latter shunts the tank circuit 4, and is, also, connected across the circuit of tube 11 including the cathode, anode electrode 17 and grid 14. The current due to E_p, the tank circuit voltage, through the combination 15—16 leads the voltage E_p. Values are selected for 15 and 16 such that the two combined appear as a capacity load upon the tank circuit. The voltage developed across resistor 16 by the current flow in the tank circuit is impressed between the grid 14 and cathode in a phase such that the current flow due to electrode 17 produces the negative capacity —C. The voltage across resistor 16 leads the voltage E_p. Since the mutual conductance between grid 14 and anode electrode 17 is negative in sign, the reactive effect produced by the current flow due to anode 17 is a negative capacity. The magnitude of the negative capacity will vary directly with the gain of tube 11. Hence, when grid 20 is made more negative and the gain of tube 11 increases, the magnitude of —C increases and the frequency of circuit 4 increases. On the contrary, if the AFC bias is positive the grid 20 is made less negative; the gain of tube 11 decreases, and decreases the magnitude of —C. This results in a frequency decrease of tank circuit 4, since C is negative in sign.

The advantage of using the negative capacity effect of tube 11 resides in the fact that the capacity range of oscillator tuning condenser 6 can be reduced for a given frequency coverage. The negative capacity —C reduces the effective capacity in the oscillator circuit, and permits a coil 4' of larger inductance value to be employed. This gives a tank circuit of high impedance and oscillation gain. An AFC of improved type will result; particularly at short waves will the AFC action be improved.

The negative capacity effect of tube 11, and its connections to a tuned circuit, can be used for wide range tuning. That is to say, the oscillator tank circuit, for example, could be varied in tuning over its entire operating range by variation of the bias of grid 20. Such a tuning mechanism can be employed instead of the variable tuning condenser 6.

What I claim is:

1. In combination with a resonant circuit, a phase-shifting device including capacity and resistance in series connected thereacross, a tube having input electrodes connected across the resistive portion of said device, means connecting the output electrodes of the tube across the circuit, the connections to said tube being such that a negative reactive effect is produced across the resonant circuit between said output electrodes, said tube being connected and constructed to have a negative mutual conductance characteristic, and means for adjusting the gain of said tube to vary the magnitude of said reactance.

2. In combination with a tuned circuit, a phase shifting device including capacity and resistance elements in series connected across the circuit, a tube including a cathode and at least three cold electrodes spaced in succession from said cathode, one of the electrodes and the cathode being connected across the resistance element, the remaining two electrodes being positive, said one electrode being disposed between the positive electrodes, the positive electrode furthest from the cathode being connected across the entire shifter device, the positive electrode nearer the cathode being connected across the entire shifter device, said last-named positive electrode being sufficiently more positive than said furthest cold electrode to impart a negative mutual conductance characteristic to said tube whereby a negative capacity effect is simulated between the last named positive electrode and the cathode across said tuned circuit.

3. In combination with a tuned circuit, a phase shifting device including capacity and resistance elements in series connected across the circuit, a tube including a cathode and at least three cold electrodes spaced in succession from the cathode, one of the electrodes and the cathode being connected across the resistance element, the remaining two electrodes being positive, said one electrode being disposed between the positive electrodes, the positive electrode furthest from the cathode being connected across the entire shifter device, the positive electrode nearer the cathode being connected across the entire shifter device, said last-named positive electrode being sufficiently more positive than said furthest cold elec-

trode to impart a negative mutual conductance characteristic to said tube whereby a negative capacity effect between the last named positive electrode and the cathode is simulated across said tuned circuit, and means for adjusting the gain of the tube thereby to vary the value of said negative capacity.

4. In combination with a resonant oscillatory circuit, means for adjusting the frequency thereof comprising an electron discharge tube having input electrodes and output electrodes, a phase shifting network connected across the resonant circuit, means connecting the output electrodes of said tube across the resonant circuit whereby output current of said tube flows through the phase shifter network and produces an alternating voltage thereacross in phase quadrature with the voltage developed across the oscillatory circuit by said tube output electrodes, means connecting the tube input electrodes across at least a portion of said phase shifter network whereby the said quadrature voltage is applied to the input electrodes and produces a reactive effect across the resonant circuit between said output electrodes, said tube being constructed and arranged to have a negative mutual conductance, and said shifter network portion being so constructed and related to the tube input electrodes as to impart a negative sign to said reactive effect, and means for adjusting the gain of said tube thereby to vary the magnitude of said negative reactive effect and the frequency of said resonant circuit.

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