

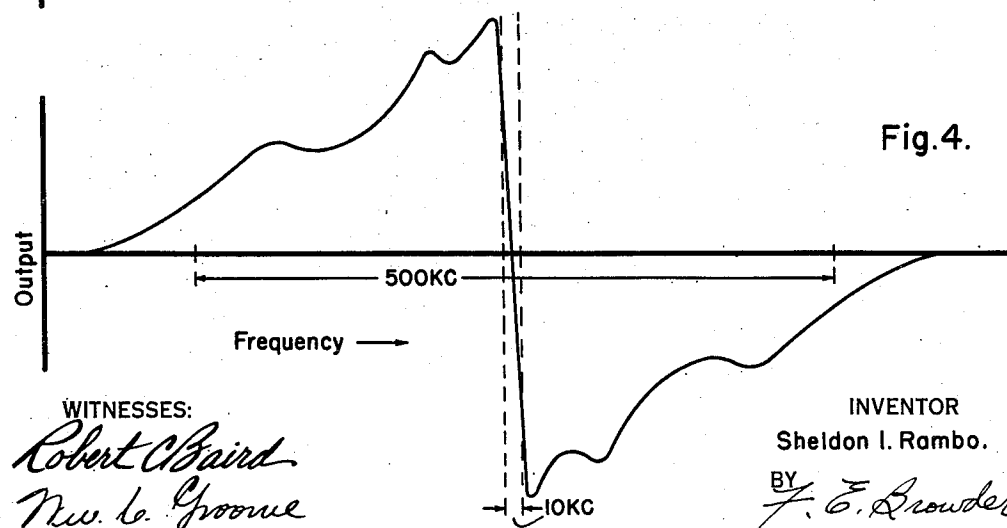
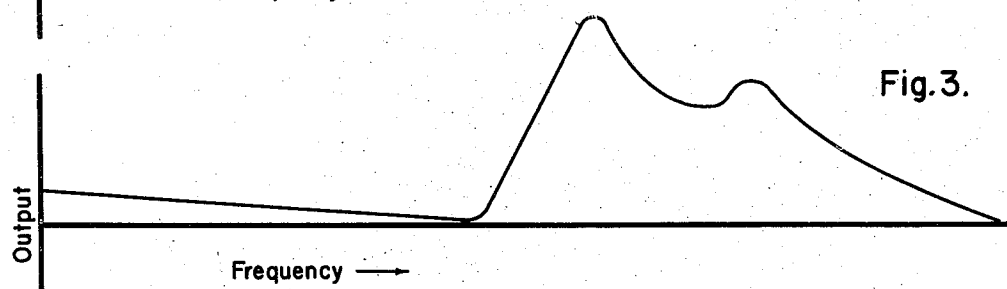
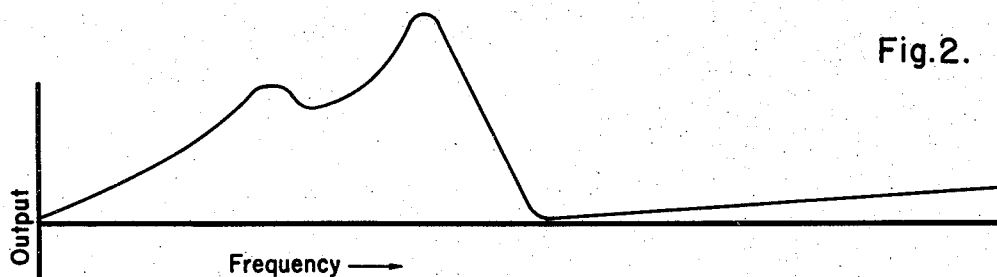
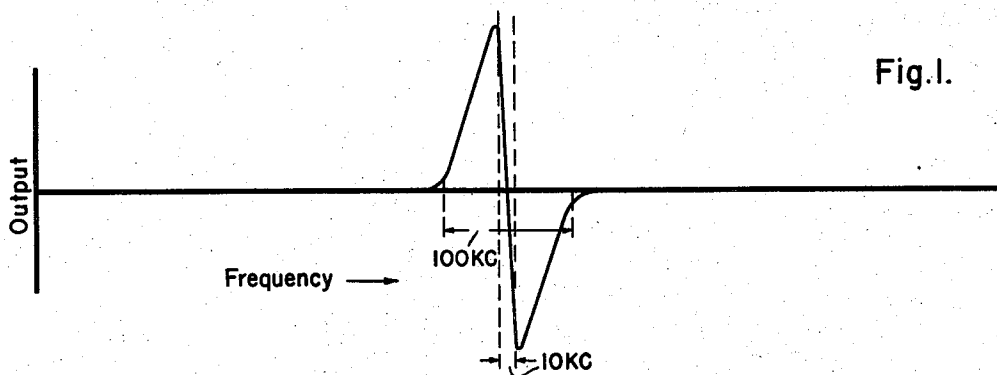
June 26, 1951

S. I. RAMBO
FREQUENCY STABILIZER

2,558,100

Filed Nov. 2, 1948

3 Sheets-Sheet 1



WITNESSES:

Robert Baird
New. L. Groome

INVENTOR
Sheldon I. Rambo.

BY *F. E. Browder*
ATTORNEY

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3 Sheets-Sheet 2

Fig. 5.

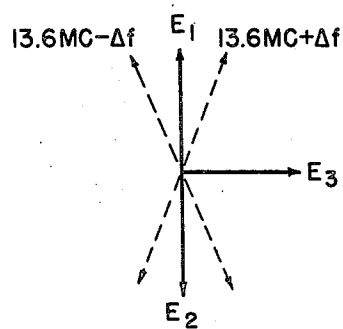
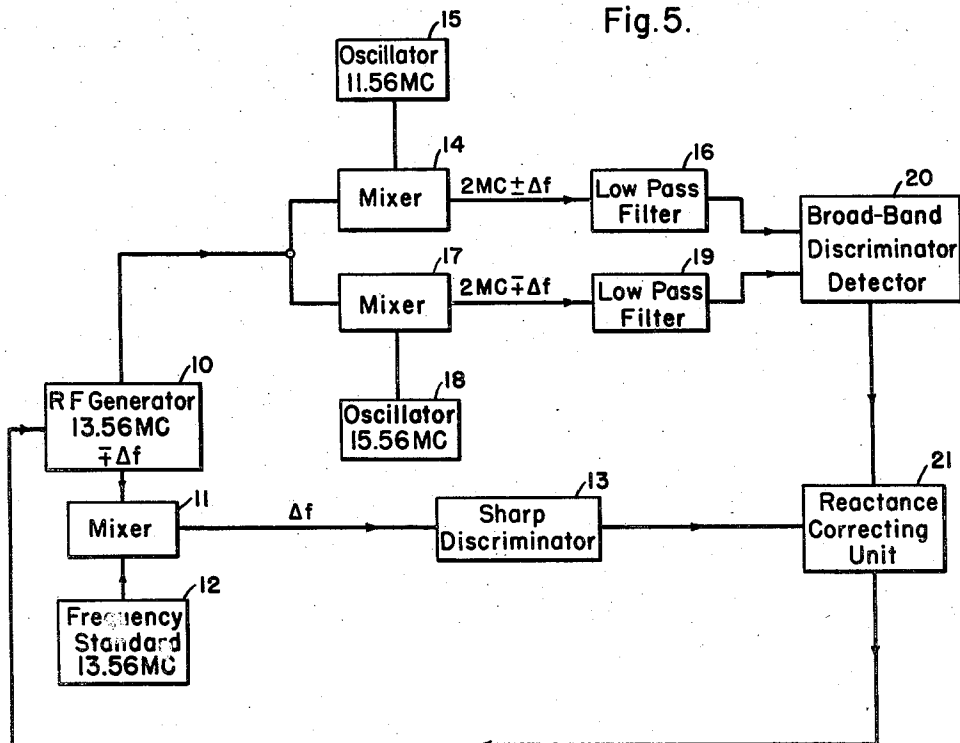


Fig. 7.

WITNESSES:

Robert C. Baird
New. L. Groome

INVENTOR

Sheldon I. Rambo.

BY

F. E. Browder
ATTORNEY

June 26, 1951

S. I. RAMBO

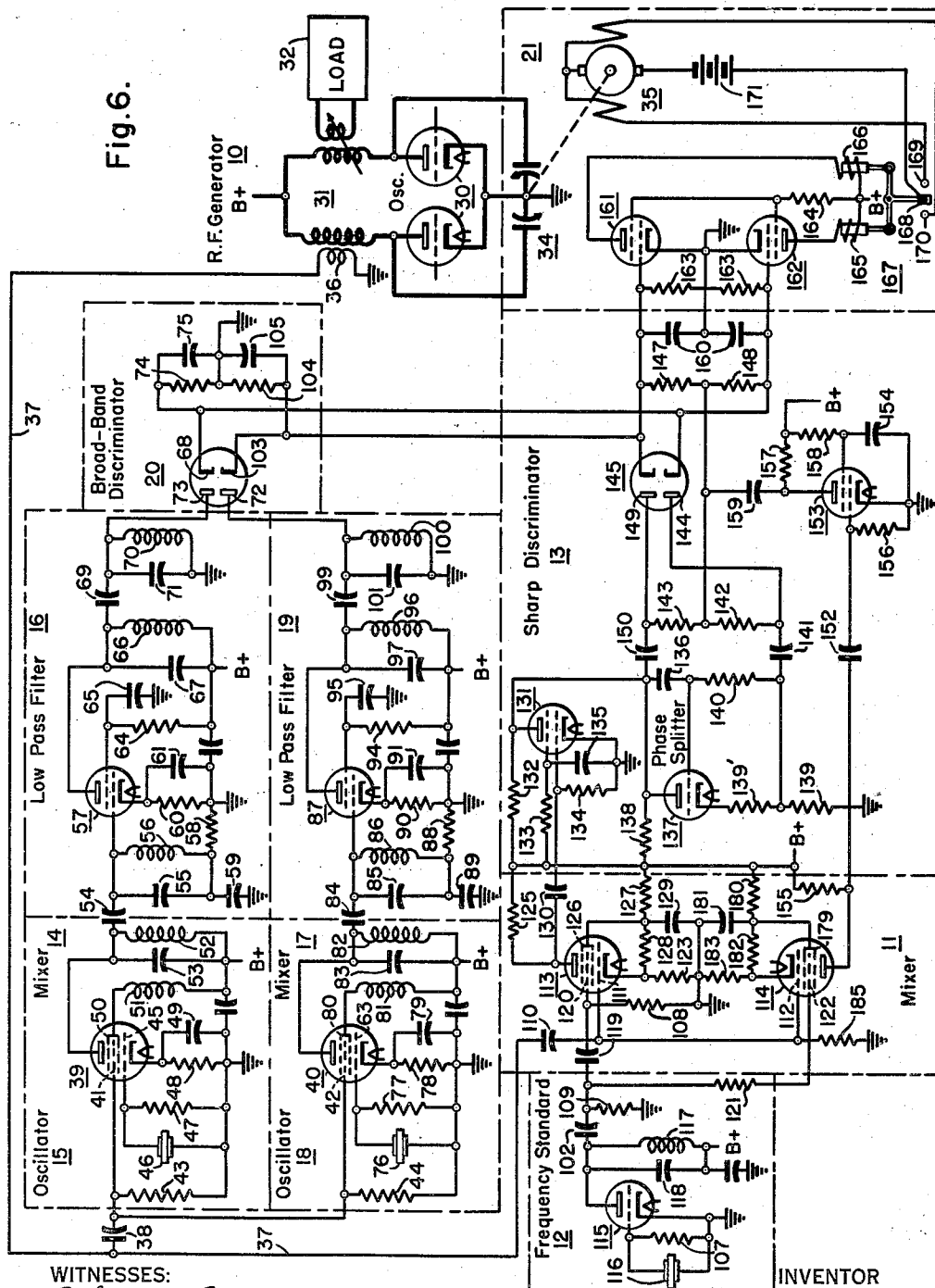
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3 Sheets-Sheet 3

Fig. 6.



WITNESSES:

Robert C. Baird.
New. L. Groome

INVENTOR

Sheldon I. Rambo.

BY *F. E. Crowder*
ATTORNEY

UNITED STATES PATENT OFFICE

2,558,100

FREQUENCY STABILIZER

Sheldon I. Rambo, Baltimore, Md., assignor to
Westinghouse Electric Corporation, East Pitts-
burgh, Pa., a corporation of Pennsylvania

Application November 2, 1948, Serial No. 57,966

12 Claims. (Cl. 250—36)

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This invention relates to frequency stabilizers for radio frequency generators, and it relates more particularly to automatically operated, frequency stabilizers for radio frequency generators used in high frequency induction and dielectric heating systems.

A material heated by energy from a radio frequency generator in conventional circuits, has an impedance which is reflected back into the load circuit of the generator, and as the impedance of the material changes with the changes in temperature, the generator is detuned from its assigned frequency. Other conditions such as changes in the characteristics of circuit components, and fluctuations in voltage of the power source, may act to change the frequency of the generator.

It is desirable for reasons of efficiency, and for compliance with the requirements of the Federal Communications Commission, that the assigned frequency of a radio frequency generator used for heating, be maintained within close limits. Accordingly, it is the practice to provide automatically operated, frequency adjusting systems which retune a radio frequency generator to its assigned frequency when it departs therefrom. Many such systems use discriminators of considerably narrower band widths than the total tunable ranges of the generators, requiring means for automatically bringing the generator frequency within the discriminators' band width in order to correct for large abrupt load changes during operation, or for marked changes in conditions between the end of one heat cycle and the beginning of another. A so-called search system may be used to accomplish this purpose. Such a system is disclosed in the copending application Serial No. 750,970, now Patent No. 2,542,837, in which I am a joint applicant.

A disadvantage of such a search system is that it has no "sense." That is to say, when the discriminator relinquishes control to the search circuit near the discriminator band edge, the search circuit may drive the correcting variable reactance in the generator tank circuit in the wrong direction for frequency correction instead of in the right direction, since search circuit operation depends merely upon the magnitude of voltage developed across a parallel circuit resonant at the desired, mean generator frequency. If the control circuit happens to be in the condition which causes searching in the wrong direction for frequency correction, the variable reactance operating element must run to its limit to trip a reversing switch, and then run all the

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way back in the proper direction to bring the frequency back within the discriminator band, and allow it to make the final correction. Obviously, such a system allows the generator to sweep almost completely across its entire tunable band width before locking in, if the frequency changes abruptly beyond the range of the discriminator.

If the discriminator band width were wider than the total tunable range of generator, then no search system would be necessary since the discriminator would maintain "sense" even for sudden changes of frequency. A discriminator must, however, have a sharp characteristic at cross-over, and it is not practical to provide a single discriminator having such a characteristic, and at the same time covering such a wide band that a search system would not be needed.

This invention overcomes the difficulties of the prior systems by combining in a single system a sharp discriminator and a broad-band discriminator. In one embodiment of the invention for maintaining the frequency of a radio frequency generator at 13.56 megacycles (mc.) within plus or minus 6780 cycles, a sharp discriminator which crosses over from one maximum to the other in 10 kilocycles (kc.) is provided. The generator has a variable, frequency adjusting reactance, the range of which is about 250 kc. on each side of 13.56 mc. The broad-band discriminator has an effective width of 500 kc., and has its cross-over point coincident with that of the sharp discriminator. The peaks of the broad-band discriminator are within approximately 50 kc. of cross-over so as to overlap the peaks of the sharp discriminator.

A feature of this invention is that the broad-band discriminator is provided by using a first band-pass filter to provide one-half of the desired broad-band characteristic on one side of cross-over, and by using a second similar band-pass filter to provide the other half of the desired broad-band characteristic on the other side of cross-over. Energy from the generator, the frequency of which is to be controlled, is mixed with energy from a fixed frequency generator, operating at a frequency which may be 2 mc. above the mean frequency to be maintained, and supplied into the input of one of the band-pass filters. Energy from the generator is mixed with energy from a fixed frequency generator, operating at a frequency which may be 2 mc. below the frequency to be maintained, and supplied into the input of the other band-pass filter. The outputs of the two filters are fed 180° apart in

phase, into a common detector for providing the desired wide band discriminator characteristic.

An object of the invention is to maintain the frequency of a radio frequency generator constant within narrow limits.

Another object of the invention is to combine in a frequency stabilizer circuit for a radio frequency generator, sharp and broad-band discriminators.

Another object of the invention is to provide the two halves of a broad-band discriminator on the opposite sides of cross-over, with the outputs of two band-pass filters.

Another object of the invention is to combine the outputs of two, similar, band-pass filters, 180° apart in phase, to provide a broad-band discriminator.

The invention will now be described with reference to the drawing of which:

Figure 1 is a graph illustrating the output characteristics of a sharp discriminator which may be used in this invention;

Fig. 2 is a graph illustrating the output characteristic of one of the band-pass filters used in the broad-band discriminator of this invention;

Fig. 3 is a graph illustrating the output characteristic of the other of the band-pass filters used in the broad-band discriminator of this invention;

Fig. 4 is a graph illustrating the output characteristics of the sharp and broad-band discriminators as combined in this invention;

Fig. 5 is a simplified block diagram illustrating a circuit embodying this invention;

Fig. 6 is a circuit schematic illustrating components which may be used in the blocks of Fig. 4; and

Fig. 7 is a vector diagram illustrating the phase relations of the voltages at the input at the sharp discriminator detector.

Figure 1 is an output-frequency characteristic curve of a sharp discriminator, and shows that in order to have a desired sharp characteristic at cross-over, one which for example, crosses over from one maximum to the other in 10 kc. cannot ordinarily have a band width greater than 100 kc.

Fig. 2 illustrates the output characteristics of one band-pass filter of the broad-band discriminator of this invention, its total band width extending from 1.6 mc. to 2 mc., and Fig. 3 illustrates the output characteristic of the other band-pass filter before it is inverted, its band width extending from 2 mc. to 2.4 mc.

Fig. 4 illustrates the output characteristics of the sharp and broad-band discriminator and shows that the effective band width is at least 500 kc. wide, and that there is a cross-over of 10 kc. from peak-to-peak.

Referring now to Fig. 5, it is assumed by way of example, that the radio frequency (RF) generator 10 is designed to operate at an assigned frequency of 13.56 mc., plus or minus a tolerance frequency of Δf which may be 6780 cycles. It is desired that the discriminator used in the frequency control system have a sharp output characteristic at cross-over of 10 kc. peak-to-peak, and at the same time to have a wide-band characteristic of 500 kc. To accomplish this, energy from the generator 10 at 13.56 mc. $\pm \Delta f$ is mixed in the mixer 11 with energy from the frequency standard 12 at 13.56 mc. The mixer 11 supplies energy at the difference frequency Δf to the sharp discriminator 13.

Energy is also fed from the generator 10 at 13.56 mc. $\pm \Delta f$ to the mixer 14 where it is com-

bined with energy from the oscillator 15 operating at 11.56 mc. Energy at the difference frequency of 2 mc. $\pm \Delta f$ is passed through the band-pass filter 16, the output of which has the characteristic shown by the curve of Fig. 2.

Energy is also fed from the generator 10 at 13.56 $\pm \Delta f$ to the mixer 17 where it is combined with energy from the oscillator 18 operating at 15.56 mc. Energy at the different frequency of 2 mc. $\mp \Delta f$ is passed through the band-pass filter 19, the output of which has the characteristic shown by the curve of Fig. 3.

The outputs of the band-pass filters 16 and 19 are fed into the broad-band discriminator detector 20 in which the output of the filter 19 is inverted and mixed with the output of the filter 16, the combined rectified energy being supplied together with the output of the sharp discriminator 13, into the reactance correcting unit 21, which acts to retune the generator 10 when, due to load or other changes, it departs from the tolerance limits of its assigned frequency.

The output of the broad-band discriminator detector 20, combined with the output of the sharp discriminator 13, provides the output characteristic curve shown by Fig. 4.

The total band width of the combined discriminators extends over a frequency band of 2.4 mc.—1.6 mc. which equals 0.8 mc. or 800 kc. There is seen to be sufficient gain at 500 kc. to cause the control system which will be described in the following, to operate satisfactorily. The combined discriminators have substantially the same cross-over characteristic as that of the sharp discriminator alone.

Referring now to Fig. 6, the RF generator 10 is a conventional vacuum tube oscillator using the two, push-pull vacuum tubes 30, the plates of which are connected through the tank inductance 31 to a positive terminal (B+) of a plate voltage supply source which is not illustrated. The tank inductance is inductively coupled to the load 32 which may be a dielectric, inductive, or other load. The tank circuit is tuned by the variable capacitors 34, the rotors of which are adapted to be rotated by the electric motor 35 when the oscillator departs from its assigned frequency of 13.56 mc. The tuning range provided by the capacitors 34 extends about 250 kc. each side of 13.56 mc.

The pick-up coil 36 is inductively coupled to the inductance 31, and is connected at one end to ground, and at the other end through the wire 37 and the coupling capacitor 38, to the grids 41 and 42 of the two similar pentagrid converter tubes 39 and 40.

The resistor 43, connected between the grid 41 of the tube 39 and ground, and the resistor 44 connected between the grid 42 of the tube 40 and ground, are bias resistors for the tubes. The tube 39 performs the functions of the oscillator 15 and the mixer 14 of Fig. 5, and the tube 40 performs the function of the oscillator 18 and the mixer 17 of Fig. 5.

The grid 45 of the tube 39 is connected through the piezo-electric crystal 46 to ground, the grid resistor 47 being shunted across the crystal. The cathode of the tube 39 is connected through the bias resistor 48 to ground, the bypass capacitor 49 being shunted across the resistor 48. The screen grid 50 of the tube 40 is connected through the inductance 51 to B+.

The oscillator portion of the tube 39 employs a tuned-grid tuned-anode circuit. The crystal 46 is in the tuned grid circuit and determines

the frequency of oscillation. The screen grid 50 serves as an anode in the oscillator circuit in which the inductance 51 is tuned to the frequency of the crystal 46, which in this case is 11.56 mc. The feed-back is through the inter-electrode capacity.

The plate of the tube 39 is connected through the inductance 52 to B+, the capacitor 53 being shunted across the inductance 52 and forming therewith a parallel-resonant circuit which is tuned slightly higher than 2 mc., the difference frequency between the 11.56 mc. frequency of the oscillator portion of the tube 39, and the mean frequency 13.56 mc. of the generator 10.

This difference frequency voltage from the plate circuit of the tube 39 is supplied to the input of the band-pass filter 16, through the capacitor 54 to the parallel circuit consisting of the capacitor 55 shunted across the inductor 56, and which is tuned to a frequency slightly lower than that to which the plate circuit of the tube 39 is tuned. The inductor 56 is connected at one end to the control grid of the tube amplifier 57, and at the other end to ground through the grid leak 58 and its bypass capacitor 59. The voltage developed across the inductor 56 is applied to the control grid of the tube 57.

The cathode of the tube 57 is connected to ground through the bias resistor 60 across which is shunted the bypass capacitor 61. The screen grid of the tube 57 is connected through the resistor 64 to B+, and is connected through the bypass capacitor 65 to ground. The plate of the tube 57 is connected through the inductor 66 to B+, the capacitor 67 being shunted across the inductor 66. The parallel circuit formed by the inductor 66 and the capacitor 67 is resonant at approximately the same frequency as the plate circuit of the tube 39.

The coupling capacitor 69 is connected to the plate of the tube 57, to the diode plate 73 of the broad-band discriminator diode tube 20, and to one side of the inductor 70, the other side of which is grounded. The capacitor 71 is shunted across the inductor 70. The load resistor 74 is connected to the diode cathode 68 of the tube 20 and to ground, the bypass capacitor 75 being shunted across the resistor 74. A direct-current voltage is developed across the load resistor 74 which is proportional to the radio frequency voltage appearing across the inductor 70.

The grid 63 of the tube 40 is connected through the piezo-electric crystal 76 to ground, the grid resistor 77 being shunted across the crystal. The cathode of the tube 40 is connected through the bias resistor 78 to ground, the bypass capacitor 79 being shunted across the resistor 78. The screen grid 80 of the tube 40 is connected through the inductance 81 to B+.

The oscillator portion of the tube 40 employs a tuned-grid tuned-anode circuit. The crystal 76 is in the tuned grid circuit and determines the frequency of oscillation. The screen grid 80 serves as an anode in the oscillator circuit in which the inductor 81 is tuned to the frequency of the crystal 76, which in this case is 15.56 mc. The feed-back is through the inter-electrode capacity.

The plate of the tube 40 is connected through the inductor 82 to B+, the capacitor 83 being shunted across the inductor 82 and forming therewith a parallel-resonant circuit which is tuned slightly higher than 2 mc., the different frequency between the 15.56 mc. frequency of

the oscillator portion of the tube 40, and the mean frequency 13.56 mc. of the generator 10.

This difference frequency voltage from the plate circuit of the tube 40 is supplied to the input of the band-pass filter 19, through the capacitor 84 to the parallel circuit consisting of the capacitor 85 shunted across the inductor 86, and which is tuned to a frequency slightly lower than that to which the plate circuit of the tube 40 is tuned. The inductor 86 is connected at one end to the control grid of the amplifier tube 87, and at the other end to ground through the grid leak 88 and its bypass capacitor 89. The voltage developed across the inductor 86 is applied to the control grid of the tube 87.

The cathode of the tube 87 is connected to ground through the bias resistor 90 across which is shunted the bypass capacitor 91. The screen grid of the tube 87 is connected through the resistor 94 to B+, and is connected through bypass capacitor 95 to ground. The plate of the tube 87 is connected through the inductor 96 to B+, the capacitor 97 being shunted across the inductor 96. The parallel circuit formed by the inductor 96 and the capacitor 97 is resonant at approximately the same frequency as the plate circuit of the tube 40.

The coupling capacitor 99 is connected to the plate of the tube 87, to the diode plate 12 of the broad-band discriminator diode tube 20, and to one side of the inductor 100, the other side of which is grounded. The capacitor 101 is shunted across the inductor 100. The load resistor 104 is connected to the diode cathode 103 of the tube 20 and ground, the bypass capacitor 105 being shunted across the resistor 104. A direct-current voltage is developed across the load resistor 104 which is proportional to the radio frequency voltage appearing across the inductor 100.

The output voltages of the two band-pass filters are supplied 180° apart in phase into the detector tube 20 so that the characteristic curve of Fig. 3 is inverted and combined with the characteristic curve of Fig. 2 so as to form a curve below the frequency base line of the upper curve which is similar to the upper characteristic curve but inverted, the two curves merging together.

Radio frequency from the generator 10 is also applied from the pick-up coil 36 through the wire 37 and the coupling capacitor 110 to the grids 111 and 112 of the pentagrid converter tubes 113 and 114 respectively, in the mixer 11, and is combined in the mixer with the oscillations supplied by the crystal controlled frequency standard 12.

The frequency standard 12 includes a triode vacuum tube 115, with the piezo-electric crystal 116 connected between its grid and cathode, and providing a tuned grid circuit. The grid resistor 107 is connected between the grid and cathode of the tube 115, the cathode being grounded. The plate of the tube 115 is connected to B+ through the plate inductor 117 across which the capacitor 118 is shunted, the inductor 117 and the capacitor 118 providing an output circuit tuned to the frequency of the crystal 116 which in this case is 13.56 mc., the mean assigned frequency of the RF generator 10. Feed-back is through the inter-electrode capacitance.

The output of the oscillator tube 115 is connected through the series-connected coupling capacitors 102 and 119, to the grid 120 of the tube 113, and through the coupling capacitor 102 and the resistor 121 to the grid 122 of the tube 114. The midpoint connection of the capacitors

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102 and 119 is connected through the resistor 109 to ground. The grid 120 of the tube 113 is connected through the grid resistor 108 to ground. The capacitor 119 and the resistor 108 produce a voltage at grid 120 leading by 45° that appearing across resistor 109. The resistor 121 and input capacitance (not shown) of tube 114 produce a voltage at grid 122 lagging by 45° that appearing across resistor 109. Hence, a phase shift of 90° results between the voltage provided to the grid 120 of the mixer tube 113 and that applied to the grid 122 of the mixer tube 114.

The output circuits of the mixer tubes 113 and 114 have RF currents flowing therein which have a frequency equal to the difference between the 13.56 mc. voltage from the oscillator 115 and the $13.56 \text{ mc.} \pm \Delta f$ voltage from the generator 10, the RF current in the output circuit of the tube 113 being displaced 90° from that in the output circuit of the tube 114.

The plate of the mixer tube 113 is connected through the resistor 125 to B+, and its screen grid 126 is connected through the resistor 127 to B+, is connected through the bypass capacitor 129 to ground, and through the resistor 128 to the cathode of the tube 113. The cathode of the tube 113 is connected through the bias resistor 123 to ground. The capacitor 129 bypasses the screen 126 to ground.

The plate of the mixer tube 113 is also connected to the input of the sharp discriminator 13, through the coupling capacitor 135 which is connected to the control grid of the amplifier tube 131, the plate of which is connected through the resistor 132 to B+, and the screen grid of which is connected through the resistor 133 to B+, the bypass capacitor 135 being connected between the screen grid and ground. The grid resistor 134 is connected between the control grid of the tube 131 and its cathode which is grounded.

The plate of the amplifier tube 131 is connected through the coupling capacitor 136 to the control grid of the phase-splitter tube 137, the plate of which is connected through the resistor 138 to B+. The cathode of the tube 137 is connected through the series-connected resistors 139' and 139 to ground, the junction-point connection of the resistors 139' and 139 being connected to the grid resistor 140, and through the capacitor 141 to one end of the resistor 142 and to one diode plate 144 of the sharp discriminator diode tube 145. The resistor 142 is connected in series with the similar resistor 143 which is connected to the diode plate 149 of the diode 145. The junction point of the resistors 142 and 143 is connected to the junction point of the series-connected, load resistors 147 and 148 which are connected to the two cathodes of the diode 145.

The plate of the phase-splitter tube 137 is connected to the diode plate 149 of the tube 145 through the coupling capacitor 150 which has the same value as the capacitor 141.

The voltages at the plate of the phase-splitter tube 137 which are supplied to the plate 149 of the diode 145, are 180° out-of-phase with the corresponding voltages at its cathode which are supplied to the diode plate 144 of the diode 145, so that the voltages at the two diode plates are 180° apart-in-phase.

The plate and the screen grid 179 of the mixer tube 114 are connected through the resistors 155 and 180 respectively, to B+. The resistor 182 connects the screen grid of the tube 114 to its cathode. The bias resistor 183 connects the

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cathode to ground. The grid resistor 185 connects the grid 112 of the tube 114 to ground. The capacitor 181 bypasses the screen 179 to ground.

The plate of the mixer tube 114 is connected to the input of the sharp discriminator 13, through the coupling capacitor 152 which is connected to the control grid of the amplifier tube 153. The plate of the tube 114 is connected through the resistor 155 to B+, and its screen grid 179 is connected through the resistor 180 to B+, the bypass capacitor 181 being connected between the screen grid and ground. The resistor 182 is connected between the cathode of the tube 114 and its screen grid. The bias resistor 183 is connected to the cathode of the tube 114 and to ground.

The grid resistor 156 connects the control grid of the tube amplifier 153 to its cathode and to ground. The plate and the screen grid of the tube 153 are connected through the resistors 157 and 158 respectively, to B+. The screen grid is connected through the bypass capacitor 154 to ground. The plate of the tube 153 is also connected through the coupling capacitor 159 to the junction points of the resistors 142 and 143 and of the resistors 147 and 148.

The two outputs of the phase-splitter tube 137 are supplied 180° apart in phase to the diode plates of the tube 145, and the output of the tube 153 is supplied to the diode plates 90° apart in phase from the outputs of the phase-splitter tube.

The voltages at the input of the diode tube 145 may be best understood by reference to Fig. 7. The solid line, voltage vector E_1 represents the voltage from the plate of the phase-splitter tube 137. The equal and opposite, solid line, voltage vector E_2 represents the voltage from the cathode of the phase-splitter tube. These equal voltages are seen to be 180° apart in phase. The solid line vector E_3 represents the voltage from the plate of the amplifier tube 153 and is seen to be 90° apart in phase from the vectors E_1 and E_2 .

When the difference between the frequency of the RF generator 10 is within its tolerance limits, the voltages of opposite phase from the phase-splitter tube, and the voltage from the amplifier tube 153 are in phase quadrature, as illustrated by the solid line vectors of Fig. 7, so that the voltage drop across the load resistors 147 and 148 connected between the cathodes of the diode tube 145 is substantially zero.

The capacitors 141 and 150, and the resistors 142 and 143 in the output circuit of the phase-splitter tube 137 have such values that when the frequency of the RF generator exceeds the tolerance limits, the opposite phase voltages E_1 and E_2 shift in phase with respect to the quadrature voltage E_3 , an amount proportional to the difference frequency between the RF generator 10 and the frequency standard 12, as illustrated by the dashed line vectors of Fig. 7. The output of one or the other of the diode sections of the tube 145 then predominates, and a voltage of one polarity or the other is impressed between the resistors 147 and 148 interconnecting its cathodes.

The cathodes of the diode 145 are connected to ground through the bypass capacitors 160. The cathodes of the broad-band discriminator diode 20 are connected to the corresponding cathodes of the sharp discriminator diode 145 so that the outputs of the two diodes are superimposed to provide the overall characteristic curve shown by Fig. 4.

The cathodes of the diodes 20 and 145 are connected to the control grids of the push-pull amplifier tubes 161 and 162, the grid resistors 163 being connected between the control grids of the tubes 161 and 162 and ground, the screen grids of the tubes 161 and 162 being connected through the resistor 164 to B+. The plates of the tubes 161 and 162 are connected to the series-connected, relay energizing windings 166 and 165 respectively, of the relay 167, the junction connection of the windings being connected to B+.

The armature 168 of the relay 167 is connected to one side of the battery 171, the other side of which is connected to the reversible electric motor 35. The relay armature 168 is movable between the contacts 169 and 170, and the field winding of the motor 35 is so connected to its armature and to the contacts 169 and 170 in a conventional motor reversing circuit, that when the relay armature touches the contact 169, the battery 171 rotates the motor in one direction, and when the relay armature touches the contact 170, the battery is reversely applied to the motor field, causing the motor to rotate in the opposite direction.

As a result of the actions in their input circuits as described in the foregoing, corresponding cathodes of the diode tubes 20 and 145, those cathodes connected to the control grids of the amplifier tube 161 will provide voltages on the grids of the tubes 161 and 162 which will cause the tube 161 to draw more plate current than the tube 162, and to thereby energize the winding 166 of the relay 167 more strongly than the relay winding 165 is energized, when the frequency of the RF generator 10 increases above its tolerance levels. This will cause the relay armature 168 to touch the contact 169, causing the field and armature of the motor 35 to be connected together and to the battery 171 in such a way that the motor will revolve to rotate the rotor of the capacitor 34 in a direction to increase the capacity in the tank circuit of the RF generator, until its frequency is decreased to its mean assigned value.

When the frequency of the RF generator decreases below the tolerance limits, the diode cathodes will provide voltages at the grids of the amplifier tubes 161 and 162 which will cause the tube 162 to draw more plate current than the tube 161 and to thereby energize the relay winding 165 more strongly than the relay winding 166 is energized. This will cause the relay armature 168 to strike the contact 170 causing the field and armature of the motor 35 to be connected to the battery 171 in a direction to cause the motor 35 to rotate the rotor of the capacitor 34 in a direction to decrease the capacity in the tank circuit of the RF generator, until its frequency is increased to its mean assigned frequency.

When the RF generator is operating within the tolerance limits of its assigned frequency, both of the amplifier tubes 161 and 162 will be conductive to the same extent so that their plate currents will be balanced with both relay windings energized the same, causing the relay armature to be spaced from both contacts 169 and 169 so the motor 35 will be deenergized, and the rotors of the tank capacitor 34 will remain stationary.

I claim as my invention:

1. A frequency stabilizing system for a radio frequency generator, comprising a first oscillator operating at the mean assigned frequency of said generator, a first mixer connected for receiving

energy from said generator and from said first oscillator, a sharp discriminator connected to said first mixer, a second oscillator operating at a frequency above said assigned frequency, a second mixer connected for receiving energy from said generator and from said second oscillator, a first band-pass filter connected to said second mixer, a third oscillator operating at a frequency below said assigned frequency, a third mixer connected for receiving energy from said generator and from said third oscillator, a second band-pass filter connected to said third mixer, means for inverting the output of one of said filters and for combining the inverted output with the output of the other filter, reactance adjusting means for tuning said generator, and means for connecting the outputs of said sharp discriminator and the combined outputs of said filters together and to said reactance adjusting means so as to cause same to retune said generator to said assigned frequency when it departs therefrom.

2. A frequency stabilizing system for a radio frequency generator, comprising a first oscillator operating at the mean assigned frequency of said generator, a first mixer connected for receiving energy from said generator and from said first oscillator, a sharp discriminator connected to the output of said first mixer, a second oscillator operating at a frequency on one side of said assigned frequency, a second mixer connected for receiving energy from said generator and from said second oscillator, a third oscillator operating at a frequency on the other side of said assigned frequency, a third mixer connected for receiving energy from said generator and from said third oscillator, means for inverting the output of said third mixer and for combining the inverted output with the output of said second mixer, reactance adjusting means for turning said generator, and means for connecting the output of said sharp discriminator and the combined outputs of said second and third mixers to said reactance adjusting means so as to cause same to retune said generator to said assigned frequency when it departs therefrom.

3. A frequency stabilizing system for a radio frequency generator, comprising a first oscillator operating at the mean assigned frequency of said generator, a first mixer connected for receiving energy from said generator and from said first oscillator, a sharp discriminator having its input connected to the output of said first mixer, said sharp discriminator including means for rectifying its output, a second oscillator operating at a frequency at one side of said assigned frequency, a second mixer connected for receiving energy from said generator and from said second oscillator, a band-pass filter having its input connected to the output of said second mixer, a third oscillator operating at a frequency on the other side of said assigned frequency, a third mixer connected to receive energy from said generator and from said third oscillator, a second band-pass filter having its input connected to the output of said third mixer, means for inverting the output of one of said filters and for combining the inverted output with the output of the other of the filters and for rectifying the combined outputs, reactance adjusting means for tuning said generator, and means for combining the rectified outputs of said filters and of said sharp discriminator and for applying same to said reactance adjusting means for retuning

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said generator to said assigned frequency when it departs therefrom.

4. A frequency stabilizing system as claimed in claim 3 in which the second and third oscillators operate at frequencies which are spaced the same number of cycles from the assigned frequency of the generator.

5. A frequency stabilizing system as claimed in claim 4 in which the band-pass filters are similar.

6. A frequency stabilizing system as claimed in claim 3 in which the band-pass filters are similar.

7. A broad-band discriminator for use with a radio frequency generator having an assigned frequency, comprising a first oscillator operating at a frequency on one side of said assigned frequency, a first mixer connected to receive energy from said generator and from said first oscillator, a band-pass filter having its input connected to the output of said first mixer, a second oscillator operating at a frequency on the other side of said assigned frequency, a second mixer connected to receive energy from said generator and from said second oscillator, a second band-pass filter having its input connected to the output of said second mixer, and means for inverting the output of one of said filters and for combining it with the output of the other filter.

8. A broad-band discriminator for use with a radio frequency generator having an assigned frequency, comprising a first oscillator operating at a fixed frequency higher than said assigned frequency, a first mixer connected to receive energy from said generator and from said first oscillator, a first band-pass filter having its input connected to the output of said first mixer, a second oscillator operating at a fixed frequency which is below said assigned frequency by the same number of cycles the operating frequency of said first oscillator is above said assigned frequency, a second mixer connected to receive energy from said generator and from said second oscillator, a second band-pass filter having its input connected to the output of said second mixer, and means for inverting the output of one of said filters and for combining its inverted output with the output of the other filter.

9. A broad-band discriminator as claimed in claim 8 in which the filters are similar.

10. A frequency stabilizing system for a radio frequency generator, comprising a source of fixed frequency, a first mixer connected for receiving energy from said generator and from said source, a sharp discriminator having its input connected to the output of said first mixer, a first, fixed frequency oscillator operating at a frequency spaced a predetermined number of cycles above the mean assigned frequency of said generator, a second mixer connected to receive

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energy from said generator and from said oscillator, a second, fixed frequency first fixed frequency oscillator operating at a frequency spaced said predetermined number of cycles below said assigned frequency, a third mixer connected to receive energy from said generator and from said second fixed frequency oscillator, means for inverting the output of one of said second and third mixers and for combining the inverted output with the output of the other thereof, reactance adjusting means for tuning said generator, and means for connecting the output of said sharp discriminator and the combined output of said second and third mixers to said adjusting means for retuning said generator to its assigned frequency when it departs therefrom.

11. A frequency stabilizing system for a radio frequency generator, comprising a source of fixed frequency, a first mixer having its input connected for receiving energy from said generator and from said source, a sharp discriminator having its input connected to the output of said mixer, a first, fixed frequency oscillator operating at a frequency spaced a predetermined number of cycles above the mean assigned frequency of said generator, a second mixer having its input connected for receiving energy from said generator and from said first fixed frequency oscillator, a first band-pass filter having its input connected to the output of said second mixer, a second fixed frequency oscillator operating at a frequency spaced said predetermined number of cycles below said assigned frequency, a third mixer having its input connected to receive energy from said generator and from said second fixed frequency oscillator, a second band-pass filter having its input connected to the output of said third mixer, reactance adjusting means for tuning said generator, means for inverting the output of one of said filters and for combining the inverted output with the output of the other filter, and means for connecting the output of said sharp discriminator and the combined output of said filters to said adjusting means for retuning said generator to its assigned frequency when it departs therefrom.

12. A frequency stabilizing system as claimed in claim 11 in which the band-pass filters have similar characteristics.

SHELDON I. RAMBO.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
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