

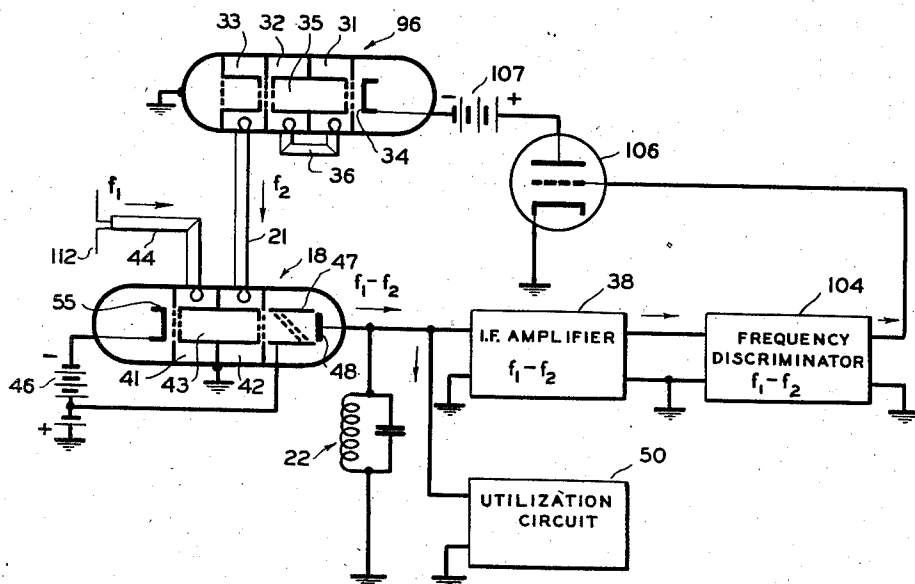
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AUTOMATIC FREQUENCY CONTROL SYSTEM.

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AUTOMATIC FREQUENCY CONTROL
SYSTEM

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5 Claims. (Cl. 250—40)

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The present invention relates, generally, to ultra-high-frequency systems operating at frequencies of the order of 10^9 or 10^{10} cycles per second and, more specifically, to superheterodyne receiving systems operating at such frequencies. The present application is a division of applica-
tion Serial No. 426,986, filed January 16, 1942, and is a continuation-in-part of U. S. Patent No. 2,294,942 for Fixed frequency difference and stabilization system, granted September 8, 1942.

In ultra-high-frequency receiving systems of the superheterodyne type, difficulty is experienced in maintaining proper operation due to the inherent tendency of local oscillators operating at such high frequencies to drift appreciably in frequency, whereby the intermediate frequency produced by beating the received frequency with the local oscillator frequency may drift so widely as to pass beyond the frequency acceptance range of the intermediate-frequency amplifiers or other intermediate-frequency stages of the system. According to the present invention, and to prevent this harmful effect, improved apparatus is provided to maintain the local oscillator frequency at a fixed frequency difference with respect to the received wave. In particular, the local oscillator utilized is of the velocity-modulation type, such as described in U. S. Patent No. 2,242,275, granted May 20, 1941. The output of this ultra-high-frequency local oscillator is combined with the received wave in an ultra-high-frequency mixer or first detector, also of the velocity-modulation type. The intermediate frequency output of this ultra-high-frequency mixer, after suitable amplification of any convenient type, is supplied to a frequency discriminator of conventional type which is adapted, as is well known, to produce zero voltage output when the input frequency is equal to the tuned frequency of the discriminator, which is made to correspond to the desired intermediate frequency. The discriminator also produces an output voltage of predetermined polarity when the input frequency is greater than the desired intermediate frequency, and an output voltage of opposite polarity when the input frequency is lower than the desired value.

This output of the frequency discriminator is then utilized to control the local oscillator frequency by controlling one of the frequency-determining characteristics of this oscillator. In the present instance, this is illustrated as controlling the local oscillator frequency by controlling the electron-beam-accelerating voltage in the velocity-modulation type of local oscillator. It is to be noted that the present system is also

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equally adapted to maintain a controlled ultra-high-frequency oscillator, corresponding to the local oscillator, at a fixed frequency difference from a reference frequency corresponding to the received wave in the superheterodyne system discussed above.

Accordingly, it is an object of the present invention to provide an improved frequency-stabilized ultra-high-frequency superheterodyne receiving system.

It is another object of the present invention to provide improved ultra-high-frequency apparatus for maintaining a controlled frequency source at a fixed frequency difference with respect to a reference frequency.

It is still another object of the present invention to maintain the output frequency of an ultra-high-frequency velocity-modulation oscillator at a fixed frequency difference with respect to a reference frequency, by controlling the electron-beam-accelerating voltage of the controlled oscillator.

Other objects and advantages of the present invention will become apparent from the specification and attached drawing, wherein the single figure illustrates a schematic wiring diagram of a preferred embodiment of our invention.

Referring to the single figure of the drawing, the controlled local oscillator is shown in the form of a velocity-modulation oscillator-buffer 96, having three cavity resonators 31, 32 and 33, each of which has a pair of electron-permeable grids defining a gap. An electron beam derived from cathode 34 is adapted to be projected successively through these resonator gaps by means of the accelerating battery or other unidirectional voltage source 107. The gaps of resonators 31 and 32 are separated by a field-free drift space 35, while the gaps of resonators 32 and 33 may be made to adjoin one another closely.

It is to be understood that resonators 31, 32, and 33 are all tuned (that is, have their resonant frequencies suitably adjusted, by any well-known means) to the desired operating frequency for oscillator 96.

In operation, the electron beam from cathode 34 passes first through the gap of resonator 31 and is therein velocity-modulated by any ultra-high-frequency electric field existing at this gap by virtue of oscillations within the resonator 31. Such velocity-modulation of the beam is converted into bunching or grouping of the electrons of the beams by their subsequent traversing of drift space 35. The bunched electron beam then passes across the gap of resonator 32 and deliv-

ers ultra-high-frequency energy to this resonator 32.

In this manner the electron beam excites an ultra-high-frequency electromagnetic field within resonator 32. Some of this energy is fed back to resonator 31 by way of the feed-back coupling loop or transmission line 36 to sustain oscillations within resonators 31 and 32 by regenerative action. In this way the bunching of the electron beam is self-sustained. The bunched beam also passes across the gap of buffer resonator 33 and thereby excites this resonator to oscillation also. The oscillatory energy of resonator 33, indicated as being of the frequency f_2 , may then be extracted from resonator 33 by a suitable coupling transmission line 21. Since resonator 33 is coupled to the oscillating system of resonators 31 and 32 only by the electron beam, the external circuit coupled to resonator 33 cannot react on the oscillator to vary its frequency.

Also shown in the figure is an ultra-high-frequency velocity-modulation mixer-detector 18 which comprises a pair of cavity resonators 41 and 42 separated by a field-free drift space 43. Resonator 41 is coupled to a receiving antenna 112 by means of the coupling line 44 and is tuned to the frequency of the received wave, indicated as f_1 . Resonator 42 is coupled to resonator 33 of oscillator 96 by way of transmission line 21 and is tuned to the frequency f_2 .

An electron beam is projected successively through the gaps between the grids of resonators 41 and 42 from a cathode 45 by means of a suitable accelerating voltage source 46. By virtue of the fields excited within resonators 41 and 42 by antenna 112 and oscillator 96, the electron beam is bunched both at the frequency f_1 and the frequency f_2 . A detector electrode 47, maintained at a potential near that of cathode 45 and preferably negative with respect to the ground potential of the grids of the resonators 41 and 42, supplies a retarding field for the bunched beam. By adjusting the potential of electrode 47 to a value such that all electrons of less than average velocity are repelled thereby, the electron beam current passing through the grids of the detector electrode 47 and collected by a suitable target electrode 48 will have a component of frequency $f_1 - f_2$, corresponding to the beat frequency between the frequencies f_1 and f_2 .

A tuned circuit 22 tuned to this beat or intermediate frequency is then connected between the target electrode 48 and ground, and serves to pass only the intermediate-frequency wave to the intermediate-frequency amplifier 38, which may be of any conventional type. The output of amplifier 38 is then supplied to the conventional frequency discriminator 104 which is also tuned to this same intermediate frequency. The output of the discriminator 104 is then supplied to the control grid of a tube 106 connected in series with the accelerating voltage source 107 for oscillator 96.

The output frequency of a velocity-modulation type of oscillator such as 96 has been found to depend upon the electron-beam-accelerating voltage. By controlling the electron beam voltage by tube 106, in response to the output of discriminator 104, the output frequency of oscillator 96 may be adjusted to the proper value to maintain the intermediate frequency closely to the desired value $f_1 - f_2$ at which the discriminator 104 is tuned.

In this way any variation in intermediate fre-

quency, such as due to drifting of the oscillator 96 or to changing of the received frequency f_1 , is automatically compensated by varying the accelerating voltage of the electron beam of oscillator 96 to maintain the difference between the two frequencies f_1 and f_2 at the value determined by the discriminator 104.

The intermediate-frequency wave derived from circuit 22 may also be supplied to any desired type of utilization circuit 50, such as that disclosed more fully with respect to Fig. 2 of parent application Serial No. 426,986.

It is to be understood that antenna 112 may be replaced by any suitable type of source of reference frequency with respect to which the output frequency of oscillator 96 is to be maintained at the fixed frequency difference determined by the tuned frequency of discriminator 104.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. High frequency superheterodyne receiver apparatus comprising a high frequency oscillator having a pair of coupled cavity resonators, a buffer cavity resonator, and means including a source of beam accelerating voltage for projecting an electron beam successively through said resonators; a mixer-detector having a pair of cavity resonators, an output electrode, and means for projecting a beam of electrons through said resonators to said electrode; a source of received wave; means for coupling said source to one of said mixer-detector resonators; means for coupling said buffer resonator to the other of said mixer-detector resonators; a frequency discriminator tuned to a desired frequency difference between the output frequency of said oscillator and the frequency of said source; means for connecting said discriminator to said electrode; and means responsive to the output of said discriminator for controlling said beam accelerating voltage, to maintain said oscillator frequency at the value required to produce said desired frequency difference, said last-named means comprising a triode having its anode-cathode circuit in series with said accelerating voltage source and its grid energized by said discriminator output.
2. High frequency apparatus comprising a high frequency oscillator having an output cavity resonator and means for exciting oscillations in said resonator, said exciting means including a cathode and a source of electron-accelerating voltage for projecting an electron beam through said resonator; a mixer-detector having a pair of cavity resonators and means for projecting a beam of electrons through said resonators to provide an output corresponding to the beat frequency of the waves supplied to said resonators; means for coupling a source of reference frequency to one of said mixer-detector resonators; means for coupling said output resonator to the other of said mixer-detector resonators, a frequency discriminator tuned to a desired frequency difference between the output frequency of said oscillator and said reference frequency; means for energizing said discriminator from the output of said mixer-detector; and means responsive to the output of said discriminator for

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controlling said accelerating voltage source to maintain said oscillator frequency at said desired frequency difference with respect to said reference frequency, said last-named means including an electron discharge device having a cathode, a control electrode and an anode, said cathode and anode being connected in series with said source, and said control electrode being connected to said discriminator output for controlling the conductivity of said device in accordance with said discriminator output.

3. High frequency apparatus comprising a high frequency oscillator having a pair of coupled cavity resonators, a buffer cavity resonator, and means including a source of beam-accelerating voltage for projecting an electron beam successively through said resonators; a source of reference frequency; means for obtaining the beat frequency between said reference frequency and the output frequency of said oscillator derived from said buffer resonator; a frequency discriminator tuned to a desired frequency difference between said oscillator frequency and said reference frequency; means for actuating said discriminator by said beat frequency; and means responsive to the output of said discriminator for controlling said beam-accelerating voltage, to maintain said oscillator frequency at a value producing said desired frequency difference, said last-named means comprising a triode having its anode-cathode circuit in series with said accelerating voltage source and its control grid energized by said discriminator output.

4. High frequency apparatus comprising a high frequency oscillator having a pair of coupled cavity resonators and a buffer cavity resonator, and means including a source of beam-accelerating voltage for projecting an electron beam successively through said resonators; a source of

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reference frequency; means coupled to said buffer resonator and to said source for producing a beat frequency between said reference frequency and the output frequency of said oscillator; and means responsive to deviation of said beat frequency from a desired value for controlling said oscillator frequency to maintain said desired beat frequency value, said last-named means including means for producing a signal corresponding to said frequency deviation, and an electron discharge device connected to said source and having a control electrode connected to be controlled by said signal, whereby said beam-accelerating voltage is controlled in accordance with said frequency deviation.

5. High frequency apparatus comprising a high frequency oscillator having an output cavity resonator, and means for projecting an electron beam through said resonator to excite oscillations therein, said last-named means including a source of electron-beam-accelerating voltage; a source of reference frequency; means for producing a beat frequency between said reference frequency and the output frequency of said oscillator; and means responsive to deviation of said beat frequency from a desired value for varying said oscillator frequency to maintain said desired beat frequency value, said last-named means including means responsive to said frequency deviation for producing a control signal, an electron discharge device connected to said accelerating voltage source and having a control electrode, and means energizing said control electrode by said signal, whereby said accelerating voltage is controlled in response to said frequency deviation.

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