

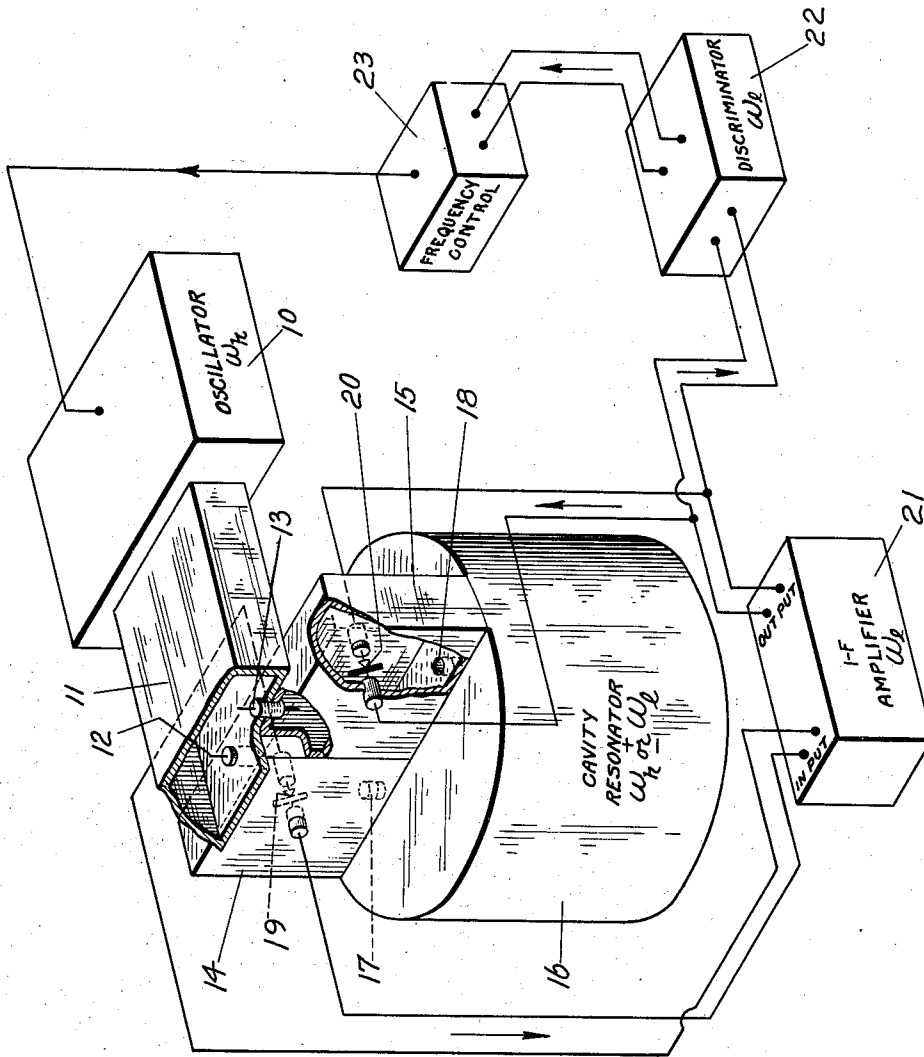
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G. G. BRUCK

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FREQUENCY STABILIZING DEVICE

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INVENTOR
GEORGE G. BRUCK
BY *Elmer J. Gorn*
ATTY.

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FREQUENCY STABILIZING DEVICE

George G. Bruck, East Orange, N. J., assignor to
Raytheon Manufacturing Company, Newton,
Mass., a corporation of Delaware

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This invention relates to apparatus for stabilizing the frequency of a carrier wave, for example, the carrier wave generated at the master terminal station of a frequency-modulated radio communication system.

Examples of the type of apparatus to which the present invention relates are found in the copending applications of George G. Bruck and Philip E. Volz, entitled "Frequency stabilizing system," Ser. No. 647,008, filed February 12, 1946, of George G. Bruck and Paul J. Pontecorvo, entitled "Frequency stabilizing system," Ser. No. 655,074, filed March 18, 1946, Patent No. 2,462,841, issued March 1, 1949, and of George G. Bruck, Robert M. Sprague and Malcolm C. Vossburgh, entitled "Radio communication system," Ser. No. 660,596, filed April 9, 1946.

While the devices disclosed in said copending applications have been found efficiently to perform their intended functions, they are more or less complicated, and are critical in their adjustment.

It is, therefore, the main object of the present invention to provide frequency-stabilizing apparatus which is simpler than that heretofore proposed for the purpose, and which is easier to set up and adjust.

These, and other objects of the present invention, which will become more apparent as the detailed description thereof progresses, are attained, briefly, in the following manner:

The present invention provides means, in the form, for example, of appropriate wave-guiding apparatus, for deriving from the carrier wave to be stabilized two carrier-wave portions of like phase. One of these carrier-wave portions is mixed with an intermediate-frequency wave to produce sideband waves, said intermediate-frequency wave being generated by a novel oscillation generator hereinafter more fully referred to. The other carrier-wave portion is mixed with one of said sideband waves to recover said intermediate-frequency wave. The two mixing devices may comprise non-linear impedances, such as crystals.

Said mixing devices are connected, respectively, to the output and input circuits of a broad-band amplifying device the center frequency of which corresponds to the frequency of the aforementioned intermediate-frequency wave. This amplifying device is caused to oscillate and produce said intermediate-frequency wave by positive feedback between its output and input circuits, said feedback being obtained by interposing between the mixing devices con-

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nected, respectively, to said output and input circuits a tuned circuit, for example, a cavity resonator which is resonant to one of the sideband waves produced by the combination of the first above-mentioned carrier-wave portion and said intermediate-frequency wave.

A portion of said intermediate-frequency wave is applied to means, such as a frequency discriminator, for deriving from said intermediate-frequency wave a unidirectional output whose amplitude and sense are functions, respectively, of the magnitude and sense of any deviation of the frequency of said intermediate-frequency wave from its initial frequency, such deviation being brought about, as will hereinafter be more fully explained, by any deviation of the frequency of the carrier wave from its initial frequency.

Finally, the unidirectional output thus obtained is applied to any appropriate device, electronic or mechanical, for altering the frequency of the source of said carrier wave to compensate for any such frequency deviation.

In the accompanying specification there shall be described, and in the annexed drawing shown, an illustrative embodiment of the frequency-stabilizing system of the present invention. It is, however, to be clearly understood that the present invention is not to be limited to the details herein shown and described for purposes of illustration only, inasmuch as changes therein may be made without the exercise of invention, and within the true spirit and scope of the claims hereto appended.

In said drawing, the single figure is a partial block, partial schematic diagram of a frequency-stabilizing system assembled in accordance with the principles of the present invention, certain of the components of said system being appropriately broken away more clearly to show internal construction.

Referring now more in detail to the aforesaid illustrative embodiment of the present invention, with particular reference to the drawing illustrating the same, the numeral 10 designates an oscillator adapted to generate a carrier wave ω_c , preferably, in the microwave region of the electromagnetic spectrum, having a frequency, for example, of 10,000 mc./sec. It is the frequency of this carrier wave that it is desired to stabilize.

The output of the oscillator 10 is applied to an energy-transmission system, for example, a wave guide 11, at the outer end of which (not shown) there may be connected any appropriate load device, for example, an electromagnetic horn adapted to radiate said carrier wave.

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By means of suitable coupling devices, such as probes 12 and 13, two carrier-wave portions of like phase are fed from the wave guide 11 into a pair of wave-guide sections 14 and 15. The wave-guide sections 14 and 15 also communicate with a cavity resonator 16, respectively, through openings 17 and 18, said cavity resonator being tuned to a sideband wave having a frequency which is either the sum of or the difference between the frequency of the carrier wave ω_h , generated by the oscillator 10, and the frequency of an intermediate-frequency wave ω_i , generated as will hereinafter be more fully explained. Assuming that the intermediate-frequency wave has a frequency of 50 mc./sec., the cavity resonator 16 may be tuned to a frequency of either 10,050 mc./sec. or 9,950 mc./sec. For the purposes of this specification, it will be assumed that said cavity resonator is tuned to the frequency of the upper sideband wave $\omega_h + \omega_i$.

Disposed in the wave-guide sections 14 and 15 are non-linear impedance devices, for example, crystals 19 and 20, the former being connected to the input terminals of an amplifying device 21, and the latter being connected to the output terminal of said device.

Assuming, for the moment, that the amplifying device 21 is feeding an intermediate-frequency wave ω_i to the crystal 20, said intermediate-frequency wave will combine with the carrier wave portion ω_h entering the wave-guide section 15 from the wave guide 11 to produce sideband waves $\omega_h \pm \omega_i$. The upper sideband wave thus produced will enter the cavity resonator 16, which is tuned thereto, and will pass from said cavity resonator to the wave-guide section 14 to excite the crystal 19. The latter will also be excited by the carrier wave portion ω_h entering the wave-guide section 14 from the wave guide 11 to reproduce, across the crystal 19, the intermediate-frequency wave ω_i . The latter, being applied to the input terminals of the amplifying device 21, will cause the cycle just described to continue, provided the energy fed back from the output terminal thereof is of the proper phase to sustain oscillation.

This condition is satisfied if:

$$\phi_1 \pm \phi_2 = n2\pi \quad (1)$$

where ϕ_1 is the phase shift inherent in the feedback circuit consisting of the cavity resonator 16, ϕ_2 is the phase shift inherent in the amplifying device 21, and n is any integer.

Now,

$$\phi_1 \approx 2\Delta \frac{(\omega_h + \omega_i)}{\omega_h + \omega_i} Q_c \quad (2)$$

where $\Delta(\omega_h + \omega_i)$ is the frequency deviation of the sideband wave from the frequency to which the cavity resonator 16 is tuned, $\omega_h + \omega_i$ is the resonant frequency of said cavity resonator, and Q_c is the Q of the cavity resonator;

And,

$$\phi_2 = 2\frac{\Delta\omega_i}{\omega_i} Q_a \quad (3)$$

where $\Delta\omega_i$ is the frequency deviation of the intermediate-frequency wave from the frequency to which the amplifying device 21 is tuned, ω_i is the resonant frequency of said amplifying device, and Q_a is what might be termed the equivalent Q of said amplifying device.

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Substituting Equations 2 and 3 into Equation 1, and differentiating,

$$\pm \left| \frac{\Delta\omega_h}{\Delta\omega_i} \right| = 1 + \frac{Q_a}{Q_c} \left(\frac{\omega_h}{\omega_i} \pm 1 \right) \quad (4)$$

Now, inasmuch as

$$Q_a \ll Q_c \text{ and } \frac{\omega_h}{\omega_i} \gg 1$$

$$\frac{\Delta\omega_h}{\Delta\omega_i} = \pm \left(1 + \frac{\omega_h}{\omega_i} \frac{Q_a}{Q_c} \right) \quad (5)$$

Thus, if the frequency of the carrier wave ω_h changes by $\Delta\omega_h$, due to random drift of the oscillator 10, the frequency of the intermediate-frequency wave ω_i , generated by the oscillating amplifying device 21, changes by $\Delta\omega_i$ in accordance with the ratio expressed by Equation 5.

In order to utilize any change in the frequency of the intermediate-frequency wave ω_i to stabilize the oscillator 10, a portion of the output of the amplifying device 21 is applied to a conventional frequency discriminator 22 whose center frequency corresponds to the initial or normal frequency of the intermediate-frequency wave, and as the frequency of said intermediate-frequency wave varies in response to deviations from the initial or normal frequency of the carrier wave, a unidirectional output is produced having an amplitude and sense which are functions, respectively, of the magnitude and sense of said frequency deviation.

Said unidirectional output is applied to any appropriate control device 23 designed, in turn, to retune the oscillator 10 so as to compensate for the aforesaid frequency deviation.

This completes the description of the aforesaid illustrative embodiment of the present invention. It will be noted from all of the foregoing that the frequency stabilizing apparatus of the present invention is relatively simple in its component parts, requires less skill initially to set up the same than devices heretofore known for similar purposes, and is not as critical to adjust as the heretofore known devices.

Other objects and advantages of the present invention will readily occur to those skilled in the art to which the same relates.

What is claimed is:

1. Apparatus for stabilizing the frequency of a carrier wave comprising: means for deriving from said carrier wave two carrier-wave portions of like phase; means for mixing one of said carrier-wave portions with an intermediate-frequency wave to produce a sideband wave; means for mixing the other of said carrier-wave portions with said sideband wave to recover therefrom said intermediate-frequency wave; an amplifying device, resonant to said intermediate-frequency wave, and having output and input circuits coupled, respectively, to said first and second-named mixing means; means, resonant to said sideband wave, for transmitting the same between said first and second-named mixing means, whereby said amplifying device is caused to oscillate at the frequency of said intermediate-frequency wave; means, receptive of a portion of said intermediate-frequency wave, for deriving therefrom a unidirectional output whose amplitude and sense are functions, respectively, of the magnitude and sense of any deviation of the frequency of said carrier wave from its initial frequency; and means, receptive of said unidirectional output, for altering the frequency of said carrier wave to compensate for any such frequency deviation.

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2. Apparatus for stabilizing the frequency of a carrier wave comprising: means, including a wave guide receptive of said carrier wave, a pair of wave-guide sections, and a coupling device intermediate each of said wave-guide sections and said wave guide, for deriving from said carrier wave two carrier-wave portions of like phase; means for mixing one of said carrier-wave portions with an intermediate-frequency wave to produce a side-band wave; means for mixing the other of said carrier-wave portions with said sideband wave to recover therefrom said intermediate-frequency wave; an amplifying device, resonant to said intermediate-frequency wave, and having output and input circuits coupled, respectively, to said first and second-named mixing means; means, resonant to said sideband wave, for transmitting the same between said first and second-named mixing means, whereby said amplifying device is caused to oscillate at the frequency of said intermediate-frequency wave; means, receptive of a portion of said intermediate-frequency wave, for deriving therefrom a unidirectional output whose amplitude and sense are functions, respectively, of the magnitude and sense of any deviation of the frequency of said carrier wave from its initial frequency; and means, receptive of said unidirectional output, for altering the frequency of said carrier wave to compensate for any such frequency deviation.

3. Apparatus for stabilizing the frequency of a carrier wave comprising: means, including a wave guide receptive of said carrier wave, a pair of wave-guide sections, and a coupling device intermediate each of said wave-guide sections and said wave-guide, for deriving from said carrier wave two carrier-wave portions of like phase; a non-linear impedance device, disposed in one of said wave-guide sections, for mixing one of said carrier-wave portions with an intermediate-frequency wave to produce a sideband wave; another non-linear impedance device, disposed in the other of said wave-guide sections, for mixing the other of said carrier-wave portions with said sideband wave to recover therefrom said intermediate-frequency wave; an amplifying device, resonant to said intermediate-frequency wave, and having output and input circuits coupled, respectively, to said first and second-named impedance devices; means, resonant to said sideband wave, for transmitting the same between said wave-guide sections, whereby said amplifying device is caused to oscillate at the frequency of said intermediate-frequency wave; means, receptive of a portion of said intermediate-frequency wave, for deriving therefrom a unidirectional output whose amplitude and sense are functions, respectively, of the magnitude and sense of any deviation of the frequency of said carrier wave from its initial frequency; and means, receptive of said unidirectional output, for altering the frequency of said carrier wave to compensate for any such frequency deviation.

4. Apparatus for stabilizing the frequency of a carrier wave comprising: means, including a wave guide receptive of said carrier wave, a pair of wave-guide sections, and a coupling device intermediate each of said wave-guide sections and said wave-guide, for deriving from said carrier wave two carrier-wave portions of like phase; means, disposed in one of said wave-guide sections for mixing one of said carrier-wave portions with an intermediate-frequency wave to produce a sideband wave; means, disposed in the other

of said wave-guide sections, for mixing the other of said carrier-wave portions with said sideband wave to recover therefrom said intermediate-frequency wave; an amplifying device, resonant to said intermediate-frequency wave, and having output and input circuits coupled, respectively, to said first and second-named mixing means; a cavity resonator, resonant to said sideband wave, for transmitting the same between said first and second-named mixing means, whereby said amplifying device is caused to oscillate at the frequency of said intermediate-frequency wave; means, receptive of a portion of said intermediate-frequency wave, for deriving therefrom a unidirectional output whose amplitude and sense are functions, respectively, of the magnitude and sense of any deviation of the frequency of said carrier wave from its initial frequency; and means, receptive of said unidirectional output, for altering the frequency of said carrier wave to compensate for any such frequency deviation.

5. Apparatus for stabilizing the frequency of a carrier wave comprising: means, including a wave guide receptive of said carrier wave, a pair of wave-guide sections, and a coupling device intermediate each of said wave-guide sections and said wave guide, for deriving from said carrier wave two carrier-wave portions of like phase; a non-linear impedance device, disposed in one of said wave-guide sections, for mixing one of said carrier-wave portions with an intermediate-frequency wave to produce a sideband wave; another non-linear impedance device, disposed in the other of said wave-guide sections, for mixing the other of said carrier-wave portions with said sideband wave to recover therefrom said intermediate-frequency wave; an amplifying device, resonant to said intermediate-frequency wave, and having output and input circuits coupled, respectively, to said first and second-named impedance devices; a cavity resonator, resonant to said sideband wave, for transmitting the same between said wave-guide sections, whereby said amplifying device is caused to oscillate at the frequency of said intermediate-frequency wave; a frequency-discriminator, receptive of a portion of said intermediate-frequency wave, for deriving therefrom a unidirectional output whose amplitude and sense are functions, respectively, of the magnitude and sense of any deviation of the frequency of said carrier wave from its initial frequency; and means, receptive of said unidirectional output, for altering the frequency of said carrier wave to compensate for any such frequency deviation.

6. An oscillation generator comprising: means, receptive of a first periodic wave, for deriving therefrom two periodic-wave portions of like phase; means for mixing one of said periodic-wave portions with a second periodic wave to produce a third periodic wave whose frequency is an arithmetic function of the frequencies of said first and second periodic waves; means for mixing the other of said periodic wave portions with said third periodic wave to recover therefrom said second periodic wave; an amplifying device, resonant to said second periodic wave, and having output and input circuits coupled, respectively, to said first and second-named mixing means; and means, resonant to said third periodic wave, for transmitting the same between said first and second-named mixing means, whereby said amplifying device is caused to os-

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cillate at the frequency of said second periodic wave.

7. An oscillation generator comprising: means, including a wave guide receptive of a first periodic wave, a pair of wave-guide sections, and a coupling device intermediate each of said wave-guide sections and said wave guide, for deriving from said first periodic wave two periodic-wave portions of like phase; means for mixing one of said periodic-wave portions with a second periodic wave to produce a third periodic wave whose frequency is an arithmetic function of the frequencies of said first and second periodic waves; means for mixing the other of said periodic-wave portions with said third periodic wave to recover therefrom said second periodic wave; an amplifying device, resonant to said second periodic wave, and having output and input circuits coupled, respectively, to said first and second-named mixing means; and means, resonant to said third periodic-wave, for transmitting the same between said first and second-named mixing means, whereby said amplifying device is caused to oscillate at the frequency of said second periodic wave.

8. An oscillation generator comprising: means, including a wave guide receptive of a first periodic wave, a pair of wave-guide sections, and a coupling device intermediate each of said wave-guide sections and said wave guide, for deriving from said first periodic wave two periodic-wave portions of like phase; a non-linear impedance device, disposed in one of said wave-guide sections for mixing one of said periodic-wave portions with a second periodic wave to produce a third periodic wave whose frequency is an arithmetic function of the frequencies of said first and second periodic waves; another non-linear impedance device, disposed in the other of said wave-guide sections, for mixing the other of said periodic-wave portions with said third periodic wave to recover therefrom said second periodic wave; an amplifying device, resonant to said second periodic wave, and having output and input circuits coupled, respectively, to said first and second-named impedance devices; and means, resonant to said third periodic wave, for transmitting the same between said wave-guide sections, whereby said amplifying device is caused to oscillate at the frequency of said second periodic wave.

9. An oscillation generator comprising: means, including a wave guide receptive of a first periodic wave, a pair of wave-guide sections, and a coupling device intermediate each of said wave-guide sections and said wave guide, for deriving from said first periodic wave two periodic-wave

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portions of like phase; means, disposed in one of said wave-guide sections, for mixing one of said periodic-wave portions with a second periodic wave to produce a third periodic wave whose frequency is an arithmetic function of the frequencies of said first and second periodic waves; means, disposed in the other of said wave-guide sections, for mixing the other of said periodic-wave portions with said third periodic wave to recover therefrom said second periodic wave; an amplifying device, resonant to said second periodic wave, and having output and input circuits coupled, respectively, to said first and second-named mixing means; and a cavity resonator, resonant to said third periodic wave, for transmitting the same between said first and second-named mixing means, whereby said amplifying device is caused to oscillate at the frequency of said second periodic wave.

10. An oscillation generator comprising: means, including a wave guide receptive of a first periodic wave, a pair of wave-guide sections, and a coupling device intermediate each of said wave-guide sections and said wave guide, for deriving from said first periodic wave two periodic-wave portions of like phase; a non-linear impedance device, disposed in one of said wave-guide sections, for mixing one of said periodic-wave portions with a second periodic wave to produce a third periodic wave whose frequency is an arithmetic function of the frequencies of said first and second periodic waves; another non-linear impedance device, disposed in the other of said wave-guide sections, for mixing the other of said periodic-wave portions with said third periodic wave to recover therefrom said second periodic wave; an amplifying device, resonant to said second periodic wave, and having output and input circuits coupled, respectively, to said first and second-named impedance devices; and a cavity resonator, resonant to said third periodic wave, for transmitting the same between said wave-guide sections, whereby said amplifying device is caused to oscillate at the frequency of said second periodic wave.

GEORGE G. BRUCK.

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