

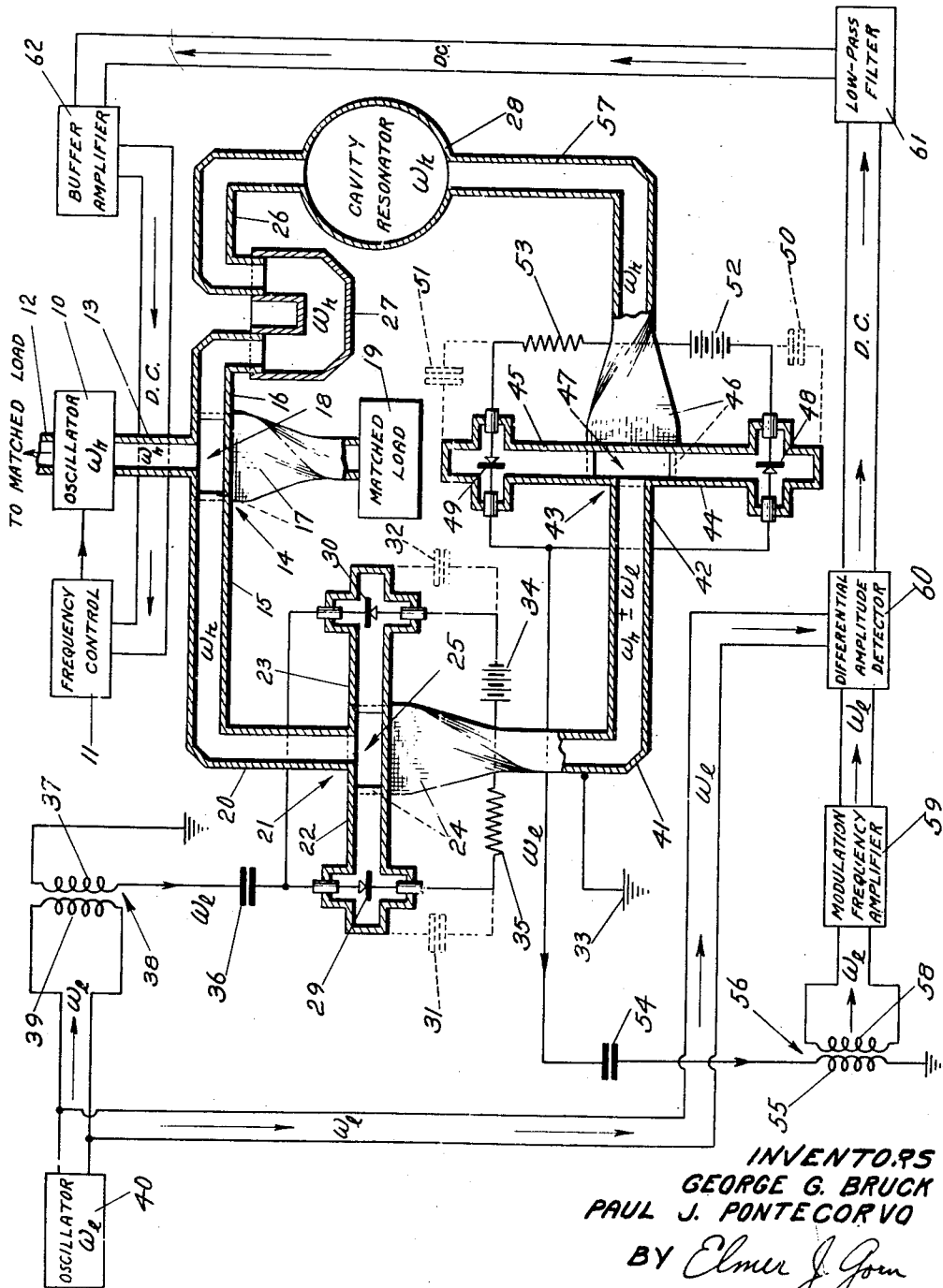
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G. G. BRUCK ET AL

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FREQUENCY STABILIZING SYSTEM

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FREQUENCY-STABILIZING SYSTEM

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14 Claims. (Cl. 250—36)

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This invention relates to frequency-stabilizing systems, and constitutes an improvement over the system disclosed in the copending application of George G. Bruck and Philip E. Volz, entitled "Frequency stabilizing system," Serial No. 647,008, filed February 12, 1946.

While not limited thereto, the present invention is admirably adapted to the control of the carrier wave of a communication system, such as is disclosed in the copending application of George G. Bruck, Philip E. Volz, Paul J. Pontecorvo and Malcolm C. Vosburgh, entitled "Radio communication system," Serial No. 650,716, filed February 27, 1946, and comprising, for example, two widely separated terminal stations and a plurality of intermediate relay stations, the system permitting the two-way transmission of intelligence between any and all of the stations included therein, with the carrier wave emanating from each relay station under the control of the carrier wave received at each relay station, and all under the master control of the carrier wave originating at one of the terminal stations.

In the frequency-stabilizing system disclosed in the first of the above referred to copending applications, reflections, within the system, of energy from certain of the components thereof have been found to interfere with the efficient functioning of other of said components. In addition, said system has been found to be so sensitive that its initial adjustment becomes unduly critical and presents impedance-matching problems which are difficult of solution.

It is, therefore, an object of the present invention to so decouple the various components thereof as to eliminate the effects of energy reflected thereby.

It is another object of the present invention to simplify the procedure for initially setting up the system.

It is still another object of the present invention to simplify the impedance-matching problems thereof.

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:

A portion of a carrier wave, which may have a frequency, say, of 10,000 mc., and which is to be frequency stabilized, is divided into two parts, one of which is amplitude modulated at a relatively low frequency, say, 50 mc., and the other of which is transmitted through a cavity resonator whose natural resonant frequency constitutes a reference frequency corresponding to the mean fre-

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quency desired of said carrier wave. The amplitude-modulating means are, preferably, such that the carrier wave itself is suppressed, and only the resultant sidebands subsequently utilized. By so doing, as will hereinafter become more apparent, the effects of energy reflections and impedance mismatches between the components of the system are eliminated.

The lengths of the paths of the portions of the carrier wave which are amplitude modulated and applied to the cavity resonator, respectively, are made to differ, preferably, by $n\lambda/4$ where n is an odd integer and λ is the wave-guide wavelength corresponding to the frequency desired of the carrier wave. As a result of this difference in length, when the sidebands produced as aforesaid and a portion of the carrier wave coming from the cavity resonator are combined in a mixer, the effect is the same as combining a portion of the carrier wave which is varying in amplitude at the modulation frequency with a portion of the carrier wave which is of constant amplitude but 90° out of phase with said first portion, and produces a substantially constant-amplitude resultant wave, provided the frequency of the carrier wave corresponds to the hereinbefore referred to reference frequency, that is, to the natural resonant frequency of the cavity resonator. If, on the other hand, the frequency of the carrier wave has drifted from the frequency desired thereof, the sidebands and the carrier wave coming from the cavity resonator do not meet at the mixer in phase quadrature, and, therefore, the in-phase components of said sidebands cause the resonator-transmitted, carrier-wave portion to become substantially amplitude modulated.

The modulation envelope of the last-named resultant wave has a phase, relative to the amplitude modulation initially applied to the carrier wave, and a magnitude, which are functions, respectively, of the sense and magnitude of any deviation of the frequency of said carrier wave from the reference frequency. Preferably, said modulation envelope is either in phase with said initially applied modulation, or it is in phase opposition thereto.

If there has been no deviation from the reference frequency, and, as a result, a substantially constant-amplitude wave is produced at the aforesaid mixer, there is no modulation envelope to recover, but if there has been deviation, the modulation envelope of the amplitude-modulated resultant wave produced at said mixer, whether it is in phase with the initially applied modulation, or in phase opposition thereto, is recovered, the

sense and magnitude of the recovered envelope being functions, respectively, of the sense and magnitude of said deviation.

The recovered modulation envelope is combined, for example, in a differential-amplitude detector, with a portion of the initially applied modulation to obtain an output having a D.-C. or unidirectional component whose sense and magnitude, likewise, are functions, respectively, of the sense and magnitude of the deviation of the frequency of the carrier wave from its desired frequency, and having an audio-frequency component corresponding to any intelligence which might have been initially impressed upon said carrier wave. The output of the differential-amplitude detector is passed through a low-pass filter to remove the audio-frequency component thereof, and the remaining D.-C. or unidirectional component is applied, through a buffer amplifier, to any preferred electronic or mechanical tuning control to adjust the frequency of the carrier wave to compensate for the deviations above referred to.

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.

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 for generating a carrier wave ω_c , preferably, in the microwave region of the electromagnetic spectrum. It is the mean frequency of this carrier wave that it is desired to stabilize, and for this purpose there is provided any appropriate frequency control 11 adapted to respond to a control signal generated as will hereinafter be fully described.

A portion of the output of the oscillator 10 is conveyed, through a wave guide 12, to a matched load, for example, a suitable antenna for radiating the same.

Another portion of the output of the oscillator 10 is applied to the so-called E arm 13 of a wave-guide assembly 14 known as a "magic T." Such a wave-guide assembly comprises, in addition to the E arm 13, a pair of collinear side branches 15 and 16 extending at right angles to said E arm 13, and a so-called H arm 17 extending outwardly from said side branches 15 and 16, mutually perpendicular thereto and to said E arm, said E arm, said side branches, and said H arm all extending from a common junction 18. As shown in the drawing, the H arm 17 recedes from the observer for a short distance from the common junction 18, then bends downwardly, and is then twisted through an angle of 90°.

The energy traveling along the E arm 13 splits at the junction 18, part traveling along the side branch 15, part traveling along the side branch 16, and part traveling along the H arm 17 which is terminated in a matched load 19.

The side branch 15 communicates with the E

arm 20 of another "magic T" 21 including side branches 22 and 23 and an H arm 24, all extending from a common junction 25, and the side branch 16 communicates, through a wave guide 26 incorporating a "line stretcher" 27 for adjusting the electrical length thereof, with a cavity resonator 28 the natural resonant frequency ω_n of which constitutes the reference frequency with respect to which it is desired to maintain the frequency of the oscillator 10 in a fixed relationship.

The side branches 22 and 23 of the "magic T" 21 terminate in oppositely-disposed crystals 29 and 30, between one side of each of which and the "magic T" itself capacitance 31 and 32 exist, the wave-guide system, generally, being grounded, as at 33, and said crystals being connected, in series with a source 34 of direct current and a resistor 35, to provide parallel inputs to ground through a capacitor 36 and the secondary winding 37 of a radio-frequency transformer 38. The primary winding 39 of the transformer 38 is connected to an oscillator 40 adapted to generate relatively low, radio-frequency energy ω_l for amplitude modulating the carrier wave ω_c . The frequency of the modulating energy may be, for example, 50 mc.

The "magic T" 21 functions as a balanced modulator as disclosed in detail in the copending application of Paul J. Pontecorvo, entitled "Modulator," Ser. No. 652,738, filed March 7, 1946. The carrier wave ω_c traveling along the E arm 20 toward the junction 25, with or without locally-generated intelligence ω_m , splits at said junction, part traveling along the side branch 22 toward the crystal 29, and part traveling along the side branch 23 toward the crystal 30. The oppositely-traveling parts of the carrier wave incident upon said crystals are, it will be noted, 180° out of phase, and each becomes amplitude modulated by the energy injected into said crystals, in parallel, from the oscillator 40. Thus, sidebands, having frequencies equal to the sum of and difference between the frequencies of the carrier and modulation waves, are produced at the crystals 29 and 30, which sidebands, together with any carrier components resulting from mismatching of the crystals to the wave-guide system, travel back along the side branches 22 and 23 toward the junction 25. The sidebands, upon reaching said junction, travel along the H arm 24 of the "magic T" 21, but the reflected carrier-wave components, being in phase opposition, are cancelled along said H arm 24, so that the final output of the "magic T" 21 is a carrier suppressed, amplitude-modulated wave.

The sidebands comprising said last-named wave are conveyed, through a wave guide 41, to the E arm 42 of another "magic T" 43 which, like that previously described, includes side branches 44 and 45 and an H arm 46, all extending from a common junction 47. The side branches 44 and 45 are terminated in crystals 48 and 49, between one side of each of which and the "magic T" itself, capacitances 50 and 51 exist, said "magic T" being grounded, and said crystals being connected, in series with a source 52 of direct current and a resistor 53, to provide parallel outputs to ground through a capacitor 54 and the primary winding 55 of a radio-frequency transformer 56. The H arm 46 of the "magic T" 43 is connected, through a wave guide 57, to the output side of the cavity resonator 28.

By adjusting the "line stretcher" 27, the electrical lengths of the paths taken by the energy

traveling from the junction 18 of the "magic T" 14 to the junction 47 of the "magic T" 43, through the balanced modulator "magic T" 21 on the one hand, and through the cavity resonator 28 on the other, are made to differ by $n\lambda/4$, where n is an odd integer and λ is the wave-guide wavelength corresponding to the natural resonant frequency of the cavity resonator 28, in other words, to the mean frequency desired of the carrier wave coming from the oscillator 10.

Now, at the junction 47 of the "magic T" 43 which, as will now be described, functions as a balanced demodulator and a buffer isolating the balanced modulator "magic T" 21 from the cavity resonator 28, the sideband waves traveling along the E arm 42 split, part traveling along the side branch 44 toward the crystal 48, and part traveling along the side branch 45 toward the crystal 49. Also at said junction 47, the carrier wave ω_c , traveling along the H arm 46 from the cavity resonator 28, splits, part traveling along the side branch 44 toward the crystal 48, and part traveling along the side branch 45 toward the crystal 49.

At each of the crystals 48 and 49, the upper sideband may be considered as a vector rotating in a counter-clockwise direction at the frequency of the carrier wave ω_c plus that of the modulation wave ω_m , and the lower sideband may be considered as a vector rotating in the same direction at a frequency of the carrier wave minus that of the modulation wave. These two vectors, rotating at different frequencies, periodically become in phase, and so, they may be considered as oppositely-rotating vectors combining to produce a non-rotating vector constituting a resultant sideband. The latter is, actually, the carrier wave varying in amplitude at the modulation frequency, and when combined, in each of the crystals 48 and 49, with carrier-wave portions coming from the cavity resonator 28, with which they are 90° out of phase, the amplitudes of said carrier-wave portions remain substantially unaffected. Therefore, no modulation envelopes are recovered at the crystals 48 and 49.

However, should the oscillator 10 drift, so that the frequency of the carrier wave differs from the reference frequency, that is, from the natural resonant frequency of the cavity resonator 28, the latter causes the phase of the carrier wave transmitted therethrough to the balanced demodulator "magic T" 43 to shift in a direction and to an extent depending, respectively, on the direction and extent of the frequency drift. Hence, at the crystals 48 and 49, the sideband resultant waves and the carrier-wave portions coming from the cavity resonator 28 are no longer in phase quadrature, and as a result, in-phase portions of said sideband resultant waves cause said carrier-wave portions to become amplitude modulated.

If the frequency of the carrier wave generated by the oscillator 10 drifts above the reference frequency, the carrier-wave portions coming from the cavity resonator 28 acquire "+ amplitude modulation," and if said frequency drifts below the reference frequency, said carrier-wave portions acquire "- amplitude modulation."

In any event, the modulation envelopes thus produced are recovered across the crystals 48 and 49, and add to each other to appear across the primary winding 55 of the transformer 56.

It now remains to extract from the output of the balanced demodulator "magic T" 43 a D.-C. or unidirectional component of proper sense and

magnitude to adjust the frequency control 11 and compensate for the deviations of the oscillator 10. For this purpose, the secondary winding 58 of the transformer 56 is connected to an amplifier 59 which is tuned to the frequency ω_m of the modulation oscillator 40. The output of the amplifier 59 is applied to a differential-amplitude detector 60 to which there is also applied a portion of the output of the modulation oscillator 40. Such a differential-amplitude detector may, for example, be similar to the one disclosed in the above referred to copending application of George G. Bruck and Philip E. Volz, entitled "Frequency stabilizing system."

The differential-amplitude detector 60 is so designed that, in the case where the oscillator 10 has not drifted at all, and as a result, no modulation envelope appears across the transformer 56, said detector has a balanced output which cancels itself. Said detector is so further designed that, in the case where the oscillator 10 has drifted, and, as a result, a modulation envelope does appear across the transformer 56, said detector produces a unidirectional output whose sense and magnitude are functions, respectively, of the sense and magnitude of said drift.

In order to remove from the output of the differential-amplitude detector any intelligence ω_m which may have been initially impressed upon the carrier wave ω_c , said output is applied to a low-pass filter 61, thereby obtaining a final D.-C. output. This output is then applied, through a buffer amplifier 62, to the tuning control 11 to compensate for any drift in the oscillator 10.

This completes the description of the aforesaid illustrative embodiment of the present invention, including the mode of operation thereof. It will be noted from all of the foregoing that the present invention enables the stabilization of a carrier wave within very close limits. Furthermore, it enables the elimination of the effects of energy reflected between the various components thereof, and it simplifies the impedance-matching problems of the system which, in turn, simplifies the procedure for initially setting up the system.

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, receptive of a portion of said carrier wave, for so amplitude modulating the same as to suppress the carrier components of the resulting sideband waves; means, receptive of another portion of said carrier wave, for shifting the phase thereof through such an angle that, upon combination of said sideband waves and said phase-shifted carrier-wave portion, a wave having a selected amplitude characteristic results; means, responsive to any drift in the frequency of said carrier wave, for altering the phase of said phase-shifted carrier-wave portion; means for combining said sideband waves and said phase-shifted carrier-wave portion whereby, in the event no frequency drift has occurred, the resultant wave has the aforesaid selected amplitude characteristic, and in the event a frequency drift has occurred, the resultant wave has a substantially different amplitude characteristic; means for deriving from said last-named resultant wave a wave having an amplitude characteristic which is a function of the difference between the amplitude characteristics of both said resultant waves; and means, recep-

tive of said difference-characteristics wave, for so tuning the source of said carrier wave as to compensate for said frequency drift.

2. Apparatus for stabilizing the frequency of a carrier wave comprising: means, receptive of a portion of said carrier wave, for deriving therefrom two constituent waves; means, receptive of a modulation wave and said constituent waves, for deriving from the former two additional constituent waves, and combining the same, respectively, with said first-named constituent waves whereby sideband waves are produced; means, receptive of said sideband waves and portions of said first-named constituent waves reflected from said last-named means, for so combining the same as to suppress the carrier components thereof; means receptive of another portion of said carrier wave, for shifting the phase thereof through such an angle that, upon combination of said sideband waves and said phase-shifted carrier-wave portion, a wave having a selected amplitude characteristic results; means, responsive to any drift in the frequency of said carrier wave, for altering the phase of said phase-shifted carrier-wave portion; means for combining said sideband waves and said phase-shifted carrier-wave portion whereby, in the event no frequency drift has occurred, the resultant wave has the aforesaid selected amplitude characteristic, and in the event a frequency drift has occurred, the resultant wave has a substantially different amplitude characteristic; means for deriving from said last-named resultant wave a wave having an amplitude characteristic which is a function of the difference between the amplitude characteristics of both said resultant waves; and means, receptive of said difference-characteristics wave, for so tuning the source of said carrier wave as to compensate for said frequency drift.

3. Apparatus for stabilizing the frequency of a carrier wave comprising: a wave-guide section, having a perpendicularly extending branch arm receptive of a portion of said carrier wave, for deriving from said carrier-wave portion two constituent waves; a pair of non-linear impedances terminating the opposite ends of said wave-guide section, receptive of a modulation wave and said constituent waves, for deriving from the former two additional constituent waves, and combining the same, respectively, with said first-named constituent waves whereby sideband waves are produced; a second branch arm extending perpendicularly from said wave-guide section, perpendicularly to said first-named branch arm, receptive of said sideband waves and portions of said first-named constituent waves reflected from said non-linear impedances, for so combining the same as to suppress the carrier components thereof; means, receptive of another portion of said carrier wave, for shifting the phase thereof through such an angle that, upon combination of said sideband waves and said phase-shifted carrier-wave portion, a wave having a selected amplitude characteristic results; means, responsive to any drift in the frequency of said carrier wave, for altering the phase of said phase-shifted carrier-wave portion; means for combining said sideband waves and said phase-shifted carrier-wave portion whereby, in the event no frequency drift has occurred, the resultant wave has the aforesaid selected amplitude characteristic, and in the event a frequency drift has occurred, the resultant wave has a substantially different amplitude characteristic; means for deriving from said last-named resultant wave a wave having an ampli-

tude characteristic which is a function of the difference between the amplitude characteristics of both said resultant waves; and means, receptive of said difference-characteristics wave, for so tuning the source of said carrier wave as to compensate for said frequency drift.

4. Apparatus for stabilizing the frequency of a carrier wave comprising: means, receptive of a portion of said carrier wave, for so amplitude modulating the same as to suppress the carrier components of the resulting sideband waves; means, receptive of another portion of said carrier wave, for shifting the phase thereof through such an angle that, upon combination of said sideband waves and said phase-shifted carrier-wave portion, a wave having a selected amplitude characteristic results; a cavity resonator, resonant to the frequency desired of said carrier wave and receptive of said phase-shifted portion thereof, for altering the phase of said phase-shifted portion in response to any drift from said desired frequency; means for combining said sideband waves and said phase-shifted carrier-wave portion whereby, in the event no frequency drift has occurred, the resultant wave has the aforesaid selected amplitude characteristic, and in the event a frequency drift has occurred, the resultant wave has a substantially different amplitude characteristic; means for deriving from said last-named resultant wave a wave having an amplitude characteristic which is a function of the difference between the amplitude characteristics of both said resultant waves; and means, receptive of said difference-characteristics wave, for so tuning the source of said carrier wave as to compensate for said frequency drift.

5. Apparatus for stabilizing the frequency of a carrier wave comprising: means, receptive of a portion of said carrier wave, for deriving therefrom two constituent waves; means, receptive of a modulation wave and said constituent waves, for deriving from the former two additional constituent waves, and combining the same, respectively, with said first-named constituent waves whereby sideband waves are produced; means, receptive of said sideband waves and portions of said first-named constituent waves reflected from said last-named means, for so combining the same as to suppress the carrier components thereof; means, receptive of another portion of said carrier wave, for shifting the phase thereof through such an angle that, upon combination of said sideband waves and said phase-shifted carrier-wave portion, a wave having a selected amplitude characteristic results; a cavity resonator, resonant to the frequency desired of said carrier wave and receptive of said phase-shifted portion thereof, for altering the phase of said phase-shifted portion in response to any drift from said desired frequency; means for combining said sideband waves and said phase-shifted carrier-wave portion whereby, in the event no frequency drift has occurred, the resultant wave has the aforesaid selected amplitude characteristic, and in the event a frequency drift has occurred, the resultant wave has a substantially different amplitude characteristic; means for deriving from said last-named resultant wave a wave having an amplitude characteristic which is a function of the difference between the amplitude characteristics of both said resultant waves; and means, receptive of said difference-characteristics wave, for so tuning the source of said carrier wave as to compensate for said frequency drift.

6. Apparatus for stabilizing the frequency of

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a carrier wave comprising: a wave-guide section, having a perpendicularly extending branch arm receptive of a portion of said carrier wave, for deriving from said carrier-wave portion two constituent waves; a pair of non-linear impedances terminating the opposite ends of said wave-guide section, receptive of a modulation wave and said constituent waves, for deriving from the former two additional constituent waves, and combining the same, respectively, with said first-named constituent waves whereby sideband waves are produced; a second branch arm extending perpendicularly from said wave-guide section, perpendicularly to said first-named branch arm, receptive of said sideband waves and portions of said first-named constituent waves reflected from said non-linear impedances, for so combining the same as to suppress the carrier components thereof; means, receptive of another portion of said carrier wave, for shifting the phase thereof through such an angle that, upon combination of said sideband waves and said phase-shifted carrier-wave portion, a wave having a selected amplitude characteristic results; a cavity resonator, resonant to the frequency desired of said carrier wave and receptive of said phase-shifted portion thereof, for altering the phase of said phase-shifted portion in response to any drift from said desired frequency; means for combining said sideband waves and said phase-shifted carrier-wave portion whereby, in the event no frequency drift has occurred, the resultant wave has the aforesaid selected amplitude characteristic, and in the event a frequency drift has occurred, the resultant wave has a substantially different amplitude characteristic; means for deriving from said last-named resultant wave a wave having an amplitude characteristic which is a function of the difference between the amplitude characteristics of both said resultant waves; and means, receptive of said difference-characteristics wave, for so tuning the source of said carrier wave as to compensate for said frequency drift.

7. Apparatus for stabilizing the frequency of a carrier wave comprising: means, receptive of a portion of said carrier wave, for so amplitude modulating the same as to suppress the carrier components of the resulting sideband waves; means receptive of another portion of said carrier wave, for shifting the phase thereof through such an angle that, upon combination of said sideband waves and said phase-shifted carrier-wave portion, a wave having a selected amplitude characteristic results; means, responsive to any drift in the frequency of said carrier wave, for altering the phase of said phase-shifted carrier-wave portion; means, receptive of said sideband waves and said phase-shifted carrier-wave portion, for deriving from the former, constituent waves of opposite phase, and from the latter, constituent waves of similar phase; means, receptive of said oppositely and similarly phased constituent waves, for combining the same whereby, in the event no frequency drift has occurred, the resultant wave has the aforesaid selected amplitude characteristic, and in the event a frequency drift has occurred, the resultant wave has a substantially different amplitude characteristic; means for deriving from said last-named resultant wave a wave having an amplitude characteristic which is a function of the difference between the amplitude characteristics of both said resultant waves; and means, receptive of said difference-characteristics wave, for

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so tuning the source of said carrier wave as to compensate for said frequency drift.

8. Apparatus for stabilizing the frequency of a carrier wave comprising: means, receptive of a portion of said carrier wave, for deriving therefrom two constituent waves; means, receptive of a modulation wave and said constituent waves, for deriving from the former two additional constituent waves, and combining the same, respectively, with said first-named constituent waves whereby sideband waves are produced; means, receptive of said sideband waves and portions of said first-named constituent waves reflected from said last-named means, for so combining the same as to suppress the carrier components thereof; means, receptive of another portion of said carrier wave, for shifting the phase thereof through such an angle that, upon combination of said sideband waves and said phase-shifted carrier-wave portion, a wave having a selected amplitude characteristic results; means, responsive to any drift in the frequency of said carrier-wave, for altering the phase of said phase-shifted carrier-wave portion; means, receptive of said sideband waves and said phase-shifted carrier-wave portion, for deriving from the former, constituent waves of opposite phase, and from the latter, constituent waves of similar phase; means, receptive of said oppositely and similarly phased constituent waves, for combining the same whereby, in the event no frequency drift has occurred, the resultant wave has the aforesaid selected amplitude characteristic, and in the event a frequency drift has occurred, the resultant wave has a substantially different amplitude characteristic; means for deriving from said last-named resultant wave a wave having an amplitude characteristic which is a function of the difference between the amplitude characteristics of both said resultant waves; and means, receptive of said difference-characteristics wave, for so tuning the source of said carrier wave as to compensate for said frequency drift.

9. Apparatus for stabilizing the frequency of a carrier wave comprising: a wave-guide section, having a perpendicularly extending branch arm receptive of a portion of said carrier wave, for deriving from said carrier-wave portion two constituent waves; a pair of non-linear impedance terminating the opposite ends of said wave-guide section, receptive of a modulation wave and said constituent waves, for deriving from the former two additional constituent waves, and combining the same, respectively, with said first-named constituent waves whereby sideband waves are produced; a second branch arm extending perpendicularly from said wave-guide section, perpendicularly to said first-named branch arm, receptive of said sideband waves and portions of said first-named constituent waves reflected from said non-linear impedances, for so combining the same as to suppress the carrier components thereof; means, receptive of another portion of said carrier wave, for shifting the phase thereof through such an angle that, upon combination of said sideband waves and said phase-shifted carrier-wave portion, a wave having a selected amplitude characteristic results; means, responsive to any drift in the frequency of said carrier wave, for altering the phase of said phase-shifted carrier-wave portion; means receptive of said sideband waves and said phase-shifted carrier-wave portion for deriving from the former, constituent waves of opposite phase, and from the latter, constituent waves of similar

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phase; means, receptive of said oppositely and similarly phase constituent waves, for combining the same whereby, in the event no frequency drift has occurred, the resultant wave has the aforesaid selected amplitude characteristic, and in the event a frequency drift has occurred, the resultant wave has a substantially different amplitude characteristic; means for deriving from said last-named resultant wave a wave having an amplitude characteristic which is a function of the difference between the amplitude characteristics of both said resultant waves; and means, receptive of said difference-characteristics wave, for so tuning the source of said carrier wave as to compensate for said frequency drift.

10. Apparatus for stabilizing the frequency of a carrier wave comprising: means, receptive of a portion of said carrier wave, for so amplitude modulating the same as to suppress the carrier components of the resulting sideband waves; means, receptive of another portion of said carrier wave, for shifting the phase thereof through such an angle that, upon combination of said sideband waves and said phase-shifted carrier-wave portion, a wave having a selected amplitude characteristic results; a cavity resonator, resonant to the frequency desired of said carrier wave and receptive of said phase-shifted portion thereof, for altering the phase of said phase-shifted portion in response to any drift from said desired frequency; means, receptive of said sideband waves and said phase-shifted carrier-wave portion, for deriving from the former, constituent waves of opposite phase, and from the latter, constituent waves of similar phase; means, receptive of said oppositely and similarly phased constituent waves, for combining the same whereby, in the event no frequency drift has occurred, the resultant wave has the aforesaid selected amplitude characteristic, and in the event a frequency drift has occurred, the resultant wave has a substantially different amplitude characteristic; means for deriving from said last-named resultant wave a wave having an amplitude characteristic which is a function of the difference between the amplitude characteristics of both said resultant waves; and means, receptive of said difference-characteristics wave, for so tuning the source of said carrier wave as to compensate from said frequency drift.

11. Apparatus for stabilizing the frequency of a carrier wave comprising: a wave-guide section, having a perpendicularly extending branch arm receptive of a portion of said carrier wave, for deriving from said carrier-wave portion two constituent waves; a pair of non-linear impedances terminating the opposite ends of said wave-guide section, receptive of a modulation wave and said constituent waves, for deriving from the former two additional constituent waves, and combining the same, respectively, with said first-named constituent waves whereby sideband waves are produced; a second branch arm extending perpendicularly from said wave-guide section, perpendicularly to said first-named branch arm, receptive of said sideband waves and portions of said first-named constituent waves reflected from said non-linear impedances, for so combining the same as to suppress the carrier components thereof; means, receptive of another portion of said carrier wave, for shifting the phase thereof through such an angle that, upon combination of said sideband waves and said phase-shifted carrier-wave portion, a wave having a selected amplitude characteristic results; a

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cavity resonator, resonant to the frequency desired of said carrier-wave and receptive of said phase-shifted portion thereof, for altering the phase of said phase-shifted portion in response to any drift from said desired frequency; means, receptive of said sideband waves and said phase-shifted carrier-wave portion, for deriving from the former, constituent waves of opposite phase, and from the latter, constituent waves of similar phase; means, receptive of said oppositely and similarly phased constituent waves, for combining the same whereby, in the event no frequency drift has occurred, the resultant wave has the aforesaid selected amplitude characteristic, and in the event a frequency drift has occurred, the resultant wave has a substantially different amplitude characteristic; means for deriving from said last-named resultant wave a wave having an amplitude characteristic which is a function of the difference between the amplitude characteristics of both said resultant waves; and means, receptive of said difference-characteristics wave, for so tuning the source of said carrier wave as to compensate for said frequency drift.

12. Apparatus for stabilizing the frequency of a carrier wave comprising: a wave-guide section, having a perpendicularly extending branch arm receptive of a portion of said carrier wave, for deriving from said carrier-wave portion two constituent waves; a pair of non-linear impedances terminating the opposite ends of said wave-guide section, receptive of a modulation wave and said constituent waves, for deriving from the former two additional constituent waves, and combining the same, respectively, with said first-named constituent waves whereby sideband waves are produced; a second branch arm extending perpendicularly from said wave-guide section, perpendicularly to said first-named branch arm, receptive of said sideband waves and portions of said first-named constituent waves reflected from said non-linear impedances, for so combining the same as to suppress the carrier components thereof; means, receptive of another portion of said carrier wave, for shifting the phase thereof through such an angle that, upon combination of said sideband waves and said phase-shifted carrier-wave portion, a wave having a selected amplitude characteristic results; a cavity resonator, resonant to the frequency desired of said carrier wave and receptive of said phase-shifted portion thereof, for altering the phase of said phase-shifted portion in response to any drift from said desired frequency; another wave-guide section, having a perpendicularly extending branch arm receptive of sideband waves, for deriving therefrom constituent waves of opposite phase; a second branch arm extending perpendicularly from said last-named wave-guide section, perpendicularly to said first-named branch arm thereof, receptive of said phase-shifted carrier-wave portion, for deriving therefrom constituent waves of similar phase; a pair of non-linear impedances terminating the opposite ends of said last-named wave-guide section, receptive of said oppositely and similarly phased constituent waves, for combining the same whereby, in the event no frequency drift has occurred, the resultant wave has the aforesaid selected amplitude characteristic, and in the event a frequency drift has occurred, the resultant wave has a substantially different amplitude characteristic; means for deriving from said last-named resultant wave a wave having an amplitude characteristic which is a function of the difference between

the amplitude characteristics of both said resultant waves; and means, receptive of said difference-characteristics wave, for so tuning the source of said carrier wave as to compensate for said frequency drift.

13. Apparatus for stabilizing the frequency of a carrier wave comprising: a wave-guide system including two branches for dividing said carrier wave into two portions; said branches differing in electrical length by $n\lambda/4$, where n is an odd integer and λ is the wave-guide wavelength corresponding to the frequency desired of said carrier wave; means in one of said branches for deriving from the carrier-wave portion traveling therethrough carrier-suppressed, sideband waves; means in the other of said branches for shifting the phase of the carrier-wave portion traveling therethrough as a function of any drift in the frequency thereof; means for combining said sideband waves and said phase-shifted carrier-wave portion whereby, in the event no frequency drift has occurred, the resultant wave is of constant amplitude, and in the event a frequency drift has occurred, the resultant wave is substantially amplitude modulated; means for deriving from said last-named resultant wave a wave whose sense and magnitude are functions, respectively, of the sense and magnitude of any such frequency drift; and means, receptive of said last-named wave, for so tuning the source of said carrier wave as to compensate for any such frequency drift.

14. An apparatus for stabilizing the frequency of a carrier wave comprising: a wave-guide system including two branches for dividing said carrier wave into two portions; said branches differing in electrical length by $n\lambda/4$, where n is

an odd integer and λ is the wave-guide wavelength corresponding to the frequency desired of said carrier wave; a balanced modulator in one of said branches for deriving from the carrier-wave portion traveling therethrough carrier-suppressed, sideband wave; a cavity resonator, having a resonant frequency corresponding to the frequency desired of said carrier wave, in the other of said branches for shifting the phase of the carrier-wave portion traveling therethrough as a function of any drift in the frequency thereof; means for combining said sideband waves and said phase-shifted carrier-wave portion whereby, in the event no frequency drift has occurred, the resultant wave is of constant amplitude, and in the event a frequency drift has occurred, the resultant wave is substantially amplitude modulated; means for deriving from said last-named resultant wave a wave whose sense and magnitude are functions, respectively, of the sense and magnitude of any such frequency drift; and means, receptive of said last-named wave, for so tuning the source of said carrier wave as to compensate for any such frequency drift.

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