July 5, 1949. W. E. BRADLEY ET AL 2,475,074

FREQUENCY STABILIZING SYSTEM

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Fig. 1.

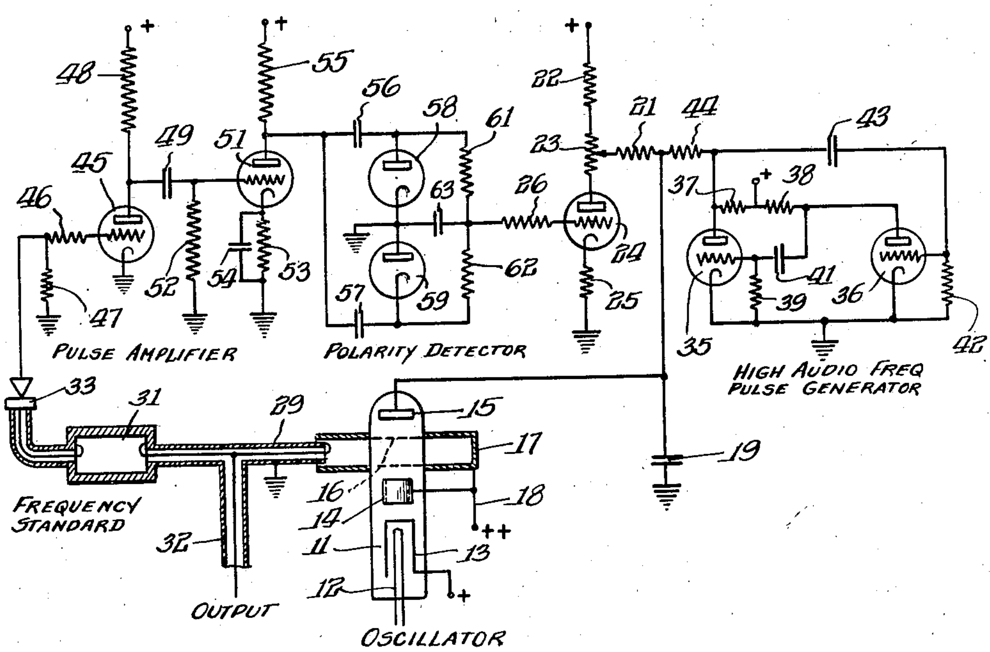
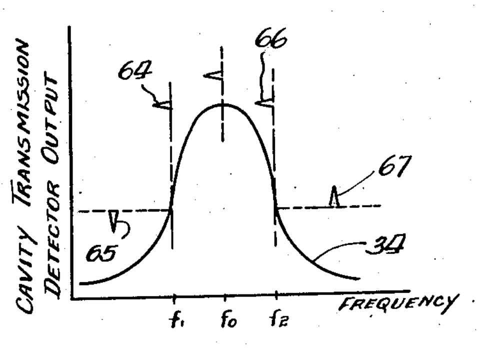


Fig. 2.



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FREQUENCY STABILIZING SYSTEM

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2 Claims. (Cl. 250—36)

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The present invention relates to automatic frequency stabilizers and more particularly to a frequency stabilization arrangement for a velocity modulated electron beam ultra high frequency oscillator.

In radar beacon systems the receivers are arranged to receive continuous waves, and accordingly a local oscillator is provided for the receiver. In order to provide proper reception it is necessary to maintain substantially constant the frequency of oscillations produced by the local oscillator. A velocity modulated electron beam ultra high frequency vacuum tube suitable for such operation has the characteristic that the frequency of oscillations depends primarily upon the dimensions of the resonant cavity used as the oscillator tank circuit and the potential supplied to the repeller. Accordingly it is proposed to provide some arrangement whereby the potential supplied may be varied or adjusted automatically to bring the frequency of oscillation back to the desired value. Such an arrangement of course would compensate for any variation in the potential supplied and also any variations in the frequency of oscillation caused by a change in the constants of the resonant cavity used as the oscillator tank circuit.

In accordance with the present invention the frequency of oscillation supplied by the oscillator is compared periodically with a frequency standard, and as a result of such comparison the potential supplied to the repeller of the oscillator tube is modified accordingly. Periodically the frequency of the oscillator is reduced for a short interval in order to provide the comparison with a frequency standard, which may be in the form of a resonant cavity tuned to the desired oscillator frequency, and which is coupled to the tank circuit of the oscillator tube. Since the power transmitted by the frequency standard resonant cavity varies in accordance with the frequency of the energy supplied to the cavity, the frequency modulation of the oscillator produces an amplitude modulation of this transmitted energy, the wave form of which is detected, amplified, and then is supplied to a balanced polarity detector circuit which determines whether the amplitude modulation indicates an increase or decrease in the power transmitted by the frequency standard resonant cavity. The balanced polarity detector is arranged to control means for varying, in appropriate magnitude and direction, the potential supplied to the repeller of the ultra high frequency oscillator so that its frequency is adjusted in the proper direction.

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It, therefore, is an object of the present invention to provide an improved method of and apparatus for maintaining relatively stable the frequency of an ultra high frequency oscillator utilizing a velocity modulated electron beam tube.

It is a further object of the present invention to provide a frequency stabilization circuit which automatically at periodic intervals operates to compare the frequency of the oscillations generated with a frequency standard.

It is another object of the present invention to provide an arrangement for periodically frequency modulating the ultra high frequency oscillator energy and for comparing the modulated frequency with the unmodulated oscillations in order that the mean frequency of the oscillation can be adjusted periodically.

Other and further objects of the present invention subsequently will become apparent by reference to the following description taken in connection with the accompanying drawing wherein

Figure 1 shows a circuit arrangement embodying the present invention; and

Figure 2 is a graphical representation explanatory of the operation of the circuit shown in Figure 1.

In accordance with the present invention there is provided a local oscillator for a receiver of the type heretofore mentioned. This local oscillator utilizes a velocity modulation electron beam tube having a resonant cavity which is coupled to an output transmission means and which also supplies energy to a frequency standard. One manner in which such an arrangement may be constructed is shown in Figure 1.

In Figure 1 there is shown a velocity modulated electron beam vacuum tube **11** of the type having a heater **12**, a heated cathode **13**, a control electrode **14**, a repeller **15**, and grids **16** which are to be connected to a resonant cavity **17**. The resonant cavity **17** and the control electrode **14** are supplied with potential from a conductor **18** which is connected to the positive terminal of a source of direct current potential. The cathode **13** is connected to a direct current potential of lower value than that supplied by the conductor **18**. The repeller **15** is at a lesser positive potential obtained through a series resistor **21** from a voltage divider circuit extending between ground and the positive terminal of a direct current source. The voltage divider circuit includes resistors **22**, **23**, vacuum tube **24**, and a cathode resistor **25**. The resistor **23** has an adjustable contact connected to the resistor 21. A small by-pass capacitor 19 is connected between ground and the repeller 15, the purpose of which subsequently will become apparent.

A portion of the energy generated within the tank circuit 17 of the vacuum tube 11 is coupled by suitable means such as a coaxial line 29 to a resonant cavity 31 which is adjusted or tuned to the frequency at which it is desired to have the oscillator operate. The coaxial line 29 may be provided with a branch 32 so that ultra high frequency energy may be supplied by the tank circuit resonant cavity 17 to the receiver with which the oscillator is associated. The resonant cavity is coupled to a microwave detector 33, which may be a crystal detector. When the oscillations generated by the vacuum tube 11 and the tank circuit 17 are of a frequency corresponding to the desired frequency to which the resonant cavity 31 is adjusted, the resonant cavity 31 will transmit the maximum amount of energy to its output detector 33. This is illustrated in Figure 2 by the curve 34 which shows that at the frequency F_0 which represents the desired frequency of operation, the maximum energy is transmitted through the resonant cavity 31. Whenever the oscillator frequency deviates from F_0, as for example F_1, which is less than the desired frequency, the resonant cavity transmits a smaller amount of energy. Similarly when the frequency is higher than the desired frequency F_0, as for example F_2, the power transmitted through the resonant cavity 31 is also less than maximum.

In order to determine as to whether the power transmitted by the frequency standard to the microwave detector has changed, the frequency of the oscillator is periodically shifted a small amount by a variation of the potential appearing at the repeller 15. In the embodiment shown in the drawing this variation of the repeller electrode potential is produced by a high audio frequency pulse generator. Generally the oscillator will be operating at its normal frequency, which is the frequency of the frequency standard resonant cavity 31. Each time that a pulse is supplied by the high audio frequency pulse generator to modify the potential at the repeller electrode of the velocity modulation electron vacuum tube the frequency of the oscillator will be shifted momentarily to a lower frequency. This shift in frequency may, for example, comprise deviation existing for approximately ten per cent of the time while for the remaining ninety per cent of the time the oscillator is operating at its normal frequency.

Since the potential change at the repeller electrode 15 of the vacuum tube 11 is in the form of a pulse, the resultant deviation in frequency will change the power transmitted by the frequency standard 31 to the microwave detector 33 which causes the output of the microwave detector 33 to produce a pulse, the polarity of which depends upon the mean frequency of the oscillator with respect to the frequency of the cavity 31. This is illustrated in Figure 2 from which it will be seen that if the frequency of oscillation prior to the action of the pulse generator is at a frequency F_1 the pulse will cause a momentary frequency deviation which will produce a momentary drop of the detector output. On the other hand if the average frequency of the oscillator is F_2 the action of the pulse produces a momentary rise of detector output.

In order to periodically shift the frequency of the ultra high frequency oscillator 11, a high audio frequency pulse generator, which may be of the asymmetrical multivibrator type, is provided utilizing a pair of vacuum tubes 35 and 36. The anodes of the vacuum tubes 35 and 36 are supplied from a suitable source of potential through series or coupling resistors 37 and 38 respectively. The grid of the vacuum tube 35, which is provided with a grid-to-cathode resistor 39, is coupled by a capacitor 41 to the anode of vacuum tube 36. The grid of vacuum tube 36 which is provided with a grid-to-cathode resistor 42 is coupled by a capacitor 43 to the anode of the vacuum tube 35. The anode of the vacuum tube 35 is connected to a series resistor 44 which is connected to the juncture of the resistor 21 and the repeller 15 of the vacuum tube 11.

Since the high audio frequency pulse generator which includes the vacuum tubes 35 and 36 has its output connected to a point on the voltage divider which supplies potential to the repeller-electrode 15 of the vacuum tube 11, each periodic pulse supplied by the generator operates to produce a momentary shift in the frequency generated by the vacuum tube 11 and the tank circuit 17. The capacitor 19 controls the magnitude of the potential change at the repeller 15 due to the pulse supplied by the pulse generator.

These pulses produced at the output of the microwave detector 33 in response to the pulse action on the oscillator may be negative or positive pulses dependent upon the mean frequency, and these pulses are supplied to a pulse amplifier. After the pulses have been amplified they are supplied to a polarity detector subsequently to be described. The microwave detector 33 is connected to the grid circuit of a vacuum tube 45 which may include a series resistor 46 and a grounded grid resistor 47. The cathode of the vacuum tube 45 is connected to ground and the anode is connected through a suitable coupling resistor 48 to a source of anode potential. The output of the vacuum tube 45 is coupled by a capacitor 49 to the grid of another vacuum tube 51. The vacuum tubes 45 and 51 together with their associated circuits comprise a two stage pulse amplifier, the output of which is fed to a balanced polarity detector circuit. The vacuum tube 51 has a grounded grid resistor 52, and a grounded cathode resistor 53 which is by-passed by a capacitor 54. The anode of the vacuum tube 51 is connected through a coupling resistor 55 to the source of anode potential. The anode of the vacuum tube 51 is coupled to the balanced polarity detector circuit by similar capacitors 56 and 57.

The polarity detector, which preferably is in the form of a balanced polarity detector comprises a pair of diode detectors 58 and 59 arranged so that the cathode of one diode detector 58 and the anode of the other diode detector 59 are connected to ground. The remaining electrodes of the diode detectors 58 and 59 are connected to the coupling capacitors 56 and 57. A pair of resistors 61 and 62 interconnect these electrodes, and the common juncture therebetween is connected to the grid of the vacuum tube 24 through grid damping resistor 26, and is by-passed to ground by capacitor 63. The balanced polarity detector circuit is arranged to control the potential supplied to the grid of the vacuum tube 24 thereby to vary the impedance of the vacuum tube 24 in accordance with variations in power transmitted by the resonant cavity 31 as detected periodically.

The balanced polarity detector has a property so that when a frequency deviation such as the pulse 66 produces a positive pulse 67 at the output of the detector 33, a negative direct current bias substantially equal to the amplified peak voltage of the pulse appears at the plate of the diode 58, while only negligible direct current is developed across the diode 59. The two resistors 61 and 62 comprise a voltage divider so that the common juncture therebetween has a potential below ground equal to about half of the potential appearing at the anode of the diode 58.

If the frequency deviation produced by a pulse corresponds to the pulse 64 shown in Figure 2, the microwave detector 33 supplies a negative pulse such as 65 to the pulse amplifier. The pulse thus amplified appearing at the anode of the vacuum tube 51 develops no potential across the diode 58 but develops a potential across the diode 59. The potential appearing at the cathode of diode 59 is a positive direct current potential which is substantially equal to the amplified peak pulse voltage; and one-half of the direct current voltage appears at the juncture of the resistors 61 and 62. The voltages thus appearing at the juncture of the resistors 61 and 62 are supplied to the control grid of the vacuum tube 24 which is connected in the voltage divider circuit supplying voltage to the repeller electrode 15 of the vacuum tube 11. The balanced polarity detector therefore develops a positive direct current potential in response to negative pulses received from the anode of the vacuum tube 51, and negative direct current potential in response to positive pulses received at the anode of the vacuum tube 51 thereby to modify the action of the control tube 24 whenever the oscillator is too high or too low in frequency.

From the above explanation of the function and operation of the balanced polarity detector, it will become apparent to those skilled in the art that such an arrangement may find other application in other types of circuits. Such circuit arrangements might include a polarity detector of this type in various measuring apparatus and in control systems.

When the oscillator comprising the vacuum tube 11 and the tank circuit 17 is operating at a frequency corresponding to the desired frequency F_0 as determined by the resonant cavity 31, the slight deviation of the frequency due to the action of the pulse supplied by the asymmetrical multivibrator circuit produces no significant change in oscillator output as detected by the microwave detector 33 as is shown in Figure 2. If it is assumed that the frequency of the oscillator is less than the desired frequency, as for example at F_1, the frequency shift produced by the pulse is as has been indicated at 64 in Figure 2. Thus for a short interval the frequency of oscillation has been reduced so that the power transmitted by the frequency standard resonant cavity 31 is less than heretofore with the result that the microwave detector 33 supplies to the pulse amplifier vacuum tubes 45 and 51 what corresponds to an amplitude modulation indicated by the negative pulse 65 in Figure 2. The frequency modulation produced by the pulse supplied by the asymmetrical multivibrator shifts the frequency of oscillation by an amount not exceeding one megacycle. This variation which corresponds to an amplitude modulation in a negative sense is amplified and supplied to the balanced polarity detector diode rectifiers 58 and 59 to produce a more positive voltage as applied to the grid of the vacuum tube 24 so as to make more negative the potential supplied to the repeller 15 of the vacuum tube 11, which in turn increases the mean oscillator frequency.

It may now be assumed that at a subsequent period a pulse supplied by the asymmetrical multivibrator produces a frequency modulation when the oscillator is at a higher frequency F_2 as indicated at 66 in Figure 2. Since this frequency change 66 shifts the frequency of oscillation supplied to the resonant cavity 31 in the direction toward F_0 there is an increase in the power supplied to the microwave detector 33 which corresponds to a positive amplitude modulation indicated at 67 in Figure 2. The wave form at this positive amplitude modulation is amplified by the pulse amplifier vacuum tubes 45 and 51 and is supplied to the balanced polarity detector to decrease the potential applied to the grid of the vacuum tube 24 which has the effect of increasing the potential supplied to the repeller 15 of the vacuum tube 11. This increase of the potential of the repeller 15 causes the oscillator frequency to be reduced to the frequency F_0. The vacuum tube 24 therefore operates as a variable resistor in the voltage divider circuit which includes the resistors 22, 23 and 25.

Whereas the embodiment of the present invention heretofore shown and described has indicated a periodic pulse generator as the means for producing periodic frequency changes or frequency modulation of the oscillator energy, it will be appreciated other wave forms may be utilized. The frequency standard resonant cavity coupled to the tank circuit of the resonant cavity of the ultra high frequency oscillator in each case will indicate a change in the power transmitted by the frequency standard cavity.

If the periodic change in oscillator frequency, for comparison purposes, is brought about by a sinusoidal wave, certain modifications as are apparent to those skilled in the art may be made in the circuit between the microwave detector and the voltage divider which supplies potential to the repeller of the vacuum tube oscillator. With a sinusoidal variation of the oscillator frequency, the microwave detector will produce a sinusoidal wave which may be compared with a sinusoidal wave supplied to modify the frequency of the oscillator by any one of a number of devices as, for example, a phase detector. As a result of this comparison a bias may be generated to modify the action of the vacuum tube in the voltage divider in a manner similar to that heretofore described.

In order to further facilitate an understanding of the embodiment herein disclosed, reference will be made to certain specific elements utilized in a device of this sort. The vacuum tube 11 may be of the velocity modulated electron beam type which is exemplified by such vacuum tubes as designated by the numbers 707,726 and 2K28. With such vacuum tubes a potential difference of approximately three hundred volts is applied between the cathode 13 and the cavity 17. The repeller is operated at a potential between fifty and two hundred volts negative with respect to the cathode. In one embodiment the pulse amplifying tubes 45 and 51 are combined in a 6SL7GT vacuum tube and the diode rectifiers 58 and 59 are combined in a 6H6 diode detector. A 6SN7GT or 6J5G is used as a control tube 24. The asymmetrical vibrator pulse generator circuit utilized a 6SL7GT. In that circuit the resistor 39 for example had a value of one megohm, the resistor 42 had a value of twenty-two thousand ohms. Capacitor 41 had a value of .00015 microfarad and 43 had a value of .000015 microfarad and the resistors 37 and 38 each had a value of fifteen thousand ohms and the anode supply potential was in the vicinity of two hundred volts. The resistors in the voltage divider circuit 22, 23, and 25 had values of ten thousand, twenty thousand, and six hundred eighty ohms respectively. The resistors 21 and 44 were twenty-five thousand, and four hundred seventy thousand ohms respectively. The by-pass capacitor 19 had a value of .00015 microfarad. A potential is developed by the diode rectifier appearing between the junction of resistors 61 and 62, each having a value of one hundred thousand ohms, and ground. The series resistor connected between the resistors 61 and 62, and the grid of the vacuum tube 24 had a value of two hundred twenty ohms and the by-pass capacitor 63 had a value of .1 microfarad. The values of other components shown in Figure 1 were such as are customarily selected by usual engineering practice and will not be enumerated for the sake of brevity.

While for the purpose of illustrating and describing the present invention, it has been mentioned that the oscillator shown is suitable for use in a local oscillator in a radar beacon system, it of course will be appreciated that other applications of this oscillator might be made and that the invention is not to be limited to the particular use mentioned nor to the specific circuit arrangements or values given as examples with a view of facilitating the understanding of the invention. The invention is set forth with particularity in the appended claims and accordingly is to be understood that such variations and modification in the circuit arrangements and in the instrumentalities employed may be made without departing from the spirit and scope of the invention defined in the claims.

This invention is hereby claimed as follows:

1. In a system for stabilizing the frequency of an ultra high frequency oscillator, a cavity resonator coupled to the output of said oscillator, said cavity resonator being continuously resonant at the desired operating frequency of said oscillator, means for periodically and impulsively shifting the frequency of said oscillator slightly in one direction, means for detecting any resultant change in the output of said cavity resonator, and for detecting the direction or sense of such change, and means for adjusting the operating frequency of said oscillator in accordance with the detected change and its sense.

2. In a system for stabilizing the frequency of an ultra high frequency oscillator, a cavity resonator coupled to the output of said oscillator, said cavity resonator being continuously resonant at the desired operating frequency of said oscillator, means for periodically shifting the frequency of said oscillator during short intervals which constitute a small percentage of the total operating time, means for detecting any resultant change in the output of said cavity resonator, and for detecting the direction or sense of such change, and means for adjusting the operating frequency of said oscillator in accordance with the detected change and its sense.

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