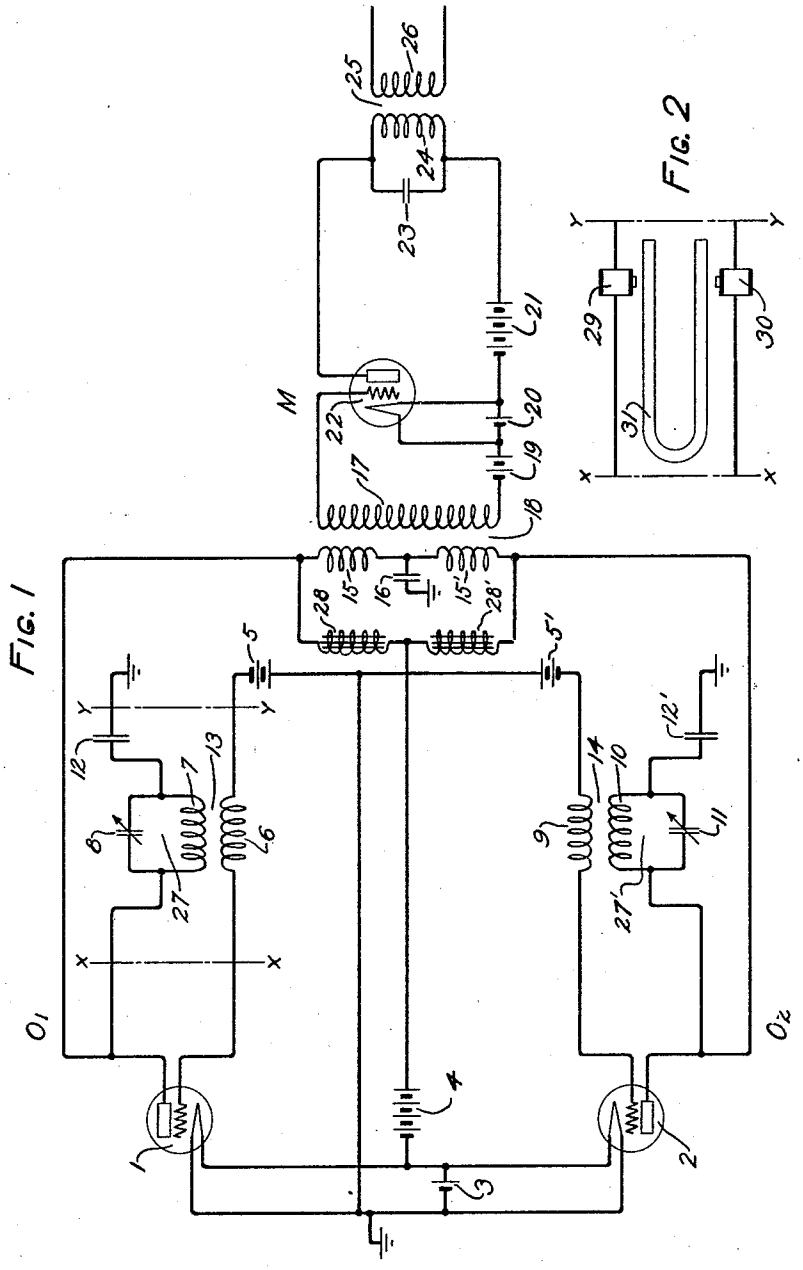
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OSCILLATION SYSTEM

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OSCILLATION SYSTEM

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This invention relates to oscillation systems and particularly to those systems possessing means for producing waves, the frequency of which is constant in respect to temperature variations affecting the elements of the system.

It is desirable for many purposes, and especially for radio transmission purposes, to maintain the frequency of oscillations generated substantially constant. One of the principal causes for such frequency variations arises from the fact that the electrical values of the elements in the frequency-determining circuit vary with temperature.

It is an object of this invention to produce oscillations of a constant frequency in respect to temperature variations affecting the system.

It is another object of this invention to produce constant frequency oscillations in respect to temperature variations without the use of vibrating or moving frequency-determining elements.

It is still another object of this invention to provide a simple and inexpensive means of obtaining the desired constant frequency oscillations.

According to the present invention these objects, as well as other related and incidental objects, are accomplished by combining waves from component frequency oscillators whose frequency variations caused by temperature changes are equal in degree. A constant sum or difference frequency is obtained, depending on whether the oscillator temperature coefficients have opposite or like signs.

More specifically, these objects are accomplished; first, by employing an inductance having a negligible coefficient in one of two oscillators so that the temperature-frequency changes result principally from the changes in capacity caused by temperature variations; then, by choosing for this oscillator a frequency-determining capacity whose temperature coefficient bears the proper mathematical relation to that temperature coefficient which the oscillator must have in order that the frequency variations of the oscillators will be equal to each other in degree; and, finally, by combining the waves from the oscillators and properly selecting either the sum or difference frequency. The frequency-determining capacity so chosen may be provided by one or several condensers and may, in general, have any value provided that, for a given frequency, the product of the inductance and capacity, and the condenser temperature coefficient have the desired values.

The nature of this invention will be more fully understood by reference to the drawings, in which:

Fig. 1 is a circuit diagram of two electric space discharge oscillators and a space discharge modulator embodying in combination one form of the invention; and

Fig. 2 is a representation of a feed-back arrangement that may be substituted for the circuits comprised between the lines X—X and Y—Y of Fig. 1.

Space discharge tubes 1 and 2 with their individual input and output circuits constitute functionally independent oscillators O_1 and O_2. Energy is fed back from the output circuit to the input circuit of tube 1 by means of the inductive coupling between windings 6 and 7 of transformer 13. The primary 7 of transformer 13 and condenser 8 comprise oscillation circuit 27 which serves to determine the frequency of the oscillations generated by this oscillator. Similarly, energy is returned from the output to the input circuit of space discharge tube 2 by means of the inductive coupling between the windings 9 and 10 of transformer 14, and the electrically oscillating circuit 27′ comprising inductance 10 and condenser 11 determines the frequency of the oscillations generated by this device.

A source of E. M. F. 3 supplies cathode heating current to space discharge devices 1 and 2. Space current is supplied to tubes 1 and 2 from a common direct current source of energy 4, which has its positive terminal connected to the anodes of tubes 1 and 2 through the retardation coils 28 and 28′, respectively, and its negative terminal connected to the cathodes of both tubes. The control electrodes of both tubes 1 and 2 are

negatively polarized by means of a common steady E. M. F. from sources 5 and 5′, respectively, included in the input circuits. The secondary transformer windings 6 and 9 of transformers 13 and 14 are also included in the input circuits of tubes 1 and 2, respectively. Condensers 12 and 12′ are merely blocking condensers of large capacity which serve in part to complete the alternating current circuits from the frequency determining circuits 27 and 27′ to the respective filaments and at the same time to segregate the source 4 to the individual circuits in which they are intended to function.

A portion of the output current of each of tubes 1 and 2 is translated by means of the primary windings 15 and 15′, respectively, and secondary winding 17 of transformer 18, to the input circuit of a third tube 22 which with its immediately associated circuits constitutes a modulator or combining device M. A low impedance path for these output currents to ground and the filaments of the respective tubes is provided by condenser 16 which also constitutes a high impedance path for direct current flow from source 4. Heating current for the cathode of tube 22 is supplied from a source of E. M. F. 20. The space current path includes a direct current source 21 having its negative terminal connected to the cathode and its positive terminal to the anode through a frequency-selecting circuit comprising condenser 23 and the primary winding 24 of transformer 25. The secondary winding 26 of transformer 25 may be connected to an amplifier or a work circuit. A source of steady E. M. F. 19 serves to supply a negative bias through secondary winding 17 to the control electrode of this tube.

The operation of the system shown in Fig. 1 as described so far is similar to that of several well known oscillator-modulator circuits. Variations in the space current of tube 1 produce in the oscillation circuit 27 oscillations whose frequency is determined by the values of capacity 8 and inductance 7. These oscillations are impressed on the input circuit of tube 1 and amplified in the space current circuit, with the result that waves of a particular frequency are supplied to the primary coil 15 of transformer 18. Similarly, oscillations of the same or another frequency are generated by space discharge tube 2 and its associated circuits and supplied to the other primary coil 15′ of transformer 18. Oscillations of both frequencies are induced in secondary coil 17 and impressed on the input circuit of the modulator tube 22, whose output contains the sum and difference frequency components of the impressed oscillations. The sum or difference output component as determined by the choice of values of capacity 23 and inductance 24 is then selected and by means of transformer 25 transmitted to the work circuit.

Fig. 2 represents a mechanically oscillating frequency-determining device and feed-back arrangement which may be employed in place of the electrically oscillating circuit 27, condenser 12, and the secondary winding 6 of transformer 13. Assuming tuning fork 31 is initially set in vibration space current through driving electromagnet 29 will maintain the vibrations of the tuning fork at its natural frequency. Potentials of this frequency are induced in pick-up electromagnet 30 and impressed on the input circuit of tube 1 to perpetuate the current in the electromagnet 29.

In accordance with this invention coil 10 is of such a type that its temperature coefficient is small enough to be disregarded, as for example, an air core coil. The capacity represented by condenser 11 is obtained by the use of one or several condensers, preferably of a type such as the so-called dry stack mica condensers described in my copending application, Serial No. 134,777, filed September 11, 1926. This type of condenser has a comparatively small temperature coefficient. The exact temperature coefficient of the condensers used to obtain the capacity 11 is determined, however, in accordance with the method to be discussed shortly.

The method of applying the invention will be readily understood from the following. The percentage temperature coefficient of space discharge tube 1 and its associated electrically or mechanically oscillating circuit at a given frequency can readily be calculated or determined from actual tests. Preferably, this oscillator, which has been referred to as oscillator O_1, should be designed to have a known minimum temperature coefficient as in accordance with the invention disclosed in my prior application, Serial No. 134,777, filed September 11, 1926. The temperature-frequency changes in the waves produced by this oscillator may be shown mathematically as follows:

Let α_1 = the known temperature coefficient of O_1

and f_1 = the normal frequency generated by O_1

and t = temperature difference between the normal and the actual operating temperatures affecting both O_1 and the other oscillator O_2.

Then $f_1 + \alpha_1 f_1 t$ = the actual frequency supplied by O_1 at any instant

and $\alpha_1 f_1 t$ = the absolute change in frequency.

In order to obtain constant sum or difference components in the output of modulator tube 22 the above frequency change $\alpha_1 f_1 t$ must equal in magnitude the temperature-frequency change produced in the other oscil-

lator O_2. The value of the temperature coefficient necessary for O_2 in order to produce the desired constancy of modulator output frequency is readily determined as follows:

Let f_2=the normal frequency generated by O_2
and α_2=the temperature coefficient of O_2, of unknown value
Then $(f_1+\alpha_1 f_1 t)-(f_2+\alpha_2 f_2 t)=f_1-f_2=$ a constant, when α_1 and α_2 have like signs
or
$(f_1+\alpha_1 f_1 t)+(f_2+\alpha_2 f_2 t)=f_1+f_2=$ a constant, when α_1 and α_2 have opposite signs.

And in either case

$$\alpha_1 f_1 t=\alpha_2 f_2 t$$

$$\alpha_2=\frac{\alpha_1 f_1}{f_2} \quad (1)$$

The frequency-determining elements of oscillator O_2 are therefore chosen so that its temperature coefficient α_2 will satisfy Equation (1). Since inductance 10 has a negligible temperature coefficient condenser 11 is substantially the only element whose change in value affects the frequency generated by O_2. The temperature coefficient, which we shall call α_3 and which this condenser should have in order that the oscillator may have a temperature coefficient of α_2, can be determined mathematically as follows:

The frequency f_2 generated by oscillator O_2 may be written:

$$f_2=\frac{1}{2\pi\sqrt{LC}} \quad (2)$$

where L and C are the inductance and capacity of the frequency-determining circuit.

Since the frequency varies inversely as the capacity the frequency at any instant resulting from a given change in temperature "t" from normal may be written:

$$f_2+\alpha_2 f_2 t=\frac{1}{2\pi\sqrt{L(C-C\alpha_3 t)}} \quad (3)$$

Dividing Equation (3) by Equation (2) and squaring we have:

$$1+2\alpha_2 t+(\alpha_2 t)^2=\frac{C}{C-C\alpha_3 t} \quad (4)$$

The term $(\alpha_2 t)^2$ is so small that it may be disregarded and we therefore have:

$$1+2\alpha_2 t=\frac{C}{C-C\alpha_3 t} \quad (5)$$

but

$$\frac{C}{C-C\alpha_3 t}=\frac{C-C\alpha_3 t+C\alpha_3 t}{C-C\alpha_3 t}=1+\frac{C\alpha_3 t}{C-C\alpha_3 t} \quad (6)$$

And, since $C\alpha_3 t$ is exceedingly small compared to C it may be disregarded and we have:

$$\frac{C}{C-C\alpha_3 t}=1+\alpha_3 t \quad (7)$$

from (5) and (7)

$$1+2\alpha_2 t=1+\alpha_3 t$$
$$2\alpha_2=\alpha_3 \quad (8)$$

Condensers having a temperature coefficient equal to twice the value of the temperature coefficient of the associated oscillator O_2 are therefore employed in the frequency-determining circuit of O_2. In this connection it should be observed that the value of capacity 11 or the number of individual condensers comprising capacity 11 are not controlled by the temperature coefficient α_3. These factors are determined from other practical considerations.

Substituting the value of α_3 shown in (8) in (1) we have:

$$\alpha_3=2\alpha_1\frac{f_1}{f_2} \quad (9)$$

This last equation gives us a quick and simple method of determining the condenser temperature coefficient of one oscillator in terms of the known temperature coefficient of another oscillator and the frequencies normally generated by the two oscillators.

Because of the approximate mathematics the frequency components are substantially, and not absolutely, constant. In carrying out the invention the best results will be obtained by keeping the frequency changes as small as practicable. This is accomplished by designing the high frequency oscillator corresponding to oscillator O_1 so as to have a minimum temperature coefficient.

It should, of course, be understood that the invention is not to be limited to the frequency producing means illustrated in the specific embodiment described above. The invention is equally applicable to other specific wave producing systems wherein the frequencies supplied to a combining means are affected by temperature changes as, for example, in a double modulation wave producing system.

Also, in order to reduce any error that might arise from the fact that the frequency-determining elements are not subjected to exactly the same temperature change the elements of both oscillators are preferably located relatively close together in the same room or oven.

What is claimed is:

1. In an oscillation system, a plurality of wave generating means, means for combining the waves from said generating means to produce a resultant wave, one of the said generating means including an electrical oscillating element adapted to equalize the temperature-frequency changes in the waves produced by said last mentioned means and another of the said generating means where-

by the resultant wave is substantially free from temperature-frequency effects.

2. In an oscillation system, a plurality of wave generating means, means jointly dependent on said first mentioned means for producing other waves, one of said generating means comprising a frequency-controlling non-vibratory element adapted to compensate for temperature-frequency changes in the waves produced by another of said generating means, whereby at least one of the resultant waves is substantially free from temperature-frequency changes.

3. In combination, an oscillating system comprising an oscillator having a frequency F_1 and a temperature coefficient of frequency T_1, and a second oscillator having a frequency F_2 controlled by an element having a temperature coefficient of frequency T_3 where

$$T_3=\frac{2T_1F_1}{F_2}.$$

4. In combination, means having a temperature coefficient of frequency T_1 for producing waves of a frequency F_1, a second means having a temperature coefficient of frequency T_2 for producing waves of a frequency F_2, said second means controlled by a capacity having a temperature coefficient T_3, where

$$\frac{F_1}{F_2}=\frac{T_2}{T_1} \text{ and } T_2=\frac{T_3}{2},$$

and means for intermodulating said waves.

5. Means for producing constant frequency oscillations comprising a plurality of wave producing means, a frequency-determining element included in one of the said means having a temperature coefficient of frequency equal to twice that of the associated means, the frequency changes caused by temperature variations in the said associated means by choice of the corresponding coefficient of said frequency-determining element being equivalent to those produced in another of the said means, and means for combining the produced waves.

6. A constant frequency wave producing system comprising a wave producing means, a second wave producing means, a non-vibratory element adapted to control said second means and having a temperature coefficient suitable for rendering the frequency changes caused by temperature variations in the waves produced equal to each other, and means for combining the waves.

7. A system for obtaining waves of a constant frequency comprising an oscillator, a second oscillator including a frequency-determining capacity whose variation with temperature substantially determines the temperature frequency changes in the waves generated, the value of said capacity being such that its variations with temperature cause a corresponding frequency change which equals that of the other oscillator, and means to intermodulate said waves.

8. The method of obtaining sustained waves of a constant frequency utilizing a modulator and component oscillators one of which has a known temperature coefficient and another of which has a non-vibratory frequency determining element which comprises designing said element so that the ratio of its temperature coefficient of frequency to the said known temperature coefficient equals twice the reciprocal of the frequencies generated by the oscillators, producing waves in said oscillators, and modulating the produced waves.

9. The method of producing waves of a constant frequency in respect to temperature variations utilizing a modulator and component oscillators the frequency of at least one of which is partly controlled by an element which comprises choosing an element having a temperature coefficient of frequency such that the frequency variations in the wave produced by the associated oscillator equals the temperature frequency variations of another of the oscillators, generating waves in said oscillators, combining the waves in said modulator, and selecting a constant frequency component in the modulator output.

10. Means for producing oscillations of a constant frequency comprising a plurality of cooperating oscillators from each of which oscillations of varying frequency are derived, means for substantially equalizing the frequency-temperature variations in the oscillations derived from said oscillators, and means for combining said oscillations.

11. In combination, means for producing distinct sets of oscillations each having frequency-temperature variations, and means for substantially equalizing the frequency-temperature variations in said sets of oscillations.

In witness whereof, I hereunto subscribe my name this 18th day of December, 1928.

ROY E. CORAM.