Sept. 22, 1936. L. COHEN 2,055,375

ART OF RADIO SIGNALING

Filed Dec. 13, 1932

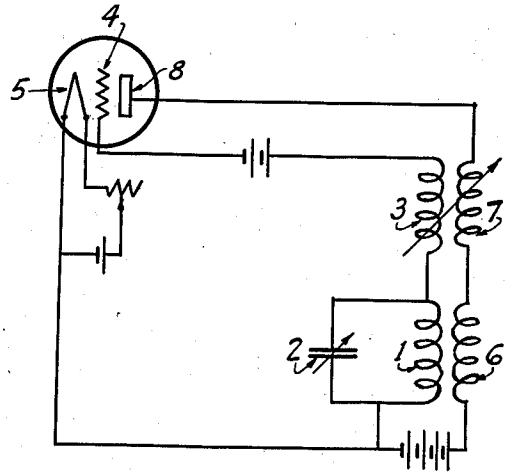


Fig. 1

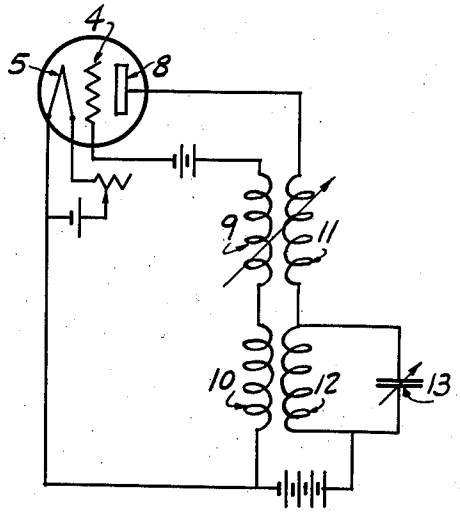


Fig. 2

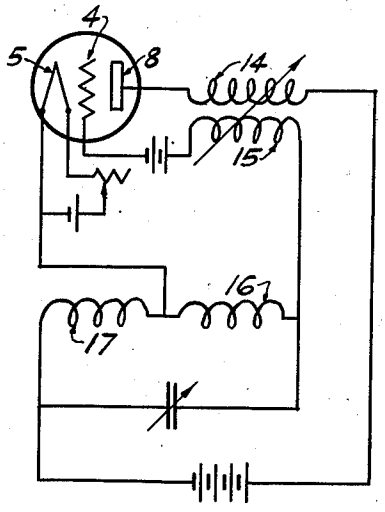


Fig. 3

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Patented Sept. 22, 1936 2,055,375

UNITED STATES PATENT OFFICE

2,055,375

ART OF RADIO SIGNALING

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Application December 13, 1932, Serial No. 647,053

13 Claims. (Cl. 250—36)

This invention relates to the art of radio signaling. It has for its particular object providing methods and means for securing constancy of frequency in the oscillations produced by vacuum tube oscillation generators.

It is well known in the art that the frequency of the oscillations produced by vacuum tube generators depends in some degree on the internal resistance (plate-filament) of the tube, and the resistance of the oscillation circuit. A variation in either of these factors causes a variation in the frequency of the oscillations. The internal resistance of the tube depends on the plate voltage, and therefore any variation in the voltage supply causes a change in the frequency of the oscillations. Also a variation in the load, that is the resistance of the oscillation circuit, causes a variation in the frequency. In the use of vacuum tube oscillators in transmitting stations, it is necessary for efficient operation, particularly from the standpoint of minimizing interference, to maintain constancy of frequency. The Federal Radio Commission has made stringent regulations in regard to the permissible deviation from the assigned frequency to a station.

In the present day practice constancy of frequency of vacuum tube generators is secured through the use of quartz crystal control, which is an effective method, but requires additional equipment adding to the cost of installation, and to difficulties in maintenance. It would be of advantage if the constancy of frequency could be maintained without the aid of crystals, and it is to the realization of this objective that this invention is directed. A circuit system is provided in this invention whereby the tendency to frequency variation resulting from changes in the internal resistance of the tube or variations in the load is automatically counteracted by a suitable additional coupling between grid and plate circuits, and the frequency of the oscillations is accordingly maintained constant. The method provided by this invention is more fully explained in connection with the accompanying drawing which forms part of this specification.

Figure I shows a circuit system in which the grid circuit is tuned; Figure II is a modification providing for the tuning of the plate circuit; and Figure III shows a modified Hartley circuit.

In the circuit arrangement shown in Figure I, a tuned circuit consisting of inductance coil 1 and variable condenser 2 in parallel together with an additional inductance coil 3 in series with the tuned circuit 1, 2, are connected in the grid filament circuit 4, 5. The coils 1 and 3 are in inductive relation to coils 6 and 7 respectively, the inductance coils 6 and 7 forming part of the plate filament circuit 8, 7, 6, 5. By the adjustment of the mutual inductance between the coils 1 and 6 a proper degree of regeneration may be established to set up oscillations in the oscillatory circuit 1, 2; this is one of the usual methods for exciting oscillations in a vacuum tube circuit by feed-back. The additional transformer 3, 7 provides a means for maintaining the frequency of the oscillations constant, and may be designated as a "stabilization transformer". By suitable adjustment of the mutual inductance between coils 3 and 7 a condition is obtained whereby the frequency of the oscillations is maintained constant independent of any variation in the internal resistance (plate-filament) of the tube, or any variation in the load, the resistance of the oscillation circuit.

Without limiting myself to any theory of operation I believe the following may be the explanation of the operation of my invention. In vacuum tube oscillators, whatever the type of regeneration circuit, the principal frequency determining elements are the inductance and capacity of the oscillatory circuit and a factor which is a function of

$$\frac{R}{\rho}$$

where R is the resistance of the oscillatory circuit and ρ is the plate-filament resistance of the tube. The form of the function of

$$\frac{R}{\rho}$$

depends on the type of regenerative circuit used. The reason for the dependence of the frequency on

$$\frac{R}{\rho}$$

is that the circuit containing the plate resistance is either in shunt or in inductive relation to the inductance of the oscillatory circuit, and in either case the effective value of the inductance is modified thereby. To eliminate the influence of the tube resistance on the frequency, it is necessary to provide additional regenerative coupling to compensate for the oscillatory energy dissipation in the tube resistance, and this is accomplished by the circuit arrangements provided in this invention.

The required mutual inductance between coils 3 and 7 to realize the condition of constant frequency is given by the formula,

$$\mu M_2 = L_1$$

where μ is the amplification factor of the tube; M_2 is the mutual inductance between coils 3 and 7; and L_1 is the self inductance of the plate circuit, coils 6 and 7 in series. The above formula was derived from a mathematical analysis of the problem, and the circuits should be designed in accordance with it to realize the objective contemplated in this invention. It is not necessary, however, to rely exclusively on the mathematical formula, the necessary condition for frequency stabilization by the method shown in Figure I in the matter of degree of coupling may be determined experimentally. Keeping L_1 the inductance of the plate circuit fixed, it is only a matter of varying M_2, the mutual inductance between coils 3 and 7, until the condition of constant frequency, which is the condition given by the formula, is obtained.

Figure II is a modification in which the tuned circuit 12, 13 is connected in the plate circuit. The coupling of the plate tuned circuit to the grid by transformer 10, 12 provides the necessary feed-back to maintain oscillations in the oscillatory circuit. The additional coupling of plate and grid circuits through transformer 9, 11 provides means for frequency stabilization, that is the maintenance of constant frequency, counteracting any tendency to frequency variation resulting from changes in either the internal resistance of the tube or in the load. To realize the condition of frequency stabilization in Figure II, the following relations must obtain:

$$L_2 = \tfrac{1}{2} L_1,$$

and

$$L_1 = 2\mu M_1,$$

where L_2 is the self inductance of coil 12 of the oscillatory circuit; L_1 is the self inductance of coil 11; μ is the amplification factor of the tube, and M_1 is the mutual inductance between coils 9 and 11. The above formulas were derived from a mathematical analysis of the problem, and give the necessary relationship between the various elements of the circuit to obtain the condition of frequency stabilization. The desired condition may be also obtained experimentally without regard to the formulas.

In Figure III a modified Hartley circuit is shown, the novel feature consisting in the additional coupling between plate and grid provided by transformer 14, 15. The transformer 14, 15 provides a means for maintaining the frequency of the oscillations substantially constant. By suitably adjusting the mutual inductance between coils 14 and 15 in relation to the other elements of the circuit system a condition is obtained whereby the frequency of the oscillations is maintained substantially constant independent of any variation in the internal resistance (plate-filament) of the tube, or any variation in the load, or the resistance of the oscillation circuit. The value of the mutual inductance between 14 and 15 required depends on the values of the inductances 16 and 17, the mutual inductance between them, and also on the self inductance of transformer coil 14, but in practice it is merely a matter of adjusting the mutual inductance between the coils 14 and 15 to attain the desired result.

The three circuits shown in the figures illustrate different embodiments of my invention. By the practice of the invention disclosed the frequency of vacuum tube oscillators is rendered substantially invariant with respect to variations in tube resistance, load, or energizing voltage. The frequency is rendered substantially invariant with respect to variations in any one or more of these factors. The same principle may be employed in connection with any other type of vacuum tube oscillator to secure constancy of frequency. Many variations in the details of the apparatus and methods disclosed will be apparent to those skilled in the art, and many applications of the invention besides those described will be apparent. I do not intend therefore to be limited except as required by the prior art and as indicated in the accompanying claims.

I claim as my invention:

1. A vacuum tube oscillation generator having a frequency determining circuit in the grid circuit thereof, an inductance in the plate circuit thereof regeneratively coupled to said frequency determining circuit so as to set up oscillations, and a magnetic coupling between the plate and grid circuits of said oscillation generator of such magnitude that

$$\mu M_2 = L_1$$

where μ is the amplification factor of the tube, M_2 is the mutual inductance of said coupling, and L_1 is the self inductance of the plate circuit, no part of said magnetic coupling being included in the frequency determining circuit.

2. The combination with a vacuum tube oscillation generator having a frequency determining circuit in the plate circuit thereof and an inductance in the grid circuit thereof regeneratively coupled to said frequency determining circuit so as to set up oscillations, of frequency stabilizing means comprising an inductance in the plate circuit and an inductance in the grid circuit coupled thereto, said coupling and said inductance being of such magnitude that

$$L_1 = \tfrac{1}{2}\mu M_1$$

where μ is the amplification factor of the tube, M_1 is the mutual inductance of said coupling, and L_1 is the self inductance of said plate circuit inductance, the self inductance of the frequency determining circuit L_2 being of such magnitude that

$$L_2 = \tfrac{1}{2} L_1$$

where L_1 has the same meaning as above, no part of said frequency stabilizing means being included in the frequency determining circuit.

3. The combination of a Hartley oscillator and frequency stabilizing means common to the plate and grid circuits thereof, said stabilizing means comprising a magnetic coupling between the plate and grid circuits of said oscillator, no part of said coupling being included in the frequency determining circuit of said oscillator.

4. An oscillation generator comprising a tube having an anode, cathode, and grid, a circuit between said anode and cathode and a circuit between said grid and cathode, two inductances in series in each of said circuits, one inductance in each circuit being coupled to one inductance only in the other circuit, and means for tuning one only of said inductances to a desired frequency.

5. An oscillation generator comprising a tube having an anode, cathode and grid, a circuit between said anode and cathode and a circuit between said grid and cathode, two inductances in series in each of said circuits, one inductance in each of circuits being coupled to one inductance only in the other circuit, means for tuning one only of said inductances to a desired frequency, and means to adjust the mutual inductance of

the coupling not involving the tuned inductance to render the frequency substantially invariant with respect to tube resistance and energizing voltage.

6. Vacuum tube oscillation generator comprising a vacuum tube having a cathode, anode and grid, a circuit between the cathode and anode and a circuit between the grid and anode, two inductances in series in each of said circuits, each inductance in each circuit being coupled to one inductance only in the other circuit, and means for tuning one inductance in the grid-cathode circuit to a desired frequency.

7. An oscillation generator comprising a vacuum tube having a cathode, anode and grid, a circuit between said anode and cathode and a circuit between said grid and cathode, two inductances in series in each of said circuits, each inductance in each of said circuits being coupled to one inductance only in the other of said circuits, means for tuning one inductance in the grid-cathode circuit to a desired frequency, and means to adjust the mutual inductance between the untuned inductance in the grid-cathode circuit and the inductance in the anode-cathode circuit coupled thereto to render the oscillation frequency substantially invariant with respect to tube resistance and energizing voltage.

8. A vacuum tube oscillation generator comprising a vacuum tube having a cathode, anode and grid, a circuit between said anode and cathode and a circuit between said cathode and grid, two inductances in series in each of said circuits, each inductance in each circuit being coupled to one inductance only in the other circuit, and means for tuning one inductance in the anode-cathode circuit to a desired frequency.

9. A device as in claim 8 wherein the tuned inductance is the one further from the anode, the inductance in the anode-cathode circuit nearest the anode being coupled to the inductance in the grid-cathode circuit nearer the grid, the constants of the system being such that

$$L_1 = \tfrac{1}{2}\mu M_1$$

and

$$L_2 = \tfrac{1}{2}L_1$$

where μ is the amplification factor of the tube, M_1 is the mutual inductance of said last named coupling, L_1 is the self inductance of the untuned inductance in the plate-cathode circuit, and L_2 is the self inductance of the tuned inductance in the anode-cathode circuit.

10. A vacuum tube oscillation generator comprising a vacuum tube having a cathode, anode and grid, a circuit between said anode and cathode and a circuit between said grid and cathode, two inductances in series in each of said circuits, each inductance in each of said circuits being coupled to one inductance only in the other of said circuits, means for tuning one inductance in the anode-cathode circuit to a desired frequency, and means to adjust the mutual inductance between the untuned inductance in the anode-cathode circuit and the inductance in the grid-cathode circuit coupled thereto to render the oscillation frequency substantially invariant with respect to tube resistance and energizing voltage.

11. In a Hartley oscillation generator comprising a vacuum tube having a cathode, anode and grid, a circuit between the anode and cathode, a circuit between the grid and cathode, and a frequency determining circuit included in both the grid-cathode and anode-cathode circuits; a frequency stabilizer comprising an inductance in the grid-cathode circuit between the grid and the frequency determining circuit and an inductance in the anode-cathode circuit between the anode and frequency determining circuit coupled to the first mentioned inductance.

12. In a Hartley oscillation generator comprising a vacuum tube having a cathode, anode, and grid, a circuit between the anode and cathode, a circuit between the grid and cathode, and a frequency determining circuit included in both the grid cathode and anode cathode circuits; a frequency stabilizing means comprising an inductance in the grid-cathode circuit between the grid and the frequency determining circuit, an inductance in the anode-cathode circuit between the anode and frequency determining circuit coupled to said first named inductance and means to adjust the mutual inductance between said inductances to render the oscillation substantially invariant with respect to tube resistance and energizing voltage.

13. A Hartley oscillator having a magnetic coupling between the plate and grid circuits of said oscillator, no part of said coupling being included in the frequency determining circuit of said oscillator, and means to vary the mutual inductance of said coupling to render the oscillation frequency substantially invariant with respect to tube resistance, load, and energizing voltage.

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