

UNITED STATES PATENT OFFICE

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FREQUENCY MODULATION SYSTEM

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My invention relates to the frequency modulation of piezo electrically controlled circuits in general and more particularly to signaling systems.

One of the objects of my invention is to provide means for modulating the frequency of a piezo electric control circuit.

Another object of my invention is to provide a circuit employing a vibratile element whereby the frequency of the energy therein is modulated at a lower frequency than the natural frequency characteristics of the element.

My invention will be more fully understood from the specification hereinafter following and by reference to the accompanying drawings, in which:

Figure 1 is a schematic circuit diagram showing an arrangement for modulating the frequency by a source of alternating current; Fig. 2 shows a frequency modulating arrangement where the modulating source may be any form of mechanical energy; Fig. 3 shows a modification of the arrangement shown in Fig. 1; and Fig. 4 shows still another modification wherein the frequency of the piezo electrically controlled circuit is modulated in accordance with sound or audio frequencies.

Current modulation has been employed heretofore in the art whereby the energy of the carrier frequency from a high frequency generator is modulated in accordance with frequency of a lower order. This may be called energy modulation as contrasted with frequency modulation employed in accordance with my invention. Energy modulation has a number of disadvantages as pointed out in my co-pending application, Serial No. 339,139, filed February 11, 1929. Frequency modulation is preferable in many instances especially where the band of frequencies occupied by energy modulation would be excessive.

Fig. 1 of the accompanying drawings is a schematic circuit diagram representing a typical piezo electric oscillator circuit. Thermionic tube 1 is shown as of the three electrode type, however, it is obvious that tubes having electrodes other than a cathode 2, control

electrode 3 and anode 4 may be employed. Cathode 2 is energized by source 5. Anode 4 is energized by source 6, through high frequency choke coil 7. Control electrode 3 is supplied with a biasing potential from source 8 through high frequency choke coil 9. Piezo electric element 10 may be a suitable mechanically vibratile element such as quartz and the like associated with control electrode 3 and cathode 2 of thermionic tube 1 by means of electrodes 11 and 12. Anode 4 of thermionic tube 1 is coupled to inductance 14 by condenser 13, the latter serving to prevent short-circuiting of source 6. The frequency characteristics of the output circuit of inductance 14 are controlled by adjustable condenser 15.

Ordinarily, the part of the circuit described thus far constitutes an oscillatory circuit, the generated energy having a frequency as determined by the frequency characteristics of element 10. The generated energy may be delivered to any circuit desired by output connection 16.

It has been found that variations in the frequency characteristics of the anode circuit 14—15, in such circuits as are shown herein, produce variations in the frequency of the energy transferred to the output circuit. If, for instance, piezo electric element 10 has a fundamental or natural frequency of 4000 kilocycles, variations in the frequency from this value to the extent of several hundred cycles can be obtained by effecting small variations in the frequency characteristics of the circuit 14—15. Many arrangements may be employed for causing this variation in the frequency characteristics of circuit 14—15, some of which are illustrated in the accompanying drawings.

In Fig. 1 this change in the frequency of the energy transferred to the output 16 is effected in a simple manner. A relay is employed which is shown as comprising a core member 20, and windings 21. An armature 19 is magnetically related to core member 20 and actuated thereby. Armature 19 carries a contact member adapted to contact with stationary contact member 18. Armature 19 is electrically connected to one end of inductance 14. Contact member 18 is posi-

tioned adjacent to the contact member carried by armature 19 and is electrically connected to one terminal of condenser 17.

The other terminal of condenser 17 is connected to a portion of inductance 14 whereby an opposite potential is impressed upon the opposite plates constituting condenser 17. Windings 21 are connected with any suitable source of alternating current supply which may or may not be periodically interrupted. When such supply energizes winding 21, armature 18 is actuated, thereby causing periodic interruption of the circuit between condenser 17 and inductance 14. The frequency characteristics of circuit 14-15 are changed at the rate of interruption to an amount determined by the capacity of condenser 17 and the amount of inductance 14 connected therewith.

Fig. 2 of the accompanying drawings is a schematic circuit digram showing a chopper wheel 19a which periodically makes electrical contact with stationary contact member 18. Chopper wheel 19a is revolved by motor 24, the latter energized by any convenient source of electrical energy. Reference characters correspond in all the drawings. The rate of interruption is determined by the chosen design of chopper wheel 19a and the speed of motor 24.

Fig. 3 is a schematic circuit diagram showing a modification of the system I employ for the frequency modulation of signaling energy. In my arrangement the movable plate carried by armature 19 of relay 20 is periodically moved nearer to and farther away from the stationary plate of condenser 17. This effects a change in frequency the frequency at each instant being proportional to the position of the movable plate with respect to the position of the stationary plate. The arrangements shown in Figs. 1 and 2 provide a rapid change in frequency between two values while the arrangement shown in Fig. 3 provides a variable frequency the rate of variation being proportional to the movement of armature 19. A motor might be provided to vary the capacitive relation of the plates constituting condenser 17.

Fig. 4 shows still another modification in that the frequency modulation is effected by sound energy. The condenser 17 for effecting the frequency modulation comprises plates 17a and 17b. Plate 17a may be fixed while plate 17b may be movably mounted and adapted to be actuated by sound waves. Sound waves directed against plate 17b, which may be termed a diaphragm, cause the distance between plates 17a and 17b to vary thereby varying the capacity and hence varying the frequency of the generated energy.

Signals from the oscillator may be observed on a receiver in connection with precision frequency measurement apparatus. By employing a non-oscillating receiver, no sig-

nals are heard which shows that no energy modulation is present and therefore none of the usual disturbing effects on other receivers due to energy modulation would be present. But with an oscillating receiver the region of zero beat is broadened by an amount depending on the value of the condenser 17 employed, or if a fixed condenser is used as is indicated in Figs. 1 and 2 of the accompanying drawings, the zero beat band is broadened depending upon the value of inductance 14 which is effectively connected with condenser 7.

A variation of from 50 to 200 cycles is readily obtained in the 4000 kilocycle band by employing a condenser of 50 micromicrofarads. The rate of this variation may be determined by the frequency of the energy supplied the windings of the relay. As a check on the accuracy of the frequency measurements, such a circuit arrangement as herein described may be provided with a frequency doubler actuated from the output of this circuit. The frequency variations in the 8000 kilocycle band then measured will be found to be twice as great as the frequency variations observed in the 4000 kilocycle band. This may also be substantiated without using a frequency doubler, by simply observing with a sensitive receiver the harmonics of the circuit herein described. Had the modulation been energy modulation, the use of the frequency doubler would not have increased the spread of the signals in the upper harmonic bands. Actually, the spreading out of the signals by this type of modulation is proportional to the order of the harmonic, being three times as much in the 12,000 kilocycle band as in the 4000 kilocycle band and four times as much in the 16,000 kilocycle band as in the 4000 kilocycle band. The frequency characteristics of the output circuit may be varied in many different ways either by varying the capacity or by varying the inductance. This variation may be effected in any part of the output circuit of the thermionic tube oscillatory circuit.

I realize that many modifications of my invention are possible other than those shown in the accompanying drawings and described in the foregoing specification and it is to be clearly understood that the embodiments of my invention are not to be restricted by the foregoing specification or by the accompanying drawings but only by such restrictions as are imposed by the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. A frequency modulation system comprising in combination a thermionic oscillator tube, input and output circuits therefor, a mechanically vibratile element connected in the input circuit, and means in the output circuit for periodically varying the frequency

characteristics of said output circuit and the frequency of the energy transferred to said output circuit.

thermionic tube, input and output circuits therefor, a piezo electric crystal element connected in said input circuit, means for tuning said output circuit, and means for periodically varying said tuning means.

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2. A frequency modulating system comprising in combination a thermionic tube, input and output circuits therefor, a mechanically vibratile element connected in said input circuit, said output circuit comprising inductance and capacity, and means in said output circuit for periodically changing the frequency characteristics of said output circuit.

3. A frequency modulating system comprising in combination a thermionic oscillator tube, input and output circuits therefor, a piezo electric crystal connected in the input circuit of said tube, and means in the output circuit for varying the frequency characteristics of said output circuit at a rate of frequency lower than the frequency characteristics of said input circuit.

4. Means for varying the frequency of the energy of a thermionic tube oscillator comprising in combination a thermionic tube, input and output circuits therefor, a mechanically vibratile element in said input circuit for controlling the frequency characteristics of said input circuit and means in the output circuit for varying the frequency characteristics of said output circuit in accordance with a frequency lower than the generated frequency.

5. An oscillatory circuit comprising in combination a thermionic tube, an input circuit and an output circuit therefor, a mechanically vibratile element included in said input circuit for controlling the frequency characteristics thereof, inductance and capacity elements for controlling the frequency characteristics of said output circuit, and means in said output circuit for periodically varying the frequency characteristics of said output circuit, whereby the frequency of the generated energy is varied.

6. In a frequency modulation system, a thermionic tube, input and output circuits therefor, a piezo electric crystal element connected in said input circuit, an output coil connected in said output circuit, a control circuit connected in parallel with at least a part of said output coil, said control circuit comprising a condenser and a periodic interrupter, whereby the frequency of the output of said tube is varied.

7. In a frequency modulation system, a thermionic tube, input and output circuits therefor, a piezo electric crystal element connected in said input circuit, an output coil connected in said output circuit, a control circuit connected in parallel with at least a part of said output coil, said control circuit comprising a condenser microphone, whereby the frequency of the output of said tube is varied.

8. In a frequency modulation system, a

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