

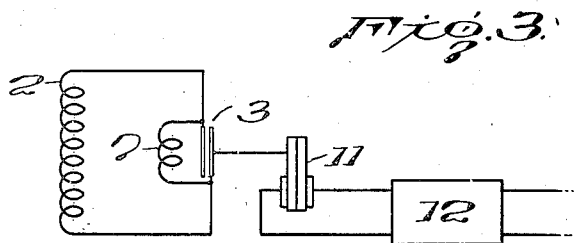
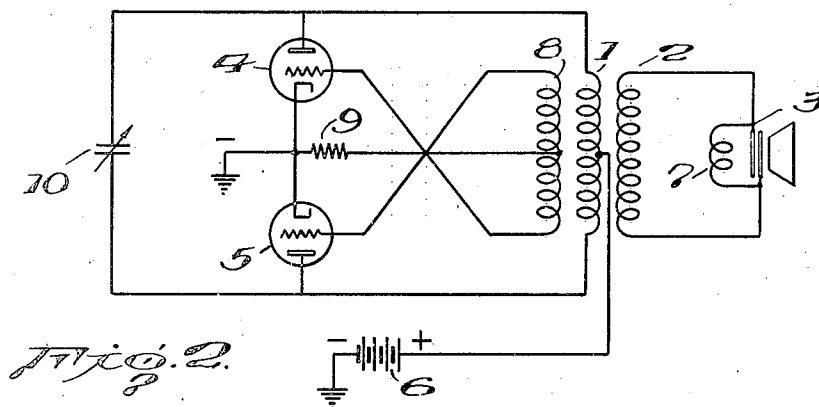
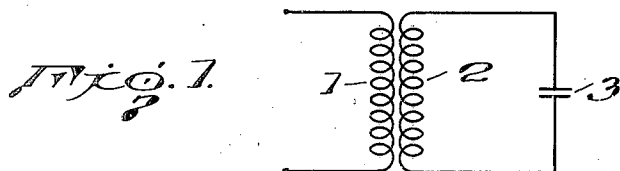
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COUPLED CIRCUIT FREQUENCY MODULATOR

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COUPLED CIRCUIT FREQUENCY
MODULATOR

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3 Claims. (Cl. 179—171.5)

This invention relates to a modulator circuit and in particular to a circuit in which the frequency of an oscillator is modulated or varied in accordance with signals to be transmitted.

An object of the invention is to devise an oscillator circuit wherein the frequency of oscillation is modulated by a microphone condenser.

A further object of the invention is to devise a frequency modulated oscillator circuit wherein the band of frequency variation secured by a condenser microphone is greatly increased.

My invention is illustrated in the accompanying drawing in which

Figure 1 is a diagram of a simple coupled circuit useful for explaining the invention;

Figure 2 is a circuit diagram illustrating the preferred form of the invention; and

Figure 3 illustrates a modified arrangement for operating the microphone condenser.

It has been known that the capacity variation in a condenser microphone, when connected in the tank circuit of an oscillator, produces frequency modulation of the oscillator. The frequency of operation, however, is limited to medium frequencies where the microphone is employed as the tuning condenser, and the percentage of frequency variation is very small. Henney in his "Principles of Radio" (4th ed.), at page 500, states that a condenser microphone connected in parallel with the tuning condenser in tank circuit of oscillator is not a practical method of frequency modulation.

The operating frequency of the oscillator may be increased by connecting the microphone in series with the tuning condenser, but the effective capacitance change in such an arrangement is made smaller, and the resultant percentage of frequency deviation is also smaller. Accordingly, ordinary oscillator circuits will not produce a satisfactory frequency change when employing a condenser microphone.

Referring to the simple coupled circuit shown in Figure 1 consisting of a primary winding 1 coupled to a secondary winding 2 and a condenser 3 connected to the secondary winding 2, if the secondary resistance is assumed to be zero, the effective inductance of the coupled circuit will be

$$L_e = L_p - \frac{WM^2}{X_s} = L_p - \frac{W^2 M^2 C}{W^2 L_s C - 1}$$

where

L_p = primary inductance
 $W = 2\pi$ times frequency
 M = mutual inductance
 X_s = secondary reactance
 L_s = secondary inductance
 C = secondary capacitance

When the capacitance is varied the greatest change in L_e will occur with a large mutual inductance. The circuit of Figure 1 was used as

the inductive element in an oscillator circuit by connecting a tuning condenser across the primary 1 and using this combination as the tank circuit of the oscillator. When operating at a normal frequency of 40 megacycles, variation of condenser 3 produced a frequency deviation of several kilocycles, and the tests indicated that greater deviation could be obtained at a still higher operating frequency providing the mutual inductance could be held at a high value. X_s cannot be made zero and still operate at the ultra-high frequencies, because of the large static capacitance of the condenser microphone and the amount of L_s required for a large mutual inductance, therefore some other method must be used. I have discovered that the frequency deviation may be greatly increased by reducing or nullifying the static capacitance of the condenser 3 which assumes the form of a condenser microphone. The greatest change in the effective inductance L_e of the coupled circuit may be obtained if the condenser microphone is shunted by an inductance and the combination is made parallel resonant near the normal operating frequency.

A practical oscillator circuit embodying the coupled circuit of Figure 1 and the microphone shunting inductance is shown in Figure 2 where the primary winding 1 is connected at opposite ends to the plate elements of two vacuum tubes 4 and 5, the center tap on the winding being connected to a suitable source of plate current represented by the battery 6. The condenser 3 in Figure 2 is shown in the form of a condenser microphone which may be operated by local sounds, produced either artificially or naturally. The microphone is shunted by an inductance 7. A second secondary winding 8 is coupled to the primary winding 1 and the ends of this winding are connected to the grids of tubes 4 and 5 as shown. The center tap of winding 8 is connected through a resistance 9 to a grounded connection which joins the two cathodes of tubes 4 and 5. The normal operating frequency of the oscillator is determined by a tuning condenser 10 connected between the plate elements of tubes 4 and 5 and therefore connected in parallel with winding 1.

In an actual embodiment of the circuit shown in Figure 2 having a normal operating frequency of 40 megacycles, the primary winding 1 consisted of eight turns of one-eighth inch copper tubing wound into a helix having a diameter of 1 1/4 inches and a length of 1 1/2 inches. The grid coil 8 was formed of celanese-covered push-back wire and was placed inside of copper tubing forming winding 1, thus providing unity coupling between windings 1 and 8. The secondary winding 2 consisted of 22 turns of the same push-back wire wound into a helix small enough to slip inside the winding 1. A 15 micromicrofarad tuning condenser 10 was employed to fix the normal op-

erating frequency. The condenser microphone 3 employed was a Western Electric type 394, and the inductance 7 connected in shunt with this microphone was only 1/2 turn of wire having a total length of approximately 1 1/2 inches which did not adjust the system for optimum condition at 40 megacycles. The value of resistance 9 depends upon the type of tube employed and can vary from 10,000 ohms to 50,000 ohms. When using a type 19 tube, a frequency deviation of 15 kilocycles was measured when talking into the microphone for several feet, and this is not for optimum conditions. Calculations show that under optimum conditions for the circuit constants given, the frequency deviation may reach 80 kilocycles.

From the foregoing it will be understood that the impedance at the terminals of winding 1 of the coupled circuit, including the secondary winding 2, condenser 3 and shunting inductance 7, is always inductive in character, and this inductive reactance in combination with the tuning condenser 10 determines the frequency of oscillation at any given instant. Variation in the capacitance of microphone 3 causes a variation in the effective inductive reactance of the winding 1 and therefore varies the frequency of the oscillator.

It can be shown that the effective inductance at the terminals of winding 1 in Figure 2 is represented by the following equation:

$$L_e = L_p - \frac{M^2(w^2L_cC-1)}{L_s(w^2L_cC-1)-L_c} \quad (1)$$

where L_c is the inductance of coil 7 and the other factors are as indicated above in connection with Figure 1.

If microphone condenser 3 is increased or decreased by an increment C' , then the capacitance of condenser 3 will be represented by $C \pm C'$, and by substituting this term for C in (1) above, the effective inductance is represented by

$$L_e = L_p - \frac{M^2(w^2L_cC-1 \pm w^2L_cC')}{L_s(w^2L_cC-1 \pm w^2L_cC')-L_c} \quad (2)$$

For the condition of resonance of condenser 3 and inductance 7 at the operating frequency, $w^2L_cC=1$, and (2) above becomes

$$L_e = L_p \pm \frac{M^2w^2C'}{\pm w^2L_cC' - 1} \quad (3)$$

The term w^2L_cC' in (3) may be neglected since it represents a distortion factor having a very small value, and (3) then becomes

$$L_e = L_p \pm w^2M^2C' \quad (4)$$

The foregoing equations do not take into consideration the resistance of the primary and secondary circuits but in actual circuits there will be appreciable resistance which will flatten the peak of the resonance curve. Accordingly, it will be found that maximum variation in the effective inductance will be obtained by tuning the parallel combination involving condenser 3 and inductance 7 to a frequency somewhat displaced from the normal operating frequency of the oscillator circuit, that is, the parallel combination 3-7 would be tuned to a point on the steepest portion of its resonance curve at the operating frequency of the oscillator. From Equation 4 it will be seen that the higher the frequency and

the tighter the coupling, the greater will be the frequency change.

It will be understood that a suitable work circuit, such as an antenna circuit or a transmission line may be coupled or otherwise connected to the oscillator circuit. Suitable amplifiers may be included between the oscillator circuit and the work circuit if desired. Also, by including well known frequency doublers between the oscillator circuit and the work circuit, it is possible to operate the oscillator at a lower frequency for a given frequency in the work circuit.

While I have shown an oscillator of the push-pull type in Figure 2, it will be understood that a simple oscillator using only one tube may be employed.

In Figure 3 I have shown a modified arrangement for operating the microphone condenser 3. In this arrangement the condenser of the microphone is operated by a connection to piezo crystal vibrator 11 which is energized from a program amplifier 12, the input for amplifier 12 being derived from any program source which is to be retransmitted. It will be obvious that other operating arrangements for the microphone are possible.

What I claim is:

1. A frequency modulator comprising a vacuum tube oscillator having a frequency determining circuit, a second circuit closely coupled to said frequency determining circuit and including a signal actuated condenser, and an inductive element connected in shunt to said condenser, said inductive element and said condenser forming a parallel tuned circuit such that in the static condition of said condenser, the parallel circuit operates at a steeply sloping portion of its resonant curve at the normal frequency of said oscillator.

2. A frequency modulator comprising a vacuum tube oscillator having plate and grid circuits, a transformer for coupling said circuits including a coil connected in the plate circuit and a coil connected in the grid circuit, a condenser connected across one of said coils to form a frequency determining circuit, a third coil on said transformer and having substantially unity coupling with said frequency determining circuit, a signal actuated condenser connected in circuit with said third coil, and an inductive element connected in shunt to said signal condenser, said inductive element and signal condenser forming a parallel tuned circuit such that in the static condition of said signal condenser, the parallel circuit operates at a steeply sloping portion of its resonant curve at the normal frequency of said oscillator.

3. A frequency modulator comprising an oscillator circuit having a frequency determining circuit, including an inductive element, a second circuit inductively coupled with said inductive element by substantially unity coupling and including a signal actuated condenser, and a second inductive element connected in shunt with said condenser, said second inductive element and condenser forming a parallel tuned circuit such that in the static condition of said signal condenser, the parallel circuit operates at a steeply sloping portion of its resonant curve at the normal frequency of said oscillator.

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