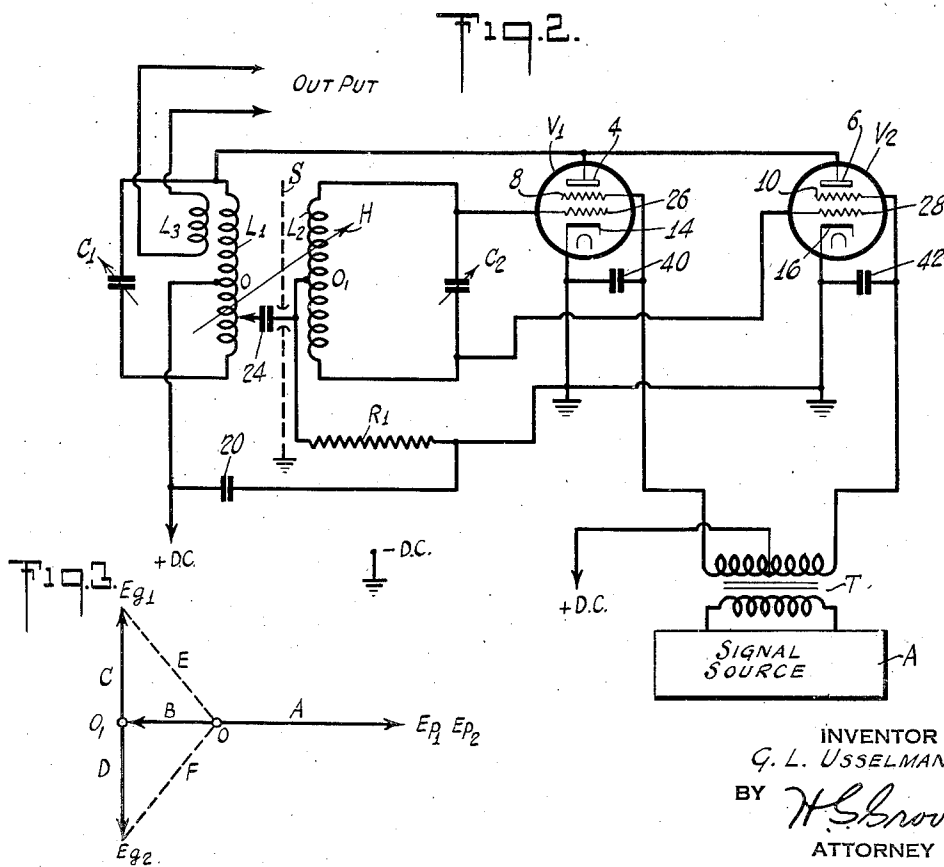


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FREQUENCY MODULATOR



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FREQUENCY MODULATOR

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The present invention relates to frequency modulation and particularly to a frequency modulated oscillator.

This type of frequency modulator like some other types uses differentially modulated tubes but the method of obtaining the desired phase relations between the tubes I believe is new in frequency modulators.

Typical embodiments of the invention are shown in Figs. 1 and 2. Fig. 3 shows the vector relations of the plate and grid voltages in the frequency modulator.

Figs. 1, 2 and 3 will be used to describe the frequency modulator. This frequency modulator consists essentially of two tubes V_1 and V_2 ; anode tank circuit L_1-C_1 ; grid tank circuit L_2-C_2 ; grid bias resistors R_1 and R_2 ; screen grid modulation transformer T ; signal source A ; and output circuit L_3 . The circuit assumes proper 60 cycle and D. C. power supply. The output circuit may be connected to any desired load or utilization circuit like a transmission line and/or a radio transmitter in which stages of amplifiers and/or frequency multiplication may be used.

Referring to Figs. 1 and 2 it may be seen that the anodes 4 and 6 of the modulator tubes V_1 and V_2 are both connected to the upper end of tank circuit L_1-C_1 . The screen grids 8 and 10 are connected to the modulation transformer T . The cathodes 14 and 16 are grounded. The center point of tank circuit L_1-C_1 is by-passed to ground for radio frequency by condenser 20 and also connected to a source of positive direct current supply. The center point of coil L_2 of tank circuit L_2-C_2 is directly connected, through a blocking condenser 24 in Fig. 2, to some desirable point on the lower half of coil L_1 as shown. This is on the opposite end from the anode connection to this inductance. The control grids 26 and 28 of these two tubes V_1 and V_2 are connected to opposite ends of tank circuit L_2-C_2 , through blocking condensers 30 and 32 in Fig. 1 and direct in Fig. 2 as shown. In Fig. 1 each control grid is connected to ground through grid bias resistors R_1 and R_2 . In Fig. 2 the center point of coil L_2 is connected to ground through a common grid bias resistor R_1' as shown. The latter supplies grid leak bias for both tubes V_1 and V_2 . The output coupling inductance L_3 is coupled to coil L_2 as shown. Other types of output couplings may be used. The screen grids are supplied with positive direct current potential from a suitable source con-

nected to the center point of the modulation transformer T . The screen grids are by-passed to the cathodes for radio frequency by condensers 40 and 42.

In Fig. 2 an electrostatic shield S is placed between coils L_1 and L_2 and grounded as shown. The coils L_1 and L_2 of tank circuits L_1-C_1 and L_2-C_2 are adjustably coupled inductively (that is magnetically) as indicated by the arrow H .

For proper operation of this frequency modulator both tank circuits L_1-C_1 and L_2-C_2 must be tuned to resonance at the operating carrier frequency. The coupling H between tank circuits L_1-C_1 and L_2-C_2 should be properly set for best results as may be seen from later description.

Reference to Fig. 3 is advantageous at this point. This is a vector diagram representing the plate and grid voltage relations in this type of frequency modulator circuit at carrier frequency.

Vector A represents the voltage (E_p) on the anodes 4 and 6 of tubes V_1 and V_2 .

Vector B represents the voltage on the center point O_1 and coil L_2 .

O and O_1 represent the origins or points of reference.

Vector E is a resultant representing the grid voltage E_{g1} of tube V_1 .

Vector F is a resultant representing the grid voltage E_{g2} of tube V_2 .

It may be noted that vector B is in 180° relation to vector A . This follows because the center point O_1 of coil L_2 is tapped on tank circuit L_1-C_1 on the opposite side of the center point O of coil L_1 from the tube anode connections, the center point O being grounded for radio frequency.

Vectors C and D have 180° relation to each other because they are connected to opposite ends of the tank circuit L_2-C_2 . Vectors C and D also have 90° relation to vectors A and B due to the coupling relations of coils L_1 and L_2 in tank circuits L_1-C_1 and L_2-C_2 . This latter relation requires that both tank circuits be tuned for the same carrier frequency and that the proper amount of inductive coupling be obtained. This follows from the fact that a 90° phase difference exists between the voltages of two loosely coupled tuned circuits each adjusted for resonance at the same frequency and adjusted for the proper amount of inductive coupling. This phase angle varies somewhat when the frequency is varied from resonance.

In the standard or typical oscillator circuit

the best condition for oscillations is that the alternating current voltages on the grid and the anode of the oscillator tube be substantially 180° out of phase with each other. However, this phase angle can be varied considerably (but less than 90°) from this figure and still maintain oscillations at the expense of efficiency and if the oscillator load is not too great. In the present invention the alternating current excitation voltages on the grids of the tubes V_1 and V_2 are not in 180° opposition to the voltage of the anodes. The alternating current excitation voltage on the grid of one tube is less than 180° out of phase and the alternating current excitation voltage on the grid of the other tube is more than 180° out of phase with voltage of the anodes (note that both anode voltages have the same phase).

In other words, the grid voltage of one tube leads the anode voltage by less than 180° and the grid voltage of the other tube lags the anode voltage by less than 180°. The amount of leading and lagging excitation voltage angle for the grids of tubes V_1 and V_2 is the same when no signal is present. These angles vary somewhat from each other during the process of frequency modulation when the signal is applied but not enough to prevent proper operation of the circuit.

It can be said that, referring to Fig. 3, as long as the grid voltage represented by vector E and the grid voltage represented by vector F do not approach too closely the 90° and the 270° positions respectively in relation to the anode voltage represented by the vector A, the circuit will continue to oscillate. In other words, as long as the voltage represented by vector B is sufficiently large, the circuit will oscillate.

It may be seen from Fig. 3 that the excitation voltage Eg_1 for the grid of tube V_1 lags the average excitation vector B while the excitation voltage Eg_2 for the grid of tube V_2 leads the average excitation vector B. When the output oscillations of tubes V_1 and V_2 are modulated differentially in amplitude by differential amplitude modulation of the screen grid voltages, the sum of the two oscillations added to the tank circuit L_1-C_1 is substantially constant. In this manner amplitude modulation is compensated and prevented. However, a change in the phase of the oscillations in the tank circuit takes place in accordance with the amplitude and frequency of the signal applied at source A. This phase change, being coupled back to the control grids 26 and 28 of tubes V_1 and V_2 , results in frequency modulation. The amount of frequency deviation from the carrier frequency is substantially proportional to the signal amplitude and the frequency of the deviation swing is the same as the signal frequency.

The amount of frequency deviation is resisted or limited by the reaction of the two tuned circuits L_1-C_1 and L_2-C_2 , partly because the 90° phase relation between the two tuned circuits changes and partly because of the control grid radio frequency potential and other potential changes in the circuit.

It may be desirable to place an electrostatic shield between the tank circuits L_1-C_1 and L_2-C_2 as shown in Fig. 2 in order to permit only inductive coupling between these elements of the circuit. This would simplify the operation of the circuit and make it easier to operate. No doubt, other arrangements of this frequency modulator could be made within the bounds of the invention.

Good frequency modulation with little or no amplitude modulation was obtained in an arrangement as illustrated in Fig. 1. In this arrangement a frequency sweep of 42,500 cycles was obtained at a carrier frequency of substantially 2,040,000 cycles per second.

In a modulator as illustrated in Fig. 2 a frequency sweep of 48,500 cycles was obtained at a carrier frequency of about 2,050,000 cycles per second. A frequency sweep of 82,000 cycles per second with a carrier of 2,000,000 cycles per second is obtainable.

In the embodiments used to illustrate my invention modulation is applied to the screen electrodes. It will be appreciated, however, that the signal modulations may be applied to any of the tube electrodes without departing from the bounds of my invention.

I claim:

1. In a wave length modulation system, a pair of electron discharge devices each having input and output electrodes, two circuits parallel tuned to the same frequency, inductive and conductive couplings between said two circuits, connections including one of said tuned circuits coupling the input electrodes of said devices in pushpull relation, connections including the other of said tuned circuits coupling the output electrodes of said devices in parallel relation, and connections for modulating the impedances of said devices in accordance with signals.

2. In a wave length modulation system, a pair of electron discharge devices each having an electron emission electrode, an electron flow control electrode and an electron receiving electrode, a circuit parallel tuned to the desired operating frequency coupling said flow control electrodes in push-pull relation, a circuit tuned to the same frequency coupling the electron receiving electrodes and electron emission electrodes of the devices in parallel, a first coupling between said circuits for applying a phase reversed in-phase voltage from the electron receiving electrodes to the electron flow control electrodes, a second coupling between said circuits for impressing opposed voltages from the electron receiving electrodes to the electron flow control electrodes said last named voltages being substantially in phase quadrature with respect to the voltages on the electron receiving electrodes, and means for differentially controlling the gain of said devices in accordance with signals.

3. In a wave length modulation system, a pair of electron discharge devices each having an electron emission electrode, an electron flow control electrode and an electron receiving electrode, a circuit including inductance parallel tuned to the desired operating frequency coupling said flow control electrodes in push-pull relation, a second circuit including inductance parallel tuned to the same frequency coupling the electron receiving electrodes and electron emission electrodes of the devices in parallel, a first coupling between said circuits for applying a phase reversed in-phase voltage from the electron receiving electrodes to the electron flow control electrodes, a loose coupling between said inductances for impressing opposed voltages from the electron receiving electrodes to the electron flow control electrodes said last named voltages being substantially in phase quadrature with respect to the voltages on the electron receiving electrodes, and means for differentially controlling the gain of said devices at signal frequency.

4. In a timing modulation system, a pair of electron discharge devices each having an electron emission electrode, an electron flow control electrode and an electron receiving electrode, two circuits including capacity and inductance parallel tuned substantially to the same carrier wave frequency, connections coupling one of said parallel tuned circuits between the electron receiving electrodes and electron flow control electrodes of said devices, said connections including the other of said parallel tuned circuits, a connection between a point on said one tuned circuit and the electron emission electrodes of said devices, whereby the voltages on the electron receiving electrodes and electron flow control electrodes are of substantially opposed phase and oscillations of the frequency to which said one circuit is tuned are generated, connections including the other of said parallel tuned circuits coupling the electron flow control electrodes of said devices in pushpull relation, the inductance of said two tuned circuits being coupled whereby phase opposed voltages are impressed on said electron flow control electrodes which voltages are substantially in phase quadrature with respect to the first mentioned voltages on said electron flow control electrodes, and cooperate with said first mentioned voltages to produce on the control electrodes resultant voltages, and connections for differentially controlling the gain of said devices to change the phase of the said resultant voltages on said electron control electrodes and correspondingly vary the timing of the oscillations generated.

5. In a timing modulation system, a pair of electron discharge devices each having an electron emission electrode, an electron flow control electrode and an electron receiving electrode, two circuits comprising parallel inductance and capacity tuned substantially to the same carrier wave frequency, connections including one of said tuned circuits and the electron receiving electrodes, electron emission electrodes and elec-

tron flow control electrodes of said devices in a regenerative circuit, said connections comprising a coupling between a point on said one tuned circuit and the electron receiving electrodes of the devices, a coupling between a second point on said one tuned circuit and the electron flow control electrodes of said devices, said last named coupling including said other tuned circuit, and a coupling between a point on said one tuned circuit intermediate said two points and the electron emission electrodes of said devices, whereby the voltages on the electron receiving electrodes and electron flow control electrodes are of substantially opposed phase and oscillations of the frequency to which said one circuit is tuned are generated, connections including the other of said tuned circuits coupling the electron flow control electrodes of said devices in pushpull relation, there being coupling between said inductances whereby phase opposed voltages are impressed on said electron flow control electrodes which voltages are substantially in phase quadrature with respect to the first mentioned voltages on said electron flow control electrodes to excite the same by resultant voltages, and connections for differentially controlling the gain of said devices to change the phases of the resultant voltages on said electron control electrodes and correspondingly vary the timing of the oscillations generated.

6. A system as recited in claim 5, wherein said coupling between said second point on said one tuned circuit and the electron flow control electrodes of said devices which includes said other of said tuned circuits comprises a connection between said second point and a point intermediate the terminals of the inductance of the said other of said tuned circuits.

7. A system as recited in claim 5, wherein an electrostatic shield is interposed between said inductances of said two tuned circuits.

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