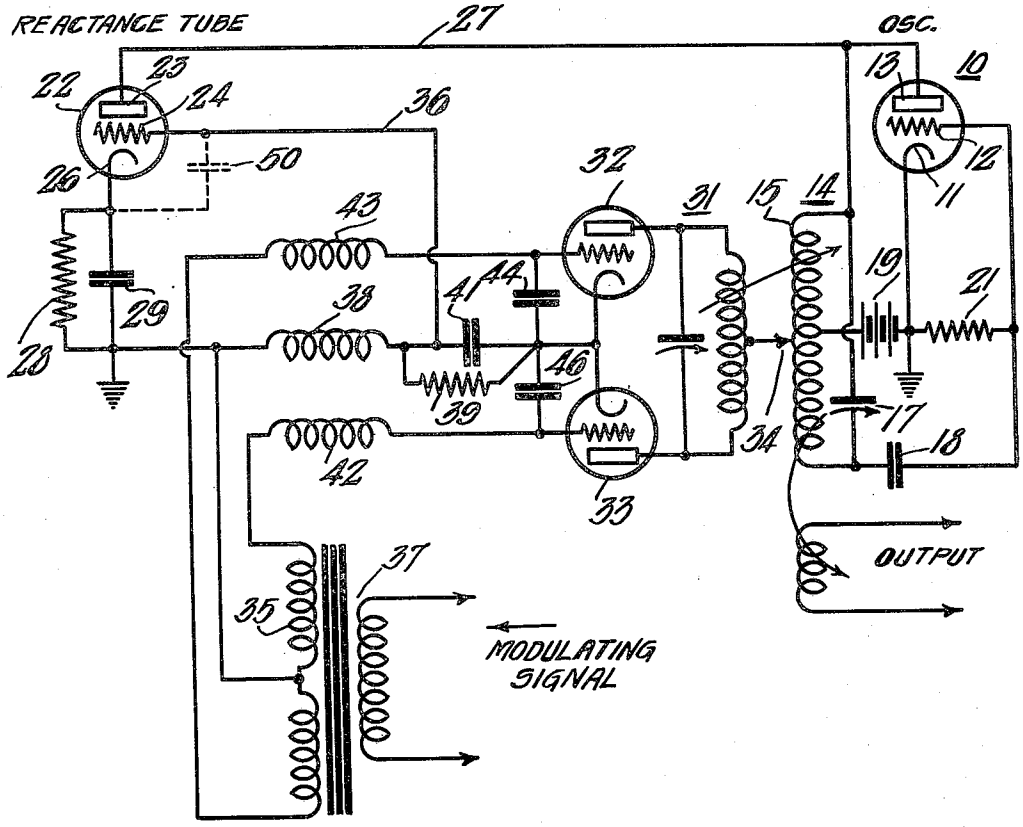
Oct. 12, 1943. E. S. WINLUND 2,331,821

FREQUENCY MODULATION

Filed Oct. 31, 1941

Fig. 1



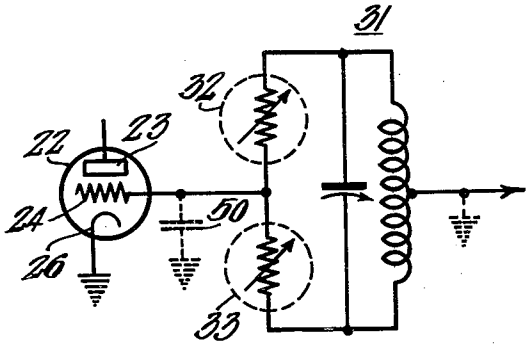


Fig. 2.

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FREQUENCY MODULATION

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7 Claims. (Cl. 179—171.5)

My invention relates to radio or carrier wave transmitters and particularly to the art of frequency modulation.

An object of the invention is to provide an improved method of and means for frequency modulating a carrier wave.

A further object of the invention is to provide an improved frequency modulation circuit of the type employing a reactance tube.

A still further object of the invention is to provide an improved modulating circuit for supplying inductive and capacitive current components alternately to the carrier wave oscillator during modulation.

In one embodiment of the invention, a reactance tube has its grid circuit coupled to the tuned circuit of the carrier wave oscillator through the plate impedances of two push-pull connected vacuum tubes and through a plate circuit for these vacuum tubes, which is tuned and coupled to the oscillator tuned circuit. These coupled tuned circuits produce the desired quadrature phase relation between the reactance tube plate and grid voltages. Modulating signal is applied in push-pull relation to the push-pull connected vacuum tubes. The current passed by one of the push-pull tubes is 180 degrees out of phase with that passed by the other tube, since the plates of tubes are connected to opposite ends of the push-pull plate circuit.

Thus, the modulating signal causes the voltage on the grid of the reactance tube to change from a leading voltage of maximum amplitude through a decreasing value until it reaches a minimum value and then from the minimum value to a lagging voltage of increasing amplitude whereby the desired frequency modulation of the oscillator is obtained.

The invention will be better understood from the following description taken in connection with the accompanying drawing in which

Figure 1 is a circuit diagram of one embodiment of the invention as applied to a radio transmitter or the like, and

Figure 2 is a simplified diagram that is referred to in explaining the invention.

Like parts in the two figures are indicated by the same reference characters.

Referring to the drawing, the carrier wave oscillator indicated at 10 comprises a vacuum tube having a cathode 11, a control grid 12, and an anode 13. It also includes a tuned circuit 14 consisting of an inductance coil 15 tuned by a condenser 17. Conventional oscillator circuit connections are shown, one end of tuned circuit 14 being connected to anode 13, the opposite end being connected through a grid condenser 18 to the grid 12, and the midpoint being connected to the grounded cathode 11 through a plate supply source 19. A grid leak resistor is indicated at 21.

A reactance tube 22 having an anode 23, a control grid 24, and a cathode 26 is employed for supplying a reactive current component to the oscillator tuned circuit 14 for varying the oscillator frequency. The anodes of the reactance and oscillator tubes are connected together by a conductor 27. The cathode of tube 22 may be connected to ground through a self-biasing resistor 28 shunted by a bypass condenser 29.

To obtain the necessary out-of-phase voltage at the grid 24 of the reactance tube, some of the oscillator output is fed from the tuned circuit 14, through a tuned circuit 31 coupled thereto, through the anode-cathode impedances of push-pull connected tubes 32 and 33 and through a conductor 36 to the reactance tube grid. It will be understood that the coupled circuits 14 and 31 are each tuned to the carrier wave frequency.

The tubes 32 and 33 are of the high vacuum type, each having an anode, a cathode, and a control grid. The tuned circuit 31 has its opposite ends connected to the anodes of these tubes and has its midpoint connected through a variable tap 34 to a point on the coil 15. The tap 34 may be either at the midpoint of coil 15 or on one side of the midpoint. It will be noted that the anode voltage for tubes 32 and 33 is supplied by the same source 19 that is supplying anode voltage for the other tubes. If the tap is at one side of the midpoint, it may be adjusted to provide a proper amount of regeneration for reducing the anode-cathode resistance of the reactance tube 22 whereby the reactance tube is made fairly insensitive to changes in the supply voltage. It will be evident that, if the tap 34 is on one side of the midpoint, there will be introduced an in-phase voltage component of constant value at the grid of the reactance tube with the result that, during modulation, the phase, as well as the amplitude of the total voltage on the reactance tube grid 24, varies during modulation.

The modulating signal is applied to the grids of tubes 32 and 33 by means of a transformer 37 connected thereto in push-pull relation. The midpoint of the transformer secondary 35 is grounded and connected to the cathodes of tubes 32 and 33 through a radio frequency choke coil 38 and through a cathode resistor 39 and by-pass condenser 41. The coil 38 keeps the cathodes of tubes 32 and 33 above ground potential at the oscillator frequency and the cathode resistor 39 maintains the tubes 32 and 33 biased to operate as class A amplifiers.

Opposite ends of the transformer secondary 35 are connected to the control grids of tubes 32 and 33 through radio frequency choke coils 42 and 43. Radio frequency filter condensers 44 and 46 hold the control grids and cathodes of the tubes 32 and 33 at the same potential for radio frequencies.

The operation of the circuit will be understood more readily by referring to Fig. 2 where the plate impedances of tubes **32** and **33** are indicated as variable resistors. This variation in resistance, of course, is caused by the modulating signal.

When no modulating signal is being applied the plate impedances of tubes **32** and **33** are equal and no quadrature radio frequency voltage is applied to the grid of the reactance tube, since the circuit is balanced.

When modulating signal is applied, radio frequency current flows through the plate impedance of either tube **32** or tube **33** and through the grid-cathode capacity **50** of the reactance tube to put radio frequency voltage on its grid. It will be noted that the plate impedance of one tube and the capacity **50** form a potentiometer.

During the positive half cycle of the modulating signal, as viewed from the tube **32**, the radio frequency current flow through the potentiometer has the phase relation of the radio frequency current through tube **32**, and the voltage applied to the reactance tube grid has the desired quadrature relation with respect to the oscillator plate voltage. It is assumed that the tubes **32** and **33** have low plate impedance compared with the reactance of the grid-cathode capacity **50** so that the potentiometer portion of the circuit causes a negligible amount of phase shift.

During the other half cycle of the modulating signal, the radio frequency current flow through the tube **33** predominates, and, since it is 180 degrees out of phase with the current through tube **32**, the radio frequency voltage now applied to the grid of the reactance tube has a quadrature relation in the opposite direction. Thus, the tubes **32** and **33** alternately apply an out-of-phase voltage to the reactance tube grid that is alternately leading and lagging the oscillator voltage, and which is changing smoothly in amplitude from maximum to minimum while leading or while lagging.

It may be noted that the tubes **32** and **33** may be biased to cut-off to operate class B, if preferred. Also, a substantial amount of phase shift in the potentiometer circuit may be allowed, especially if the tubes **32** and **33** are operated class A.

I claim as my invention:

1. In combination, an oscillator, a reactance tube connected to said oscillator for varying its frequency of oscillation, said reactance tube having a control electrode, inductively coupled and conductively connected parallel tuned circuits for feeding from said oscillator to said control electrode a voltage component that is 90 degrees out of phase with the oscillator current, and means for varying the amplitude of said voltage and for reversing its phase on each side of its zero amplitude value in accordance with a modulating signal.

2. In combination, an oscillator, a reactance tube having a control electrode and an anode and having its anode connected to said oscillator for varying its frequency of oscillation, means for feeding signal from said oscillator to said control electrode, said means including reactively coupled and conductively connected tuned circuits and a pair of vacuum tubes connected in push-pull relation to each other by one of said tuned circuits and in parallel relation to said reactance tube control grid by said one of said tuned circuits, and means for applying a modulating signal in push-pull relation to said pair of tubes.

3. In combination, an oscillator comprising an electric discharge tube and a tuned circuit, a reactance tube having a control electrode and having an anode connected directly to the anode of the oscillator discharge tube, a pair of vacuum tubes connected in push-pull relation and having a tuned plate circuit coupled to the tuned circuit of the oscillator, a connection from the cathodes of said vacuum tubes to the control electrode of said reactance tube, means for holding the control grids and cathodes of said vacuum tubes above ground potential at the oscillator frequency, and means for applying a modulating signal in push-pull relation to the control grids of said pair of tubes whereby said reactance tube is caused to frequency modulate the output of said oscillator.

4. The invention according to claim 3 wherein each tube of said pair has a plate-cathode impedance that is small compared with the reactance of the grid-cathode capacity of said reactance tube.

5. In combination, an oscillator which includes a tuned circuit, a reactance tube connected to said oscillator for varying its frequency of oscillation, said reactance tube having a control electrode, means for feeding an out-of-phase voltage from said oscillator to said control electrode, said means including a tuned circuit coupled to said first tuned circuit and a pair of vacuum tubes each having a cathode, a control grid and an anode, said anodes being connected to opposite ends of the second tuned circuit to form a push-pull connection between said oscillator and said pair of tubes, a connection from said cathodes to the control electrode of said reactance tube, and means for applying a modulating signal in push-pull relation to the control grids of said pair of tubes.

6. In combination, an oscillator which includes a tuned circuit, a reactance tube connected to said oscillator for varying its frequency of oscillation, said reactance tube having a control electrode, means for feeding an out of phase voltage from said oscillator to said control electrode, said means including a tuned circuit coupled to said first tuned circuit, and a pair of vacuum tubes each having cathode, grid and anode electrodes, a pair of like electrodes of said vacuum tubes being connected to opposite ends of the second tuned circuit to form a push-pull connection between said oscillator and said pair of tubes, a connection from another pair of like electrodes of said vacuum tubes to the control electrode of said reactance tube, and means for oppositely varying the conductivity of said vacuum tubes with a modulating signal.

7. In combination, an oscillator tube having a plate, a reactance tube having a plate directly connected to the plate of said oscillator for varying the frequency of oscillations generated by said oscillator, said reactance tube having a control electrode, reactively coupled and conductively connected parallel resonant circuits for feeding from said oscillator tube to said control electrode, a voltage component that is substantially 90 degrees out of phase with the oscillator current, and instrumentalities for varying the amplitude of said voltage and for reversing its phase on each side of its zero amplitude value in accordance with a modulating signal.

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