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REACTANCE TUBE CIRCUIT

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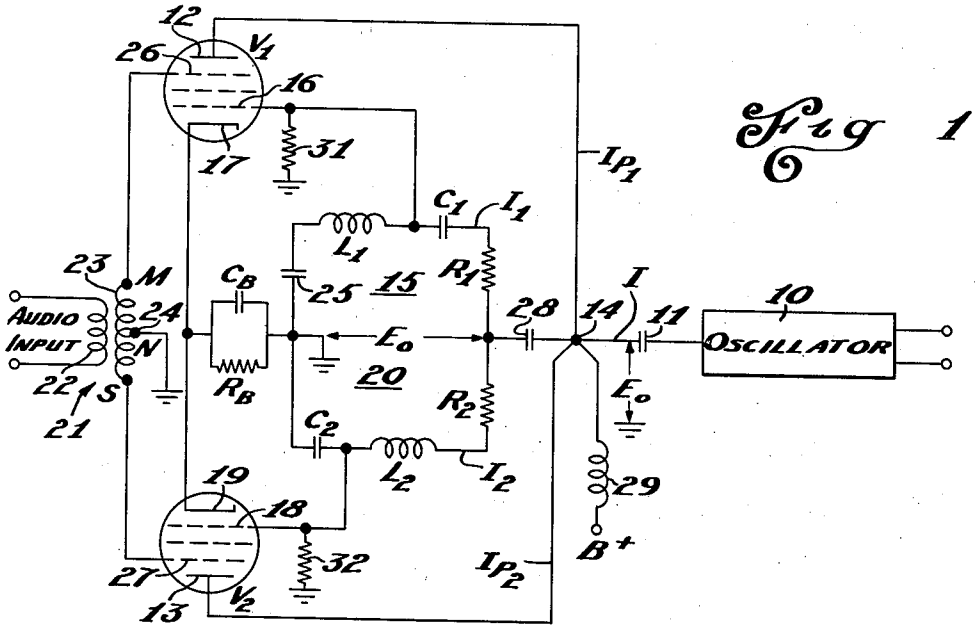


Fig 1

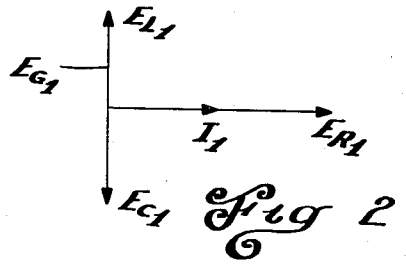


Fig 2

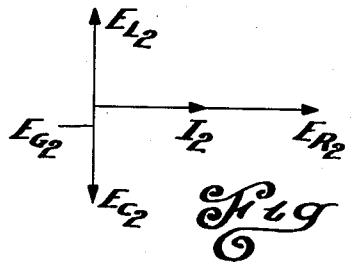


Fig 3

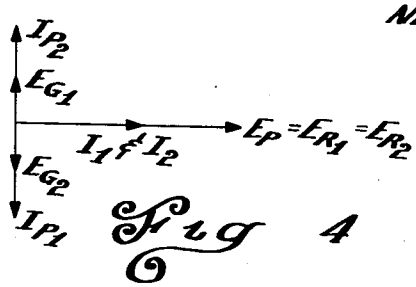


Fig 4

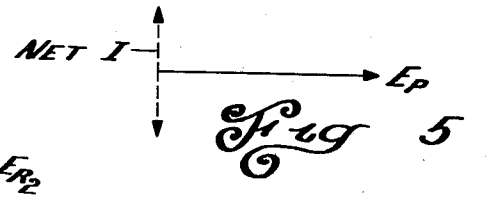


Fig 5

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REACTANCE TUBE CIRCUIT

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This invention relates in general to reactance tube circuits and in particular to reactance tube circuits which have a resonant phase shifting grid circuit.

A reactance tube circuit is similar to a capacitance or inductance. An alternating voltage placed across such a circuit will produce a quadrature current in the same manner as a voltage across a capacitance or inductance.

The reactance tube circuit, however, has an additional property in that its reactance can be made proportional to an audio voltage. It is analogous to a capacitor or inductor whose reactance varies in proportion to an audio voltage which then produces a quadrature current that varies in proportion to the audio voltage.

Two reactance tubes which produce opposite and equal quadrature currents may be connected with their plates in parallel, and their unmodulated equal plate currents will cancel each other. If the plate current of each tube is then modulated by an audio voltage which is opposite in phase on each tube, the plate current of one tube will alternately increase while the plate current of the other tube is alternately decreasing, etc. The net plate reactive current from both tubes will no longer completely cancel and their difference will be proportional to the audio voltage. The net current will lag when the audio voltage increases and lead when the audio voltage decreases or vice versa depending on which way the audio voltage is connected.

The conventional reactance tube circuit uses a resistance-capacitance phase shifting grid circuit such as shown in Terman's "Radio Engineering," 3rd edition, at page 493. The ninety degree phase shift between plate current and plate voltage is obtained in its phase shifting circuit by making the resistance very large compared to the reactance so that the current through that circuit will be substantially in phase with the plate voltage across it. Then the voltage across the reactance has a ninety degree phase relationship with the current through it and will be substantially ninety degrees out of phase with the plate voltage. The reactive voltage is then placed across the reactive tube's control grid to produce plate current which has substantially ninety degrees phase relationship with the plate voltage. A difficulty with the conventional circuit is that the very high resistance required in the phase splitter circuit to obtain the ninety degree phase shift allows only a relatively small voltage across the reactive element to drive the tube control grid, and therefore only a relatively small reactive current can be obtained from such tube when compared with its rated current. It is therefore the principal object of this invention to provide a reactance tube circuit which will provide as large a grid driving voltage as necessary to obtain as large a quadrature plate current as desired.

It is another object of this invention to provide a reactance tube circuit which will provide a large reactive current swing with a very small audio modulating signal voltage.

It is still another object of this invention to provide a reactance tube circuit which can produce large modulated reactive currents when operated at a low plate voltage which will therefore allow the modulated oscillator to operate at a low voltage level.

It is another object of this invention to provide a reactance tube modulator which can obtain a large frequency deviation proportional to a small audio signal while its oscillator is operated at a low power level.

This invention obtains a large grid voltage which is ninety degrees out of phase with the plate voltage by providing a series resonant phase shifting circuit across the plate voltage and by taking the grid voltage across a reactive element.

Other features and advantages not specifically enumerated will become apparent after considering the following detailed description and drawings, in which:

Figure 1 is a schematic diagram of the invention;

Figure 2 shows the vector relationships between current and voltage in the phase shifting circuit for one tube in the invention;

Figure 3 shows the vector relationships between current and voltage in the phase shifting circuit for another tube in the invention;

Figure 4 indicates the phase relationships among the plate voltage, plate currents, and control grid voltages of the tubes in the circuit; and

Figure 5 indicates the phase relationship between the net output current and the plate voltage.

Now considering the invention in more detail, a circuit for one embodiment is schematically shown in Figure 1 which shows an oscillator 10 that is connected at point 14 to a pair of plates 12 and 13 of a pair of tubes V_1 and V_2, respectively, through a direct current blocking condenser 11. The cathode 17 of tube V_1 is connected to the cathode 19 of tube V_2 and both cathodes are connected to ground through a biasing resistor R_B which is in parallel with a bypass condenser C_B.

Tube V_1 has a phase shifting circuit 15 which consists of a resistor R_1, a capacitor C_1 and an inductance L_1 in series. Resistor R_1 is connected to point 14 through a blocking condenser 28 and the opposite end of inductance L_1 is grounded through another blocking condenser 25. Likewise, the tube V_2 has a phase shifting circuit 20 which consists of a resistor R_2, an inductance L_2, and a capacitor C_2, all in series, with resistor R_2 connected to point 14 through blocking condenser 23 and the opposite end of capacitor C_2 grounded. Tube V_1 has a control grid 16 which is connected to the side opposite ground of inductance L_1, and tube V_2 has a control grid 18 which is connected to the ungrounded side of capacitor C_2. A B plus power supply is connected to the plates of tubes V_1 and V_2 through a choke coil 29. A grid leak resistor 31 is connected between grid 16 and ground, and a grid leak resistor 32 is connected between grid 18 and ground.

An audio signal input voltage is impressed on a primary 22 of an audio transformer 21 which has a secondary 23 with a grounded center tap 24. A suppressor grid 26 of tube V_1 is connected to one end of secondary 23, and a suppressor grid 27 of tube V_2 is connected to the other end of secondary 23.

In operation, an alternating current oscillator voltage Eo will exist across the plates of tube V_1, tube V_2, and phase shifting circuits 15 and 20. The direct current blocking capacitors 11 and 28 have negligible reactance at the operating frequency for the circuit. Tubes V_1 and V_2 have a very high plate resistance and therefore essentially all alternating plate current will be caused by grid voltage because of the transconductance of the tubes.

The voltage Eo across phase shifting circuit 15 will cause an alternating current I_1 to pass through resistor R_1, capacitor C_1 and inductance L_1 which will cause an in-phase voltage across resistor R_1, a ninety degree lagging voltage across capacitor C_1, and a ninety degree leading

voltage across inductance L_1. These voltage relationships are diagrammatically shown in Figure 2. Blocking capacitors **25** and **28** have negligible reactance at the operating frequency. Likewise, voltage Eo across phase shifting circuit **20** will cause an alternating current I_2 which will result in an in-phase voltage across resistor R_2, a ninety degree leading voltage across inductance L_2, and a ninety degree lagging voltage across capacitor C_2.

It will be noted that the alternating voltage on grid **16** of tube V_1 will be the voltage across inductance L_1, which is designated in Figure 2 as voltage E_{G_1}, since the alternating voltage across blocking capacitor **25** is small. Also the alternating voltage on control grid **18** of tube V_2 will be the voltage across capacitor C_2 which is designated in Figure 3 as E_{G_2}. When phase shifting circuits **15** and **20** are resonated, the currents I_1 and I_2 are both in phase with voltage Eo and the voltages E_{G_1} and E_{G_2} are then in quadrature with Eo and opposite in phase from each other as shown in Figure 4. Resistors R_1 and R_2 are equal, and capacitances C_1 and C_2 and inductances L_1 and L_2 are chosen so that the absolute voltage E_{G_1} at operating frequency across L_1 will be equal to the absolute voltage E_{G_2} across C_2.

Since the tubes V_1 and V_2 are identical, the equal magnitude grid voltages on each tube will cause equal magnitude plate currents to flow. Since generally plate current has an 180 degree phase relationship with grid voltage, it is seen in Figure 4 that the alternating plate current I_{P_1} of tube V_1 is equal and opposite to the alternating plate current I_{P_2} of tube V_2 because their grid voltages E_{G_1} and E_{G_2} are equal and opposite.

When there is no modulating audio voltage, the plate currents I_{P_1} and I_{P_2} will cancel each other since they are equal and opposite and will not provide any net plate current I to the oscillator tank circuit **10**. Together, tubes V_1 and V_2 will therefore have zero reactance when no modulation is applied. The only effect which the reactance tube circuit will then have on the oscillator will be due to the current drawn through phase shifting circuits **15** and **20** which can be limited to any desired value by choosing resistors R_1 and R_2. Since the load drawn from the oscillator by the phase shifting circuits will be constant regardless of the amount of loading on the oscillator, it will not be a source of instability for the oscillator.

When audio voltage is applied to primary **22**, two equal but opposite phase audio voltages will be induced in the secondary **23** because of center tap **24**. One voltage E_M will be induced in the half designated as MN and the other voltage Es will be induced in the half designated as NS. Because of their opposite phase, voltage E_M will be increasing while voltage Es will be decreasing and vice versa. Due to the transconductance of the suppressor grids **26** and **27**, the plate currents I_{P_1} and I_{P_2} will therefore proportionately increase and decrease respectively at the same instant. The currents I_{P_1} and I_{P_2} will then no longer be equal and their difference, which is the net output current I, will be proportional to the audio input voltage. This will be seen by examining Figure 4 and observing what opposite variations in the length of the I_{P_1} and I_{P_2} vectors will do. Net current I will lead when the audio voltage swings positive, and it will lag when the audio voltage swings negative as shown in Figure 5. The output impedance of the circuit will therefore vary capacitively on positive audio swings and inductively on negative audio swings which will frequency modulate oscillator tank circuit **10** about its center resonant frequency.

Blocking condenser **25** blocks grid current flow through L_1 and grid leak resistors **31** and **32** prevent charge build-up on control grids **16** and **18**.

Since a preferred embodiment of this invention has been disclosed, various modifications and changes may be made by those skilled in the art without departing from the spirit and scope of the invention as hereafter defined by the appended claims.

I claim:

1. A reactance tube circuit comprising, a pair of electron tubes, an audio transformer with its primary connected to an input signal, the mid-point of the secondary of said transformer connected to ground, one end of said secondary of said transformer connected to a first grid of said first electron tube, the other end of said secondary connected to a first grid of the second electron tube, the cathodes of said first and second electron tubes connected together, the plates of said first and second electron tubes connected together, a first phase shifting circuit comprising a first condenser and first inductor connected respectively in series between ground and the plates of said tubes, a second phase shifting circuit comprising a second inductor and second condenser connected respectively in series between ground and the plates of said tubes, a second control grid of the first electron tube connected to the ungrounded terminal of the first condenser, a second control grid of the second electron tube connected to the ungrounded terminal of the second inductor, and a tunable oscillator connected to the plates of said first and second electron tubes.

2. A reactance tube circuit comprising, a pair of electron tubes with their plates and cathodes connected together respectively, an input transformer with its primary connected to an input voltage, the midpoint of the secondary of said input transformer connected to ground, one end of said secondary connected to a first control grid of said first electron tube, the other end of said secondary connected to the first control grid of the second electron tube, a variable oscillator with its frequency controlling circuit connected to the plates of said first and second electron tubes, a first phase shifting circuit comprising a resistor, a condenser and an inductor connected serially between the plates of said electron tubes and ground with one terminal of said inductor connected to ground, a second phase shifting circuit comprising a resistor, an inductor and a condenser serially connected between the plates of the electron tubes and ground with one terminal of said condenser conected to ground, a second control grid of the first electron tube connected to the other terminal of said inductor of the first phase splitting circuit, and a second control grid of the second electron tube connected to the other terminal of said condenser of the second phase splitting circuit.

3. A reactance tube circuit comprising, a pair of electron tubes with their plates and cathodes connected together respectively, an input transformer with its primary connected to an input voltage, the midpoint of the secondary of said input transformer connected to ground, one end of said secondary connected to a first control grid of said first electron tube, the other end of said secondary connected to the first control grid of the second electron tube, a variable oscillator with its frequency controlling circuit connected to the plates of said first and second electron tubes, a first phase shifting circuit comprising a resistor, a condenser and an inductor serially connected between the plates of said electron tubes and ground with one terminal of said inductor connected to ground, a second phase shifting circuit comprising a resistor, an inductor and a condenser connected between the plates of the electron tubes and ground with one terminal of said condenser connected to ground, a second control grid of the first electron tube connected to the ungrounded terminal of the inductor of the first phase shifting circuit, a second control grid of the second electron tube connected to the ungrounded terminal of the condenser of the second phase shifting circuit, and said first and second phase shifting circuits resonant at the desired center operating frequency of the oscillator.

4. A modulator circuit for varying the frequency of an oscillator comprising, a pair of electron tubes with their plates and cathodes connected together respectively, the

oscillator connected to the plates of said first and second electron tubes, a first phase shifting circuit connected between the plates of said tubes and ground and comprising a resistor, a capacitor and an inductor and connected in series with one terminal of said inductor connected to ground, a second phase shifting circuit connected between the plates of said tubes and ground and comprising a resistor, an inductor and a capacitor and connected in series with one terminal of said capacitor connected to ground, an input transformer with its primary connected to an input voltage, the secondary of said input transformer with its center point connected to ground, one end of said secondary connected to a first control grid of the first electron tube, the other end of said secondary connected to a first control grid of the second electron tube, a second control grid of the first electron tube connected to the other terminal of said inductor of the first phase shifting circuit, and a second control grid of the second electron tube connected to the other terminal of said capacitor of the second phase shifting circuit.

5. A modulator circuit for varying the frequency of an oscillator comprising, a pair of electron tubes with their plates and cathodes connected together respectively, the oscillator connected to the plates of said first and second electron tubes, a first phase shifting circuit connected between the plates of said tubes and ground and comprising a resistor, a capacitor and an inductor and connected in series with one terminal of said inductor connected to ground, a second phase shifting circuit connected between the plates of said tubes and ground and comprising a resistor, an inductor and a capacitor and connected in series with one terminal of said capacitor connected to ground, an input transformer with its primary connected to an input voltage, the secondary of said input transformer with its center point connected to ground, one end of said secondary connected to a first control grid of the first electron tube, the other end of said secondary connected to a first control grid of the second electron tube, a second control grid of the first electron tube connected to the other terminal of said inductor of the first phase shifting circuit, a second control grid of the second electron tube connected to the other terminal of said capacitor of the second phase shifting circuit, and the first and second phase shifting circuits resonant at the desired center frequency of the oscillator.

6. A modulator circuit for varying the frequency of an oscillator comprising, a pair of electron tubes with their plates and cathodes connected together respectively, the oscillator connected to the plates of said first and second electron tubes, a first phase shifting circuit connected between the plates of said tubes and ground and comprising a resistor, a capacitor and an inductor and connected in series with one terminal of said inductor connected to ground, a second phase shifting circuit connected between the plates of said tubes and ground and comprising a resistor, an inductor and a capacitor and connected in series with one terminal of said capacitor connected to ground, an input transformer with its primary connected to an input voltage, the secondary of said input transformer with its center point connected to ground, one end of said secondary connected to a first control grid of the first electron tube, the other end of said secondary connected to a first control grid of the second electron tube, a second control grid of the first electron tube connected to the other terminal of said inductor of the first phase shifting circuit, a second control grid of the second electron tube connected to the other terminal of said capacitor of the second phase shifting circuit, and first and second grid resistors connected between the second grids of the first and second electron tubes and ground.

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