June 17, 1947. N. I. KORMAN 2,422,422

REACTANCE TUBE CONTROLLED GENERATOR

Filed Aug. 31, 1942 2 Sheets-Sheet 1

Fig. 1.

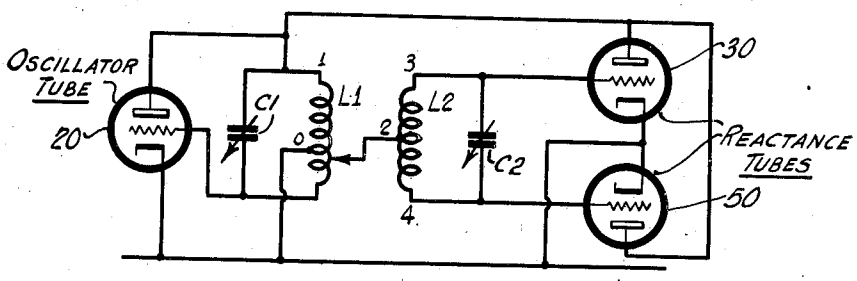


Fig. 2.

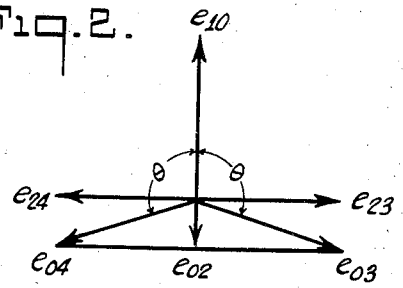
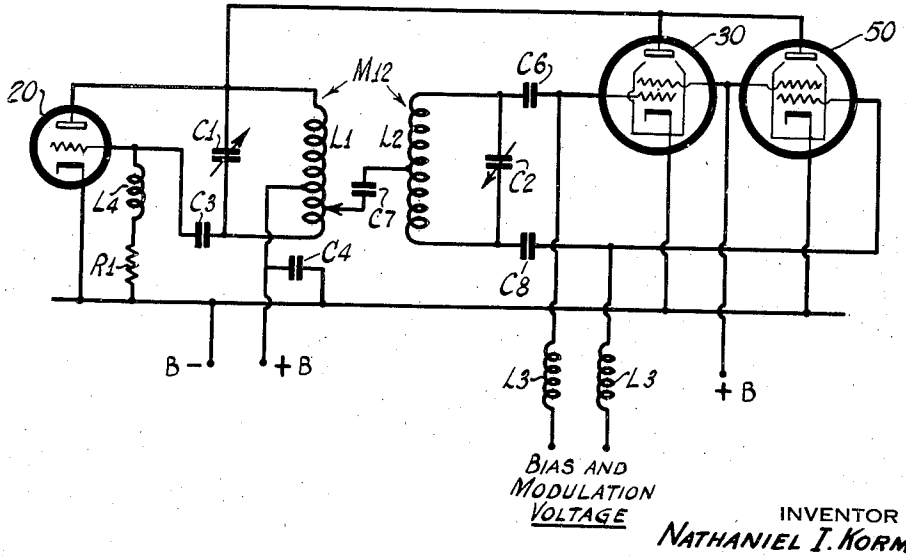


Fig. 3.



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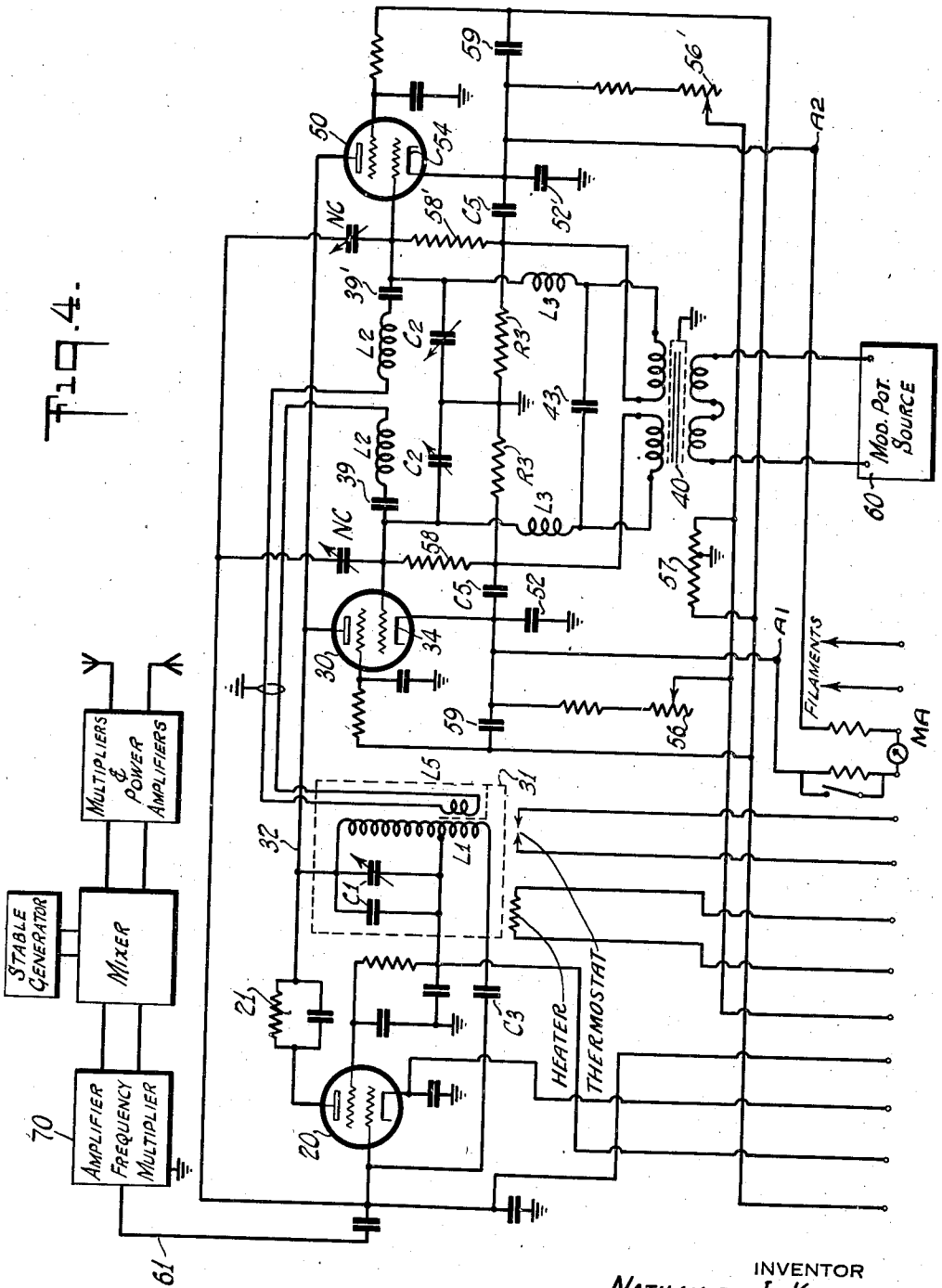
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Fig. 4.



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2,422,422

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2,422,422

REACTANCE TUBE CONTROLLED GENERATOR

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Application August 31, 1942, Serial No. 456,730

22 Claims. (Cl. 179—171.5)

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This application concerns a new and improved system for controlling the angular velocity of wave energy in accordance with control potentials, such as, signals or potentials used for automatic frequency control purposes. In my system, I employ reactance tubes in a new and improved circuit arrangement wherein oscillations are generated and modulated in phase, or in frequency, or controlled as to phase or frequency in accordance with control potentials of any nature. In the specification and claims the term "wave length modulation" will be used and it will be understood that the same means phase and frequency, as well as phase or frequency modulation.

The problem of providing a frequency modulation exciter for broadcast service is complicated by two conflicting requirements, stability of the carrier, and adequate frequency swing with low distortion. The Federal Communications Commission has specified that the carrier, in the 42–50 mc. band must have a stability better than ±2000 C. P. S. and a frequency swing of 75 kc. with an overall microphone-to-antenna distortion of less than 2%.

Commercial exciter units have been of two types, phase modulators and frequency modulators. Phase modulators, because the carrier frequency is determined by piezo-electric crystals, can easily be made to have the required stability, but inherently are low-level modulators requiring several thousand times multiplication before adequate frequency swing is obtained. The high multiplication requires many tubes and brings about a troublesome noise problem which necessitates comprising between too much distortion and too much noise. Phase modulator types of exciters have not proven very satisfactory because of the high noise, high distortion, and complication of many stages of multiplication.

Frequency modulators, comprised of reactance-tube-modulated self-excited oscillators usually have quite low distortion and noise but are inherently unstable in carrier frequency. The carrier frequency may be stabilized by some form of automatic frequency control. This expedient has been used in all commercial exciters of the frequency-modulator type and has proven successful. The main objections have been the complexity of the equipment and, in some cases, that adequate stability, even with automatic frequency control, is difficult to obtain.

A primary object of my invention is to provide a wave length modulation system which will satisfy the above requirements with respect to

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frequency drift, low distortion, etc. without the use of automatic frequency control circuits.

In describing my invention reference will be made to the attached drawings, wherein

Figure 1 is a basic wiring diagram of an oscillator and a reactance tube control therefor arranged in accordance with my invention.

Figure 2 is a vector diagram showing the phase relation of the various voltages appearing in the circuit of Figures 1, 3 and 4.

Figure 3 is a more complete diagram of a controlled oscillator of the nature shown in Figure 1.

Figure 4 illustrates somewhat completely an angular velocity of wave length modulation system arranged in accordance with my invention and including features of Figures 1 and 3 and additional improvements which work to increase the stability of my system. Figure 4 is a somewhat complete diagram of a modulated oscillator which operated well within the requirements outlined above.

The frequency drift of a reactance tube frequency modulator with plate and screen voltage changes may be analyzed into four factors: 1. Oscillator tube transconductance change; 2. Oscillator plate resistance change; 3. Reactance tube plate resistance change; 4. Reactance tube transconductance change. In general the magnitude and direction of the frequency drift due to these changes will depend on the circuit being used. A stabilized unit can be provided by adjusting the frequency drifts due to one or more of the four factors so that the total frequency drift is made very small.

Consider, now, the effect of the reactance tube on the oscillator. If the reactance tube grid voltage is exactly in quadrature with the reactance tube plate voltage (this is the same as the oscillator tank voltage, usually), then the reactance tube will appear to the oscillator tank circuit as a pure reactance shunted by the plate resistance of the reactance tube. If, on the other hand, the reactance tube grid voltage is more than 90° out of phase with the plate voltage, the reactance tube will appear to the oscillator tank as a reactance and a resistance equal to the plate resistance, and also a negative resistance, all in parallel. The magnitude of this negative resistance will depend on the phase angle mentioned above. If the phase is less than 90°, the negative resistance becomes a positive resistance.

Thus, the adjustment of the phase angle, between the reactance tube grid voltage and the plate voltage enables us to regulate the size of

the equivalent shunt resistance of the reactance tube. Since this equivalent shunt resistance changes with plate and screen voltages in the same way that the oscillator plate resistance changes and inversely as the oscillator tube transconductance changes, adjustment of this phase angle provides a convenient means of adjusting the frequency stability.

A circuit for providing this adjustment is given in Figure 1 (supply voltages, grid biases, blocking condensers, etc. have been omitted from this figure).

In Figure 1, 20 is the oscillator tube. Tubes 30 and 50 are the reactance tubes. The oscillator has a tank circuit comprising capacitor C1 and inductance L1 coupling its anode and control grid in a regenerative circuit. The anodes of the reactance tubes 30 and 50 are tied together and connected to the oscillator tube anode end of tank circuit C1—L1. The cathodes of the reactance tubes 30 and 50 are tied together and to the cathode of the oscillator tube 20 and to a point 0 on the tank circuit inductance L1. The control grids of the reactance tubes are coupled in push-pull relation by a phasing tank circuit including inductance L2 and condenser C2. The inductance L2 is inductively coupled to the inductance L1 and the electrical center 2 of L2 is connected by a movable tap to a point on L1.

The generated voltage on the tank circuit between the points 1 and 0 (the cathodes of tubes 30 and 50 are also connected to this point) is represented by $e10$ in Figure 2, and since the anodes of the reactance tubes 30 and 50 are tied together, this voltage may also be considered as being applied to the anodes of reactance tubes 30 and 50. The voltage between the point 0 on L1 and the point 2 on L2 is represented by the vector $e02$ in Figure 2, and, obviously, this voltage being tapped from a point on L1 on the other side of the point 0 with respect to point 1 is 180° out of phase with respect to the voltage represented by $e10$. A voltage is induced from L1 to L2 and appears across L2. This voltage between the points 2 and 3 is represented by the vector $e23$ in Figure 2 and the voltage between the points 2 and 4 is represented by the vector $e24$. Note that these vectors also may be considered as representing the voltages applied differentially to the control grids in the absence of the movable tap connection between L1 and L2 which forms a part of my improved system and introduces the voltage represented by vector $e02$. The voltage between the points 0 and 4 is represented by $e04$ and this also represents the voltage on the grid of reactance tube 50. The vector $e03$ represents the voltage between the points 0 and 3 and also represents the generated voltage on the grid of tube 30. The vector $e04$ is a resultant of vectors $e02$ and $e24$, while the vector $e03$ is a resultant of the vectors $e02$ and $e23$. In the position shown vector $e02$ represents a voltage in phase opposition to the voltage represented by vector $e10$ and the phase angle θ is more than 90° so that the tube reactances are complex and include a negative resistance component as well as a reactive component. By adjusting this tap, the resultant voltage set up on the control grids of the reactance tubes 30 and 50 may be adjusted to have 90° displacement relative to voltages on the anodes of tubes 30 and 50 or more than 90° or less than 90°.

By moving the tap up on inductances L1 past point 0, this phase angle may be made less than 90° to provide positive resistive components.

As explained in columns 2 and 3, adjustment of this phase angle to give a positive or negative component is valuable because we can use this adjustment to obtain a greater freedom from frequency drift due to plate and screen supply voltage fluctuations.

The arrangement of Figure 3 is in principle the same as that of Figure 1. In Figure 3 I have shown in more detail a tube generator with a pair of tube modulators connected thereto and in so doing reference letters and numerals corresponding to those in Figure 1 are used. In Figure 3 I have shown the biasing circuits for the oscillator tube 20 comprising a choking inductance L4 and biasing resistor R1. The oscillator circuit also includes a blocking condenser C3 and there is a second blocking condenser C7 in the connection between the points on L1 and L2 and a potential source bypassing condenser C4. The reactance tube tank circuit L2—C2 is coupled to the grids of reactance tubes 30 and 50 by blocking and coupling condensers C6 and C8. In Figure 3, the reactive effect with or without a resistive component, which may be negative or positive, is obtained as disclosed hereinbefore. The reactive effect may be controlled by applying modulation voltages differentially between the control grids of the reactance tubes by way of radio frequency choking inductances L3. Bias for the reactance tubes is also supplied to these leads. This bias may be supplied to the center tap of a biasing resistor shunting the leads or to a point on the secondary winding of a transformer connected to the leads.

A modulation system including the features of my invention discussed above and additional novel features has been shown in Figure 4 of the drawings. In Figure 4 the oscillator comprises a tube 20 having its anode and control grid regeneratively coupled by a tank circuit comprising inductance C1—L1. The anode connection includes a plate supply voltage dropping means 21 comprising a resistance and condenser in parallel. The tube, as arranged and coupled, operates in a well known manner to produce sustained oscillations which appear in the tank circuit. The electrode supply potential connections have been shown somewhat completely in the drawings and will not be described herein.

The modulating reactance tubes 30 and 50 have their anodes tied together and connected by lead 32 to the anode end of tank circuit C1—L1. The cathodes 34 and 54 of the reactance tubes are connected to ground for oscillations of the generated frequency by condensers 52 and 52′ so that the impedances between the output electrodes of tubes 30 and 50 are in parallel with a part at least of the tank circuit C1—L1. The control grids of the reactance tubes 30 and 50 are connected in push-pull by a phasing tank circuit comprising split inductances L2 shunted by adjustable tuning condensers C2. Condensers 39 and 39′ are bypass condensers which do not impede the flow of radio frequencies but which do prevent inductances L2 and L5 from shorting the audio transformer 40.

The electrical center of the condenser system is connected to ground and by damping resistors R3 to the cathodes of the tubes through coupling and bypassing condensers C5.

The inductances L2 are, as stated above, in two sections and include in the connection therebetween an inductance L5 inductively coupled to L1. This inductance L5 picks up generated voltages and supplies them substantially differ-

entially to the control grids of tubes **30** and **50**.

The control grids of reactance tubes **30** and **50** are also differentially coupled to the split secondary windings of a transformer **40**. The couplings between secondary windings of transformer **40** and the control grids of the reactance tube include high frequency choking inductances **L3** and the secondary windings are shunted by a radio frequency bypass condenser **43**. Adjacent terminals of the secondary windings of the transformer **40** are connected to the respective reactance tube cathodes by way of the coupling and blocking condensers **C5**, which are of sufficient size to pass readily potentials of control or modulation frequency. The screen grids of reactance tubes **30** and **50** are connected to the supply sources by circuits including filter networks as are the control grids and anodes.

Bias for the control grids is derived by adjustable biasing resistors **56** and **56'**. These bias circuits are completed by way of resistor **57** and ground and from ground to resistors R3 and resistors **58** and **58'** to the control grids of the two reactance tubes. Note that since the control grids are connected to the end of the cathode resistors remote from the cathodes and since in this bias circuit potentials of modulation frequency are shunted by **C5**, direct current degeneration is obtained for reasons pointed out hereinafter.

As will be understood from the foregoing description, the generated voltages on the reactance tube's anodes are of like phase, while the reactance tube's control grid voltages are of substantially opposed phase with one tube's grid voltage advanced substantially 90° with respect to that tube's anode voltage and the other grid voltage retarded substantially 90° with respect to the latter tube's anode voltage. One tube, as a consequence, reflects or adds to the tank circuit **C1**—**L1** and inductive reactance component, while the other tube adds thereto a capacitive reactance component so that differential modulation of the tubes changes the tuning of the tank circuit and, as a consequence, the tuning of the tank circuit is controlled by the modulation potentials from source **60**.

Since the modulation is differential, in general it may be stated that variations in electrode potential, which are in phase, cancel out, while differential variations in accordance with control potential aid each other in their effect on the reactance reflected into the tank circuit.

In the system, instability of the oscillator due to changes in the oscillator tube are minimized by the use of a large oscillator tank capacitance at **C1**. However, the size of this capacitor is limited by the frequency swing required and the amount of reactive current available from the reactance tubes. Push-pull reactance tubes are used to permit the use of a larger oscillator tank capacitor and to balance out the effects on frequency drift due to supply voltage changes. To minimize frequency drift due to variations in the input circuit of the apparatus to be driven by this oscillation, the output is taken by lead **61** from the grid circuit of tube **20**, and it is intended that the input circuit of the driven apparatus at **70** be the grid of a tube operated in Class A.

A serious cause of drift in reactance tube oscillators arises from changes in contact potential between cathode and grid of the reactance tube. The contact potential is of the order of —0.7 volt and varies erratically with life and heater voltage over a range of several tenths of a

volt. Since the audio voltage that may be applied between grid and cathode of a type 1614 tube is of the order of 5.0 volts peak, it follows that the ratio of drift due to contact potential to useful frequency swing will be in order of magnitude about

$$\frac{.20}{5.0}=.04$$

F. C. C. requirements call for a ratio of drift to useful frequency swing to be less than

$$\frac{2000}{75000}=.027$$

Evidently, the effect of these contact potential variations must be reduced considerably if the drift requirements are to be met.

In my system direct current degeneration is used to reduce the effect of changes in contact potential. The cathode resistors **56** and **56'** are made large in order to obtain the desired amount of degeneration. Where tubes of 1614 type were used at **30** and **50** in order to obtain a degeneration of ten times, a cathode resistor of 1800 ohms is necessary. The direct current drop across these resistors will be 130 volts. It is, therefore, necessary to obtain the correct control grid bias from a voltage divider **57** in the power supply.

Degeneration in the reactance tube circuits at audio frequencies must be avoided because its effect is to destroy the linearity of the transconductance vs. grid bias characteristic and to introduce distortion. Such degeneration at the audio frequency or modulation potential frequency is kept down to a sufficiently small degree by use of the audio voltage input directly from cathode to grid of each reactance tube as shown. It is also necessary in this connection to prevent an audio voltage from developing between cathode and screen grid. This is accomplished by using large capacitors **59** in the screen grid to cathode circuits.

An important cause of frequency drift in oscillators is due to the change of inductance and capacitance in the tank circuit with temperature variations and I include the tank circuit in a chamber **31**, which is temperature controlled by means shown. The tank circuit is also shielded to prevent reaction thereon from the phase adjusting circuits **L2**—**C2** except as desired and obtained by couplings thereto.

As explained previously, the effects of contact potential changes in the reactance tubes are minimized by the use of degeneration. The effects of changes in transconductance of the reactance tubes are minimized by the push-pull connection. A meter MA and variable resistors are incorporated in the circuit between points A—**1** and A—**2** for indicating and readjusting this balance.

It has been noted experimentally that a sizeable quadrature grid voltage appears on the reactance tubes even though the pickup coil for the phasing circuit is disconnected. This voltage appears on the grid because of residual plate-to-grid capacitance in the reactance tube and is undesirable because it has the same phase on both reactance tube grids (for push-pull operation, the reactance tube grid voltage must be 180° out of phase with each other) and results in inequalities in the radio-frequency voltages on the reactance tube grids.

It is of extreme importance that the radio-frequency voltage on the grids of the two reactance tubes be equal. To assure this, I have found it necessary to neutralize the reactance tubes be-

cause the unneutralized plate-to-grid capacitance causes a serious unbalance of the reactance tubes and, consequently, a large frequency drift with plate supply voltage change. The neutralizing condensers are shown at NC and are connected between the control grid of the reactance tubes **30** and **50** and the control grid of the oscillator **20**. These neutralizing condensers feed from the grid of tube **20** to the grids of tubes **30** and **50** voltages substantially equal to the voltages fed from the anodes of tubes **30** and **50** through the tubes to the control grids. The voltages fed to the grids are of opposed phase and thereby neutralize each other.

The function of the grid-phasing circuit L2—C2 is to couple from the oscillator tank to the grids of the reactance tubes in such a way as to make the voltages on the grids of the reactance tubes equal, and approximately 90° out of phase with the voltage across the oscillator tank, one leading phase and the other lagging.

If the (quadrature components of the) reactance tube grid voltages are not equal, the reactance tube blance will be destroyed and plate supply voltage changes will cause a comparatively large frequency shift. If the reactance tube grid voltages are not exactly 90° out of phase with the oscillator tank voltage, the effect will be to introduce a negative (or a positive, depending on the phasing) resistance component into the reactance tube plate currents. This resistive component of reactance tube plate current will vary with modulation and cause amplitude modulation. A moderate amount of negative resistance due to the phasing is desirable since its manner of variation with modulation will be correct to cancel the effect of plate resistance of the reactance tube which also varies with modulation.

When the phasing tank capacitors C2 are correctly tuned, the reactance tube grid voltages are maximum and exactly 90° out of phase with the oscillator tank voltage. When the phasing is tuned correctly, it has been found that minimum distortion is obtained. Also the amplitude modulation, as observed on a cathode ray oscilloscope, is mostly second harmonic and contains no fundamental component. The minimum distortion criterion of tuning is not a critical one but the amplitude modulation criterion is quite sensitive to slight detuning. It has been found that when the phasing tank is detuned far from resonance, the resistive component of reactance tube plate current may be sufficient to throw the circuit out of oscillation over part or all of the modulation cycle. For other conditions of extreme detuning, the negative resistance component of reactance tube plate current may predominate and increase the amplitude of oscillation enough to overload the reactance tube grids with radio frequency voltage and thus cause severe distortion when modulation is attempted. It will be noted that a shield, 31, has been placed between the oscillator tank and the pickup coil. This shielding has been found to be quite important. Capacity coupling from oscillator tank to the pickup coil results in quadrature and resistive components of reactance tube grid voltages which have the same phase on both the grids. The results of such capacity coupling are amplitude modulation which may be severe enough to put the circuit out of oscillation during part or all of the modulation cycle and an unbalance of the reactance tubes which allows plate supply voltage changes to cause frequency drift.

A moderate amount of amplitude modulation

is not serious succeeding class C amplifier stages in the transmitter are effective in removing it. However, as has been stated before, a tendency to excessive amplitude modulation can overload the grid of the reactance tubes and also may put the circuit out of oscillation for part of the modulation cycle.

In the modifications illustrated in Figures 1 and 3 a connection is supplied between the electrical center of inductance L2 and a point on the inductance L1 to supply the voltage represented by the vector *e*02 (Figure 2) to thereby introduce the more than or less than phase quadrature relation between the generated voltages on the grids and anodes of tubes **30** and **50**. In some cases the connection shown in Figures 1 and 3 is necessary to provide this voltage. In other cases, such as, for example, the modulator illustrated in Figure 4, stray capacitance between L5 and L1 accomplishes the same result, and the direct connection is not desirable or necessary. The polarity of the voltage represented by vector *e*02 can be made to oppose the voltage represented by vector *e*10 as shown in Figure 2, or to be the same as that of the voltage represented by *e*10 depending on the point on coil L1 at which the stray capacity originates.

If the stray capacitance is predominantly from the bottom of L1 the resistance component will be negative. If the stray capacitance is predominantly from the top of L1 the resistive component will be positive. Thus, by adjusting the position of L5 with respect to L1 the sign of the resistive component introduced into the oscillator tank may be controlled.

I claim:

1. A simulated reactance comprising two electron discharge systems each having an electron receiving electrode, an electron flow control electrode, and an electron emission electrode, an inductive reactance across which alternating voltages appear, connections tying the electron receiving electrodes together and to a terminal of said inductive reactance to set up on said electron receiving electrodes voltages of a first phase, a connection between a point on said inductive reactance and the electron emission electrodes of said systems, a circuit, including an inductance tuned to the frequency of said alternating voltages, connected between said flow control electrodes, a coupling between said inductances whereby voltages of a second phase are set up in phase opposition on said electron flow control electrodes, and means for supplying a third voltage of reversible phase and adjustable amplitude in phase to said flow control electrodes to thereby modify the phase of said voltages of said second phase.

2. In a signalling system, a tube generator having electrodes regeneratively connected in an oscillation generating circuit, a reactance tube having two electrodes coupled to the generator to derive therefrom voltages of the generated frequency substantially in phase quadrature whereby a reactive effect is provided in said reactance tube, connections between the reactance tube and the generating circuit to add said reactive effect to said circuit to determine in part the frequency of the oscillations generated, and a neutralizing reactance coupling a point on said generating circuit to an electrode in said reactance tube to compensate the reactance coupling within said reactance tube between said two electrodes.

3. In apparatus of the nature described, a pair of electron discharge tubes each having an anode,

a cathode, and a control grid, a reactance comprising an inductance, the tuning of which is to be controlled, a connection between one terminal of said inductance and the anodes of both of said tubes, a connection between a point on said inductance and the cathodes of both of said tubes, a pair of inductances in series between the control grids of said tubes, a coupling between said series inductances and said first mentioned inductance, two condensers in series in shunt to said pair of inductances, a connection between adjacent terminals of said condensers and the cathodes of said tubes, and means for impressing control potentials differentially on said control electrodes.

4. In a wave length modulating system, an oscillation generator comprising an electron discharge tube having an anode, a cathode, and a control grid connected in an oscillation generating circuit including a tuned inductance enclosed in a shield member, a pair of electron discharge devices each having an anode, a cathode, and a control grid, a connection tying the anodes of said devices together and to a terminal of said inductance, a connection betwen the cathodes of said devices and a point on said inductance, a circuit comprising an inductance tuned to the frequency of the oscillations generated coupling the control grids of said devices in push-pull relation, a coupling between said last-named inductance and said first-named inductance, an electro-static shield in the coupling between said inductances, and means for differentially modulating the discharge devices in accordance with signals.

5. In a wave length modulation system, an oscillation generator comprising an electron discharge tube having an anode, a cathode and a control grid connected in an oscillation generating circuit including a tuned inductance enclosed in a shield member, a pair of electron discharge devices each having an anode, a cathode, and a control grid, a connection tying the anodes of said devices together and to a terminal of said inductance, a connection between the cathodes of said devices and a point on said inductance, a circuit comprising an inductance tuned to the frequency of the oscillations generated coupling the control grids of said devices in push-pull relation, a coupling between said last-named inductance and said first-named inductance, an electro-static shield in the coupling between said inductances, a neutralizing condenser connecting the control grid of each of said devices to said generator, and means for differentially modulating the discharge devices in accordance with signals.

6. In apparatus of the nature described, an electron discharge system having an electron receiving electrode, an electron flow control electrode, and an electron emission electrode, a connection for impressing alternating current voltage of a first frequency and phase on the electron receiving electrode, a connection for impressing alternating current voltage, of the same frequency and of a phase displaced substantially 90° with respect to the phase of said voltage of said first phase on the electron flow control electrode, whereby a reactive effect is produced in said system between said electron receiving electrode and said electron emission electrode, and a coupling for impressing an additional voltage of adjustable amplitude and reversible phase on the said electron flow control electrode in phase displaced relation with respect to the said other voltage impressed on said electron flow control electrode so that the resultant voltage impressed on said electron flow control electrode may be displaced 90° or more or less with respect to the voltage on the electron receiving electrode of said system.

7. In apparatus of the nature described, a pair of electron discharge systems each having an electron receiving electrode, an electron flow control electrode, and an electron emission electrode, connections for impressing alternating current voltages of like frequency and phase on the electron receiving electrodes, connections for impressing alternating current voltages of the same frequency and of opposed phase on the electron flow control electrodes, said last-named voltages being displaced substantially 90° with respect to said voltages on the electron receiving electrodes, whereby reactive effects are produced in said systems between said electron receiving electrodes and said electron emission electrodes, and a coupling for impressing an additional voltage of adjustable amplitude and reversible phase on the said electron flow control electrodes in like phase and substantially in phase quadrature with respect to the said other voltages on said electron flow control electrodes so that the resultant voltages on said electron flow control electrodes may be displaced 90° or more or less with respect to the voltage on the electron receiving electrodes of said systems.

8. A simulated reactance comprising two electron discharge systems each having an electron receiving electrode, an electron flow control electrode, and an electron emission electrode, an inductive reactance across which alternating voltages appear, connections tying the electron receiving electrodes together and to a terminal of said inductive reactance, a connection between a point on said reactance and the electron emission electrodes of said systems, a circuit, including an inductance tuned to the frequency of said alternating voltages, connected between said flow control electrodes, a coupling between said last-named inductance and said first-named inductance, and high resistances in the circuit of said electron emission elements and electron flow control electrodes for causing direct current degeneration in said systems and circuits.

9. A simulated reactance comprising an electron discharge system having an electron receiving electrode, an electron flow control electrode, and an electron emission electrode, an inductive reactance across which alternating voltages appear, a coupling between the electron receiving electrode and a point on said inductive reactance to set up on said electron receiving electrode a voltage of a first phase, a coupling between a second point on said inductive reactance and the electron emission electrode of said system, a coupling between said inductive reactance and said flow control electrode for setting up thereon a voltage which is displaced in phase about 90° with respect to phase so that the tube simulates a reactance, and a second coupling between a point on said last named inductance and said electron flow control electrode to apply thereto a second voltage of reversible polarity and adjustable amplitude to modify the phase of the said voltage of second phase, so that the same may be displaced 90° or more or less with respect to said voltage of first phase to include in said simulated reactance a resistive component of adjustable amplitude and reversible phase.

10. In a signalling system, a tube generator having electrodes regeneratively connected in an

oscillation generating circuit, a reactance tube having a cathode and two electrodes coupled to the generator to derive therefrom voltages of the generated frequency substantially in phase quadrature whereby a reactive effect is provided in said reactance tube, connections between the reactance tube and the generating circuit to add said reactive effect to said circuit to determine in part the frequency of the oscillations generated, a source of direct current potential and circuits including contacts coupling the same to electrodes in said reactance tube and means for reducing the effect of changes in contact potential on the frequency of the oscillations generated as controlled by said reactance tube comprising a direct current degenerative connection between said cathode and one of said other electrodes.

11. In a signalling system, a tube generator having electrodes regeneratively connected in an oscillation generating circuit, a reactance tube having a cathode and two electrodes including a control electrode coupled to the generator to derive therefrom voltages of the generated frequency substantially in phase quadrature whereby a reactive effect is provided in said reactance tube, connections between the reactance tube and the generating circuit to add said reactive effect to said circuit to determine in part the frequency of the oscillations generated, a source of direct current potential and circuits including contacts coupling the source to electrodes in said tube, an impedance degeneratively arranged in a direct current circuit between the cathode and control grid, and a voltage divider connected to said source and connected to said control electrode for supplying biasing potential thereto.

12. In a simulated reactance, an electron discharge tube having an electron receiving electrode, an electron flow control electrode, and an electron emission electrode, a reactance across which alternating voltage appears, a coupling between said reactance and the electron emission electrode of said tube, a coupling between the electron receiving electrode and said reactance to set up on said electron receiving electrode a voltage of a first phase, a coupling between said reactance and said electron flow control electrode for setting up thereon a voltage which is about in phase quadrature with respect to said voltage of said first phase so that a reactive effect is produced in said tube between said electron receiving electrode and said electron flow control electrode, and an additional coupling between said reactance and said electron flow control electrode to set up on said control electrode a second voltage of reversible phase and adjustable amplitude to modify the phase of said voltage of second phase so that it may be displaced more than, equal to, or less than 90° with respect to said voltage of said first phase to provide with the said reactive effect a resistive component of adjustable size and reversible sign.

13. In a simulated reactance, an electron discharge tube having an electron receiving electrode, an electron flow control electrode, and an electron emission electrode, a reactance across which alternating voltage appears, a coupling between said reactance and the electron emission electrode of said tube, a coupling between the electron receiving electrode and said reactance to set up on said electron receiving electrode a voltage of first phase, a coupling between said reactance and said electron flow control electrode for setting up thereon a voltage of a second

phase, a second coupling between said reactance and said electron flow control electrode to apply to said control electrode a second voltage to modify the phase of said voltage of second phase so that it is displaced about 90° with respect to said voltage of said first phase, and a neutralizing reactance for neutralizing the capacity in the tube between the electron flow control electrode and the electron receiving electrode.

14. In a simulated controllable reactance, an electron discharge tube having an electron receiving electrode, an electron flow control electrode, and an electron emission electrode, a reactance across which alternating voltage appears, a coupling between said reactance and the electron emission electrode of said system, a coupling between the electron receiving electrode and said reactance to set up on said electron receiving electrode a voltage of a first phase, a coupling between said reactance and said electron flow control electrode for setting up thereon a voltage of a second phase, a second coupling between said reactance and said electron flow control electrode to apply thereto a second voltage to modify the phase of said voltage of second phase so that it is displaced in phase more than, equal to, or less than 90° with respect to the phase of said voltage of first phase, connections for controlling the gain of said tube in accordance with control potentials to control the value of said simulated reactance, and connections including a reactance for neutralizing the capacity in the tube between the electron flow control electrode and the electron receiving electrode.

15. In a simulated reactance, an electron discharge tube having an anode electrode, a control electrode and a cathode, a reactance across which alternating voltage appears, a coupling between the cathode of said device and said reactance, a coupling between the anode electrode and said reactance to set up on said anode electrode a voltage of a first phase, a coupling between said reactance and said control electrode to apply thereto a voltage of a second phase, a second coupling between said reactance and said control electrode to apply thereto a second voltage to modify the phase of said voltage of second phase on said control electrode, a source of direct current potential and circuits coupling the same to electrodes in said tube and a high resistance in a direct current circuit between said cathode and control electrode for causing direct current degeneration in said tube and circuits.

16. In a modulation system, a simulated reactance including an electron discharge tube having an anode electrode, a control electrode and a cathode, a reactance across which alternating voltage appears, a coupling between the cathode of said device and said reactance, a coupling between the anode electrode and said reactance to set up on said anode electrode a voltage of a first phase, a coupling between said reactance and said control electrode to apply thereto a voltage of a second phase, a second coupling between said reactance and said control electrode to apply thereto a second voltage to modify the phase of said voltage of said first phase on said control electrode, a source of modulating potentials coupled to said tube to control the gain in accordance with modulating potentials, direct current biasing circuits and a source of direct current potential connected with electrodes of said tube and a high resistance in the direct current circuit of said cathode and control

electrode for causing direct current degeneration in said systems and circuits.

17. A system as recited in claim 16 wherein the coupling between said source of modulating potentials and said tube is substantially direct to reduce degeneration at the modulation frequency.

18. In a simulated reactance, a pair of electron discharge tubes each having an electron receiving electrode, an electron flow control electrode and an electron emission electrode, a reactance across which alternating voltage appears, a coupling between said reactance and the electron emission electrodes of said tubes, a coupling between the electron receiving electrodes and said reactance to set up on said electron receiving electrodes a voltage of a first phase, a coupling between said reactance and said electron flow control electrodes for setting up thereon voltages of substantially opposed phase, the voltages on each of said electron flow control electrodes being substantially in quadrature with said voltage of said first phase, a second coupling between said reactance and said electron flow control electrodes to apply to each of said control electrodes an additional voltage to modify the phase of said voltages of opposed phase so that they are displaced in phase more than, equal to, or less than 90° with respect to the phase of said voltages of said first phase, and neutralizing reactances for neutralizing the capacity in the tubes between the electron flow control electrodes and the electron receiving electrodes.

19. In a signalling system, a reactance across which alternating voltage appears of a frequency determined by the value of the reactance, a pair of reactance tubes each having a cathode and two electrodes including a control electrode coupled to the said reactance to derive therefrom voltages of the generated frequency substantially in phase quadrature on the said two electrodes of each tube whereby a reactive effect is provided in each reactive tube, connections between the reactance tubes and the first named reactance to supplement the same by the said provided reactive effects, direct current biasing circuits and a source of direct current potential connected with the electrodes of said tubes and a high resistance in the direct current circuit between the cathode and another electrode in each tube for causing direct current degeneration in said circuits, and means for controlling the gain of the tubes to correspondingly control the provided reactive effects.

20. In a signalling system, an inductive reactance wherein oscillating voltages determined by the value of the reactance appear, two reactance tubes each having two electrodes coupled to the first mentioned reactance to derive therefrom voltages of the generated frequency substantially in phase quadrature whereby a reactive effect is provided in each of said reactance tubes, connections between the reactance tubes and the first mentioned reactance to supplement said first

mentioned reactance by the reactances provided in said tubes, and a neutralizing reactance coupling a point on said first mentioned reactance to an electrode in each of said tubes to compensate the reactance coupling within each of said tubes between said two electrodes.

21. In a modulation system an oscillation generator comprising an electron discharge device having an anode, a cathode and a control grid, a circuit including an inductance regeneratively coupling the electrodes of said device for the production of oscillatory energy when direct current operating potentials are applied to the electrodes of said device, direct current connections to said electrodes for applying operating potential thereto including positive direct current for said anode, a reactance tube having two electrodes coupled to said generator to derive therefrom voltages of the generated frequency substantially in phase quadrature whereby a reactive effect is provided in said reactance tube, connections between the reactance tube and the generating circuit to add said reactive effect to said circuit to determine in part the frequency of the oscillations generated, means for controlling the gain of the tube in accordance with signals to correspondingly control the value of the reactive effect and swing the frequency of the oscillations generated, and a resistance and condenser in parallel in the direct current connections to said anode of said device for reducing the said anode voltage to increase said reactive effect and said frequency swing.

22. In apparatus of the nature described, a tuned inductance enclosed in a shield member, means for setting up oscillatory energy of the frequency to which said inductance is tuned in said tuned inductance, a pair of electron discharge devices each having an anode, a cathode and a control grid, a connection tying the anodes of said devices together and to a terminal of said tuned inductance, a connection between the cathodes of said devices and a point on said inductance, a circuit comprising an inductance tuned to the frequency of the oscillations generated coupling the control grids of said devices in pushpull relation, there being mutual inductance between said last named inductance and said first named inductance, and an electrostatic shield between said inductances.

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