

Oct. 13, 1942.

G. L. USSELMAN

2,298,438

FREQUENCY MODULATION SYSTEM

Filed Oct. 17, 1940

4 Sheets-Sheet 1

Fig. 1

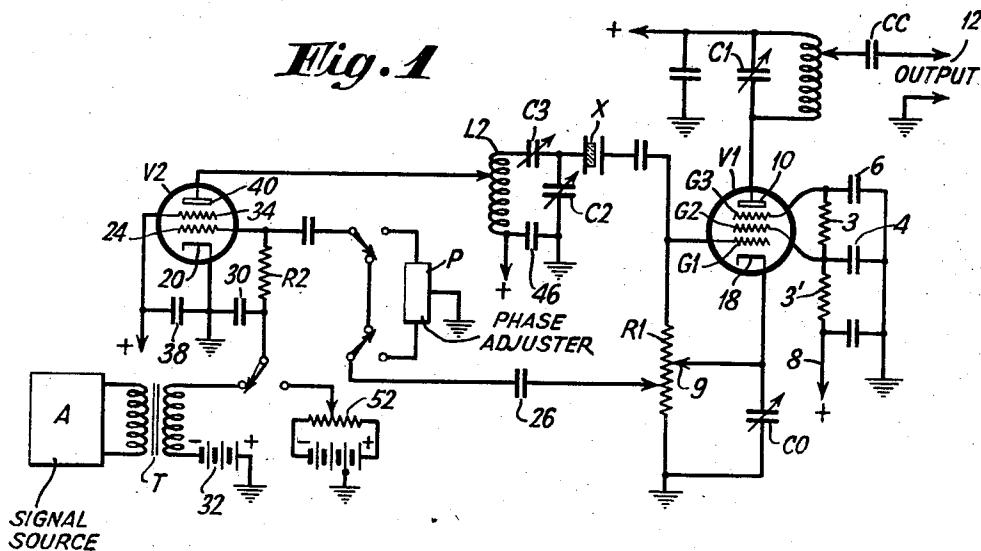
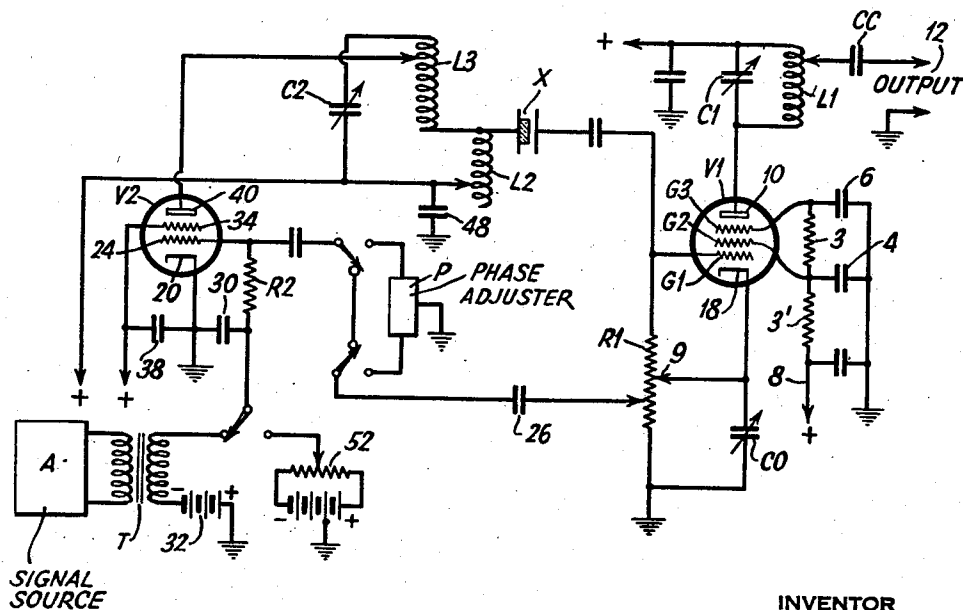


Fig. 2



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Fig. 5

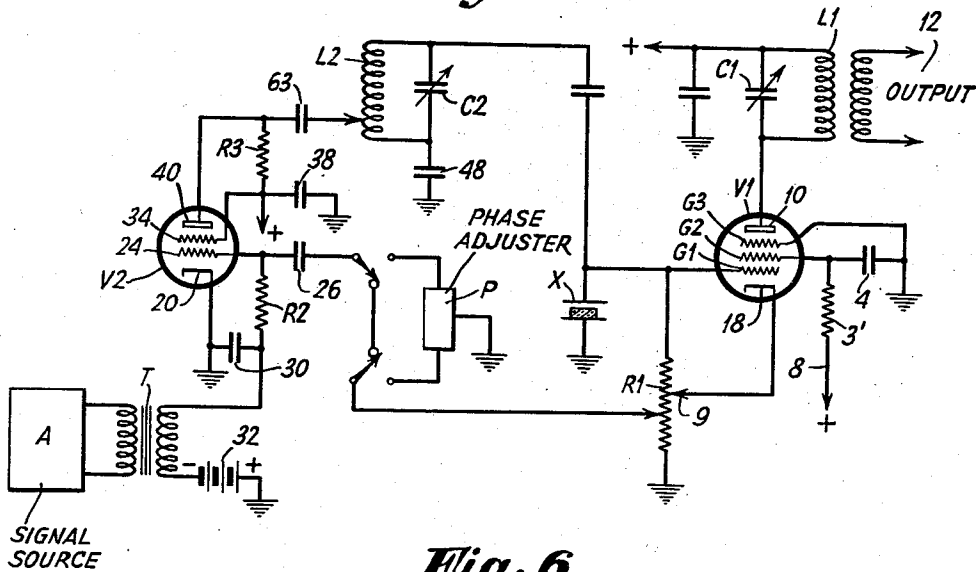
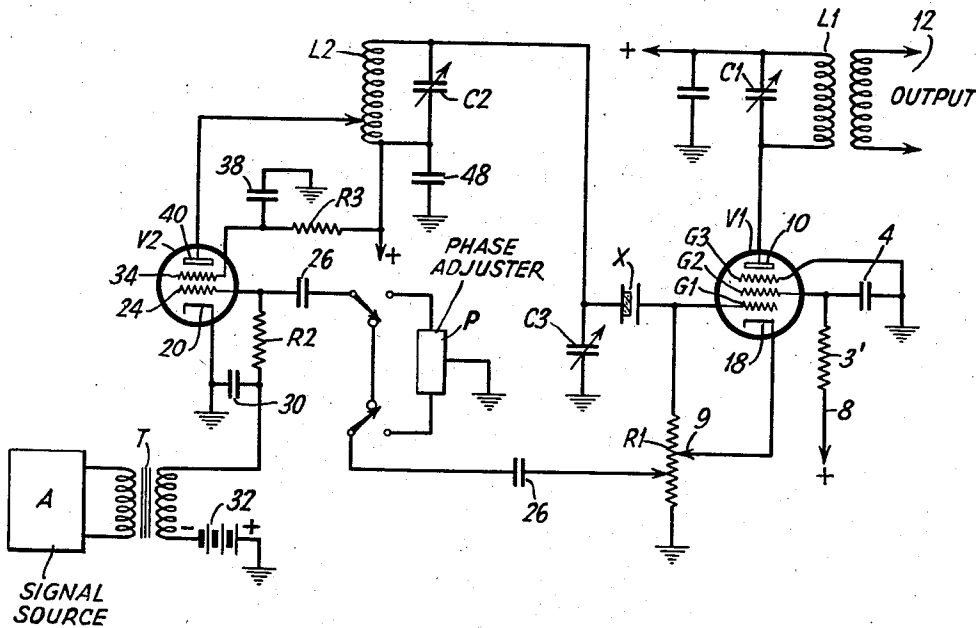


Fig. 6



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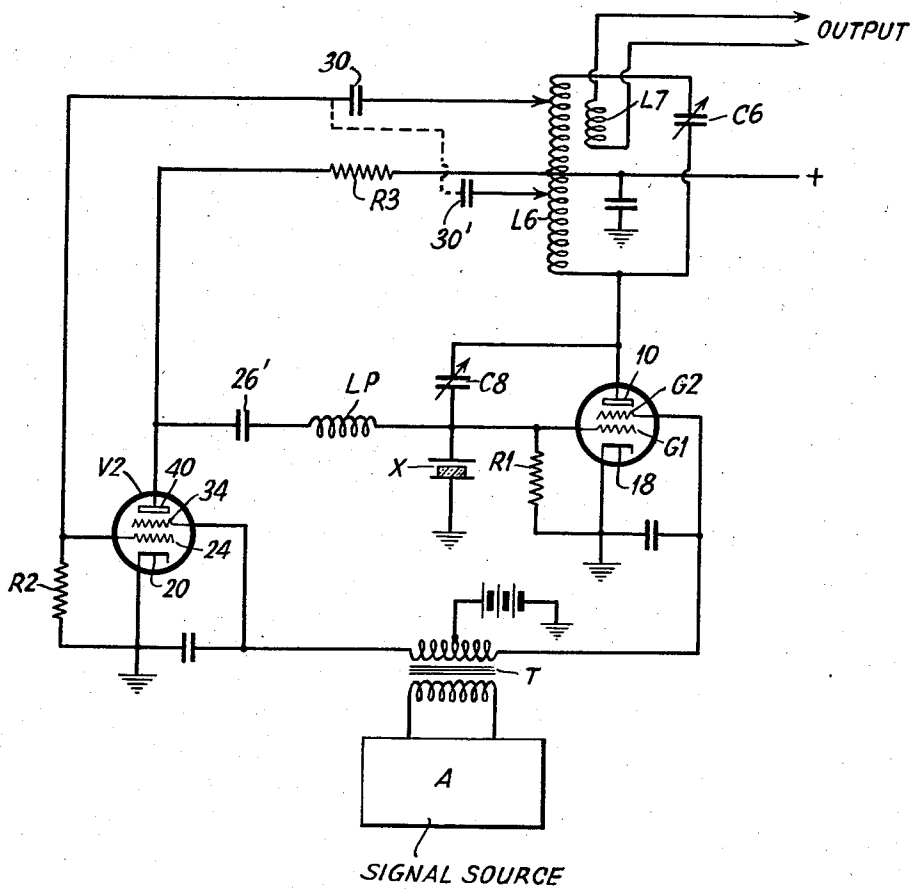
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4 Sheets-Sheet. 4

Fig. 7



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2,298,438

FREQUENCY MODULATION SYSTEM

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Application October 17, 1940, Serial No. 361,506

6 Claims. (Cl. 179-171.5)

This application concerns a new and improved method of and means for producing wave energy the frequency of which is modulated in accordance with signals.

The crystal oscillator circuit used in this frequency modulator is of the aperiodic type, except for the piezo-electric crystal, having the anode grids grounded for radio frequency. These features contribute considerably to the improved operation of this circuit. The principles involved in my present disclosure are similar in many respects to those involved in my United States application #338,837 filed June 5, 1940 and in my United States application #338,838 filed June 5, 1940.

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

Figs. 1 to 7, inclusive, each show the essential features of a system for generating wave energy and modulating the frequency thereof in accordance with control potentials; in Fig. 1, an oscillator tube of the electron-coupled type has its anode connected to an output circuit, other electrodes connected to an oscillation generating circuit including a piezo-electric crystal with means for deriving a voltage from said circuit, supplying the same to an amplifier tube the gain of which is controlled in accordance with control potentials with means for supplying the amplified voltage back to the generator circuits in phase displaced relation with respect to the voltage generated therein to produce a controllable reactive effect for frequency modulation purposes. The phase shift may be derived by a grid phase shifter or by a detuned coupling. In the modifications shown in Figs. 2, 3, 4, 5, and 6, the circuits coupling the output of the modulator tubes to the oscillation generating circuits are modifications of the corresponding couplings of Fig. 1.

In Fig. 7, the excitation voltage for the modulator tube is derived from the output circuit of the oscillator and the oscillator, as well as the modulator, are controlled by the controlling potentials to produce frequency modulation and balance out amplitude modulation.

The oscillators in the circuits of Figs. 1 to 6, inclusive, are all of the same general type. These oscillators are of the crystal controlled grounded anode type in which the second grid G2 of tube V1 serves as the anode of the oscillator and is bypassed to ground for radio frequency by means of condenser 4. The third grid G3 may be grounded directly as shown in Figs. 5 and 6 or it may be biased through a resistance 3 and bypassed to ground for radio frequency by means

of a separate condenser 5 as shown in Figs. 1, 2, 3 and 4. If desirable, a tube having only two grids may be used in place of V1. In this case, grid G2 as shown in Fig. 7 serves in place of the present grids G2 and G3. Both the second and third grids in Figs. 1, 2, 3 and 4 are supplied with positive potentials through resistors 3 and 3' from a source not shown by means of lead 8. Resistors 3 and 3' act as a periodic smoothing impedances to keep radio frequency out of lead 8. The anode 10 of tube V1 is supplied with positive current and potential through tank circuit C1, L1, from a power source not shown. This source may be the same as the source which supplies voltage to lead 8 or it may be a separate source. The output circuit 12 for the frequency modulator is coupled through a coupling condenser CC to the tank coil L1 in Figs. 1 to 4, inclusive. The output coupling may be inductive as shown in Figs. 5 and 6. The control grid G1 of the oscillator tube V1 is connected to one of the crystal electrodes, the other crystal electrode being connected to the cathode of tube V1 through circuits described in detail later to thereby be included in the oscillator circuits. The potentiometer grid leak resistor R1 is connected between the control grid G1 of tube V1 and ground. The cathode 18 of tube V1 is connected to a movable tap 9 on resistor R1.

The modulator circuits comprising reactances L2, C2, C3, tube V2, etc., are substantially alike except for minor differences as stated below. In all of the modifications shown in Figs. 1 to 6, inclusive, the cathode 20 of tube V2 is grounded. The control grid 24 of tube V2 is excited by high frequency oscillations because it is connected to a tap on resistor R1 through a blocking condenser 26 as shown. The high frequency oscillations are amplified in V2 and returned via the crystal X in shunt or in series to the grid G1 of tube V1 so that the phase of excitation of grid G1 is made up of two voltage components, one due to regeneration in V1 and the other fed back through V2. The latter varies in phase as will be described later and this produces phase and frequency modulation of the generated wave. Fig. 1 shows a phase shifting reactance P connected in this modulator grid radio-frequency excitation circuit. The modification of Fig. 7 will be taken up separately because of the differences between it and the circuits of the prior figures.

The two voltage components on grid G1 discussed above are displaced in phase in the unmodulated condition and during modulation this phase displacement is varied as will be described

more in detail hereinafter. The phase displacement may be introduced by a phase shifter P or by proper tuning of the circuits L2, C2, as will be described later.

A resistor R2 is connected to the control grid 24 of tube V2. The other end of resistance R2 is by-passed to ground for radio frequency by means of a condenser 30 and it is also connected to one terminal of the secondary winding of transformer T. The other terminal of this secondary winding is connected through a source of negative bias 32 to ground. The primary winding of transformer T is connected to a signal source A. The screen grid 34 of tube V2 is by-passed to ground for radio frequency by condenser 38 and connected to a source of positive potential, not shown, which may be the same source connected to lead 8.

The anode 40 of modulator tube V2 is tapped to a point on L2 and is supplied with positive current and potential through the coil L2 of tank circuit C2, L2, in Figs. 1, 3, 4, and 6. In Fig. 2, the anode 40 of V2 is tapped to a point on an inductance L3 in series with coil L2 and receives its positive current and potential supply through these inductances. In Fig. 4, a resistance R3 is included in the direct-current circuit of anode 40 of tube V2. In Fig. 5, the anode alternating-current circuit of tube V2 includes a blocking condenser 63 tapped on coil L2 and the direct-current circuit includes resistance R3. In Fig. 6, the anode 40 of V2 is tapped to a point on L2 which is connected to the plate source.

In Fig. 1, the coil L2 is paralleled by variable condensers C2 and C3 connected through coupling and blocking condensers 46. The connection between condensers C2 and 46 is grounded directly thereby including condenser C2 and crystal X in the grid circuit of the oscillator V1. The condensers C2 and C3 and inductance L2 form a tank circuit for the modulator tube V2. The anode 40 is connected substantially at one end of the said tank circuit, while one terminal of crystal X is connected to a point intermediate the ends thereof.

Fig. 2 is quite similar to Fig. 1, the main difference being that in Fig. 2, an inductance L3 replaces condenser C3 of Fig. 1 so that the tank circuit in Fig. 2 comprises condenser C2 and inductances L3 and L2.

In Fig. 3, the modulator tank circuit is similar to that of Fig. 1 except that C2 is in the position of C3 of Fig. 1 and L3 is in the position of C2 of Fig. 1.

In Fig. 4, the coil L2 is paralleled by variable condensers C2 and C3 and the connection between these condensers is grounded directly. The condensers C2 and C3 are preferably operated by one control shaft. Note in this figure that the anode 40 of modulator tube V2 is connected near one end of tank circuit L2, C2, C3, and the electrode of crystal X is connected to the other end of the coil L2. The other electrode of crystal X is connected or coupled to the grid G1 of tube V1 so that it is in a series grid circuit including condenser C3 to ground, etc.

In Fig. 5, the modulator tank circuit comprises L2, C2, and the anode 40 of tube V2 is coupled by condenser 63 to a point on L2. One terminal of crystal X is grounded and one terminal of C2 is grounded for radio frequency through condenser 48. The crystal X, which is in the grid circuit of the oscillator tube V1, is in parallel with condenser C2 in this figure whereas in the prior

figures it is in series with one or more elements of the tank circuit connected with anode 40. The anode 40 is tapped through condenser 63 to a point on the tank circuit coil and the crystal has one electrode coupled to the high end of the tank circuit.

In Fig. 6, C2 and C3 are in parallel while the crystal X is connected in series with C3 so that it is included in the grid circuit of oscillator V1. One terminal of crystal X is connected to one end of inductance L2 of the tank circuit so that, as in all figures, an excitation voltage from the modulator tank circuit is fed to the crystal.

As stated above, Fig. 7 will be described separately in detail hereinafter. The general description and comparison of Figs. 1 to 6 will now be followed by detailed description of each of Figs. 1 to 6 and the operation thereof.

In Figs. 1, 2, 3, 4, 5 and 6, the operation of the crystal oscillator circuit with tube V1 is the same. The operation of grounded anode crystal oscillator circuits has been described in prior art and need not be described here.

The operation of the modulators in these circuits requires either the use of a phase shifting network P in the grid excitation circuit of tube V2 or the slight detuning of the modulator tank circuit L2, C2, etc., to obtain the phase shift in the modulating radio-frequency excitation energy to be delivered to tube V1. When the phase shifter at P is used, the modulator tank circuit comprising inductance L2, L3 and condenser C2 and C3 is either detuned a large amount or it is substantially tuned.

In Fig. 1, assume the phase shifter P is in the grid excitation circuit of tube V2. The tank circuit L2, C2, C3 is detuned substantially from resonance at the frequency of the excitation voltage. Excitation energy is taken from resistor R1 and after passing through phase shifter P it is delivered to the control grid 24 of tube V2. This excitation energy is of the frequency of operation of the oscillator of tube V1. In passing through the phase shifting network P the phase of the excitation energy is rotated say about 90 degrees lagging (it could be 90 degrees or any other angle in the leading direction depending on the type of phase shifter P used). In passing through the tube V2 this energy is amplified and reversed substantially (180°) in phase. Since the anode 40 and crystal X are both connected to the tank circuit on the same side of the radio frequency ground which is at one end of the tank circuit, no further displacement of the phase of the wave energy takes place here. This energy is delivered to the crystal X with a lagging phase angle of about 90 degrees. Now the oscillating current from the grid of tube V1 passes through the crystal and through condenser C2 to ground. Since condenser C2 carries both the crystal oscillating current and the modulator tank oscillating current, this is the element which couples the modulator tank circuit to the crystal oscillator circuit. The modulator current in condenser C2 and the crystal current in condenser C2 provide the two controlling voltage components. These two voltage components are adjusted to a phase displaced relation when no modulation is applied to the grid 24 of tube V2. The excitation voltage on the control grid of oscillator tube V1 is the resultant of these two components.

As stated before, the radio-frequency excitation potential on the control grid of the oscillator tube V1 is the resultant of these two excitation

components. If the amplitudes of the currents and voltages in the modulator tube V2 are modulated by the signal oscillations from source A, the amplitude of the modulator excitation energy component delivered from the modulator circuit through the crystal X to the control grid of the oscillator tube V1 will also be modulated in accordance with the signal. This causes corresponding changes in the frequency of operation of the oscillator. Thus, we have two components displaced in phase one of which components is modulated in amplitude at signal frequency. As a consequent, the resulting excitation on grid G1 changes in phase at signal frequency. There is another factor which has an effect on the phase angle of the modulator excitation energy component. The anode of modulator tube V2, if it is tapped across a portion of the inductance coil L2 of the modulator tank circuit, constitutes a variable resistance across part of this inductance. Consequently, during the process of modulation, the variation of anode current in effect causes some change in the tuning of the modulator tank circuit. Therefore, the modulation excitation energy component, which we assumed to have a 90 degree phase relation to the oscillation energy component at the grid G1, not only is modulated in amplitude but also is varied in phase angle a few degrees each side of the average assumed 90 degree relationship during the modulation cycle. As seen from the vector relations, this causes the amplitude and the phase angle of the resultant grid excitation energy of the oscillator to vary according to the signal oscillations. These phase changes are added to each cycle of the oscillations and, consequently, causes a change in the frequency of the oscillations. For any value of modulator bias within the operating range, the frequency shift or change is limited to a value where an equal and opposite excitation energy phase shift occurs which is caused by the opposite tuning of the various circuits due to the frequency change. There is also a limit to the possible total range of modulation caused by limitations in modulator tube current and by the angle of the excitation energy components.

Now assume that the phase shifter P is removed from the excitation circuit for grid G1 of the modulator tube V2 and that the phase displaced relation between the crystal excitation voltage for grid G1 and the voltage fed back from V2 is to be obtained in a different manner. The tank circuit L2, C3, C2 is slightly detuned from resonance preferably on the low capacity side of resonance. Then the tank circuits represent a reactance. In this case the phase of the excitation energy on the control grid G1 of modulator tube V2 is the same as that on the control grid G1 of the oscillator tube V1. In passing through the modulator tube V2 this energy is amplified and reversed substantially (180 degrees) in phase. If the modulator tank circuit was in tune it would represent a resistance but since the modulator tank circuit is slightly detuned, it represents a reactance and gives the excitation energy an additional phase rotation of say about 90 degrees in a direction depending on the direction of detuning. When detuned on the low capacity side the reactance is inductive. Consequently, the component fed from the modulator to the oscillator and the oscillator components of the grid excitation are at approximately 90 degrees phase displacement and the control grid radio-frequency excitation voltage

for the grid G1 of oscillator tube V1 is the resultant of these two components. This resultant varies in phase due to amplitude and/or phase variations of the component fed back by tube V2 as described above and results in frequency modulation of the oscillations generated.

The output circuit C1, L1 of this frequency modulator is electronically coupled to the oscillation circuit by means of the anode 10 of tube V1. This insures minimum reaction on the modulating system.

An advantage which this circuit has is that when modulator currents are cut off the crystal oscillator will continue to function as long as it is supplied with steady electrode potentials.

In Fig. 1, it appears preferable to obtain the phase shift necessary for providing on the grid of V1 the phase displaced excitation voltages as described hereinbefore, by slightly detuning the modulator tank circuit L2, C2, etc. Under these circumstances the phase shifting element is not included in the connection between the grid G1 and grid 24. When the phase shift is obtained by slightly detuning the tank circuit, the excitation from the modulator, that is the voltage supplied from R1 to 26, is amplified in V2, and supplied to crystal X from the modulator in phase displaced relation with respect to the voltage of the oscillator V1 due to the phase shift occasioned by detuning the tank circuit L2, C2, etc.

In my United States application Serial No. 338,838 filed June 5, 1930, I have illustrated several modifications wherein the piezo-electric crystal is effectively in series with the grid and cathode of the tube V1 as illustrated in Figs. 1 to 4 and 6 of the present application. In my said other application, Serial No. 338,837 filed June 5, 1940, the crystal is effectively shunted by the impedance between the grid G1 and the cathode of tube V1, as illustrated in Fig. 5 of this application.

Moreover, I found during operation that a small air gap in the crystal holder gives a greater range of frequency modulation than a wide air gap does.

The amplitude modulation incidentally caused by the frequency modulator is nearly all suppressed by the following stage and that little which remains can be eliminated in a radio transmitter by the use of subsequent amplitude limiter stages such as the usual frequency multiplier stages. The frequency modulated carrier energy may then be amplified and/or multiplied in frequency in succeeding transmitter stages before it is delivered to the antenna.

Any suitable type of phase shifting network P may be used in these circuits. It may be of the type shown in Fig. 1 or of my United States application No. 338,838 filed June 5, 1940, Fig. 5. It may instead be a series coil, parallel condenser arrangement. It may be a combination of resistances and coils or condensers or both. There may be only one stage or many stages in the phase shifting network.

It should be noted that the terminating load on the phase shifting network P, such as the resistor R2 and the control grid capacity of the modulator tube V2, affects the operation of the network and must be taken into consideration for phase shift calculations. The necessary adjustment of the modulator circuit may be accomplished by connecting R2 to source 52.

It may be noted that a condenser CO has been connected between the cathode of tube V1 and

ground. This capacity seems to aid and strengthen the oscillator oscillations.

The modification of Fig. 2 is similar to the modification of Fig. 1 described in detail above and a detailed description of the modification of Fig. 2 and its operation is believed undesirable. It is noted, however, that in Fig. 2 the inductance L2 is common to the alternating current tank circuit and the oscillator grid and crystal circuit and forms the coupling means between the circuits. In Figs. 2 and 3, the coils L2 and L3 may have mutual magnetic coupling between these coils.

In Fig. 3, which is in many respects like Fig. 2, the positions of L2, C2 and L3 have been altered in the tank circuit with respect to their positions in Fig. 2. In this modification L3 is in series with the crystal in the oscillator grid circuit and also in the modulator tank circuit.

In Fig. 4, C3 is the reactance common to the oscillator grid circuit and the modulator tank circuit.

In Figs. 3 and 4, it should be noted that the anode 40 is connected to a point on the tank circuit at one side of the radio-frequency ground connection, while the crystal X is connected to a point on the tank circuit at the other side of the radio-frequency ground connection. This causes a phase reversal of the amplified energy to take place in the tank circuit. That is, the radio-frequency voltage at the crystal is substantially reversed with respect to the radio-frequency voltage at the anode 40 due to the said connections. In Figs. 1 and 2, no such reversal took place. Now if a phase displacing means is used at P, the phase reversal is added to the phase displacement produced in P and the phase of the amplified voltage at the crystal leads or lags the phase of the generated voltage at that point depending on the direction of phase displacement at P.

When the phase shifter at P is omitted from the arrangements at Figs. 3 and 4, the tank circuit is detuned and the same phase reversals take place supplemented by a phase shift depending on the direction of detuning of the tank circuit.

The frequency modulator circuit of Fig. 5 consists of a crystal oscillator circuit and a modulator circuit. The crystal oscillator circuit is of the grounded anode type. It consists of tube V1, resistor R1, crystal X and tank circuit C1, L1. The second grid of tube V1 is grounded through condenser 4 for radio frequency and acts as the grounded anode for the oscillator. The third grid may be grounded directly. The anode is connected to one end of tank circuit C1, L1, while the other end of the tank circuit is grounded for radio frequency. The crystal X is connected between the control grid of tube V1 and ground. The resistor R1 is connected between the control grid and ground. The cathode of tube V1 is connected part way up on resistor R1. The modulator circuit consists of signal source A, transformer T, tube V2 and tuned circuit C2, L2. The cathode of tube V2 is grounded. The screen grid 34 of tube V2 is grounded for radio frequency by condenser 38. Signal source A is connected to the control grid 24 of tube V2 through transformer T and resistor R2. Negative bias potential is supplied to this grid from source S through the secondary of transformer T and through resistor R2. The lower end of resistor R2 is grounded for radio frequency with a bypass condenser 30. The control grid of tube V2 is

tapped on resistor R1 through a blocking condenser 26. One end of tank circuit C2, L2 is connected to the grid of tube V1 through a blocking condenser 64. The other end of the tank circuit is grounded for radio frequency by condenser 48. The anode of tube V2 is tapped on coil L2 directly or through a blocking condenser 63 of the tank circuit is grounded directly. R3 supplies the anode with positive potential.

In Fig. 6, which is similar in many respects to Fig. 5, the crystal X connected to ground through a condenser C3 and the tank circuit C2, L2 is connected in parallel across condenser C3.

The operation of the arrangement of Fig. 5 will now be given. As in the prior modification, the grid G1 and cathode 18 of oscillator V1 operate at relatively high radio-frequency potential while the anode G2 is at ground radio-frequency potential, and the grid is in phase with but operates at a higher potential than the cathode, the same as in most ground anode types of oscillators. The crystal X acts as a frequency stabilizer.

Now, before this circuit can operate as a frequency modulator, the tank circuit C2, L2 must be slightly detuned from resonance, we will assume on the low capacity side for this case. Also, assume proper steady potentials applied to the frequency modulator circuit. The excitation on the control grid of tube V2 is in phase with that on the control grid of tube V1. In passing through tube V2 this energy is amplified and reversed in phase. In passing through the tank circuit C2, L2, the modulating excitation energy is again given a phase shift or rotation of say 90 degrees lagging. Consequently, the excitation on the control grid of tube V1 is the resultant of two components (assumed in this case to be disposed at 90 degrees angle) and the resultant excitation leads the normal oscillator excitation. If tank circuit C2, L2 had been detuned on the high capacity side, the modulating excitation energy would be given a phase rotation of say 90 degrees in the leading direction so that the resultant excitation on the control grid of tube V1 would lag the usual phase of the oscillator excitation. Now, if tube V2 is modulated in amplitude by the signal oscillations from source A through transformer T, the amount of excitation reaching the control grid of tube V1 from the modulator circuit V2, C2, L2 will also be modulated in amplitude. This causes the phase angle of the resultant excitation on the grid of tube V1 to change and vary in accordance with the signal. Consequently, the oscillator frequency is caused to vary in accordance with the signal. The output frequency modulated carrier will contain some amplitude modulation but this can be eliminated by the use of ordinary limiter stages in the transmitter. As a matter of fact, practically all frequency multiplier stages of a transmitter act as fairly efficient amplitude limiters. When anode current is blocked off in the modulator tube V2 the crystal oscillator functions normally. The frequency is then slightly different from that when modulator current flows.

A modification, Fig. 5, is shown in Fig. 6. In Fig. 6, the modulating excitation energy from tube V2 is applied to the grid of tube V1 in series with the crystal X (across the condenser C3) instead of being applied in parallel with the crystal X as in Fig. 5. Condenser C3 can be omitted altogether, if desirable. The general theory of the operation of Fig. 6 is about the same as for Figs. 1, 2 and 5 and will be fully understood by

those versed in the prior art from the foregoing description.

The frequency modulator circuit of Fig. 7 consists of a crystal oscillator circuit and a modulator circuit as in the prior arrangements. The crystal oscillator circuit consists of a tube V1, tank circuit C6, L6 connected with the anode 10, crystal X, grid resistor R1 and feedback condenser C8. The cathode of V1 is grounded. The crystal X is connected between the control grid G1 and the cathode 18 of tube V1. The grid leak R1 parallels the crystal X. The feedback condenser C8 is connected between the anode 10 and the control grid G1 of tube V1. The center point of tank coil L6 is grounded by condenser 60 for radio frequency and one end of the tank circuit L6, C6 is connected to the anode 10 of tube V1. The modulator consists of tube V2, the phase shifter element LP, the grid resistor R2 and the anode resistor R3. The cathode 20 of tube V2 is grounded and the grid resistor R2 is connected between the control grid 24 and cathode 20 of tube V2. The anode 40 of tube V2 is connected to a source of positive potential through the center point of coil L6, and through resistor R3. The anode 40 of tube V2 is also coupled to the grid of tube V1 through a blocking condenser 26' and through a phase shifting element coil LP. The grid 24 of tube V2 is coupled to the tank coil L6 through a blocking condenser 30 as shown. The screen grids G2 and 34 of tube V1 and V2 are modulated in phase opposition from signal source A through transformer T.

Assuming proper steady potentials applied to the circuit of Fig. 7, the crystal oscillator circuit will oscillate by virtue of the feedback to the control grid from the anode of tube V1 through condenser C8 and the piezo-electric action of the crystal X, grid bias being by the rectified grid current passing through resistor R1. The crystal tends to hold constant frequency for the oscillator. The theory of piezo-electric oscillators for regulating radio frequencies has been described in prior art. The control grid 24 of tube V2 is excited from tank circuit C6, L6 as shown. This energy is amplified in the anode of tube V2 and fed back to the grid of V1 by way of phase shifter LP. If we assume that the grid of V2 is tapped on the upper end of tank circuit C6, L6, L1, its excitation will be in phase with the grid of V1. Passing through tube V2 reverses the modulation excitation energy, i. e., (0-180). Passing through phase shifter LP causes the modulation excitation energy from tube V2 to lag say 90 degrees. The resultant excitation on the grid of V1 swings between the limits of zero to 90 degrees leading in the case assumed. If the grid of V2 is tapped on the anode end of tank circuit C6, L6 its excitation will be opposite to that on the grid of V1 because of the reversal in the tube V1. Then the reversal in tube V2 brings the amplified modulating excitation back in phase with the voltage on grid G1 of tube V1. However, the phase shifter LP again causes a lag of 90 degrees, and the resultant excitation is lagging, which is opposite to the first case cited. The excitation on the grid G1 of tube V1 will, in either case, be the resultant of the oscillator V1 excitation and the modulating excitation from the tube V2. Now, if the tube V2 is modulated in amplitude the amount of modulating excitation delivered from V2 to the grid of V1 will also be modulated in amplitude. If the oscillator delivers steady excitation, the result is a varying excitation phase angle on the grid of V1. This

causes the frequency of the oscillator to vary. Since the modulating transformer circuit T modulates tubes V1 and V2 in opposite sense a greater degree of phase change in the resulting radio-frequency voltage on the grid of V1 is produced and, consequently, a greater degree of frequency modulation is obtained. If the ground and bias tapping point on the secondary of transformer T is properly chosen any amplitude modulation in the output is balanced out, leaving only wave energy modulated in frequency in accordance with the signal oscillations from source A.

What is claimed is:

1. In a wave length modulation system, an oscillation generator of the electron discharge tube type having electrodes including a control grid, a cathode, and an electrode serving as an anode, connected in an oscillation generating circuit including a piezo-electric crystal and a reactance in series between said control grid and cathode, said tube having other electrodes connected in an output circuit, an additional electron discharge tube having an anode and having a control electrode coupled to said oscillation generating circuit to derive excitation voltages of the generated frequency therefrom, a tank circuit including a second reactance the first mentioned of said reactances and a third reactance, said third reactance being connected in series with said first reactance, said series arrangement of said first and third reactances being connected in shunt to said second reactance, a coupling between one end of said second reactance and ground, a coupling between the anode of said second named tube and a point above ground radio frequency potential on one reactance, said couplings serving to feed amplified voltages to said generating circuit in phase displaced relation relative to the voltages generated therein, and means to control the gain of said second tube at signal frequency to thereby control the amplification of the voltages fed to said generating circuit and frequency modulate the oscillations generated.

2. In a wave length modulation system, an oscillation generator of the electron discharge tube type having electrodes including a control grid, a cathode, and an electrode serving as an anode, connected in an oscillation generating circuit including a piezo-electric crystal and a reactance in series between said control grid and cathode, said tube having other electrodes connected in an output circuit, an additional electron discharge tube having an anode and having a control electrode coupled to said oscillation generating circuit to derive excitation voltages of the generated frequency therefrom, a tank circuit including an inductance the first mentioned reactance and a second reactance, said second reactance being connected in series with said first reactance, said series arrangement of first and second reactances being connected in shunt to said inductance, a coupling between one end of said inductance and ground, a coupling between the anode of said second named tube and a point on said inductance, said couplings serving to feed amplified voltages to said generating circuit in phase displaced relation relative to the voltages generated therein, and means to control the gain of said second tube at signal frequency to frequency modulate the oscillations generated.

3. In a wave length modulation system, an oscillation generator of the electron discharge tube type having electrodes including a control grid, a cathode, and an electrode serving as an anode,

connected in an oscillation generating circuit including a piezo-electric crystal and a capacity in series between said control grid and cathode, said tube having other electrodes connected in an output circuit, an additional electron discharge tube having an anode and having a control electrode coupled to said oscillation generating circuit to derive excitation voltages therefrom, a tank circuit including an inductance said first mentioned capacity and a second capacity, said second capacity being connected in series with said first capacity, said series arrangement of first and second capacities being connected in shunt to said inductance, a coupling between one end of said inductance and ground, a coupling between the anode of said second named tube and a point adjacent the other end of said inductance, said couplings serving to feed amplified voltages to said generating circuit in phase displaced relation relative to the voltages generated therein, and means to control the gain of said second tube at signal frequency to frequency modulate the oscillations generated.

4. In a wave length modulation system, an oscillation generator of the electron discharge tube type having electrodes including a control grid, a cathode, and an electrode serving as an anode, connected in an oscillation generating circuit including a piezo-electric crystal and a reactance in series between said control grid and cathode, said tube having other electrodes connected in an output circuit, an additional electron discharge tube having an anode and having a control electrode coupled to said oscillation generating circuit to derive excitation voltages therefrom, a tank circuit including a capacity said first mentioned reactance and a second reactance, said second reactance being connected in series with said first reactance, said series arrangement of said first and second reactances being connected in shunt to said capacity, coupling between one end of said capacity and ground, a coupling between the anode of said second named tube and a point on said third reactance, said couplings serving to feed amplified voltages to said generating circuit in phase displaced relation relative to the voltages generated therein, and means to control the gain of said second tube at signal frequency to frequency modulate the oscillations generated.

5. In a wave length modulation system, an oscillation generator of the electron discharge tube type having electrodes including a control grid, a cathode, and an electrode serving as an anode,

connected in an oscillation generating circuit including a piezo-electric crystal and an inductance in series between said control grid and cathode, said tube having other electrodes connected in an output circuit, an additional electron discharge tube having an anode and having a control electrode coupled to said oscillation generating circuit to derive excitation voltages of the generated frequency therefrom, a tank circuit including a capacity said first mentioned inductance and a second inductance, said second inductance being connected in series with said first inductance, said series arrangement of said first and second inductances being connected in shunt to said capacity, a coupling between a terminal of said first inductance and ground, a coupling between the anode of said second named tube and said second inductance, said couplings serving to feed amplified voltages to said generating circuit in phase displaced relation relative to the voltages generated therein, and means to control the gain of said second tube at signal frequency to thereby control the amplification of the voltages fed to said generating circuit and frequency modulate the oscillations generated.

6. In a wave length modulation system, an oscillation generator of the electron discharge tube type having electrodes including a control grid, a cathode, and an electrode serving as an anode, connected in an oscillation generating circuit including a piezo-electric crystal and a reactance in series between said control grid and cathode, said tube having other electrodes connected in an output circuit, an additional electron discharge tube having an anode and having a control electrode coupled to said oscillation generating circuit to derive excitation voltages therefrom, a tank circuit including a second reactance said first mentioned reactance and a third reactance, said third reactance being connected in series with said first reactance, said series arrangement of said first and third reactances being connected in shunt to said second reactance, a coupling between one end of said second reactance and ground, a coupling between the anode of said second named tube and a point adjacent said one end of said second reactance, said couplings serving to feed amplified voltages to said generating circuit in phase displaced relation relative to the voltages generated therein, and means to control the gain of said second tube at signal frequency to frequency modulate the oscillations generated.

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