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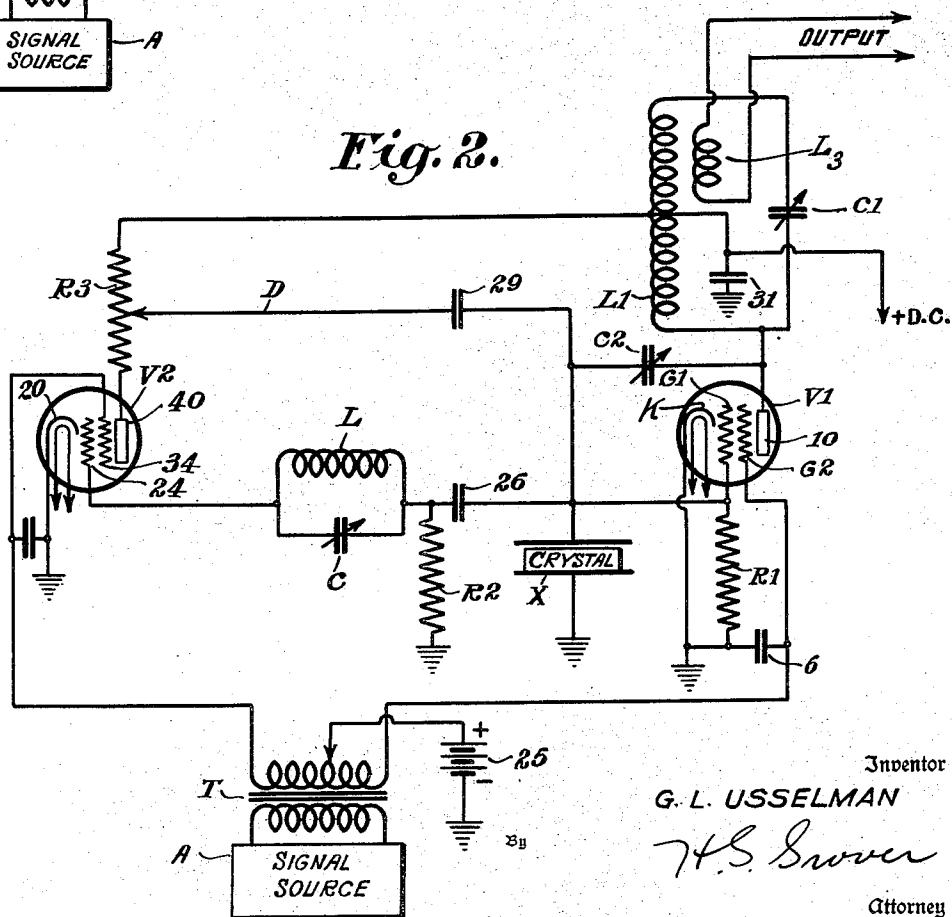
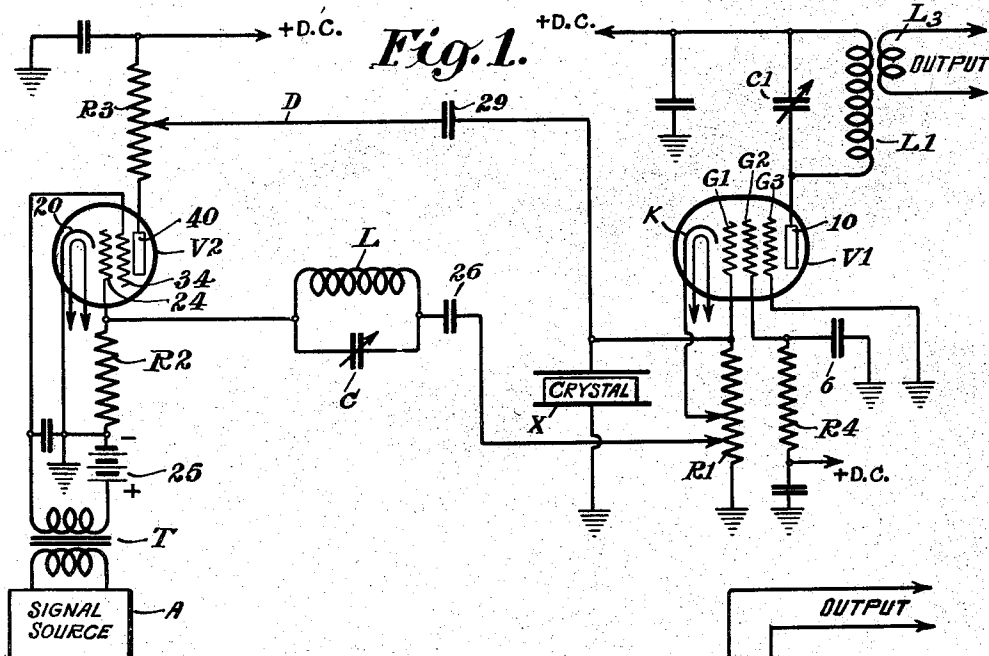
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2,298,436

FREQUENCY MODULATION

Filed June 5, 1940

3 Sheets-Sheet 1



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Fig. 3.

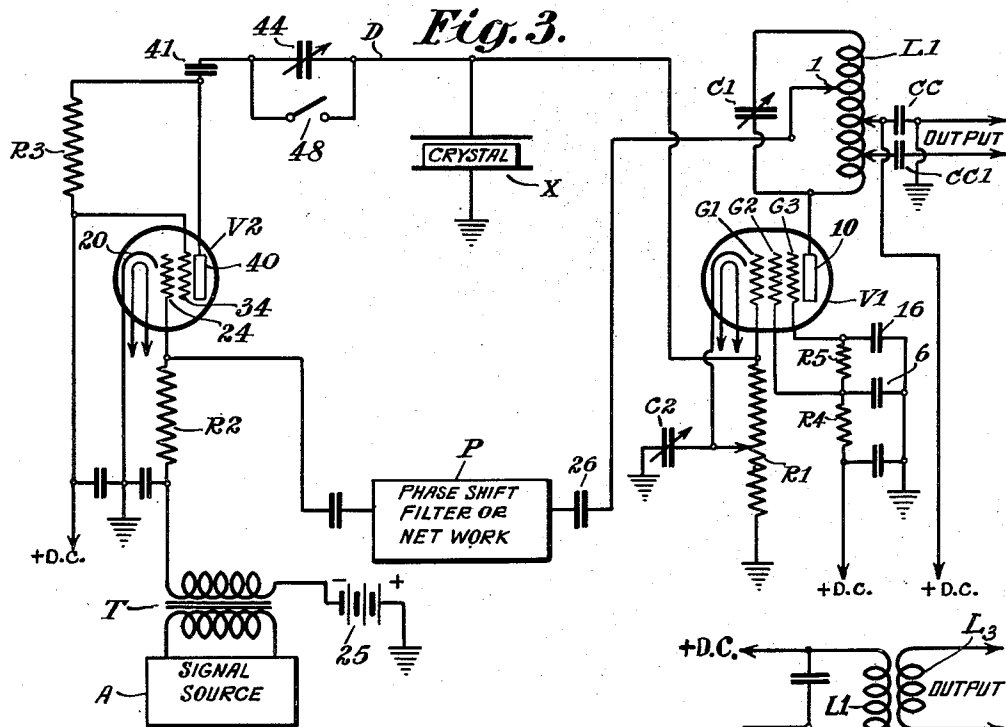
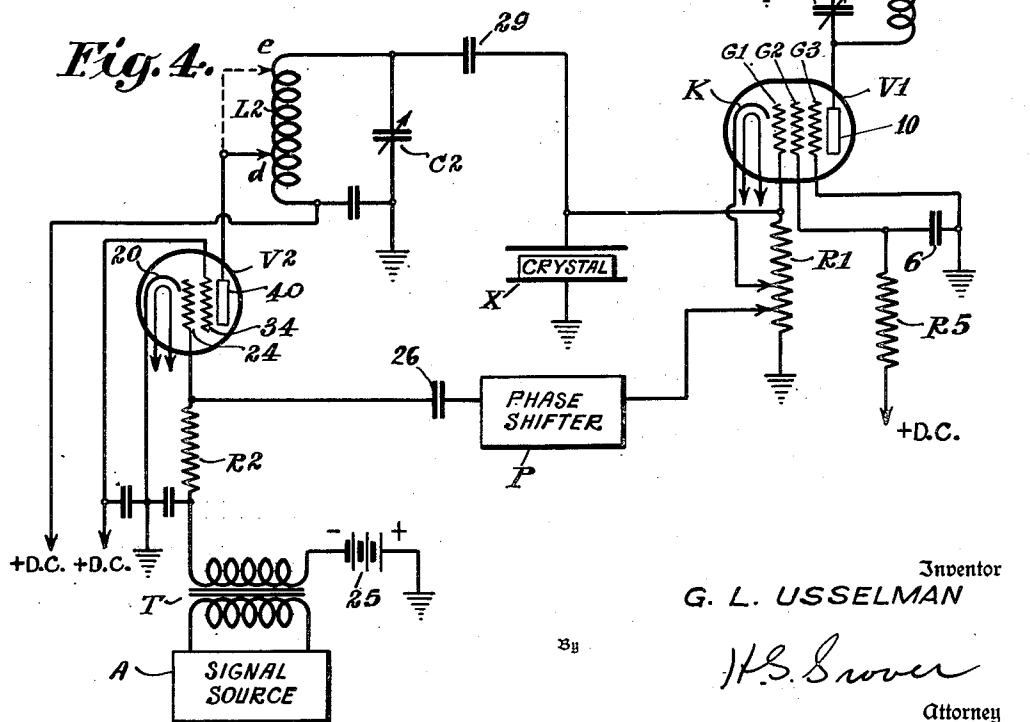


Fig. 4.



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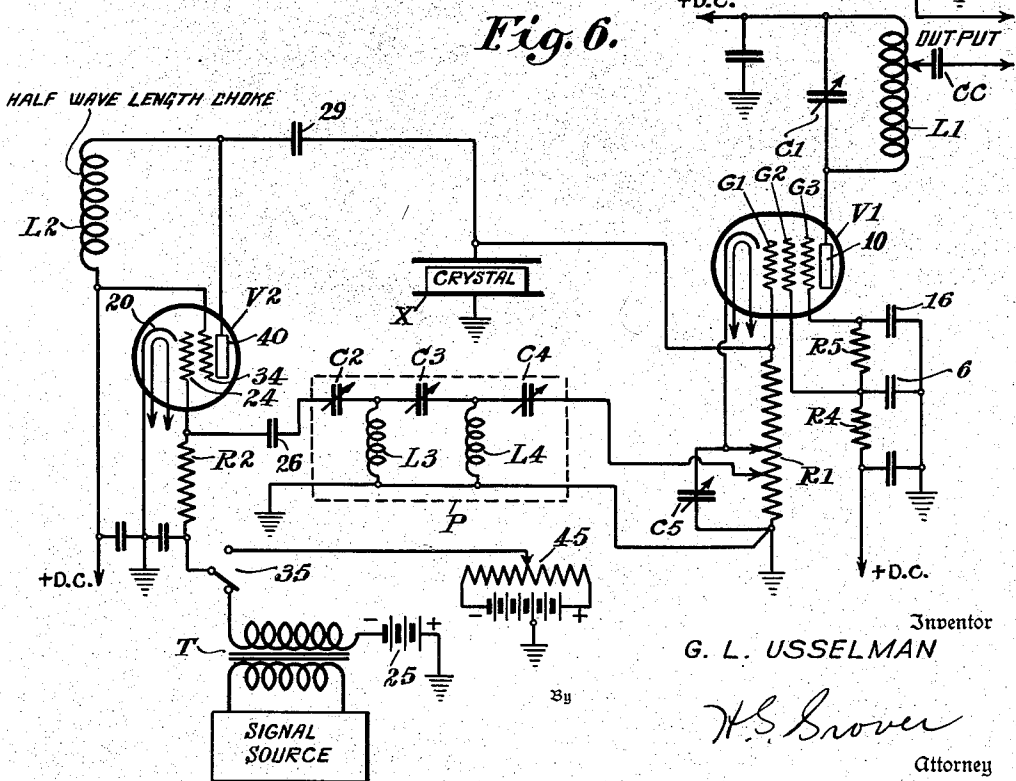
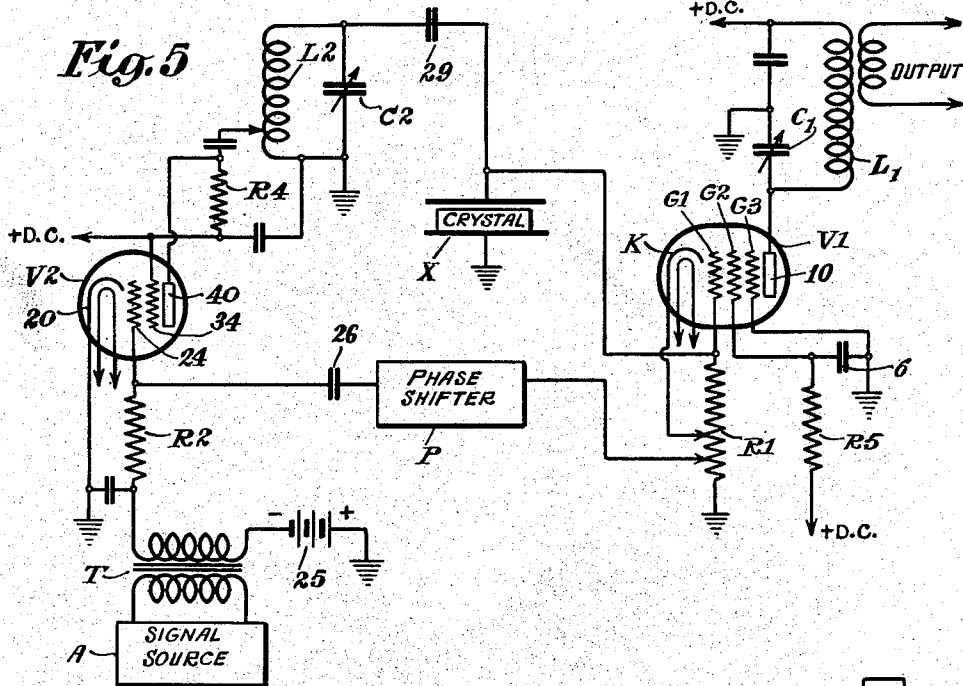
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FREQUENCY MODULATION

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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FREQUENCY MODULATION

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Application June 5, 1940, Serial No. 338,837

12 Claims. (Cl. 179—171.5)

This application concerns a new and improved method of and means for producing wave energy and modulating the frequency thereof in accordance with control waves such as for example voice signals, telegraphy signals, space wave keying signals, etc. The invention disclosed here involves broadly the principle disclosed in my United States application Serial No. 338,838 filed June 5, 1940. In the present application I have shown several modifications of the system comprising the oscillator, the modulator, and the connections between the oscillator and the modulator tube. The modulation system of this application also involves modified phase shifting means in the circuits coupling the modulator to the generator.

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

Figs. 1 to 6, inclusive, each illustrate a different modification of my system. Each modification comprises an oscillation generator the frequency of oscillation of which is stabilized by a piezo-electric crystal or equivalent means, a tube device, excited by voltages developed in the oscillator, which is arranged to amplify the said voltages and feed them back in phase displaced relation to the oscillator. Means is also provided to modulate the said tube which, for convenience, has been designated as the modulator tube.

In the modification illustrated in Fig. 1, the oscillation generator is of the electron coupled type, the excitation circuit between the oscillation generator and the modulator tube includes as a phase shifting means a parallel inductance and capacity, and the modulator tube is of the multi-grid electrode type with the screen grid electrode modulated. In Fig. 2, the oscillator tube has its main anode and control grid coupled in a regenerative circuit and modulating potentials are applied to the oscillator screen grid as well as to the modulator screen grid. In Fig. 3, the excitation voltage is derived from the circuit coupled to the main anode of the oscillator tube and the phase shifter is shown by block diagram. In this modification the control grid of the modulator tube is modulated instead of the screen grid. In the modification of Fig. 4, the oscillator and excitation circuits are connected as shown in Fig. 1, control grid modulation is used, and a parallel tuned circuit is connected with the anode of the modulator tube and coupled to the oscillation generating circuit crystal.

Fig. 5 is quite similar to Fig. 4 except for the anode circuit of the modulator tube and its coupling to the crystal in the oscillator circuit. The same remarks apply to the modification of Fig. 6 wherein a particular type of phase shifter in the excitation circuit is also shown.

Referring to all of the figures of the drawings except Fig. 2, V1 is an electron discharge device having a grid G3 grounded, grids G1 and G2

connected in an oscillation producing circuit including the piezo-electric crystal. The grid G2 is coupled to ground by blocking condenser 6 and to a source of biasing potential by means of a resistor R4. In Fig. 2 the blocking condenser is omitted as is the resistance R4, and grid G2 is connected to the modulation transformer T. In all figures the control grid G1 is connected to one terminal of the piezo-electric crystal X the other terminal of which is grounded. This grid G1 is also connected to ground through a potentiometer resistor R1 and the cathode K is tapped to a point on R1. The anode 10 of tube V1 is connected to a tank circuit C1, L1 and an output circuit may be coupled to the inductance L1; this output circuit in Figs. 1, 2, 4 and 5 comprising a coupling inductance L3, and in Figs. 3 and 6 a coupling condenser CC.

The modulator tube V2 in Fig. 1 has its cathode 20 grounded and connected to the negative terminal of a source of potential 25, the positive terminal of which runs through the secondary winding of a transformer T to the screen grid electrode 34. The control grid electrode 24 is connected to a parallel tuned phase adjusting circuit LC one terminal of which is connected by a blocking condenser 26 to a point on resistor R1 to derive excitation voltage therefrom for the grid 24. The anode electrode 40 is connected by a resistor R3 to a source of potential not shown. A point on R3 is coupled by a blocking condenser 29 to the high radio-frequency potential terminal of the piezo-electric crystal X, and to the control grid G1. A direct-current circuit for the control grid 24 is completed by a resistance R2.

The arrangement shown in Fig. 2 is somewhat similar to the arrangement shown in Fig. 1. In Fig. 2, however, the oscillator tank circuit L1, C1 which is connected with the anode 10 of tube V1, has the mid-point thereon connected to ground by a blocking condenser 31. This mid-point connection is also connected to the terminal of R3 remote from the anode 40 of tube V2 and also to a source of direct-current potential. In both modifications the output is derived from a reactance L2 coupled to the inductance L1. In the modification shown in Fig. 2, a coupling capacity C2 is connected between the grid G1 and the anode 10 of tube V1, oscillation generation being produced by virtue of the anode to control grid coupling C2. In other words, the oscillator in Fig. 1 is of the electron coupled type whereas the oscillator of Fig. 2 has its output electrode coupled to its grid electrode by a capacity. In Fig. 2, the excitation circuit for the grid 24 of the modulator tube in Fig. 2 is connected to the high radio-frequency potential end of the crystal X and to the resistance R1 which, in this figure, is between the grid G1 and ground, the cathode K being at ground po-

tential. In Fig. 1, the tube V2 only is modulated whereas in Fig. 2 differential modulating potentials are supplied by the transformer T to the screen grids 34 and G2 respectively of tubes V2 and V1.

The modification shown in Fig. 3 is somewhat similar to the modification shown in Fig. 1. In Fig. 3, however, the phase shifting circuit P is connected between the control grid 24 of tube V2 and a point on the inductance L1 of the tank circuit L1, C1 instead of being coupled to a point on the resistance R1 as in Fig. 1. In Fig. 3 the blocking condenser 41 is coupled by a variable condenser 44 to the electrode of X and the control grid G1 of tube V1. In Fig. 3 the anode 40 derives its direct-current potential as in Fig. 1 and this supply of direct-current potential is also impressed on the screen electrode 34. The modulation potentials are applied to the control grid 24 instead of to the screen grid 34 as was the case in the prior figures.

The crystal oscillator circuits of Figs. 4, 5 and 6 are similar to those of Figs. 1 and 3 and are of the grounded anode type in which the second grid G2 of tube V1 acts as the oscillator anode and it is grounded for radio frequency through a by-pass condenser 6. The third grid G3 is either grounded directly or by-passed to ground by a condenser 16 and serves to shield the output circuit from the generating circuits. Both grids are supplied with positive potential. In these modifications as in Figs. 1 and 3, the anode of tube V1 works into a tuned output circuit C1, L1 and is only electronically coupled to the crystal oscillator circuit. The crystal X is connected to the control grid of tube V1 and to ground. Grid leak resistor R1 is also connected to the control grid of tube V1 and to ground. The cathode of tube V1 is tapped up on resistor R1. It was found that as shown in the circuit of Fig. 6, a condenser C5 connected between the cathode of tube V1 and ground aided or strengthened the oscillations in the oscillation generator.

The control grid of modulator tube V2 in Figs. 4, 5 and 6, as in Fig. 1, is supplied with excitation from resistor R1 of the crystal oscillator through an excitation phase shifter P which, in these modifications, serves the function of LC of the prior figures. This phase shifter may be of any desirable type. The circuit of Fig. 6 shows a series condenser parallel coil combination for the phase shifter unit P. The cathode of tube V2 is grounded, the same as in the prior figures. In Figs. 4, 5 and 6, as in Fig. 3, modulation is applied to the control grid of tube V2 by resistance R2 one end of which is connected to the cathode by a radio-frequency by-pass condenser and to the secondary winding of transformer T. The other end of this transformer winding is connected to a negative bias potential source 25.

The circuit of Fig. 6 includes a switch 35 for connecting the control grid 24 to a test bias potential source 45. The primary winding of transformer T is connected to a signal source A. The screen grid of tube V2, as in the prior figures, is by-passed to ground for radio frequency and is also connected to a source of positive potential not shown. The anode of tube V2, in Figs. 4 and 6, is supplied with positive potential through coil L2, which is connected to a source of positive voltage and current. The lower end of coil L2 is by-passed to ground for radio frequency through a condenser. In the circuit of Fig. 4

the coil L2 is paralleled by a condenser C2 to form a tuned circuit. But the coil L2 in the circuit of Fig. 6 is a half wave electrically, or, in other words, the coil L2 is substantially resonant, and therefore having a minimum of wattless or circulating current. The high radio-frequency potential end of coil L2 is coupled to the control grid G1 of tube V1 and the crystal through a blocking condenser 29 in Figs. 4, 5 and 6. The crystal itself forms the blocking condenser between its ground connection and the control grid of tube V1.

Fig. 5 shows a slight modification of Fig. 4. In Fig. 5 a somewhat different method of supplying the anode 40 of tube V2 with positive current and potential is used. This potential is supplied by means of resistor R4 instead of through coil L2.

The circuits all show different embodiments of this invention. The circuits of Figs. 1, 3, 4, 5 and 6 have crystal oscillator circuits which are substantially the same but the modulator circuits are somewhat different. In these modifications the output circuit of V1 is coupled electronically to the generating circuits, and shielded therefrom by grounded grid G3. This is not so in Fig. 2 where G1 is coupled to the anode by condenser C2. The oscillators shown in Figs. 1, 3, 4, 5 and 6 are of the grounded anode type of crystal oscillator in which the second grid acts as the grounded anode. The real anode works into a tuned output circuit and electronic coupling is used. The crystal X is connected between the control grid G1 of tube V1 and ground (or G2 potential). The resistor R1 is also connected between the control grid and ground, with the cathode tapped up on this resistor. The tuned circuit C, L of Figs. 1 and 2 in the grid circuit of the modulator tube acts as phase shifters. The anode resistor R3 of tube V2 is tapped with a conductor D and a blocking condenser 29 for coupling the anode circuit of tube V2 to the control grid G1 of tube V1. In Fig. 3 the phase shifter network unit P takes the place of the tuned circuit C, L. The crystal oscillator circuit shown in Fig. 2 is of the grounded cathode type using a screen grid tube V1 and a tuned anode circuit L1, C1. Anode feedback in the oscillator is supplied through condenser C2. The screen grid of V2 is modulated in the circuit shown in Fig. 1 whereas in Fig. 3 the control grid of tube V2 is modulated. In Fig. 2 the screen grids of tubes V1 and V2 are modulated in opposition to reduce the amplitude modulation in the output.

The operations of the crystal oscillator and modulator circuits will now be described. The modulators in all circuits operate on substantially the same principle. In the system of Figs. 1 and 2 the circuit C, L must be slightly detuned to act as phase shifters. The action of these frequency modulator circuits is as follows, assuming that proper steady potentials are applied. A small amount of excitation is picked up from the oscillator circuit say of like oscillator grid excitation phase by the tap on R1 in Figs. 1, 2, 4 and 6 and the tap on L1 in Fig. 3. In passing through the phase shifters C, L or P, the phase of the excitation is retarded say 90 degrees. Of course, most phase shifter networks depend on the terminating resistance or impedance as one of the elements in the mechanism of phase shifting or phase rotation, so that the excitation voltage reaching the control grid 24 of tube V2 is say lagging 90 degrees in phase behind the voltage at the oscillator grid. In passing through the

tube V2 the modulating excitation energy is amplified and is reversed or rotated 180 degrees in phase. This modulating excitation energy is then applied to the control grid G1 of oscillator tube V1 through conductor D and its blocking condenser 26. The modulating excitation energy therefore leads the oscillator excitation energy by 90 degrees in phase. It should be stated that this phase angle can be made more or less than these assumed values by adjustments of the phase shifters. In some cases this is desirable in order to change the degree of frequency modulation. The resultant excitation on the grid of tube V1 is then leading the normal oscillator excitation.

When the tube V2 is modulated by the signal the amount of modulating excitation energy delivered to the grid of tube V1 from the anode of tube V2 is also modulated. Consequently, addition of the two components of excitation on the grid of tube V1 causes the phase angle of this excitation to swing between the limits of the two components. This, in turn, causes the frequency to be modulated in accordance with the signal oscillations.

If in the phase shifting circuits C, L, or P the excitation energy is advanced in phase, by the same process or reasoning, the modulating excitation delivered to tube V1 by tube V2 will be retarded in phase and the resultant excitation on the grid of tube V1 will lag the normal oscillator phase. The frequency modulation in this case would be in opposite direction to that described in the first case.

It should be pointed out that the phase shift in the oscillator excitation occurs for each cycle, thus resulting in frequency shift or frequency modulation. This phase shift continues for each cycle until the frequency shift produces an equal and opposite phase shift in the circuits.

The modulators shown in Figs. 1 and 3 produce some amplitude modulation along with the frequency modulated carrier. However, the use of limiters in succeeding stages of the transmitter will eliminate the undesired amplitude modulation from the output.

The frequency modulation circuit shown in Fig. 2 eliminates the amplitude modulation from the frequency modulated carrier output by modulating the amplitude of the output from tubes V1 and V2 in opposite sense. In this modification changes in generated wave amplitude caused by modulating tube V2 are opposed and compensated by corresponding but opposed modulations on the grid of V1. That is, if the ground and bias point on the secondary winding of transformer T is properly chosen, substantially all amplitude modulation is eliminated from the output circuit in Fig. 2. This would also increase the efficiency of the frequency modulation.

The circuit in Fig. 3 has a condenser 44 which can be used for minor adjustment of phase shift and a switch 48 short-circuiting condenser 44 when it is not required. This circuit can be operated with the tap from phase shifter P on coil L1. The position of this tap on L1 depends on the sense of the phase shift in P. Condenser 44 can be very large, and phase shifter P and condenser 44 can be interchanged. The lead to phase shifter P can also be connected to a point on R1. A push-pull arrangement may be had by adding another tube V3 excited through another phase shifter and coupled at its anode to crystal X by a second condenser 44'.

The operation of the frequency modulators of Figs. 4 and 6 is substantially the same. Assum-

ing that proper steady potentials are applied to these circuits, the grounded anode crystal oscillator operates in the same manner as it has been described hereinbefore. In both circuits some excitation energy is taken from the crystal oscillator circuit resistor R1 and is delivered to the control grid 24 of modulator tube V2 by way of the phase shifter unit P. The phase of the energy taken from resistor R1 is the same as that on the control grid G1 of the oscillator tube V1. In passing through the phase shift network P the phase of the excitation energy is rotated say 90 degrees lagging, so that the control grid of tube V2 is, as we have assumed, excited 90 degrees out of phase, lagging in this case, with respect to the excitation on the grid of tube V1. In passing through tube V2 this energy is amplified and reversed 180 degrees in phase. Consequently, the modulating excitation energy fed back to the control grid G1 of oscillator tube V1 from the anode of the modulator tube V2 is approximately 90 degrees leading in phase compared to the voltage of the oscillator. If we assume the phase shift in unit P to be 90 degrees leading, then the modulating excitation energy delivered from tube V2 to tube V1 will be about 90 degrees lagging in phase. This phase shift, accomplished in the phase changer network P, may be made any amount desirable such as, 60, 90, or 120 degrees. However, 90 degrees is assumed to be the best value. Now the excitation on the control grid of the oscillator tube V1 is the resultant of the two excitation components, that is one from the modulator circuit and the other from the oscillator circuit. If the amplitude of the modulator (output) component of the excitation energy is modulated in amplitude by the signal, from source A through transformer T, then the resultant on the control grid of oscillator tube V1 will also be modulated somewhat in amplitude and what is more important, the resultant excitation will be modulated in phase. This resultant excitation phase shift is added to each cycle of the oscillation until an opposite reaction limits the amount of phase shift. Since these are oscillator circuits and the phase shifts are added to each cycle of oscillation, the resultant modulation is a combination of amplitude and frequency modulation. When this frequency modulator circuit is included in a radio transmitter some amplitude limiter stages may be used which will eliminate the undesired amplitude modulation and which passes on only the frequency modulated carrier energy. The latter then can be amplified and multiplied in frequency before it is utilized in the antenna system.

The phase changing network P may be of any desirable type. It may be made as shown in Fig. 6 or it may instead be a series coil, parallel condenser combination arrangement. It may be coils or condenser arrangements with resistors. It may consist of one stage or a many stage filter. It should also be recognized that the terminating load on a filter, in this case R2, and control grid capacity of tube V2 are part of the circuit with the filter P affecting the change in excitation energy phase angle.

The undesired amplitude modulation may be eliminated from the output of the modulator circuits by introducing some opposite amplitude modulation on the anode of oscillator tube V1 through coil L1 and through a transformer T2 connected to the signal source A. The amount of opposite amplitude modulation would have to be just sufficient to cancel and balance out the

amplitude modulation caused by modulator tube V2.

What is claimed is:

1. In a wave generating and wave length modulation system, an electron discharge device having electrodes including an anode, a cathode and a control grid electrode, an oscillation generating circuit coupled to electrodes of said tube including said grid electrode and said cathode, a piezo-electric crystal in a holder and an impedance in parallel included in said circuit between said grid electrode and said cathode, an output circuit coupled with said anode and cathode, a modulator tube having an anode, a cathode and a control grid, means coupling said modulator tube cathode to said cathode of said device, means coupling said modulator tube anode to said grid electrode, said crystal being in shunt in the coupling between the anode and cathode of the modulator tube and the grid and cathode of said device, means coupled with the control grid of said modulator tube for applying thereto voltage of the frequency of the oscillations generated by said oscillation generating circuit, phase shifting means in said last named coupling, and means for modulating the impedance of said modulator tube in accordance with control potentials to thereby modulate the length of the waves generated.

2. In a wave generating and wave length modulation system, an electron discharge device having a cathode, a grid electrode and an electrode serving as an anode, an oscillation generating circuit coupled to said grid electrode, said electrode serving as an anode and said cathode, a piezo-electric crystal in a holder in said circuit between said grid electrode and said cathode, an output circuit coupled with said generating circuit, a modulator tube having an anode, a cathode and a control grid, means coupling said modulator tube anode to said grid electrode to which said crystal is coupled, a parallel tuned circuit coupling the control grid of said modulator tube to a point on said oscillation generating circuit at which generated voltage of substantial amplitude appears to apply excitation voltages to said modulator tube grid, and means for modulating the impedance of said modulator tube in accordance with control potentials to thereby modulate the length of the waves generated.

3. In a wave generating and wave length modulation system, an electron discharge device having a cathode, a grid electrode and an anode like electrode, an oscillation generating circuit coupled to said grid electrode, said anode like electrode and said cathode, a piezo-electric crystal in said circuit coupled to said grid and to another electrode in said device, an output circuit coupled to said generating circuit, a modulator tube having an anode, a cathode and a control grid, a parallel tuned circuit coupling said modulator tube anode to said grid of said device to which said crystal is coupled, means coupling the control grid of said modulator tube to a point on said oscillation generator circuit at which the generated oscillations are of substantial amplitude to apply excitation voltage of the generated frequency to said modulator tube grid, phase shifting means in one of said last two couplings, and means for modulating the impedance of said modulator tube in accordance with control potentials to thereby modulate the length of the waves generated.

4. In a wave generating and wave length modulation system, an electron discharge device having an anode like electrode, a cathode and a grid electrode, an oscillation generating circuit coupled to said grid electrode, said anode like electrode and said cathode, a piezo-electric crystal in said circuit, an output circuit coupled to said generating circuit, a modulator tube having an anode, a cathode and a control grid, a reactance electrically equivalent to a fraction of the length of the oscillations generated for connecting said modulator tube anode to a source of potential, means coupling said modulator tube anode to said generating circuit, a circuit coupling the control grid of said modulator tube to a point on said oscillation generating circuit at which the generated oscillations are of substantial amplitude to apply excitation voltage of the generated frequency to said modulator tube grid, and means for modulating the impedance of said modulator tube in accordance with control potentials to thereby modulate the length of the waves generated.

5. In a wave length modulation system, an oscillation generator of the electron discharge tube type having electrodes including a cathode and a control grid coupled in an oscillation generator circuit including a piezo-electric crystal in a holder having one terminal coupled to the control grid of said tube and having another terminal coupled to the cathode of said tube, said tube having output electrodes coupled in an output circuit, an additional electron discharge tube having an anode and having a control electrode coupled to one of said first two circuits to derive excitation voltages therefrom, a coupling between the cathodes of said tubes, a coupling between the anode of said second named tube and that terminal of the crystal holder connected to the control grid of said first tube to feed amplified voltage thereto, means for shifting the phase of the excitation voltage amplified and fed by said second tube to said control grid, and means for modulating the impedance of the second tube in accordance with signals.

6. In a wave length modulation system, an oscillation generator of the electron discharge tube type having electrodes including a cathode and a control grid coupled in an oscillation generator circuit including a piezo-electric crystal in a holder having two terminals, with a coupling between one of said terminals and the grid of said tube and a coupling between the other terminal and the cathode of said tube, said tube having an anode electrode coupled in an output circuit, an additional electron discharge tube having an anode and having a control electrode coupled to one of said first two circuits to derive excitation voltages therefrom, a coupling between the cathodes of said tubes, a coupling between the anode of said second named tube and the terminal of said holder coupled to the grid of said first tube to feed amplified voltage thereto, means for shifting the phase of the excitation voltage fed to the control grid of said second tube, and means for modulating the impedance of the second tube in accordance with signals.

7. In a wave generating and wave length modulation system, an oscillation generator comprising, an electron discharge device having a cathode, an output electrode, and a control electrode, an oscillation circuit coupled with electrodes of said device including said cathode and control electrode, said oscillation circuit including a pie-

zo-electric crystal in a holder having two terminals with a coupling between one terminal and the grid of said device and a coupling between the other terminal of the holder and the cathode of said device, an output circuit coupled with said output electrode and cathode, a modulator tube having an anode, a cathode and a control electrode, a coupling between said control electrode of said modulator tube and one of said first two circuits to derive excitation voltage therefrom, a coupling between the cathodes of said device and tube, a coupling between the anode of said modulator tube and the terminal of said holder coupled to the grid of said device, phase displacing means in the said coupling between the control electrode of said modulator tube and said one of said first two circuits, and means for modulating the potential of the control electrode of said modulator tube in accordance with signals.

8. In a wave generating and wave length modulation system, an oscillation generator comprising, an electron discharge device having a cathode, an output electrode, and a control electrode, an oscillation circuit coupled with electrodes of said device including said cathode and said control electrode, said oscillation circuit including a piezo-electric crystal in a holder having two terminals with a coupling between one terminal and the grid of said device and a coupling between the other terminal and the cathode of said device, an output circuit coupled with said output electrode and cathode, a modulator tube having an anode, a cathode and a plurality of control electrodes, a coupling between the cathodes of the device and tube, a coupling between one control electrode of said modulator tube and one of said first two circuits to derive excitation voltage therefrom, a coupling between the anode of said modulator tube and the terminal of the holder coupled to the grid of said device, phase displacing means in one of said last two couplings, and means for modulating the potential on another control electrode in said modulator tube in accordance with signals.

9. In a wave generating and wave length modulation system, an oscillation generator comprising, an electron discharge device having a cathode, an output electrode, and control electrodes, an oscillation circuit coupled with electrodes of said device including said cathode and said control electrodes, a piezo-electric crystal in a holder having two terminals with a coupling between one of said terminals and one of the control electrodes and a coupling between the other terminal and the cathode of said device, an output circuit coupled with said output electrode and cathode, a modulator tube having an anode, a cathode and a control electrode, a coupling between the cathodes of said device and tube, a coupling between said control electrode of said modulator tube and one of said first two circuits, a tuned circuit coupling the anode of said modulator tube to the terminal of said crystal holder coupled to said one control electrode, phase displacing means in one of said last two couplings, and means for modulating the potential on an electrode in said tube in accordance with signals.

10. In a wave generating and wave length modulation system, an oscillation generator comprising, an electron discharge device having a cathode, an output electrode, and a control electrode, an oscillation circuit coupled with electrodes of said device including said cathode and

said control electrode, an impedance connected between said control electrode and cathode, a piezo-electric crystal in said circuit in a holder coupled between the control grid and cathode of said device, an output circuit coupled with said output electrode and cathode, a modulator tube having an anode, a cathode and a control electrode, a coupling between the cathodes of the device and tube, a coupling including a phase shifter between said control electrode of said modulator tube and a point on said impedance, a circuit including an inductance and capacity in parallel tuned substantially to the frequency of operation of said generator, a connection between the anode of said modulator tube and a point on said inductance, a coupling between said parallel tuned circuit and the junction point between said crystal holder and the control grid of said device and means for modulating the potential on the control electrode in said tube in accordance with signals.

11. In a wave generating and wave length modulation system, a generator including an electron discharge device having a cathode, an electrode serving as an anode, and a control electrode, an oscillation generating circuit including a piezo-electric crystal regeneratively coupling said control electrode said electrode serving as an anode and said cathode for the production of sustained oscillations, an output circuit coupled to said generating circuit, and means for modulating the length of the oscillations generated in accordance with signals including a source of signals, a modulator tube having an anode, a cathode and a control electrode, an excitation circuit coupling said oscillation generating circuit to said control electrode of said modulator tube to feed to said control electrode voltages of the generated frequency, a phase shifter in said last named coupling for shifting the phase of the voltages fed to said control electrode about 90°, connections coupling the internal impedance between the anode and cathode of said modulator tube effectively in shunt to said crystal, and connections coupling said source of signals to said modulator tube to modulate the conductivity thereof in accordance with said signals.

12. In a wave generating and wave length modulation system, a generator including an electron discharge device having a cathode, an electrode serving as an anode, and a control electrode, an oscillation generating circuit including a piezo-electric crystal regeneratively coupling said control electrode said electrode serving as an anode and said cathode for the production of sustained oscillations, an output circuit coupled to said generating circuit, and means for modulating the length of the oscillations generated in accordance with signals including a source of signals, a modulator tube having an anode, a cathode and a control electrode, an excitation circuit coupling said oscillation generating circuit to said control electrode of said modulator tube to feed to said control electrode voltages of the generated frequency, connections coupling the internal impedance between the anode and cathode of said modulator tube effectively in shunt to said crystal, and connections coupling said source of signals to said modulator tube to modulate the conductivity thereof in accordance with said signals.

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