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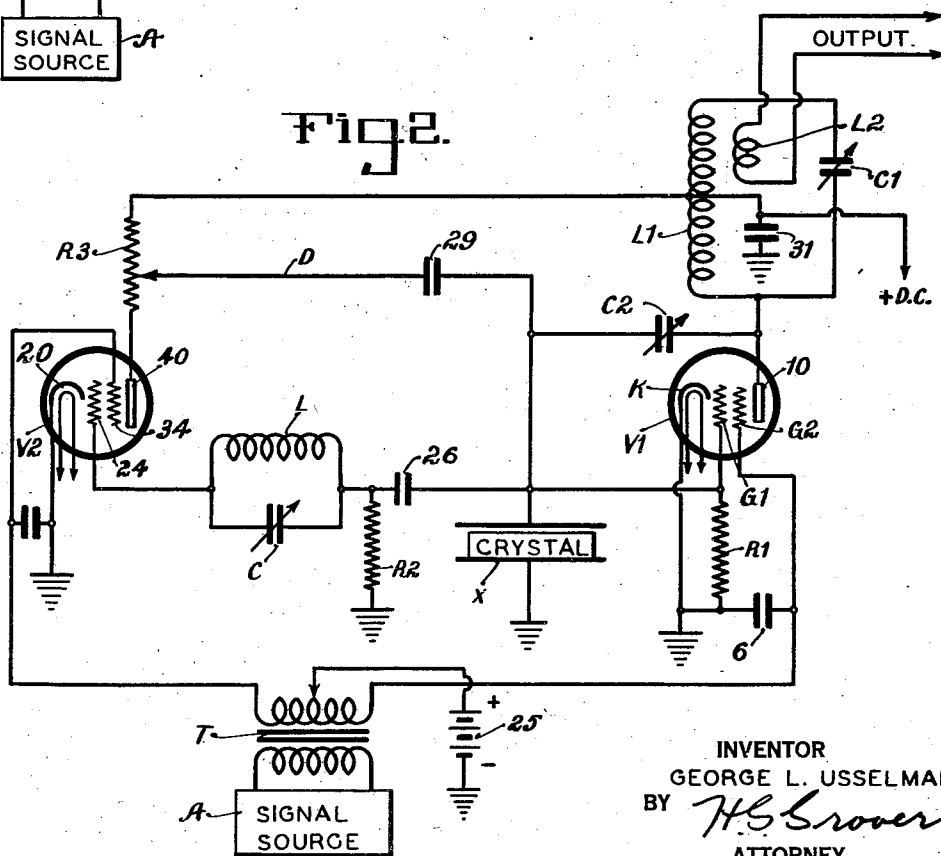
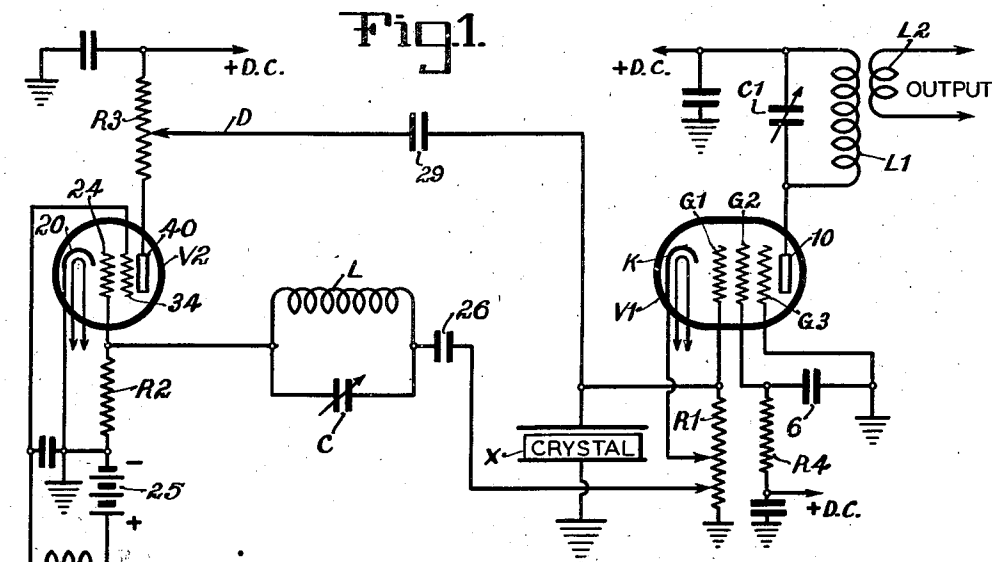
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2,343,099

FREQUENCY MODULATION SYSTEM

Filed Sept. 9, 1942

2 Sheets-Sheet 1



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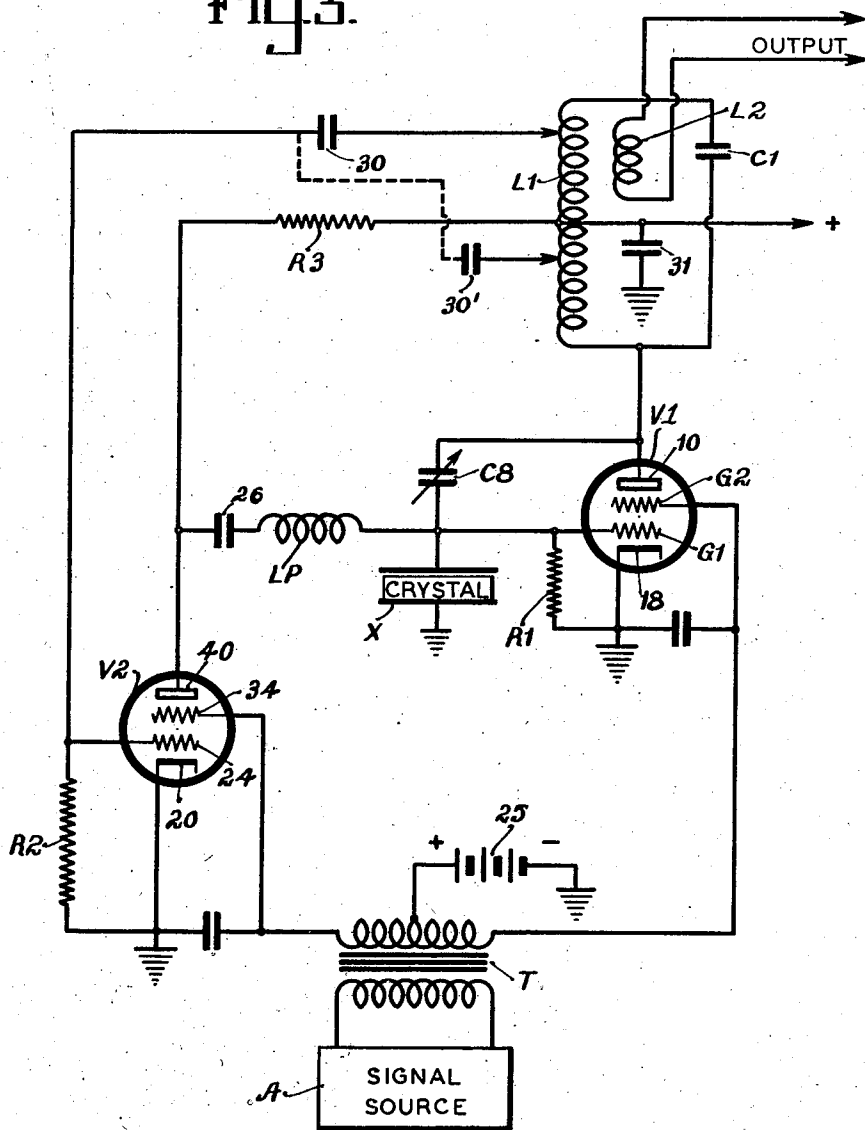
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2 Sheets-Sheet .2

Fig.3.



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FREQUENCY MODULATION SYSTEM

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Application September 9, 1942, Serial No. 457,702

7 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.

This application is a continuation-in-part of my United States applications Serial No. 338,837, filed June 5, 1940, now U. S. Patent #2,298,436, dated October 13, 1942, and Serial No. 361,506, filed October 17, 1940, now U. S. Patent #2,298,438, dated October 13, 1942.

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 3 inclusive each illustrates 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 of Figs. 2 and 3 the oscillator tube is also modulated and differentially with respect to the modulation on the modulator tube to thereby balance out concomitant amplitude modulation.

Referring to Fig. 1 of the drawings, 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 radio frequency by-passing and direct current blocking condenser 6 and to a source of charging potential by means of a resistor R4. 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 Fig. 1, comprising a coupling inductance L2.

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 crystal oscillator circuit of Fig. 1 is 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 grounded directly as shown. The anode of tube V1 works into a tuned output circuit C1, L1 and is substantially only electronically coupled to the crystal oscillator circuit. The grounded grid G3 shields the output circuit with respect to the generating circuits. Grid leak resistor R1 is also connected to the control grid of tube V1 and to ground.

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 this modification, as in Fig. 1, 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 also connected between the grid G1 and the anode 10 of tube V1 and oscillation generation is produced by virtue of the anode to control grid coupling C2. Moreover, the excitation circuit for the grid 24 of tube V2 is coupled by phase adjuster LC and coupling condenser 26 to the high radio-frequency voltage terminal of the crystal X instead of to R1 as in Fig. 1. Furthermore, differential modulating potentials are supplied by the transformer T to the screen grids 34 and G2 respectively of tubes V2 and

V1. By this opposed modulation of the screen grids, amplitude modulation in the output circuit L1—C1 is reduced.

In the system of Figs. 1 and 2 the circuit C, L must be slightly detuned with respect to the frequency of the generated waves 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 a phase like the oscillator grid G1 excitation phase, by the tap on R1 in Figs. 1 and 2. In passing through the phase shifters C, L, 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 the blocking condenser 29. 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 circuit C, L 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 modulator shown in Fig. 1 produces 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 modu-

lations 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 modification in Fig. 3 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 C1—L1 connected with the anode 10, crystal X, grid resistor R1 and feedback condenser C8. The cathode 18 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 L1 is grounded by condenser 31 for radio-frequency and one end of the tank circuit L1, C1 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 L1, 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 coil LP. The grid 24 of tube V2 is coupled to the tank coil L1 through a blocking condenser 30 as shown. The screen grids G2 and 34 of tubes 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. 3, 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 control grid 24 of tube V2 is excited from tank circuit C1, L1 through coupling condenser 30. This energy is amplified in the anode of tube V2 and fed back to the grid G1 of V1 by way of phase shifter LP. If we assume that the grid 24 of V2 is tapped on the upper end of tank circuit C1, L1, its excitation will be in phase with the excitation on the grid G1 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 G1 of V1 swings between the limits of zero to 90 degrees leading in the case assumed. If the grid 24 of V2 is tapped on the anode end of tank circuit C1, L1 its excitation will be opposite in phase with respect to the excitation on the grid G1 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 effective 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 G1 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 G1 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.

The phase changing network LC may be of any desirable type. It may be made as shown in Figs. 1 and 2, 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 the control grid capacity of tube V2 are part of the circuit with the filter affecting the change in excitation energy phase angle.

What is claimed is:

1. In a wave length modulation system, an electron discharge device having oscillation generating electrodes, an oscillation generating circuit, including a frequency determining piezo-electric crystal, regeneratively coupled to said electrodes, the generated voltage on at least one of said electrodes being of a certain phase, connections for deriving voltage of the generated frequency from said circuit and feeding said derived voltage back to said one of said electrodes whereat the generated voltage phase is of said certain phase, a reactance for shifting the phase of said last named voltage fed back to said one electrode to an extent such that the said fed back voltage and the said generated voltage are substantially in phase quadrature on said one electrode, connections for modulating the amplitude of the fed back voltage in accordance with signals to thereby produce desired wave length modulation of the generated oscillations and undesired amplitude modulation thereof, and additional connections for modulating the potential on an electrode of said discharge device in a direction to compensate said undesired amplitude modulation.

2. In a wave length modulation system, an electron discharge device having oscillation generating electrodes, an oscillation generating circuit, including a frequency controlling piezo-electric crystal, regeneratively coupled to said electrodes, the generated voltage on at least one of said electrodes being of a certain phase, an electron discharge tube having input and output electrodes for deriving voltage of the generated frequency from said circuit and feeding amplified derived voltage back to said one of said electrodes whereat the generated voltage phase is of said certain phase, a reactance for shifting the phase of said amplified voltage fed back to said one electrode to an extent such that the said fed back voltage and the said generated voltage are substantially in phase quadrature on said one electrode, connections to an electrode in said tube for modulating the amplitude of the fed back voltage in accordance with signals to thereby modulate the wave length of the generated oscillations and incidentally modulating the amplitude thereof and

other connections for modulating the potential on an electrode of said device to compensate said amplitude modulation.

3. In a wave length modulation system, an electron discharge device having oscillation generating electrodes, an oscillation generating circuit, including a frequency determining piezo-electric crystal, regeneratively coupled to said electrodes, the generated voltage on at least one of said electrodes being of a certain phase, an electron discharge tube having input electrodes coupled to said circuit for deriving voltage of the generated frequency from said circuit and output electrodes coupled to said one of said electrodes for feeding said derived voltage back to said one of said electrodes whereat the generated voltage phase is of said certain phase, a reactance in one of said last two couplings for shifting the phase of said last named voltage fed back to said one electrode to an extent such that the said fed back voltage and the said generated voltage are substantially in phase quadrature on said one electrode, connections to an electrode in said tube for modulating the amplitude of the fed back voltage to thereby correspondingly modulate the length of the oscillations generated and incidentally amplitude modulate the oscillations, and connections to an electrode in said device for modulating the amplitude of the oscillations in a direction to compensate said incidental modulations.

4. In a wave length modulation system, an electron discharge device having oscillation generating electrodes, an oscillation generating circuit, including a frequency controlling piezo-electric crystal, regeneratively coupled to said electrodes, the generated voltage phase on at least one of said electrodes being of a certain phase, an output circuit coupled to said generating circuit, an electron discharge tube having input electrodes coupled to said output circuit for deriving voltage of the generated frequency from said circuit, said tube having output electrodes coupled to said one electrode for feeding said derived voltage to said one of said electrodes whereat the generated voltage phase is of said certain phase, a reactance in one of the couplings to said tube electrodes for shifting the phase of said last named voltage fed back to said one electrode to an extent such that the said fed back voltage and the said generated voltage are substantially in phase quadrature on said one electrode, a source of signals for modulating the impedance of the tube to thereby modulate the amplitude of the fed back voltage in accordance with signals, and connections between said source and device for modulating the impedance of the device in accordance with said signals.

5. In a wave generating and wave length modulation system an electron discharge device having a cathode and a plurality of control electrodes, an oscillation generating circuit connected between said cathode and two of said control electrodes, one of which operates in said oscillation generating circuit as an anode, an output circuit connected with said output electrodes and coupled to said oscillation generation circuit, a piezo-electric crystal coupled between two of the electrodes in said oscillation generating circuit, a modulator tube having an anode, a cathode and a control electrode, an excitation circuit including phase shifting means coupling said oscillation generating circuit to the control electrode of said modulator tube, and means for modulating the impedances of said device and said tube in

accordance with control potentials to thereby modulate the length of the oscillations generated.

6. In a wave generating and wave length modulation system, an electron discharge device having a cathode and a plurality of control electrodes, an oscillation circuit connected between said cathode and one of said control electrodes, a piezo-electric crystal in said circuit, a reactive output circuit connected with said output electrodes, a modulator tube having an anode, a cathode, and a plurality of control electrodes, a coupling between one of said control electrodes of said modulator tube and said oscillation circuit, a coupling between the anode of said modulator tube and said oscillation circuit, and means for modulating the potential on another control electrode in said device and on another control electrode of said tube in accordance with signals.

7. In a wave generating and wave length modulation system, an electron discharge device having a cathode, an anode, and a plurality of control electrodes, an oscillation circuit comprising a piezo-electric crystal in a holder connected between said cathode and one of said control electrodes, a reactance coupling said anode to said one of said control electrodes to provide regeneration in said tube, a reactive output circuit coupled to said anode, a second tube having an anode, a cathode and a control electrode, a coupling between a point on said reactive circuit and the control electrode of said second tube, a connection between one terminal of said piezo-electric crystal and the anode of said second tube, and means for modulating the impedances of said second named tube and said device in accordance with control potentials.

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