

May 11, 1943.

G. L. USSELMAN

2,318,979

FREQUENCY MODULATOR

Filed Oct. 2, 1941

2 Sheets-Sheet 1

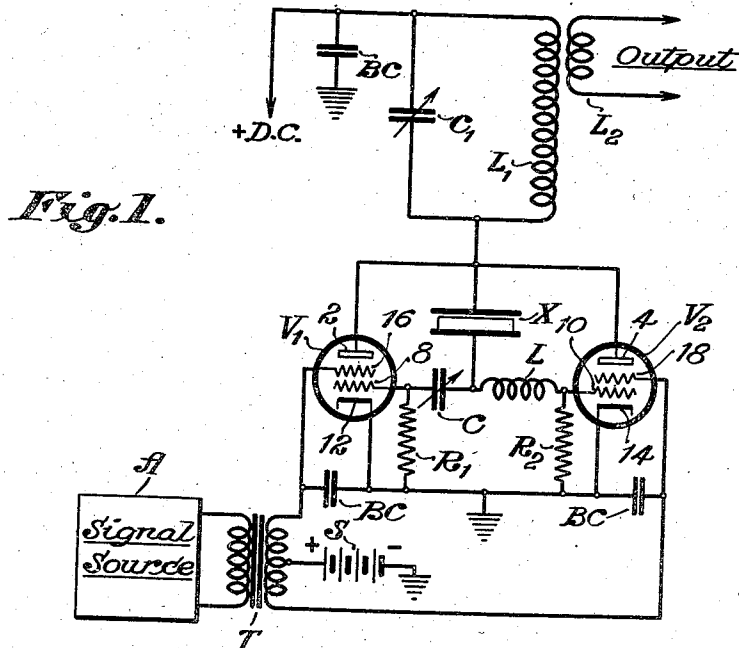
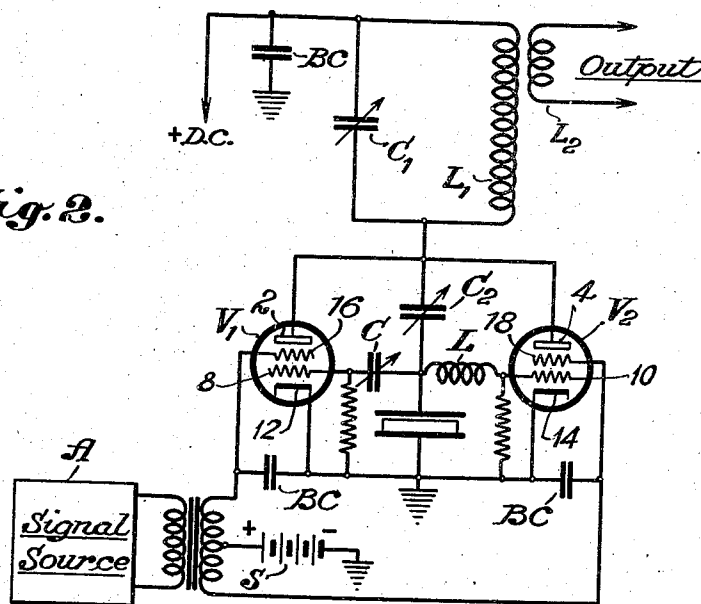


Fig. 2.



INVENTOR
George L. Usselman
BY
H. S. Grover
ATTORNEY

May 11, 1943.

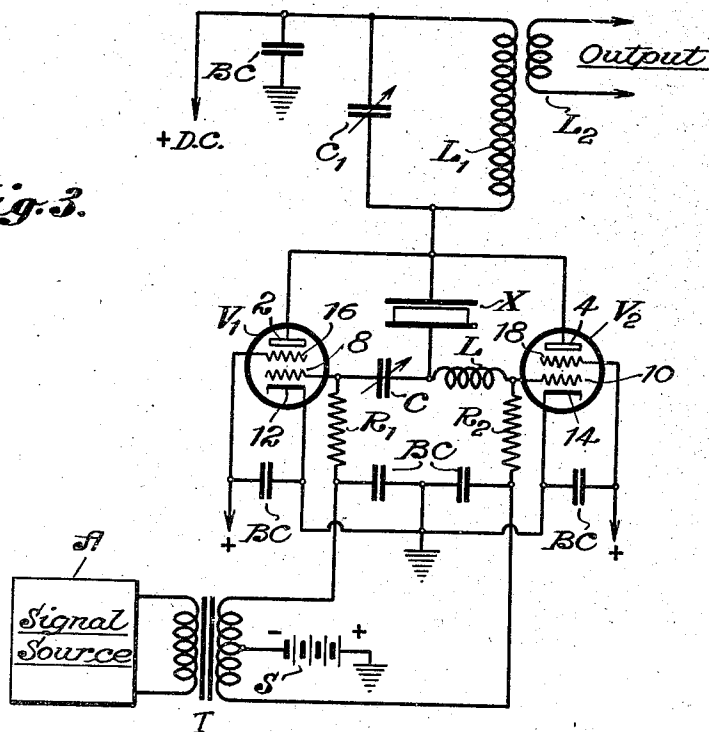
G. L. USSELMAN
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Fig. 3.



INVENTOR
George L. Usselman
BY *H. S. Srover*
ATTORNEY

UNITED STATES PATENT OFFICE

2,318,979

FREQUENCY MODULATOR

George L. Usselman, Port Jefferson, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application October 2, 1941, Serial No. 413,292

10 Claims. (Cl. 179—171.5)

This application concerns a new and improved modulator wherein substantially linear frequency modulation may be obtained. The object of the present invention is to provide a simple and efficient frequency modulator having a minimum number of tubes and a minimum amount of circuit apparatus or circuit elements in the modulator circuits.

The frequency modulator of this invention comprises a pair of electron discharge tubes having their electrodes coupled in generating circuits with a single crystal common to the oscillation circuits of the two tubes and with phase displacing reactances in connections to corresponding electrodes of the tubes so that the respective tube circuits tend to oscillate at different frequencies even though they are stabilized as to operation in a limited sense by a single crystal which, as known, inherently operates at a single frequency. The two tubes, however, are connected to a common tank circuit and thereby entrained to generate oscillations of a single frequency intermediate the frequencies at which the two tubes and circuits considered individually tend to oscillate. The tubes are then differentially modulated in accordance with signals of a desired nature to thereby modulate the resultant frequency produced by the entrained oscillators between said frequencies at which the tubes considered alone tend to operate as limits and the frequency modulated oscillations appear in said tank.

In describing my invention in detail, reference will be made to the drawings, wherein Figures 1, 2 and 3 each show a frequency modulator comprising two tubes with their electrodes regeneratively coupled in oscillation generating circuits including a single crystal. In the arrangement of Figs. 1 and 3, the crystal is connected between the anodes and grids of the tubes so that feedback energy in both tubes is by way of the crystal, whereas in Fig. 2 the crystal is connected between the grids and cathodes of the tubes, and the feedback energy from the anodes to the grids is by way of a common condenser.

Referring to Fig. 1, tubes V_1 and V_2 have their anodes 2 and 4 connected directly together and to a tank circuit L_1-C_1 , to which an output circuit may be coupled by means of inductance L_2 . The control grids 8 and 10 are connected to the cathodes 12 and 14 of tubes V_1 and V_2 respectively, by resistances R_1 and R_2 respectively. The control grid 8 of tube V_1 is connected to the anode 2 of tube V_1 by way of a variable phase shifting capacity C and the crystal X . The control grid

10 of tube V_2 is connected to the anode 4 of tube V_2 by way of a phase shifting inductance L and the crystal X . Modulation is applied differentially to the grids 16 and 18 from the secondary winding of the transformer T , the grid 16 and 18 being connected substantially directly to ground as far as radio frequency potentials are concerned by way of by-passing condensers BC .

In Fig. 1 the anodes of tubes V_1 and V_2 are connected to one end of the tuned tank circuit C_1-L_1 . The other end of the tuned tank circuit is grounded for radio frequency voltages by means of a by-pass condenser BC . Direct current for the anodes 2 and 4 is fed in at the grounded end of the tuned circuit. The cathodes of the tubes V_1 and V_2 are grounded while, as stated above, modulating potentials are applied differentially from the source A to the screen grids 16 and 18 by transformer T . A steady bias potential is applied to the screen grids from a source S through a center tap on the secondary winding of transformer T .

Since one electrode of the crystal X is connected to the anode end of the tuned circuit C_1-L_1 , and the other crystal electrode is connected to the control grids of tubes V_1 and V_2 through phase shifting elements C and L respectively, the control grids of tubes V_1 and V_2 are effectively connected in parallel to one of the crystal electrodes through the phase shifting elements C and L . Grid bias for the said control grid electrodes is obtained for the grid leak action of resistors R_1 and R_2 which, as pointed out hereinafter, serve also as phase shifting elements.

The condenser C , together with resistance R_1 and the tube resistance in parallel therewith, and the grid to cathode capacity of the tube, constitutes the feedback excitation phase shifting network for tube V_1 . Since this network is capacitive in character it advances the phase of the voltage supplied thereby from the anode to the grid by the way of the crystal. The inductance coil L , together with the resistance of the tube V_2 in parallel with resistance R_2 and the grid capacity of tube V_2 , constitutes the phase shifting (retarding) network of tube V_2 .

In the circuit of Fig. 1, it may be considered that there are two oscillation generators, one of which includes tube V_1 , tank L_1-C_1 , crystal X , and condenser C , and the other of which includes tube V_2 , tank L_1-C_1 , crystal X , and inductance L . Oscillation generation is insured in each of these oscillators considered individually due to effects somewhat similar to those obtained in

oscillators of the Pierce type. The feedback energy from the anode 2 and/or its tank circuit L_1-C_1 passes through the crystal to the control grid 8, thereby causing the crystal to oscillate in such a manner as to produce the proper phase relationship between the anode voltage and the excitation voltage reaching the control grid to maintain oscillation in the circuit. The same remarks apply to the oscillation generator including tube V_2 , crystal X , and inductance L . However, as will be noted, the phase of the feedback voltage on the grid of tube V_1 is advanced whereas the phase of the feedback voltage on the grid of tube V_2 is retarded. This causes the tubes V_1 and V_2 to tend to operate at different frequencies. However, due to the locking-in effect produced by the close coupling between the two tubes, they operate together to provide a single generated frequency to which the circuit L_1-C_1 is tuned. This is assuming conditions similar to those obtained with no modulation applied to the two tubes. In this case the tubes operate at, say, a mean frequency intermediate the frequencies at which the tubes considered individually tend to oscillate. This mean frequency may be considered the carrier frequency of the modulation system.

When modulation potentials are applied to the tubes differentially, the balance described above is upset and one tube has an output larger than the other. Due to the phase advancing and retarding network, including CR_1 and LR_2 , the phase of that tube supplying the greatest amount of power to the tank circuit L_1-C_1 will control, and the frequency of the output oscillations will shift in one direction, i. e., toward the frequency at which said tube considered alone tends to operate. When the grid potentials are modulated in an opposite sense by the modulating potentials, the resultant frequencies are shifted in the opposite direction.

The arrangement of Fig. 2 is similar in many respects to that of Fig. 1, and in Fig. 2 corresponding reference numerals have been applied to corresponding elements. In Fig. 2 it will be noted that the crystal X is connected between the control grids and cathodes of the two tubes and that the feedback voltages which provide the regenerative effect are supplied from the anodes 2 and 4 by way of a variable condenser C_2 . This condenser C_2 , as shown, is connected between the anodes and tuned tank circuit C_1-L_1 and the junction point of the phase shifting reactances C and L . The cathode end of the crystal X is grounded. This circuit is somewhat similar to the Miller crystal oscillator circuit. However, in this invention feedback excitation energy is obtained for the crystal X and the control grids of tube V_1 and V_2 from the anode circuit through common condenser C_2 . The crystal oscillates in such a manner as to produce the correct excitation potential phase relations on the control grids to maintain oscillations in the circuits. The phase of the excitation energy reaching the control grid of tube V_1 is advanced and the phase of the excitation energy reaching the control grid of tube V_2 is retarded. Thus as described above the two tubes considered as individual oscillators tend to operate at different frequencies. When both tubes deliver equal power the circuit oscillates at the crystal carrier frequency. This assumes that the tuned circuit C_1-L_1 has been tuned to operate at the crystal carrier frequency. When the power output of tubes V_1 and V_2 are differen-

tially modulated by the signal oscillations, the carrier energy will be frequency modulated in accordance with the signal oscillations.

The system of Fig. 3 is in general the same in circuit arrangement and operation as the system of Fig. 1. In Fig. 3, however, modulation is applied differentially to the grids 8 and 10 by way of biasing and phase shifting resistances R_1 and R_2 .

In all of the arrangements described above amplitude modulation is balanced out. In operation a frequency shift of 300 cycles was obtained at a carrier frequency of 2160 kc. Due to the use of a single crystal in the two individual oscillator circuits which cooperate to produce oscillations of a single frequency which can be modulated, a simple, efficient frequency modulator using a small amount of apparatus is provided.

What is claimed:

1. In a wave length modulation system, a pair of electron discharge tubes each having an anode, a cathode, and a control grid, a piezo-electric crystal in a holder having two terminals, circuits including said crystal regeneratively coupling the cathode, the anode and control grid of each of said tubes, a phase displacing reactance in at least one of said circuits whereby the voltages therein and on corresponding electrodes of the tubes are relatively displaced in phase a limited amount, a common tank circuit connected with corresponding electrodes of said tubes, and means for differentially modulating the impedances of said tubes in accordance with signals.

2. In a wave length modulation system, a pair of electron discharge devices each having an anode, a cathode, and a control grid, a piezo-electric crystal in a holder having two terminals, circuits including said crystal regeneratively coupling the anode, cathode, and control grid of each of said tubes whereby voltages are fed from the anode to the control grid in each tube to produce regeneration therein, a phase displacing reactance in at least one of said circuits for relatively displacing the voltages fed to the said grids whereby said tubes tend to operate at frequencies different than the normal frequency of operation of said crystal, means to entrain said tubes and circuits to operate at a common frequency including a common tank circuit connected with the anodes and cathodes of said tubes, and means for differentially modulating the impedances of said tubes in accordance with signals.

3. In a wave length modulation system, a pair of electron discharge tubes each having an anode, a cathode, and a control grid, a piezo-electric crystal in a holder having two terminals, a regenerative circuit coupled with the electrodes of one of said tubes, said regenerative circuit including said crystal, a regenerative circuit coupled with the electrodes of the other of said tubes, said last named regenerative circuit including said crystal, a phase advancing reactance in one of said regenerative circuits, a phase retarding reactance in the other of said regenerative circuits, a common tank circuit connected with the anodes and cathodes of said tubes, and means for differentially modulating the impedances of said tubes in accordance with signals.

4. A system as recited in claim 3, wherein said crystal in said regenerative circuits is between the anode and grid of each tube.

5. A system as recited in claim 3, wherein said crystal in said regenerative circuits is between the grid and cathode of each tube.

6. In a wave length modulation system, a pair of electron discharge tubes each having a plurality of electrodes, including output electrodes, a piezo-electric crystal in a holder, a tank circuit coupling the output electrodes of said tubes in parallel, connections coupling electrodes of one of said tubes in a regenerative circuit including said crystal, other connections coupling electrodes of the other of said tubes in a regenerative circuit including said crystal, phase shifting reactances in said circuits for causing said tubes and their respective circuits to tend to generate oscillations of different frequencies stabilized by said crystal, couplings in said circuits for entraining said tubes and circuits to generate oscillations of a third frequency, and connections for modulating the impedances of said tubes in phase displaced relation at signal frequency.

7. In a wave length modulation system, a pair of electron discharge devices, each having an anode, a cathode, and a control grid, a piezo-electric crystal in a holder having two terminals, connections including said crystal coupling the anode, cathode and control grid of one of said devices in a regenerative circuit, a phase advancing reactance in said regenerative circuit between a terminal of said crystal and an electrode of said one device, connections including said piezo-electric crystal coupling the anode, cathode and control grid of the other of said devices in a regenerative circuit, a phase retarding reactance in said last circuit between a terminal of said crystal and an electrode of said other device, an output circuit coupled to said regenerative circuits, and means for differentially modulating the impedances of said devices in accordance with signals.

8. In a wave modulation system, a pair of electron discharge devices, each having an anode, cathode and a control grid, a piezo-electric crystal in a holder having two terminals, connections including said piezo-electric crystal coupling the anode, cathode and control grid of one of said devices in a regenerative circuit, a phase advancing reactance in said connections

between a terminal of said crystal and the control grid of said one device, connections including said piezo-electric crystal coupling the anode, cathode, and control grid of the other of said devices in a regenerative circuit, a phase retarding reactance in said connections between said one terminal of said crystal and the control electrode of the other of said devices, an output circuit coupled to said regenerative circuits and connections for differentially modulating the impedances of said devices in accordance with signals.

9. In a wave length modulation system, a pair of electron discharge devices, each having an anode, a cathode, and a control grid, a piezo-electric crystal in a holder having two terminals, connections including a phase advancing reactance coupling said crystal between the anode and the control grid of one of said devices, an impedance coupling the control grid of said one of said devices to the cathode of said one of said devices, connections including a phase retarding reactance coupling said piezo-electric crystal between the anode and control grid of the other of said devices, an impedance coupling the control grid of said other of said devices to the cathode of said other of said devices, connections for differentially modulating the impedances of said devices in accordance with signals, and an output circuit connecting the anodes and cathodes of said devices in parallel.

10. In a wave length modulation system, two electron discharge devices, each having an anode, a cathode and a control grid, a piezo-electric crystal in a holder having two terminals, connections including a phase advancing reactance coupling said crystal between the control grid and cathode of one of said devices, connections including a phase retarding reactance coupling said crystal between the control grid and cathode of the other of said devices, a coupling between the anode of each of said devices and the control grid of each of said devices, connections for differentially modulating the impedances of said devices in accordance with signals, and an output circuit coupling the anodes and cathodes of said devices in parallel.

GEORGE L. USSELMAN.