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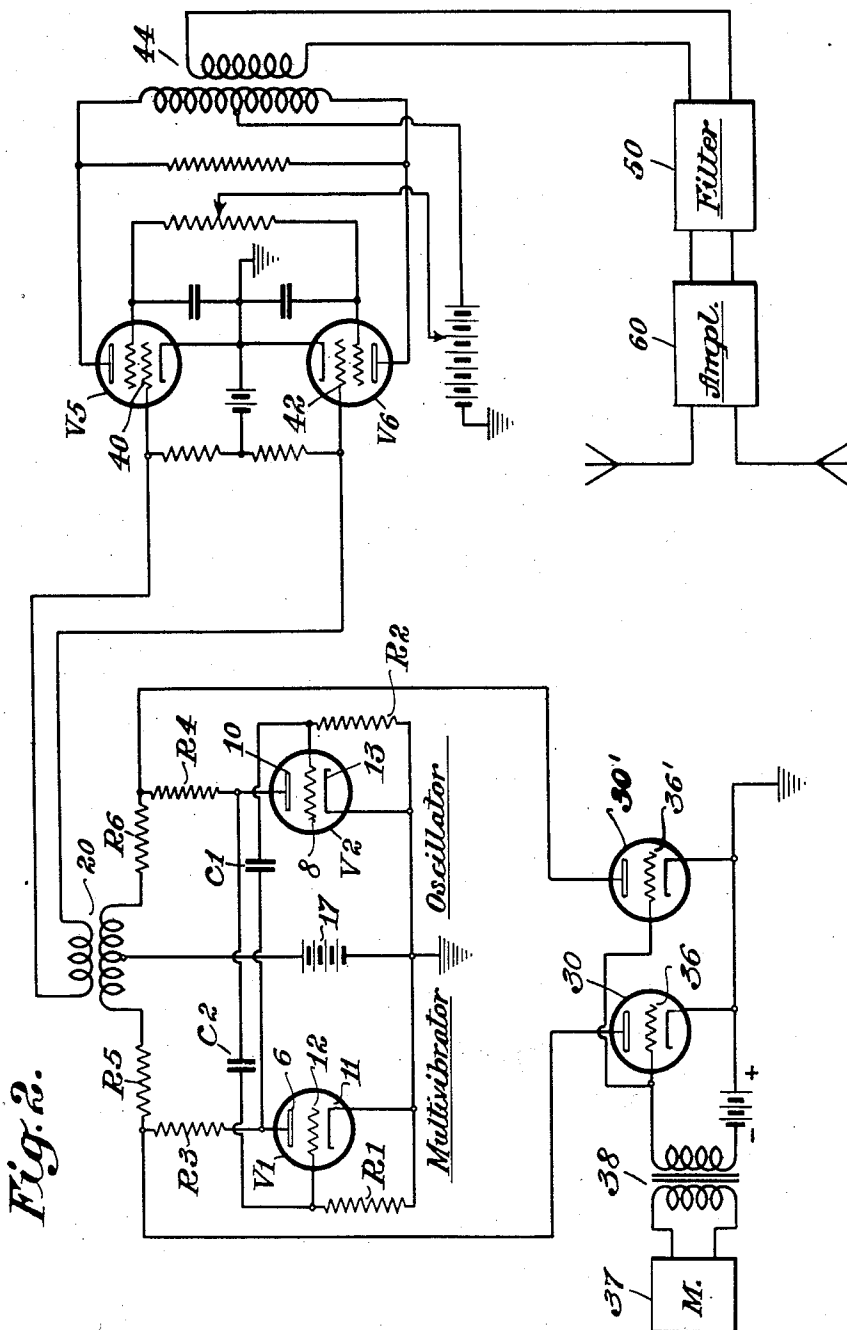
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2,297,926

FREQUENCY MODULATED TRANSMITTER

Filed Oct. 30, 1940

5 Sheets-Sheet 2



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Fig. 3.

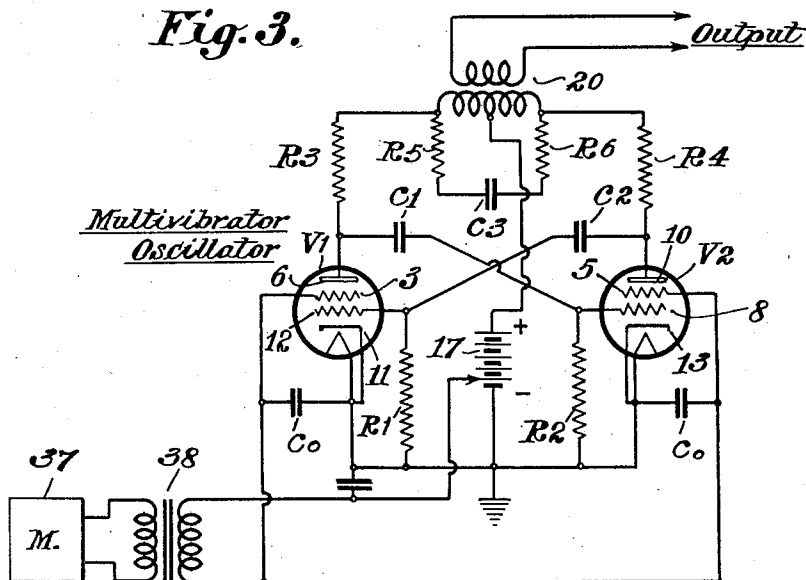
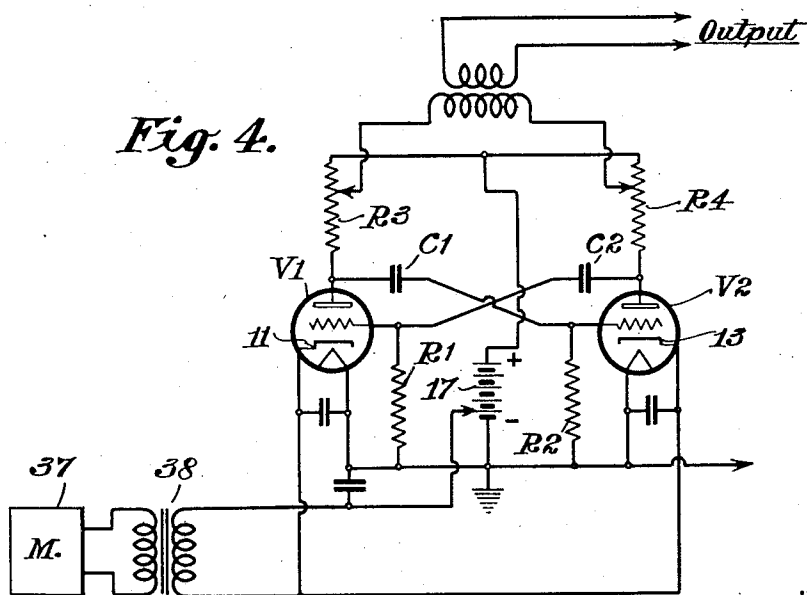


Fig. 4.



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Fig. 5.

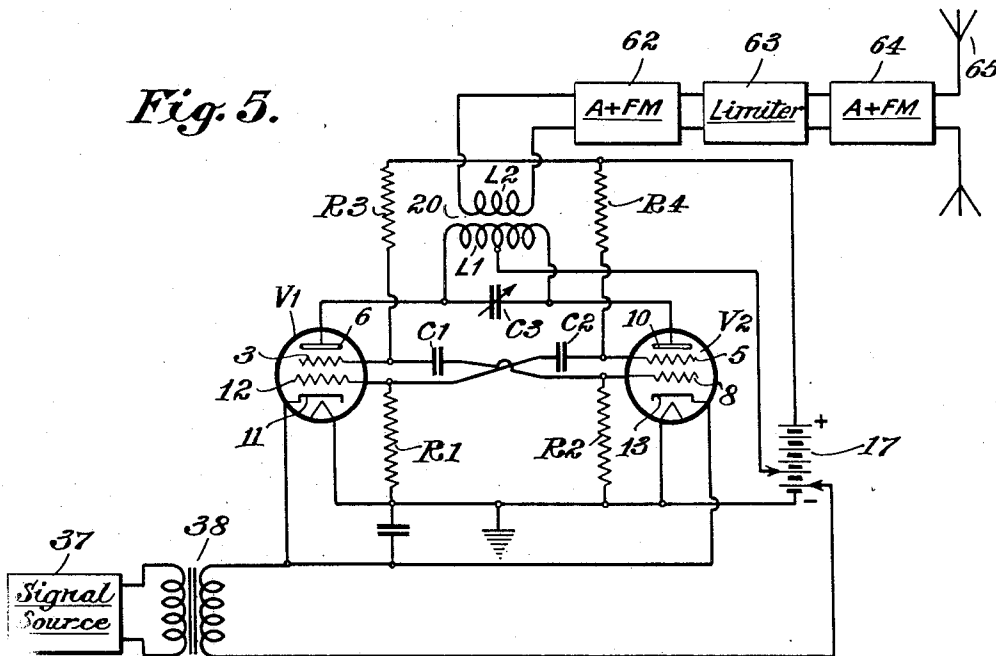
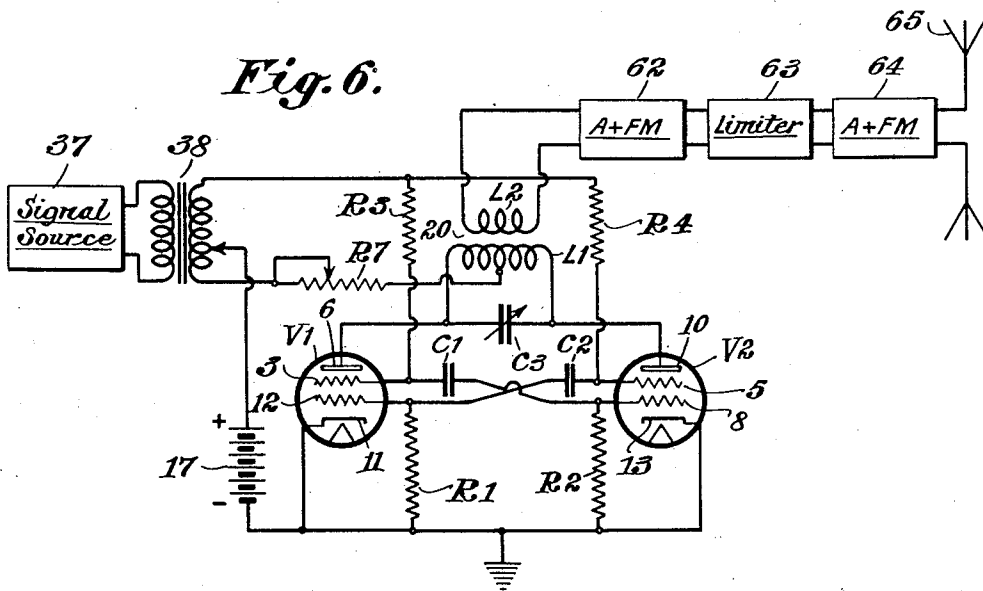


Fig. 6.



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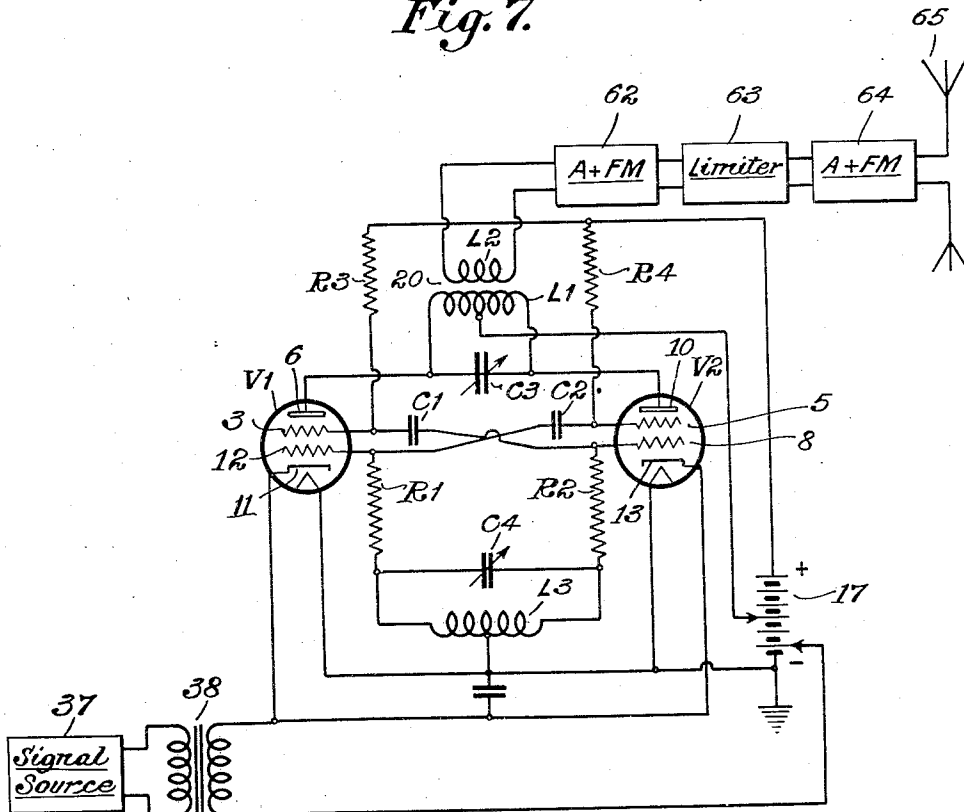
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Fig. 7.



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2,297,926

FREQUENCY MODULATED TRANSMITTER

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Application October 30, 1940, Serial No. 363,447

9 Claims. (Cl. 179—171.5)

The present invention relates to frequency modulators and, more particularly, to a frequency modulator using the multivibrator principle.

Most prior art frequency modulators use reactance tubes to vary the effective reactance of an oscillator circuit to obtain frequency modulation. This usually requires one or more extra tubes. In the present invention, in the preferred circuits, I apply the audio modulating potentials directly to the multivibrator tubes; that is, to the tubes which produce the oscillations and wherein modulation takes place. In my arrangement, a pair of tubes connected in reactive and resistive circuits of the multi-vibrator type are used and the resistance in the circuits is varied at signal frequency to vary the frequency of operation of the multi-vibrator circuit.

In a modification, means is included for balancing amplitude variations produced by change of potential on one tube electrode by opposite and equal variations of the potential on another tube electrode to thereby produce substantially frequency modulation only of the oscillations generated with little or no amplitude modulation.

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

Figs. 1 to 7, inclusive, each show a frequency modulator comprising a pair of multi-vibrator tubes with means for modulating elements in the multi-vibrator circuits to thereby modulate the frequency at which they operate.

In Fig. 1, an external grid circuit resistance of the tubes is modulated, this being one of the elements which determines the time constant of the multi-vibrator circuits and, consequently, the frequency of operation thereof.

In Fig. 2, a resistance in the plate circuit of each tube in the multi-vibrator circuits is varied.

In Fig. 3, the screen grid potentials are modulated to thereby modulate the tube impedances and means is provided for stabilizing the mean frequency of operation of the multi-vibrator.

In Figs. 4 and 7, the cathode potentials are modulated, while in Fig. 6, the screen grid potentials are modulated.

In Fig. 5, the anodes of the tubes are connected with a tank circuit which tends to stabilize the multi-vibrator.

Fig. 6 is a modification wherein means is provided for balancing out any amplitude modulation produced.

Fig. 7 is somewhat like Fig. 5 but has the tank circuit connected with the grids of the multi-vibrator tubes not with the plates as in Fig. 5.

The modulators of all of the systems may feed

the frequency modulated wave energy to the necessary and well known amplifying, amplitude limiting and frequency multiplying circuit some of which have been illustrated.

In Fig. 1, two tubes V1 and V2 have their anodes and grids cross-connected by condensers C1 and C2. That is, the anode 6 of tube V1 is connected by condenser C2 to the grid 8 of tube V2, while the anode 10 of tube V2 is connected by condenser C1 to the grid 12 of tube V1. The grid 12 of tube V1 is connected to its cathode 11 by a resistance R1 while the grid 8 of tube V2 is connected to its cathode 13 by a resistance R2. The anodes 6 and 10 are connected by resistors 14 and 18 and the primary winding of a transformer 20. A source of potential 17 is connected between a point on the primary winding of transformer 20 and the cathodes 11 and 13 to supply plate potential to anodes 6 and 10. The secondary winding of this transformer 20 supplies the output of the modulated multi-vibrator to a pair of amplifier tubes V5 and V6.

The condensers C1 and C2 and resistances 14, 18, R1 and R2 form the time constants of the circuit which determines the frequency of operation thereof. The condensers C1 and C2 are charged, discharged and recharged at a rate determined by their size and the size of resistances 14, 18, R1 and R2. During each impulse the condensers C1 and C2 are discharged and charged in reverse sense at a high frequency.

In a multi-vibrator circuit the condenser charging circuit consists of the condenser, the grid resistor and the opposite tube anode resistor. Anything that affects the current in this circuit will affect the condenser charging rate. That is, if the value of condenser or any resistor is changed the charging rate and the oscillator frequency will be changed. If the potentials are changed in such a way as to change the charging current the charging rate and frequency of operation will be changed. If the tube resistances are changed by applying modulating potentials to some of the tube elements, that will change the charging rate of the condensers by changing the voltage drop in the anode resistor due to the change in tube current. In other words, if the anode potential is considered as the source of current passing through the condenser C1 or C2 and through the grid leak resistor R1 or R2 to ground then it can be seen that a change in the anode potential, such as occurs during modulation of the tube current, changes the charging

rate of the condensers and thereby changes the oscillator frequency.

Another way to look at it is to consider that the condenser C1 or C2 and grid leak resistor R1 or R2 are connected in parallel to the opposite tube anode to cathode tube resistance. This combination is connected in series with the tube anode supply resistance. This latter resistance serves to limit the total current so that when the tube current increases the condenser current decreases and vice versa. When a higher condenser discharge rate exists then a higher frequency of push-pull oscillations exists in the multi-vibrator circuit. The operation of a multi-vibrator circuit is well known to the art. It is a sort of self regenerating tripping circuit.

Since the frequency of operation depends in part on the resistances R1 and R2, modulation of said resistances at signal frequency will correspondingly modulate the frequency of oscillation of the multi-vibrator. I modulate the resistances R1 and R2 by means of a modulation amplifier 30 having a pair of anodes 32 and 34 connected to points on R1 and R2, respectively. The control grid 36 of tube 30 is connected to a source of modulating potentials 37 by way of transformer 38. The source of modulating potentials may represent voice signals, television signals, video signals, etc.

The frequency modulated oscillations are supplied to the grids 40 and 42 of amplifiers V5 and V6 for amplification therein. The anodes of tubes V5 and V6 supply the amplified modulated oscillations to a transformer 44 and from the transformer 44 by way of a filter 50 to a frequency multiplier and amplifier and limiter 60.

In Fig. 2, I also illustrate a frequency modulator circuit using a multi-vibrator oscillator. In this circuit the modulation is applied to the anodes 6 and 10 of the oscillator tubes V1 and V2 through resistors R3 and R4 and R5 and R6. Modulation of tubes 30 and 30' in effect varies the resistance in the anode circuit of the multi-vibrator, thereby varying the frequency. The output is passed through amplifiers and filters also before it reaches the load.

In Fig. 3, I modulate the screen grids 3 and 5 in phase by modulating potentials from the source 37. Changing the screen grid potential changes the resistance or impedance of the tubes V1 and V2. These tube resistances are part of the time constant circuits and, consequently, partly control the frequency of operation thereof. Thus, the frequency variations correspond to the amplitudes of the modulating potentials. In Fig. 3, the output circuit, comprising the inductance of the primary winding of transformer 20, condenser C3 and resistances R5 and R6, is a broadly tuned resonant circuit, the purpose of which is to introduce some degree of frequency stability to thereby hold the oscillator at an approximately fixed mean frequency, to improve the output wave shape of the modulator and yet to permit wide band frequency modulation to be accomplished.

In Fig. 4, I modulate the potential on the cathodes 11 and 13 and the circuit of Fig. 4 was demonstrated to change its frequency as the current through tubes V1 and V2 were modulated. This changes the charging rate of condensers C1 and C2, thereby causing corresponding changes in the frequency of operation of the system.

Fig. 5 shows a preferred arrangement of this

frequency modulator. In this circuit, I use screen grid or four element tubes. Of course, shielding grids or electrodes could be used to advantage placed between the electrodes of the tubes V1 and V2 of Fig. 5. In Fig. 5, the signal modulating potentials from source 37 pass through transformer 38, and are applied to the cathodes 11 and 13 of tubes V1 and V2 in like audio phase, that is "push-push." Modulating potentials may be applied to any electrode of tubes V1 and V2 by proper circuit arrangements. The modulation of the potential on the cathodes of tubes V1 and V2, modulates the current passing through these tubes. This changes charging time of condensers C1 and C2 and, consequently, modulates the oscillator frequency in accordance with the signal amplitude and frequency. Now, as a rule, the current and voltage wave shape of a multi-vibrator is not like a sine wave and the frequency stability is poor because it changes with power voltage variations. In this circuit it may be noted that the cathodes 11 and 13, control grids 12 and 18 and the screen grid electrodes 3 and 15 of tubes V1 and V2 are used for the multi-vibrator oscillator circuit of the modulator, while the anodes of tubes V1 and V2 are used in the output circuit of the modulator. The anodes 6 and 10 of tubes V1 and V2 are connected in push-pull relation to tuned circuit L1, C3. The center point of inductance L1 is connected down on power source 17. The inductance L1 and the variable condenser C3 form a tank circuit which is tuned to the carrier frequency. Of course, condensers C1, C2 and resistors R1, R2, R3, R4 must also have the correct values to operate at the carrier frequency. The tank circuit L1, C3 acts both as a frequency stabilizer and as a filter to give a substantially sine wave shape output. In other words, the sine wave current oscillations in tank circuit L1, C3 are maintained by and guided by the multi-vibrator current oscillations which are not sine wave shape. To obtain correct operation the proper ratio of voltages supplied from source 17 must be maintained between the anodes 6 and 10 and the screen grids 3 and 5. Too much control by the oscillator screen grid circuit will result in poor wave shape output. Too much control by the anode circuit will cause reduction of modulator band width.

The output circuit L1, C3 of the modulated multi-vibrator is coupled through coil L2 to the amplifier and/or frequency multiplier stage 62. Since this frequency modulator does not balance out amplitude modulation, it is desirable to pass the modulated energy from the modulator and stage 62 through an amplitude limiter 63. The output of stage 63 is passed through amplifier and/or frequency multiplier stage 64 and to load or antenna 5 where it is radiated. If the amplifiers and/or frequency multiplier stages act also as amplitude limiters then a separate limiter stage 3 is not necessary.

A modification of Fig. 5 is shown in Fig. 6. This circuit is arranged so that the amplitude modulation can be balanced out.

In Fig. 6 the modulating circuits are arranged in such a way as to balance out amplitude modulation. The signal modulating potentials are applied in phase to the screen grids 3 and 5 of tubes V1 and V2 of the multi-vibrator oscillator circuit of the modulator to produce the frequency changes. The signal modulating potentials from source 37 are applied to audio transformer 38. One terminal of the secondary winding of trans-

former 38 is connected to the screen grids 3 and 5 of tubes V1 and V2 through resistors R3 and R4. The other terminal of transformer 38 is connected to the anodes 6 and 10 of tubes V1 and V2 through resistor R7 and through coil L1. The power source 17 is connected between the cathodes 11 and 13 of tubes V1 and V2, and some suitable point on the secondary winding L1 of transformer 38. During the modulating cycle, take an instance when the screen grid potential is made more positive. This causes a change in the modulator frequency but it would also cause more current to reach the anodes of tubes V1 and V2. However, the fact that power source 17 is tapped somewhere between the output terminals of transformer 38 means that when the screen grid potentials are modulated in the positive direction, the anodes of tubes V1 and V2 are modulated in a negative direction and vice versa. Now if the tapped position of power source 17 on the secondary winding of transformer 37 is properly chosen, the amplitude modulation is balanced out so that only frequency modulated carrier reaches the antenna. The variable resistor R7 is placed in series with the anode circuit of tubes V1 and V2 in order that the average ratio of power delivered to the screen grid circuit and the anode circuit of the frequency modulator, may be properly adjusted. This is essential for proper operation of the modulator. The arrangement of Fig. 6 does not require a limiter stage for limiting out the amplitude modulation.

The arrangement of Fig. 7 is similar to the arrangement of Fig. 5 except that in Fig. 7 a tank circuit C4, L4 is also included in the grid circuit of the tubes V1 and V2 and the tank circuit, like tank circuit C3, L2, is tuned to the frequency of operation of the multi-vibrator. These tank circuits tend to stabilize the operation of the system.

What is claimed is:

1. In a frequency modulator, a pair of electron discharge devices each having an anode, a cathode, and a grid connected in circuits including capacity and resistance to form a multi-vibrator the frequency of operation of which is controlled by the constants of the circuits, and means for varying the potential on the cathode electrodes of said devices in accordance with signals to vary the frequency of operation thereof in accordance with signals.

2. In a wave length modulator, a pair of electron discharge devices each having an anode, a cathode, a control grid and a screen grid, circuits including capacity and resistance interconnecting the screen grids, control grids, and cathodes of said devices to form a multi-vibrator oscillator, a source of direct-current potential connected to the cathodes, the anodes and the screen grids of said devices, means for modulating the potentials on the cathode of said devices in accordance with signals to thereby modulate a constant of said multi-vibrator and correspondingly vary the frequency of operation thereof, and an output circuit connected to the anodes of said devices.

3. In a wave length modulator, electron discharge devices each having electrodes including an electrode serving as an anode, a cathode, and a control grid, means coupling said electrode serving as an anode, said control grid and said cathode of each tube in circuits including capacity and resistance to form a multi-vibrator the frequency of operation of which is controlled

by the resistance in the circuits, a source of modulating potentials coupled to the cathodes of said devices for varying the potentials thereof in phase in accordance with signals for varying the resistance in said circuits in accordance with signals to vary the frequency of operation thereof in accordance with signals, and an output circuit coupling corresponding electrodes of said devices in push-pull relation.

4. A system as recited in claim 3 wherein said output circuit is tuned to the frequency of operation of said multi-vibrator.

5. In a frequency modulation system, a pair of electron discharge devices each having an anode, a cathode, and a control grid electrode, capacities interconnecting the anode of each of said devices with the control grid of the other of said devices, a source of direct current potential, resistances connecting the anode and control grid of each of said devices to said source of direct current for applying direct current potentials to the said electrodes of said devices, an output circuit coupled in push-pull relation with the anodes of said devices, and connections for varying the potentials on the cathodes of said devices in phase in accordance with signals.

6. In a frequency modulation system, a pair of electron discharge devices each having an anode, a cathode, a control grid and a screen grid electrode, capacities interconnecting the screen grid of each of said devices with the control grid of the other of said devices, a source of direct current potential, resistances connecting the screen grids and control grids of said devices to said source of direct current potential for applying direct current potentials to the said electrodes of said devices, an output circuit coupled in push-pull relation with the anodes of said devices, and connections for varying the potential on the cathodes of said devices in phase in accordance with signals.

7. In a wave length modulator, a generator of wave energy to be modulated including a pair of electron discharge tubes each having electrodes including a cathode, a control grid, and an electrode serving as an anode, a condenser coupling the control grid of one tube to the electrode serving as an anode of the other tube, a condenser coupling the control grid of the other tube to the electrode serving as an anode of said one tube, a source of direct current potential, a resistance coupling the electrode serving as an anode of each tube to a point of positive potential on said source, a resistance coupling the control grid of each tube to the cathode of each tube, a connection tying the cathodes of said tubes together and to a point on said source, negative with respect to said first named point, an output circuit coupling corresponding electrodes of said tubes in push-pull relation, and a source of modulating potentials coupled to said cathodes for modulating the potentials thereon in phase.

8. A modulator as recited in claim 7 wherein a tuned circuit is connected between said control grids of said tubes to couple the same in push-pull relation.

9. A modulator as recited in claim 7 wherein said corresponding electrodes of said tubes are main anodes and wherein said output circuit coupling said corresponding electrodes in push-pull relation is tuned.

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