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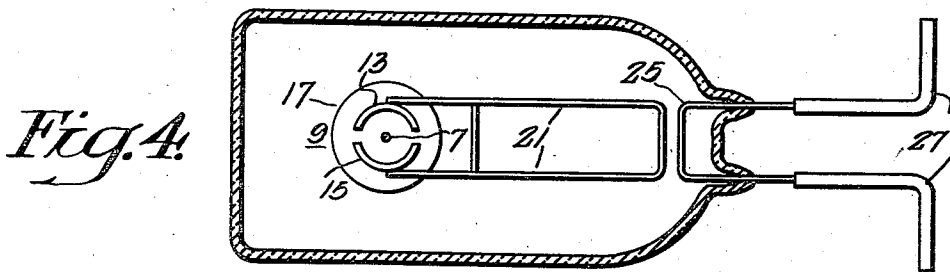
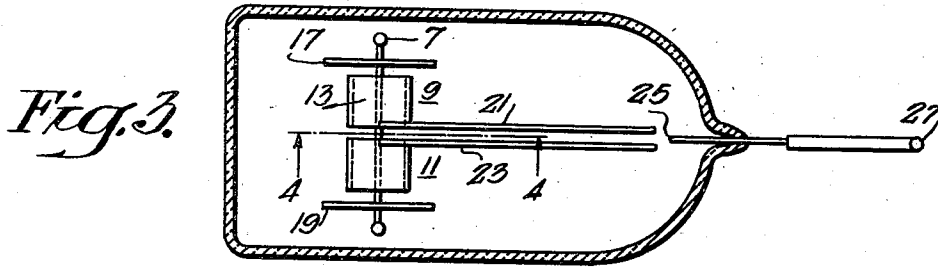
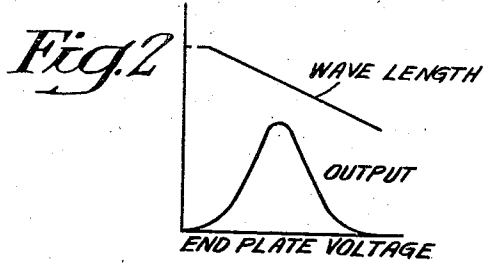
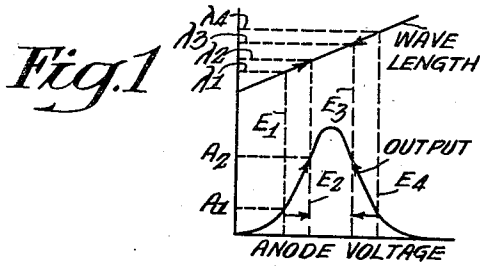
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2,293,798

MODULATION OF MAGNETRON OSCILLATORS

Filed May 24, 1939

2 Sheets-Sheet 1



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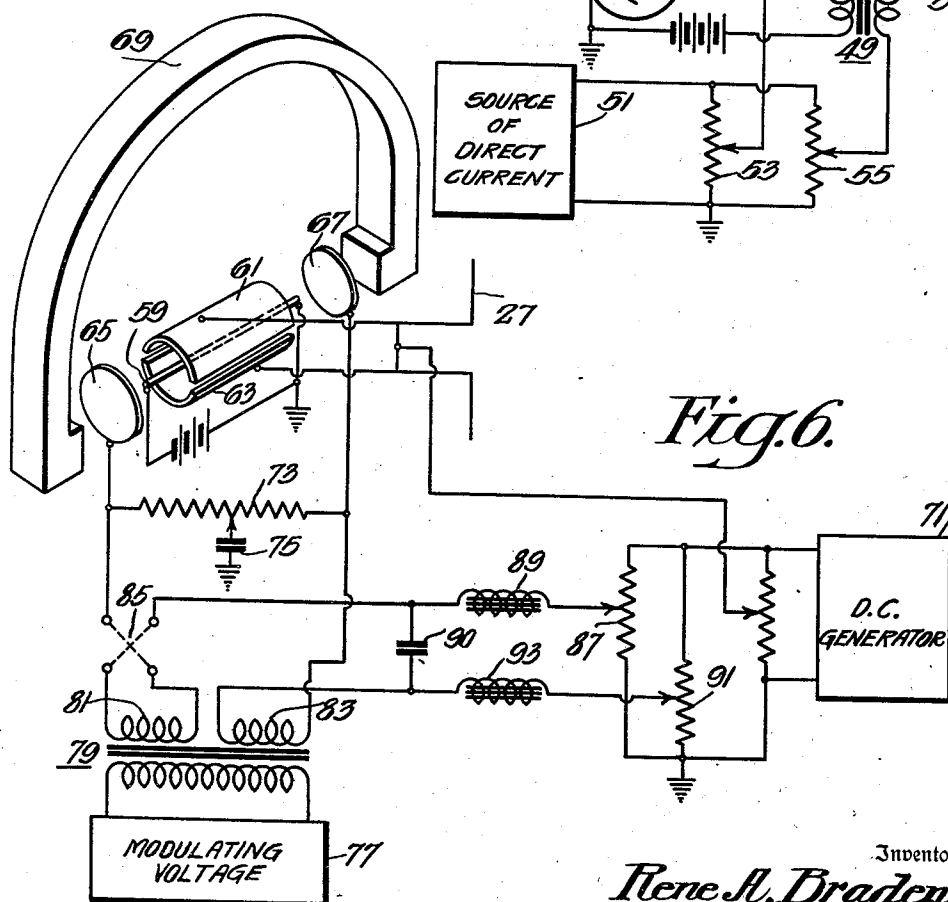
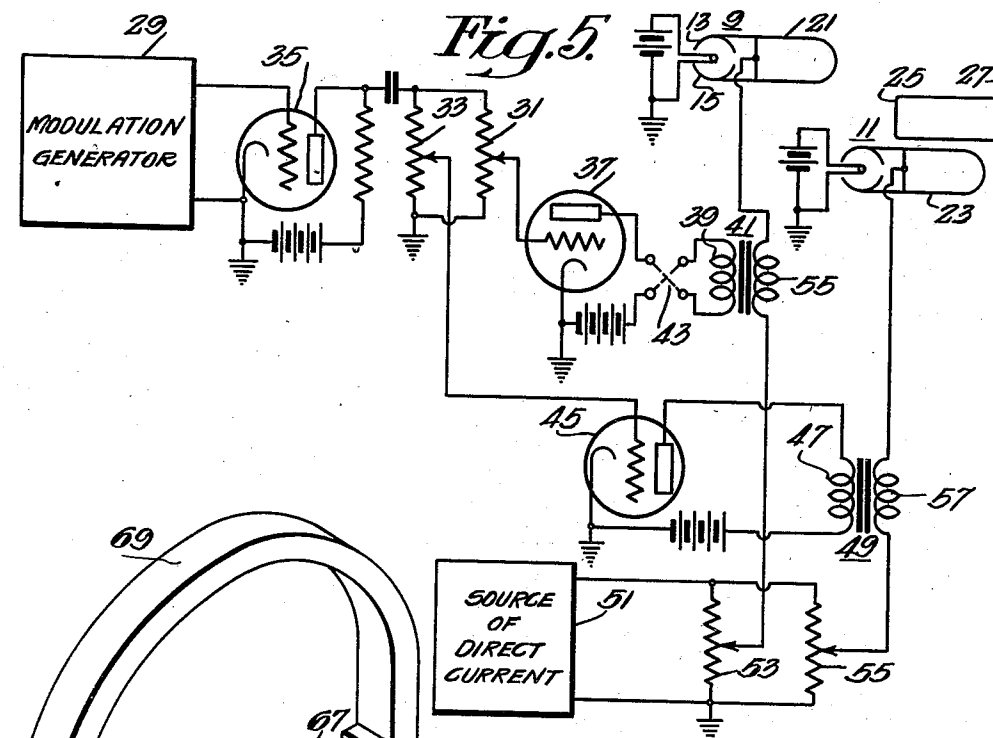
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MODULATION OF MAGNETRON OSCILLATORS

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2 Sheets-Sheet 2



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## UNITED STATES PATENT OFFICE

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MODULATION OF MAGNETRON  
OSCILLATORSRene A. Braden, Collingswood, N. J., assignor to  
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Application May 24, 1939, Serial No. 275,343

9 Claims. (Cl. 179-171.5)

This invention relates to the modulation of magnetron oscillators and, in particular, to a method of and means for modulating a magnetron oscillator so that undesired wave length modulation is minimized and amplitude modulation attained, or vice versa.

The principal object of this invention is to provide an improved method of modulating a magnetron oscillator and to provide means for carrying out the method. Other objects of this invention include means for reducing undesired frequency modulation which inherently results from the amplitude modulation of a magnetron oscillator; means for applying differential modulating voltages to similar pairs of electrodes in a magnetron; and to provide a magnetron oscillator of improved design.

This invention will be better understood from the following description when considered in connection with the accompanying drawings in which Figures 1 and 2 are curves representing operating characteristics of magnetron oscillators; Figure 3 is a plan view of a magnetron made in accordance with this invention; Figure 4 is an elevational view of the magnetron illustrated in Fig. 3; Figure 5 is a circuit diagram of a modulation system embodying the oscillator illustrated in Figs. 3 and 4; and Figure 6 is a circuit diagram of a system by which compensation of an undesired mode of oscillation may be attained by applying separate voltages to end plate electrodes.

While this invention will be explained in connection with a split anode magnetron, it is not to be limited thereto. The invention is applicable to various other types which are well known to those skilled in the art, such as the internal tank circuit magnetron, the resonant tank circuit magnetron, or magnetrons having a greater number of electrodes than those illustrated in the drawings. The application of this invention to the other magnetron types will be apparent to those skilled in the art and need not be considered in detail.

Experiments have shown that the modulation of a magnetron oscillator by varying the anode or the end plate electrode voltages affects the amplitude and wave length of the oscillations as shown in the curves of Figs. 1 and 2, to which reference is now made.

Fig. 1 represents a typical curve illustrating the characteristic of a magnetron oscillator when the anode voltage is varied. It is seen that the amplitude of oscillation increases to a maximum and then decreases. At the same time, the wave length increases substantially as shown. It is to

be understood that the actual operating curve obtained may not be absolutely symmetrical as to its output or linear as to its wave length; however, for all practical purposes and within reasonable voltage ranges, the operating characteristics may be considered to be substantially as shown.

Fig. 2 is a similar curve in which the output and wave length are plotted as a function of the end plate voltage. It is to be noted that the output curves are similar in the two figures, while the curves representing the wave length have similar slopes, but increase in one case and decrease in the other. Modulation of magnetron oscillators is frequently accomplished by varying either the anode or the end plate voltage in a region which falls on either slope of the corresponding output curve. Satisfactory amplitude modulation is accomplished by this method, but it is evident from a consideration of Figs. 1 and 2 that there will be, in addition, wave length or frequency modulation which, in some instances, is highly undesirable.

It would appear at first glance that the undesired frequency modulation could be eliminated by applying a modulating voltage simultaneously to the anode and to the end plate electrodes, since the effect on the output amplitude would be additive while the effect of the modulating voltage on the anode would compensate for the change of wave length due to the modulating voltage on the end plate. I have found, however, that there is a reaction between the end plate and anode electrodes, the effect of which is such that a change in the output produced by the modulating voltage on the anode is counteracted by the application of the modulating voltage to the end plate, so that substantially no amplitude modulation is obtained. This effect is due to the fact that a change in the static end plate voltage shifts the curve representing the anode voltage in a direction which tends to maintain the output constant. While effective amplitude modulation may be had by varying the anode and end plate voltages in opposite directions, a consideration of Figs. 1 and 2 will indicate that this produces wave length modulation in the same direction in both cases, so that the desired compensation is not achieved.

In accordance with one modification of this invention, the anode electrodes of a magnetron are split in a plane parallel to the electron path into two similar halves or segments which are insulated from each other with respect to direct currents but which are closely coupled to each other at the operating wave length. Separate

modulating and biasing voltages are applied to the two halves, the phase of the modulating voltages, and the amplitudes of the biasing voltages being chosen so that the two anode segments operate independently to generate oscillations and are modulated by the applied voltage so that they produce a like effect on the amplitude and an opposite effect on the frequency. Due to the close mutual coupling between the two anode segments, the oscillatory circuit tends to oscillate at a wave length which is the mean of the wave lengths at which each segment would operate if independent of the other.

Referring to Figs. 3 and 4, a construction is illustrated by which this principle of operation may be carried out. The magnetron structure includes a filamentary cathode 7 which is concentrically mounted within two coaxial anodes 9 and 11. While each segment may consist of a single cylindrical electrode, a magnetron of the split anode type illustrated is preferred due to its greater efficiency. Each anode segment 9 and 11, therefore, comprises two axially divided sections 13 and 15. End plate electrodes 17 and 19 may or may not be provided, as desired.

The resonant circuit of this oscillator includes two resonant lines 21 and 23. The lines terminate at respective anode sections of the two segments 9 and 11. The lines 21 and 23 are parallel to each other and positioned in close proximity so that the mutual coupling between them is a maximum. The lines are of identical construction and consequently tend to synchronize the oscillators at a single wave length. Output is obtained by a coupling loop 25 which may be connected to an antenna 27 or other suitable load.

A circuit diagram by which the magnetron illustrated in Figs. 3 and 4 may be operated is shown in Fig. 5. The two magnetron segments and the two resonant lines 21 and 23 have been shown widely separated in Fig. 5 in order to avoid confusion in the illustration, but it is to be understood that the coupling is maintained in the manner described above, and that the two apparently independent magnetrons are preferably combined within a single envelope.

A modulation generator 29 is coupled to a pair of potentiometers 31 and 33 by means of an amplifier 35. The movable arm of the first potentiometer 31 is connected to the input electrode of an amplifier tube 37. The output electrode of amplifier 37 is connected to the primary 39 of a transformer 41 through a reversing switch 43 which permits the modulating voltages to be applied co-phasally, that is, either in phase or in phase opposition. The movable arm of the second potentiometer 33 is connected to the input electrode of an amplifier tube 45, the output electrode of which is connected to the primary 47 of a transformer 49. A source of direct current 51 delivers energy to two voltage dividers 53 and 55. A variable tap on the first divider 53 is connected through the primary 55 of transformer 41 to the anode sections 13 and 15. This connection may be achieved by means of a connection to a point of zero radio frequency voltage on the resonant line 21, or any other means well known to those skilled in the art. The variable contact on the second divider 55 is similarly connected to the anode segment 11 through the secondary 57 of transformer 49.

The operation and adjustment of the device illustrated in Fig. 5 will now be explained by reference to Fig. 1. By means of the divider 53 the static or bias voltage applied to anode seg-

ment 9 is adjusted so that oscillation occurs on the rising slope of the output versus anode voltage characteristic. By means of divider 55 the bias on anode segment 11 is adjusted so that oscillations are produced on the falling slope of the operating characteristic. Potentiometers 31 and 33 permit the adjustment of the relative amplitudes of the modulating potentials which are applied to the two halves of the oscillator. The polarity reversing switch 43 is placed in that position which causes the modulating voltage, which is applied to one anode segment, to be in phase opposition to the voltage which is applied to the other anode segment.

Upon the application of the modulating voltages, the potential on anode segment 9 increases from E1 to E2, while, at the same time, the voltage on anode segment 11 decreases from E4 to E3. The increase in voltage on the one anode segment and the decrease in voltage on the other tend to increase the oscillator output so that amplitude modulation is accomplished. The output voltage is the vector sum of the voltages produced by the two oscillating sections. As the anode voltage of segment 9, considered alone, increases, the wave length likewise increases from  $\lambda_1$  to  $\lambda_2$ . However, as the voltage upon anode segment 11, considered alone, decreases from E4 to E3, the wave length of that section decreases from  $\lambda_4$  to  $\lambda_3$ . The wave lengths represented correspond to the values which would be produced by the two segments operating independently, as pointed out above. Due to the close coupling of the two segments, however, they oscillate in synchronism at a mean value which necessarily remains constant when the tendency to change is exerted in equal and opposite directions. If it is found that complete compensation is not achieved, due to dissymmetries in the wave length or output curves, the amplitudes of the modulating potentials may be adjusted by means of potentiometers 31 and 33 until the wave length modulation is minimized. Instead of applying both the modulating and the bias potentials to the anode electrodes, it is feasible to operate the modulated anodes at a fixed bias and to apply the controlled bias potentials to end plate electrodes. As pointed out above, changing the end plate potential shifts the anode characteristic so that the desired effect is produced.

In certain instances wave length modulation is desired. In such instances, it is also desirable to eliminate inherent changes in the amplitude of the output. This invention is readily modified to accomplish this purpose by reversing the phase of the modulating potentials by means of switch 43. If the potential of anode segment 9 increases from E1 to E2, while that of anode segment 11 increases from E3 to E4, a consideration of Fig. 1 will show that the amplitude from one segment increases, while that from the other decreases. Consequently, the total output remains substantially constant. At the same time, the wave lengths of both sections of the oscillator are affected in a similar manner so that a resultant change in the operating wave length is produced.

An alternative arrangement by which the method of compensating for undesired modes of modulation can be effectuated is illustrated in connection with Fig. 6. In accordance with the method which is now to be described, a standard split anode magnetron having two end plates is utilized. This invention, therefore, may be practiced without resorting to modified magnetron structures.

A magnetron oscillator comprising a filamentary cathode 59, two semi-cylindrical anodes 61 and 63, and a pair of end plate electrodes 65 and 67 is positioned between the opposing pole pieces of a magnet 69. The anodes are connected through a resonant circuit to an antenna 27 or other load device in the usual manner. Anode potential is obtained from the direct current generator 71. The end plate electrodes are connected to the outer ends of a potentiometer 73, the contact arm of which is grounded through a by-pass capacitor 75. A source of modulating voltage 77 is connected to the primary of a transformer 79 having two secondary windings 81 and 83. One of the secondary windings 81 is connected through a polarity reversing switch 85 to end plate 65 and to the movable contact of a variable potentiometer 87, which is, in turn, connected across the direct current generator 71. A choke coil 89 may be included in this circuit to prevent modulating currents from entering the direct current generator circuit. The other secondary winding, 83, is connected between end plate electrode 67 and potentiometer 91, which is likewise energized by the direct current generator 71. This circuit also may include a choke coil 93. A capacitor 95 is connected between the alternating current ends of the two chokes to complete the alternating current path between the two transformer secondaries 81 and 83.

In order to obtain amplitude modulation which is compensated to minimize the undesired wave length modulation the static or bias potentials which are applied to the end plate electrodes are individually adjusted by means of potentiometers 87 and 91 so that one end plate operates upon the rising slope of the operating characteristic and the other end plate operates upon the falling slope of the operating characteristic illustrated in Fig. 2. By modulating the end plates in phase opposition, a cumulative output modulation is obtained while the undesired wave length modulation is minimized. Potentiometer 73 permits the relative modulating voltages applied to the two end plates to be adjusted.

By operating the reversing switch 85 so that the modulating potentials are applied in phase to the end plate electrodes, wave length modulation may be achieved, while amplitude modulation is minimized.

I claim as my invention:

1. In a magnetron oscillator, a thermionic tube having a pair of similar oscillatory electrodes, a pair of closely coupled oscillatory circuits connected one to each of said oscillatory electrodes to form a pair of oscillation-producing circuits which oscillate at the same frequency and in which an increase of voltage on one electrode produces an increase in the oscillation amplitude for a given static electrode voltage and a decrease in the oscillation amplitude for another static electrode voltage, said increase of electrode voltage likewise tending to produce a change in a given direction of the wave length of said oscillations corresponding to both of said static conditions, means for separately applying to said oscillatory electrodes static voltages of differing amplitudes and modulating voltages of a desired phase so that wave length modulation is obtained and amplitude modulation minimized.

2. In a magnetron oscillator comprising a tube including first oscillation producing means in which the oscillation wave length increases upon the application of a modulating voltage which tends to increase the amplitude of said oscilla-

tions, second oscillation producing means in which the oscillation wave length decreases upon the application of a modulating voltage which tends to increase the amplitude of said oscillations, and means including a pair of separate oscillatory tank circuits coupled to each other, and to said first and second oscillation producing means, respectively, for combining and synchronizing said oscillations to produce a resultant whose wave length is equal to the mean value of the wave lengths of said separate oscillatory tank circuits.

3. In a modulated magnetron oscillator, first and second oscillation producing means including a pair of resonant tank circuits mounted in closely coupled relation within an evacuated envelope, means for applying modulating voltages to said first and second oscillation producing means, said voltages similarly affecting the amplitudes and tending dissimilarly to affect the wave lengths of said oscillations, and a pair of closely coupled oscillatory circuits connected to said first and second oscillation producing means, respectively, for combining and synchronizing said oscillations to produce a resultant.

4. In a modulated magnetron oscillator, a thermionic tube containing first and second oscillation producing means, means for applying modulating voltages to said first and second oscillation producing means, said voltages similarly affecting one characteristic of said oscillations and dissimilarly affecting another characteristic of said oscillations and a pair of parallel, closely coupled resonant lines connected to said oscillation producing means, respectively, for combining and synchronizing said oscillations to produce a resultant which is substantially free from variations in said characteristic so dissimilarly affected.

5. In a modulated magnetron oscillator, the combination which includes a thermionic tube having a cathode and a pair of mutually coupled anode electrodes, a pair of mutually coupled oscillatory circuits connected respectively to said anode electrodes so that oscillations independently established in said anodes are synchronized at a common frequency, means for applying direct potentials separately to said anode electrodes, means for applying modulating voltages separately to said anode electrodes, and means for adjusting the amplitudes of said direct potentials and for reversing the relative phase of said modulating voltages.

6. In a modulated oscillator, first and second oscillation producing means having separate oscillatory circuits mounted in closely coupled relation, means for applying a modulating voltage to each of said oscillation producing means so that each of said oscillation producing means is simultaneously modulated in a first and a second mode, and means for reversing the relative phasing of said modulating voltages so that modulations of either one of said modes may be minimized.

7. In a modulated oscillator, a pair of separate resonant line oscillatory circuits mounted in closely coupled relation, oscillatory electrodes connected to said circuits for producing oscillatory currents therein, adjustable means for applying a biasing voltage between oscillatory electrodes connected to each of said circuits, and means for also applying co-phased modulating voltages between said electrodes to modulate said oscillatory currents.

8. The combination within an evacuated enve-

lope of a linear cathode electrode, a pair of anode electrodes coaxially mounted around the ends of said cathode, each of said anode electrodes being divided in the plane of said cathode into two segments, and a pair of closely coupled parallel line resonant tank circuits, each line being connected between the two segments of one of said anode electrodes.

9. In a modulated oscillator, a linear cathode electrode, a pair of anode electrodes coaxially mounted around the ends of said cathode, each

of said anode electrodes being divided in the plane of said cathode into two semi-cylindrical segments, a pair of parallel line resonant tank circuits, each line being connected between the segments of one of said anode electrodes at the adjacent ends of said anode electrodes, adjustable means for applying biasing potentials independently to said anode electrodes, and means for also applying modulating potentials to said anode electrodes.

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