Dec. 6, 1938.

E. G. LINDER

2,139,238

MODULATOR FOR HIGH FREQUENCY OSCILLATORS

Filed Aug. 20, 1935

2 Sheets-Sheet 1

Fig. I.

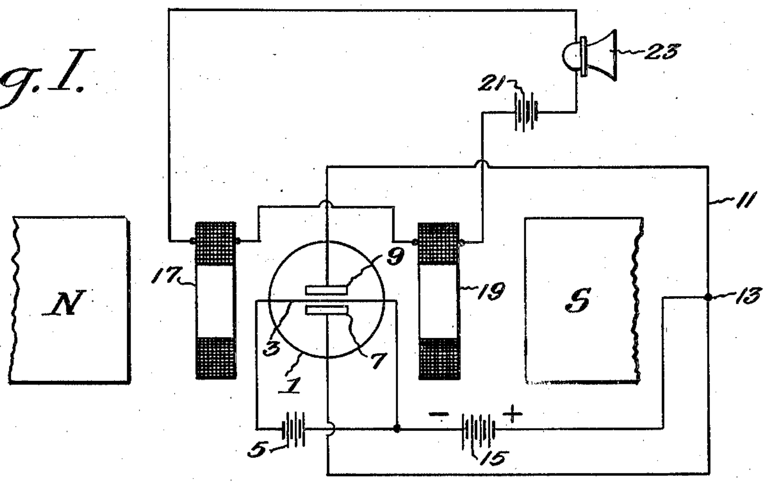


Fig. II a

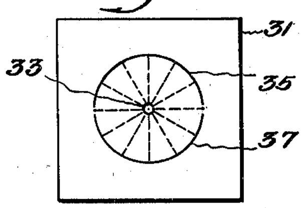


Fig. II b

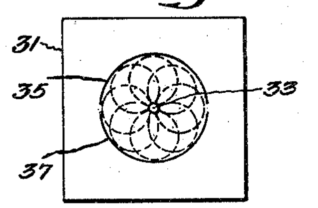
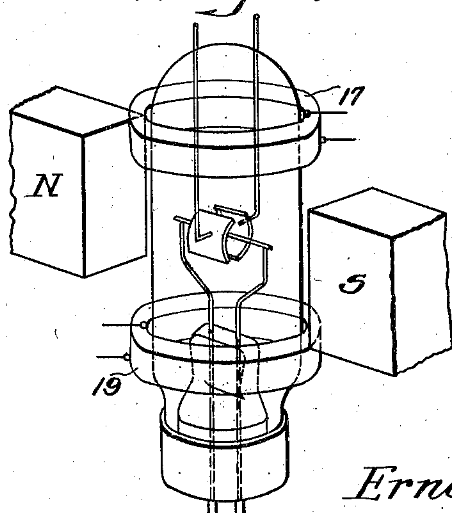


Fig. III.



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Filed Aug. 20, 1935 2 Sheets-Sheet 2

Fig. IV.

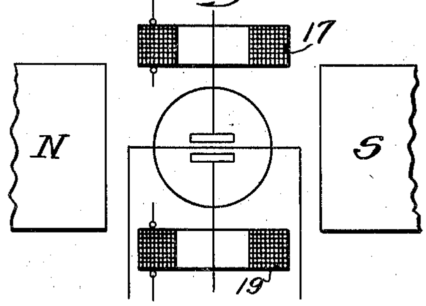


Fig. V.

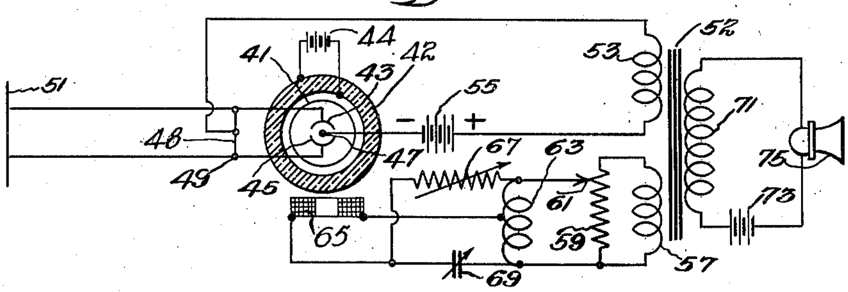
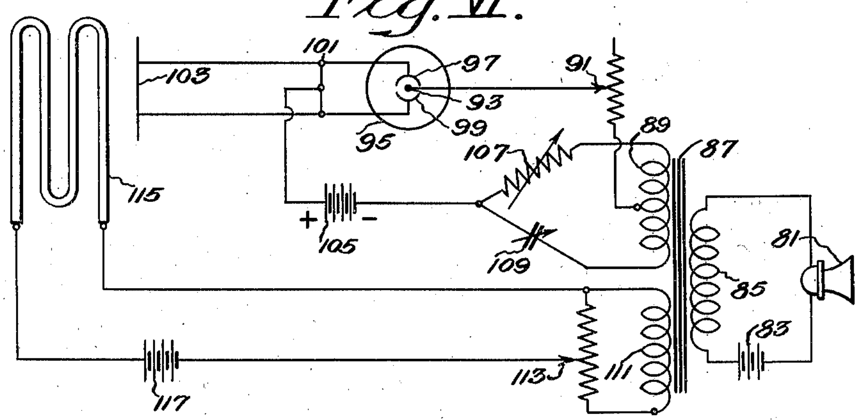


Fig. VI.



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Patented Dec. 6, 1938 2,139,238

UNITED STATES PATENT OFFICE

2,139,238

MODULATOR FOR HIGH FREQUENCY OSCILLATORS

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Application August 20, 1935, Serial No. 36,973

8 Claims. (Cl. 179—171)

My invention relates to the modulation of high frequency oscillations. More specifically, my invention applies to the modulation of magnetron oscillators.

One of the objects of my invention is to modulate an oscillator of the magnetron type.

Another object is to frequency modulate a magnetron oscillator.

Another object is to amplitude modulate an oscillator.

A further object is to frequency modulate and compensate for amplitude modulation and vice versa.

Other objects and advantages will appear from the following description of my invention.

I am aware of proposals to modulate a magnetron by varying its magnetic field. A description of this method of modulation may be found in United States Patent 2,005,793 which issued on June 25, 1935, to N. E. Lindenblad. The embodiments of my invention, which I am about to describe, are especially suited to the modulation of magnetrons employing a large inductive winding to develop the permanent magnetic field required for ultra high frequency oscillation. The details of my invention may be best understood by referring to the accompanying drawings and specification.

Figure I represents a magnetron oscillator embodying one form of my invention,

Figure II (*a*) and (*b*) are illustrations of the electron path in a magnetron oscillator with and without the magnetic field,

Figure III is a diagram of another embodiment of my invention,

Figure IV is a diagram of a further modification of my invention,

Figure V illustrates in schematic form an embodiment of my invention for applying frequency modulation, and

Figure VI is a diagram of my invention applied to a magnetron oscillator for amplitude modulation.

In Figure I, the north and south poles of a magnetic field are represented by N and S. The field may be created with a conventional solenoid with or without an iron core. Within the magnetic field is a magnetron 1. The cathode 3 lies in a line approximately parallel to the magnetic flux and is energized by a battery 5 or any suitable source of power. Two anodes 7 and 9 are symmetrically arranged about the cathode. The anodes are preferably shaped in the form of half a cylinder. The cathode lies along the central axis of the anodes. The anodes are connected together by a circuit 11 which may be resonant to the desired oscillator frequency. Between the center point 13 and the cathode is an anode battery 15. The negative terminal of 15 is connected to the cathode. A pair of modulating coils 17 and 19 are serially connected to battery 21 and microphone 23. The coils 17 and 19 are positioned so that their magnetic field is substantially in alignment with the field between N and S. The coils may be connected in series or parallel but their fields must be in the same sense. The direction of their fields may either aid or oppose the field between N and S.

In Figure II (*a*) is a diagrammatic illustration which shows a section of a magnetron oscillator. Within the evacuated envelope 31 is a cathode 33 and the anodes 35 and 37. The radial dotted lines from the cathode to the anodes represent electron paths which are not influenced by a magnetic field. When a magnetic field of proper value, whose flux is substantially parallel to the cathode, is applied, the electron paths become arcuate as shown by the curved dotted lines in Figure II (*b*). The cathode heating circuits, anode circuits, and batteries are omitted from Figures II (*a*) and (*b*) for simplicity of illustration.

Briefly, the effect of electron flow in a magnetron under the influence of the magnetic field of proper intensity is to set up high frequency oscillations. The wave length of the oscillations may be determined by the equation

$$\lambda=\frac{13000}{H}$$

where,

λ=wave length in centimeters
H=magnetic field in gauss

An inspection of the equation shows that an increase in H decreases the wave length, or increases the frequency. A decrease in H increases the wave length or decreases the frequency. If the normal steady magnetic field between N and S is varied, the radio oscillations created will be frequency modulated in accordance with the currents altering the magnetic field. It has been proposed to use a single magnetic field winding and vary the magnetizing current flowing therein. While this method may be used in some cases, it is not suited to frequency modulate an ultra high frequency magnetron oscillator. I have found that by employing separate modulating coils, such as 17 and 19, frequency modulation may be employed in cases where it would be very impractical to modulate at voice frequencies when a single large inductive electromagnet is employed to generate the normal oscillations and the modulated oscillations.

Although the separate modulating coils may be positioned so that their magnetic fields are substantially parallel to the main magnetic field, I find cases where the modulating fields may be located at an angular position. Such an arrangement is shown in simplified form in Figures III and IV. In these figures the coil or coils are arranged so that the flux generated by currents flowing in the modulating coils is at a right angle to the flux of the main magnetron field. In showing a right angle, I do not intend to be limited to precisely 90° because other angular arrangements may be used. The angular relationship is a decided advantage in that the action of the modulating coils is not greatly affected by the usual large iron core of the main magnet. The resulting flux is the vectorial sum of the modulating coil flux and the main magnetron coil flux. The combined fluxes produce frequency modulated oscillations.

It is often desirable to frequency modulate without any variations in the amplitude of the oscillatory currents. In the preceding description, the frequency modulation is accompanied by some amplitude modulation. The undesired amplitude modulation may be compensated by the arrangement shown in Figure V.

In Figure V a magnetron **41** has within its evacuated envelope, which may be of any suitable shape, two anodes **43** and **45** and cathode **47**. The anodes are connected to a resonant circuit **49**, which is coupled to the antenna **51**. The mid-point of the bridging conductor **48** is connected through the secondary **53**, of transformer **52** and anode battery **55**, to cathode **47**. The negative pole of the battery **55** is connected to cathode. A tertiary winding **57** of transformer **52** is connected to potentiometer **59**. Between the lower end of **59** and the slider **61** is connected an impedance **63**. The mid-point of **63** is connected to one terminal of modulating coil **65**. The other terminal of **65** is connected to the junction of resistance **67** and capacity **69**. The resistance **67** connects to one end of **63** and the capacity **69** to the other. The elements **63—67—69** form a phase adjusting circuit. The primary **71** of transformer **52** is serially connected to battery **73** and microphone **75**. It should be understood that any variable signal representing current may be impressed on **71**, or any of the several modulating circuits. The main magnetic field is represented by the field coil **42** and battery **44**.

The current fluctuations in **71** induce changing potentials in **57**. The varying potentials in **57** cause modulating currents to flow in the modulating coil **65**. These current changes are accompanied by magnetic flux changes which frequency and amplitude modulate the oscillations produced in **41**. The amplitude modulations may be offset by properly phased potential variations in **53** which applied to **43** and **45** primarily cause amplitude modulations. The amplitude modulations in **53**, **43**, **45** are properly phased to compensate the undesired amplitude modulations induced by **65**. The exact phasing may be effected by properly adjusting the phasing circuit **67** and **69**. The potentiometer **61** permits an adjustment of the amplitude modulations in **53**, **43**, **45** which exactly balances out the amplitude modulations induced by **65** and leaves desired frequency modulation.

In Figure VI is illustrated the embodiment of my invention which may be used to amplitude modulate with compensations for any accompanying frequency modulation. A microphone **81** is serially connected through battery **83** to the primary **85** of transformer **87**. The mid-tapped secondary **89** has its mid-tap connected through rheostat **91** to cathode **93** of the magnetron **95**. The anodes **97** and **99** are connected to the resonant circuit **101** and antenna **103**. The mid-point of **101** is connected to the positive terminal of battery **105**. The negative terminal of **105** is connected to resistance **107** and capacity **109**. The resistance **107** and capacity **109** are also connected to the outer terminals of **89**. The elements **107** and **109** form a phase correcting circuit. Potential variations in **89** cause amplitude modulations of the high frequency oscillations generated by **95** and its circuits. (The normal magnetron field is omitted for simplicity of illustration.)

The transformer **87** has a tertiary winding **111**. Across **111** is shunted a potentiometer **113**. A connection is made from the junction of **111** and **113** to one terminal of the ionic modulator **115**. The other terminal of **115** is connected to the biasing battery **117** and the slidable connection on **113**. The ionic modulator may be of the general type disclosed in the Proceedings of the Institute of Radio Engineers of June **1934**, volume **22**, No. **6**, pages **791–793**, "Note on an Ionized Gas Modulator for Short Waves" by Linder and Wolff.

By suitably adjusting the phases and relative amplitudes of the two modulating effects, the resulting modulation will be of the amplitude type with the frequency modulations substantially cancelled.

The circuit shown in Figure V is the preferred arrangement for frequency modulation. The same circuit may be adjusted for amplitude modulation with the frequency modulation effects cancelling each other. Likewise, the circuit of Figure VI may be employed to frequency modulate with amplitude modulations balanced out. It is within the scope of those skilled in the art to arrange other combinations of the arrangements I have shown such as, ionic modulation with magnetic modulation for either frequency or amplitude modulation.

The foregoing description illustrates one embodiment of my invention which may be employed to amplitude or frequency modulate a magnetron oscillation. Other modifications within the scope of my invention will occur to those skilled in the art. I do not intend to limit my invention to the precise arrangement shown except as required by the prior art and the appended claims.

I claim:

1. A magnetron oscillator including a main magnetic field, and means including an auxiliary magnetic field whose lines of force are disposed at an angle with respect to the lines of force of said main field for modulating oscillations generated by said magnetron.

2. In a magnetron oscillator of the character described, a main magnetic field, and means including an auxiliary magnetic field whose flux is angularly disposed with respect to the flux of the main magnetic field for modulating oscillations generated by said oscillator.

3. In a magnetron oscillator of the character described, a main magnetic field of a flux density sufficient to cause the generation of oscillations,

and means including an auxiliary magnetic field whose flux is angularly disposed with respect to said first mentioned flux and whose density is sufficient to vary the flux of the first mentioned field whereby the wave length of the oscillation is varied in accordance with

$$\lambda=\frac{k}{H}$$

where, λ=wave length, H=magnetic field strength and k=a constant.

4. In a magnetron oscillator, a thermionic tube containing two anodes and a cathode, an oscillatory circuit, connections between said anodes and said oscillatory circuit, a main magnetic field whose flux is substantially parallel to said cathode, and means including an auxiliary magnetic field whose flux is angularly disposed with respect to said cathode for modulating said magnetron oscillator.

5. In a magnetron oscillator of the type described, a thermionic tube containing two anodes and a cathode, an oscillatory circuit, connections between said anodes and said oscillatory circuit, a main magnetic field whose flux is substantially parallel to said cathode, and means including an auxiliary magnetic field whose flux is angularly disposed with respect to said first-mentioned flux whereby the flux from said auxiliary field varies the direction of the main flux for modulating said magnetron oscillator.

6. In a magnetron oscillator of the type described, a thermionic tube containing two anodes and a cathode, an oscillatory circuit, connections between said anodes and said oscillatory circuit, a main magnetic field whose flux is substantially parallel to said cathode, and means including an auxiliary magnetic field whose flux is angularly disposed with respect to said cathode for modulating said oscillator by varying the density of the flux adjacent said anodes and cathode.

7. The method of modulating a magnetron oscillator which comprises establishing a main magnetic field, establishing an auxiliary magnetic field at an angular relation with respect to said main magnetic field, varying the density of the auxiliary magnetic field in accordance with signal representing currents, and combining said fields about said magnetron oscillator whereby modulated oscillations are generated in accordance with the equation

$$\lambda=\frac{k}{H}$$

in which λ=wave length, k=a constant, and H=strength of magnetic field.

8. In combination, a magnetron oscillation generator comprising a linear cathode and an anode within an envelope, means for producing a magnetic field the lines of force of which traverse the zone of electron discharge, said lines normally lying parallel to the axis of said cathode, an additional field producing means suitably disposed in relation to the axis of said cathode so that the lines of force produced thereby traverse the zone of electron discharge and lie at right angles to the axis of said cathode and means for varying the directional effect of the last mentioned field producing means in accordance with variations in the modulation to be applied to said magnetron generator, whereby the electron paths in said generator are controlled.

ERNEST G. LINDER.