Dec. 30, 1958 D. B. HAAGENSEN 2,866,920

MAGNETRON MODULATOR SYSTEMS

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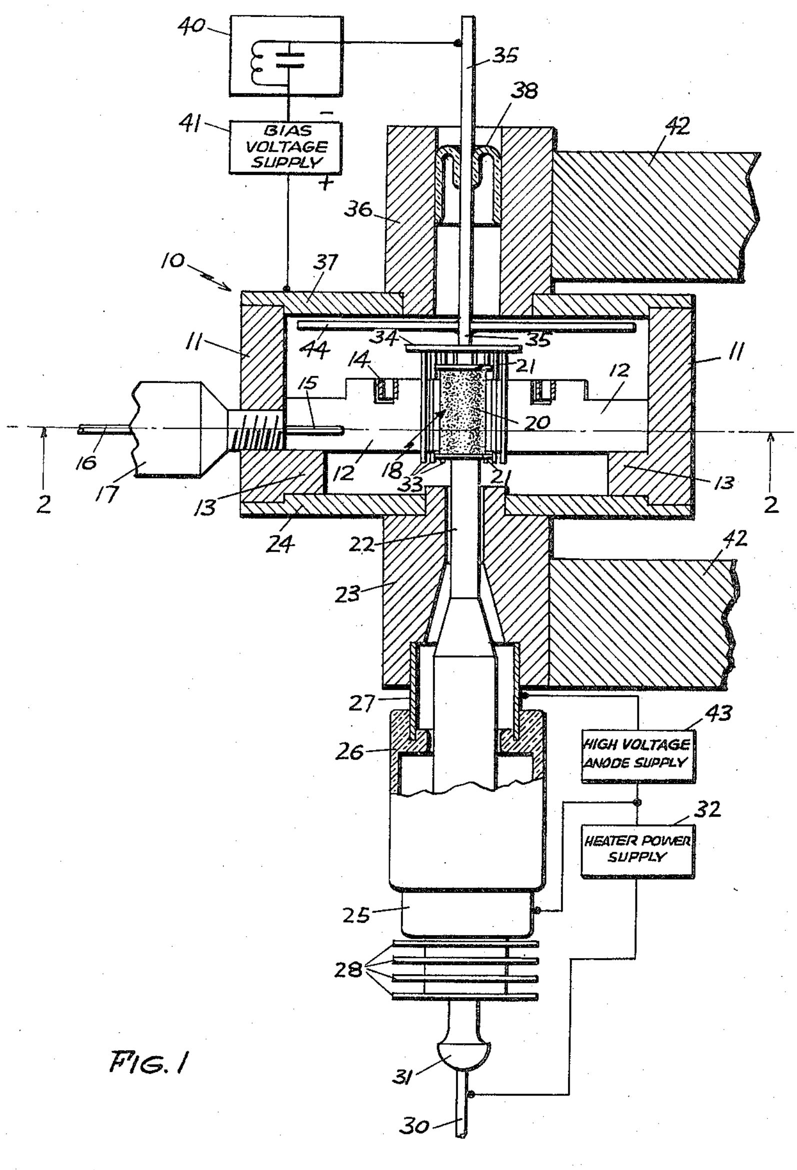


FIG. 1

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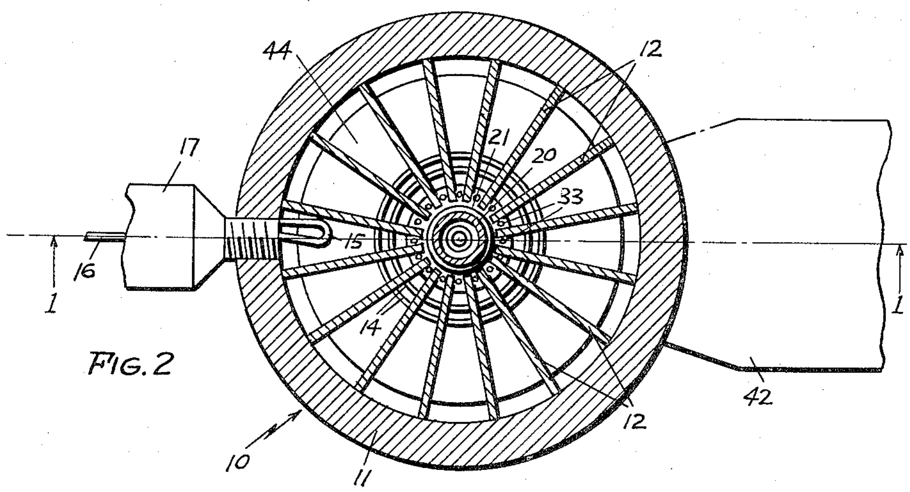


FIG. 2

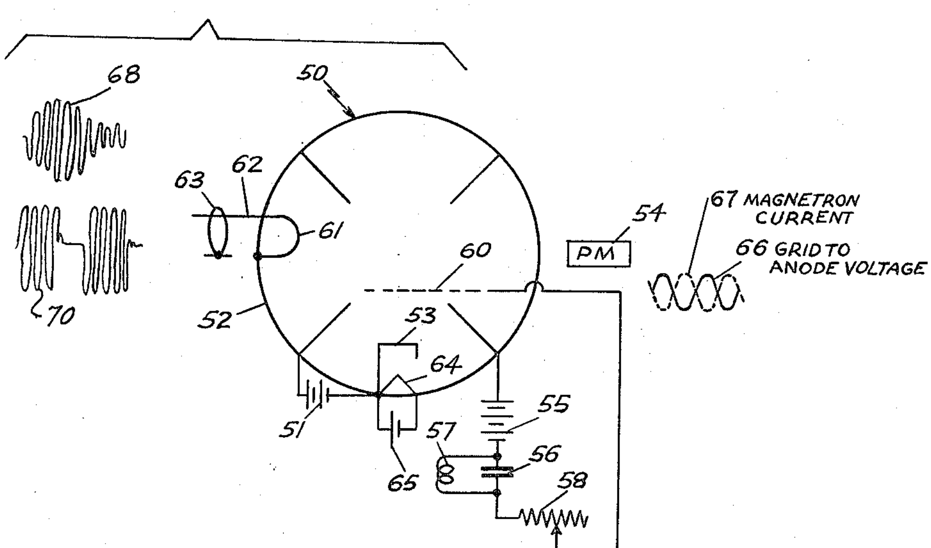


FIG. 3.

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# MAGNETRON MODULATOR SYSTEMS

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8 Claims. (Cl. 315—39.63)

This application relates to oscillators and more particularly to modulated oscillators using grid controlled magnetrons incorporating a resonant circuit. In United States Patent No. 2,784,345, issued on March 5, 1957, the copending application, Ser. No. 233,634, filed June 26, 1951, by Percy L. Spencer, there is disclosed a magnetron oscillator whose output power may be controlled by means of a grid or auxiliary electrode structure positioned adjacent to the ends of the anode members nearest the cathode and substantially outside the paths of electron flow.

This invention discloses that a grid-controlled magnetron may be modulated at a predetermined frequency by adding a circuit between the anode and the grid or auxiliary electrode structure designed to be resonant at the predetermined frequency. The result is that, in operation, negative resistance or dynatron oscillations take place in the resonant circuit between the grid and anode and serve to modulate the main cathode to anode oscillations of the magnetron. The amplitude of this modulation can be controlled by controlling the potential difference between the anode and the grid. A value of this potential can be found at which the anode to cathode current saturates and forms square waves in the output of magnetron having a repetition rate determined by the resonant frequency of the auxiliary tuned circuit between the grid and anode. Thus the magnetron can be pulse modulated without the use of a thyratron or other auxiliary tube. These modulations are steady in amplitude and stable in frequency and are produced efficiently.

Other and further objects and advantages of this invention will be apparent as the description thereof progresses, reference being had to the accompanying drawings, wherein:

Fig. 1 is a longitudinal, cross-sectional view taken along the line 1—1 of Fig. 2 of a type of grid controlled magnetron which may be used in the modulation system;

Fig. 2 is a transverse, cross-sectional view of the device shown in Fig. 1, taken along the line 2—2 of Fig. 1; and

Fig. 3 is a schematic diagram of a circuit utilizing the device illustrated in Figs. 1 and 2 to produce modulated oscillations.

In Figs. 1 and 2 the reference numeral 10 designates, generally, a magnetron anode structure comprising an anode cylinder 11 and a plurality of substantially planar rectilinear members 12 whose planar surfaces lie substantially parallel to the axis of the anode cylinder 11 and extend radially from the inner surface of the cylinder. A lip 13 is formed on the inner surface of anode cylinder 11 below anode members 12 to aid in positioning said anode members during assembly of the device. Anode members 12 are alternately connected adjacent their inner ends on their upper edges by a pair of conductive straps 14 in a well-known manner.

Positioned in one of the cavities formed by anode members 12 and the space defined therebetween is an output coupling loop 15, one end of which is connected to the central conductor 16 of a coaxial cable which extends through an opening in the anode cylinder 11. The outer conductor 17 of the coaxial cable is sealed to the opening in anode cylinder 11 into which conductor 16 passes. Central conductor 16 is insulatedly sealed to outer conductor 17 by any desired means, such as a ceramic seal, not shown.



Positioned inside the space defined by the inner ends of anode members 12 is a cathode structure 18 comprising a cathode cylinder 20 coaxial with anode cylinder 11. The outer surface of cathode cylinder 20 is coated with electron emissive material, and the ends of cylinder 20 are covered by end shields 21. End shields 21 are in the form of discs slightly greater in diameter than the cylinder 20. The purpose of the end shields 21 is to prevent movement of the electrons emitted from the surface of the cylinder 20 along paths parallel to the axis thereof. Attached to the lower end shields 21 is a tubular support member 22. Tubular support member 22 extends downwardly from the lower end shield 21 through an aperture in a lower magnetic pole piece 23 spaced therefrom. The lower magnetic pole piece 23 is sealed into the aperture in a lower cover plate 24 through which the tubular support member 22 passes. This cover plate 24 is, in turn, hermetically sealed to the lower end of the anode cylinder 11. After passage through lower magnetic pole piece 23, support member 22 is connected to a metallic cup 25 which, in turn, is sealed to a ceramic cylindrical member 26 surrounding the support member 22. This ceramic cylinder 26 is, in turn, sealed to a metallic cylinder 27 surrounding support cylinder 22 and spaced therefrom. This metallic cylinder 27 is, in turn, sealed to the lower magnetic pole piece 23. Cooling fins 28 are attached to the support member 22 after its passage through the cup member 25 to increase the cooling of this support member 22. This support member also has positioned within it a conductive rod 30 which extends upwardly into the cathode cylinder 20, where it is attached to one end of a heater coil, not shown, the other end of which is connected to the anode cylinder 11. Rod 30 is insulatedly sealed to support member 22 by means of an insulating seal 31. The application of a heater voltage between the rod 30 and the support member 35, for example, by means of a heater power supply 32, will produce a current flow through the heater coil in the cathode cylinder 20, thereby heating said cylinder to a temperature such that the electron emissive coating thereon will copiously emit electrons.

Positioned between each pair of anode members, and adjacent their inner ends, is an auxiliary electrode or grid wire 33. The grid wires 33 are spaced from anode members 12 and are set back from the ring defined by the inner ends of the anode members 12 by a few thousandths of an inch, thus positioning the grid wires outside the path of electron flow. Grid wires 33 are substantially parallel to the axis of the anode cylinder 11 and are supported by connection at their upper ends to a conductive plate 34 positioned somewhat above the upper end shield 21. Plate 34 is, in turn, rigidly connected to a conductive support rod 35 which extends upwardly through an upper magnetic pole piece 36 spaced therefrom. This upper magnetic pole piece 36 is sealed to an aperture in an upper end plate 37 through which the conductive member 35 passes. The end plate 37 is, in turn, sealed to the upper end of anode cylinder 11. The conductive member 35 is insulatingly sealed to the magnetic pole piece 36 by means of a ceramic seal 38. A resonant circuit 40, which is resonant at a frequency lower than that of the magnetron, and a source 41 of negative potential are connected in series between the support rod 35 and the anode structure 10. A magnetic field is produced between the magnetic pole pieces 23 and 36 by means of a permanent magnet 42 whose poles are attached respectively thereto. A high voltage anode supply 43 is connected between the cathode structure and the anode structure, whereby the device will oscillate at a frequency determined by the cavities defined by the anode members 12 and the spaces therebetween.

A disk 44 is attached to the rod 35 above the support disk 34 and below the upper cover plate 37. The purpose of the disk 44 is to prevent the leakage of the microwave frequency generated by the magnetron out through the aperture in the upper pole piece 36 along the grid support rod 35.

In Fig. 3 there is shown a system in which the device shown in Figs. 1 and 2 may be used to produce modulated oscillations. The reference numeral 50 represents generally a magnetron. A source of potential 51 is connected between an anode 52 and a cathode 53 to make the anode positive with respect to the cathode. A transverse magnetic field is applied by means of the permanent magnet 54 to the space between the anode and the cathode. A source of potential 55 is applied in series with a capacitor 56 shunted by an inductance 57 forming the resonant circuit indicated by the block 40 in Fig. 1 and a variable resistor 58 between the grid 60 and the anode 52. The microwave energy generated by the magnetron is extracted by means of a loop 61 which has a central conductor 62 and an external conductor 63. The cathode 53 is heated by a filament 64 that is supplied by a source 65. In operation, a portion of the electron stream is diverted to the grid structure 60 and flows through the resonant circuit comprising the capacitor 56 and the inductance 57. The electrons so diverted produce an oscillation similar to those produced in conventional vacuum tubes connected as dynatron or negative resistance oscillators. The grid to anode voltage varies in the manner shown in the waveform 66, which represents a sine wave at the resonant frequency of the capacitor 56 and the inductance 57, which is usually lower than the resonant frequency of the anode structure 10. This variation in the grid to anode voltage causes the magnetron current to vary in time as shown in the waveform 67, which is seen to be 180° out of phase of the waveform 66. The result is to amplitude modulate the output of the magnetron 50 at this lower frequency as shown by the wave form 68.

If the amplitude of this modulation is sufficient, the magnetron becomes saturated at intervals determined by the frequency of the auxiliary tuned circuit and produces substantially square wave or pulsed modulation of the magnetron output at a pulse repetition rate determined by the resonant frequency of the grid to anode circuit as shown by the wave form 70 of Figure 3. The amplitude of the oscillations is determined in part by the variable resistor 58.

With the circuit of the invention a minimum of additional power is required to produce the modulation, and the modulation frequency is stable. Except for the amplitude modulation of its output, the operation of the magnetron is not interfered with. If the desired modulating frequency is high enough to make its use practical, a transmission line or resonant cavity may be substituted for the lumped capacitor and inductance shown.

This invention is not limited to the particular details of construction, materials and processes described, as many equivalents will suggest themelves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. An electron discharge system comprising a grid controlled magnetron oscillator having an anode resonant at a first frequency, a cathode, and a grid positioned between said anode and said cathode and an auxiliary resonant circuit coupled between the anode and the grid to cause the output of the system to be modulated at the resonant frequency of the auxiliary resonant circuit.

2. An electron discharge system comprising a grid controlled magnetron oscillator having an anode, resonant at a first frequency, a cathode and a grid positioned between said anode and said cathode and an auxiliary circuit resonant at a lower frequency than the anode to cathode circuit of the magnetron coupled between the anode and the grid to cause the output of the system to be modulated at the resonant frequency of the auxiliary resonant circuit.

3. An electron discharge system comprising a grid controlled magnetron oscillator having an anode resonant at a first frequency and a grid positioned between said anode and said cathode, an auxiliary resonant circuit coupled between the anode and the grid to cause the output of the system to be modulated at the resonant frequency of the auxiliary resonant circuit, and means to maintain the grid at such a negative potential with respect to the anode as to cause the output of the system to be pulse modulated at a repetition rate determined by the auxiliary resonant circuit.

4. An electron discharge system comprising a grid controlled magnetron oscillator having an anode resonant at a first frequency, a cathode and a grid positioned between said anode and said cathode, an auxiliary circuit resonant at a lower frequency than the anode to cathode circuit of the magnetron coupled between the anode and the grid to cause the output of the system to be modulated at the resonant frequency of the auxiliary resonant circuit, and means to maintain the grid at such a negative potential with respect to the anode as to cause the output of the system to be pulse modulated at a repetition rate determined by the auxiliary resonant circuit.

5. An electron discharge system comprising an evacuated envelope containing an electron source, a signal wave transmission network comprising a plurality of anode members resonant at a first frequency, means for directing electrons along paths adjacent said network comprising means for producing a magnetic field in the region of said paths, an auxiliary substantially non-electron emissive electrode structure comprising a plurality of grid elements, said grid elements being positioned adjacent to and between portions of said anode structure which are nearest to said electron source and an auxiliary circuit resonant at a second frequency coupled between the anode and the auxiliary electrode structure to cause the output of the system to be modulated at the resonant frequency of the auxiliary circuit.

6. An electron discharge system comprising an evacuated envelope containing an electron source, a signal wave transmission network comprising a plurality of anode members resonant at a first frequency, means for directing electrons along paths adjacent said network comprising means for producing a magnetic field in the region of said paths, an auxiliary substantially non-electron emissive electrode structure comprising a plurality of grid elements, said grid elements being positioned adjacent to and between portions of said anode structure which are nearest to said electron source and an auxiliary circuit resonant at a second frequency, lower than the operating frequency of the transmission network, coupled between the anode and the auxiliary electrode structure to cause the output of the system to be modulated at the resonant frequency of the auxiliary circuit.

7. An electron discharge system comprising an evacuated envelope containing an electron source, a signal wave transmission network comprising a plurality of anode members resonant at a first frequency, means for directing electrons along paths adjacent said network comprising means for producing a magnetic field in the region of said paths, an auxiliary substantially non-electron emissive electrode structure comprising a plurality of grid elements, said grid elements being positioned adjacent to and between portions of said anode structure which are nearest to said electron source, an auxiliary circuit resonant at a second frequency coupled

between the anode and the auxiliary electrode structure to cause the output of the system to be modulated at the resonant frequency of the auxiliary circuit, and means to maintain the auxiliary electrode structure at such a negative potential with respect to the anode as to cause the output of the system to be pulse modulated at a repetition rate determined by the auxiliary resonant circuit.

8. An electron discharge system comprising an evacuated envelope containing an electron source, a signal wave transmission network comprising a plurality of anode members resonant at a first frequency, means for directing electrons along paths adjacent said network comprising means for producing a magnetic field in the region of said paths, an auxiliary substantially non-electron emissive electrode structure comprising a plurality of grid elements, said grid elements being positioned adjacent to and between portions of said anode structure which are nearest to said electron source, an auxiliary circuit resonant at a second frequency, lower than the operating frequency of the transmission network, coupled between the anode and the auxiliary electrode structure to cause the output of the system to be modulated at the resonant frequency of the auxiliary circuit, and means to maintain the auxiliary electrode structure at such a negative potential with respect to the anode as to cause the output of the system to be pulse modulated at a repetition rate determined by the auxiliary resonant circuit.

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