Feb. 12, 1952 J. KURSHAN ET AL 2,585,794

MAGNETRON

Filed Oct. 25, 1947 2 SHEETS--SHEET 1

Fig. 1.

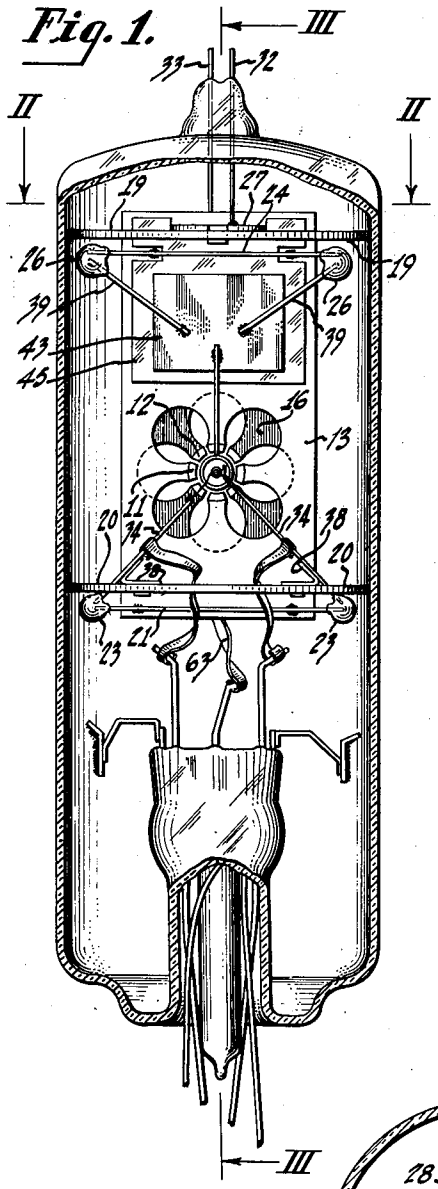
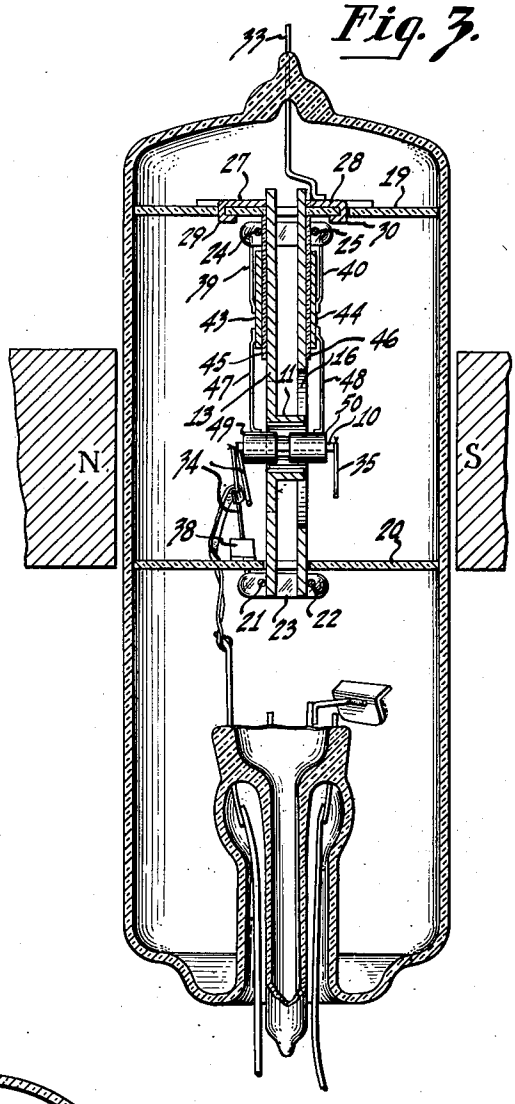


Fig. 3.



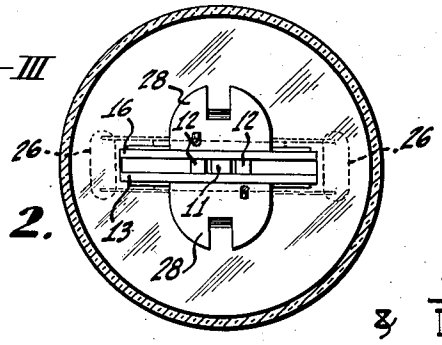


Fig. 2.

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Fig. 4.

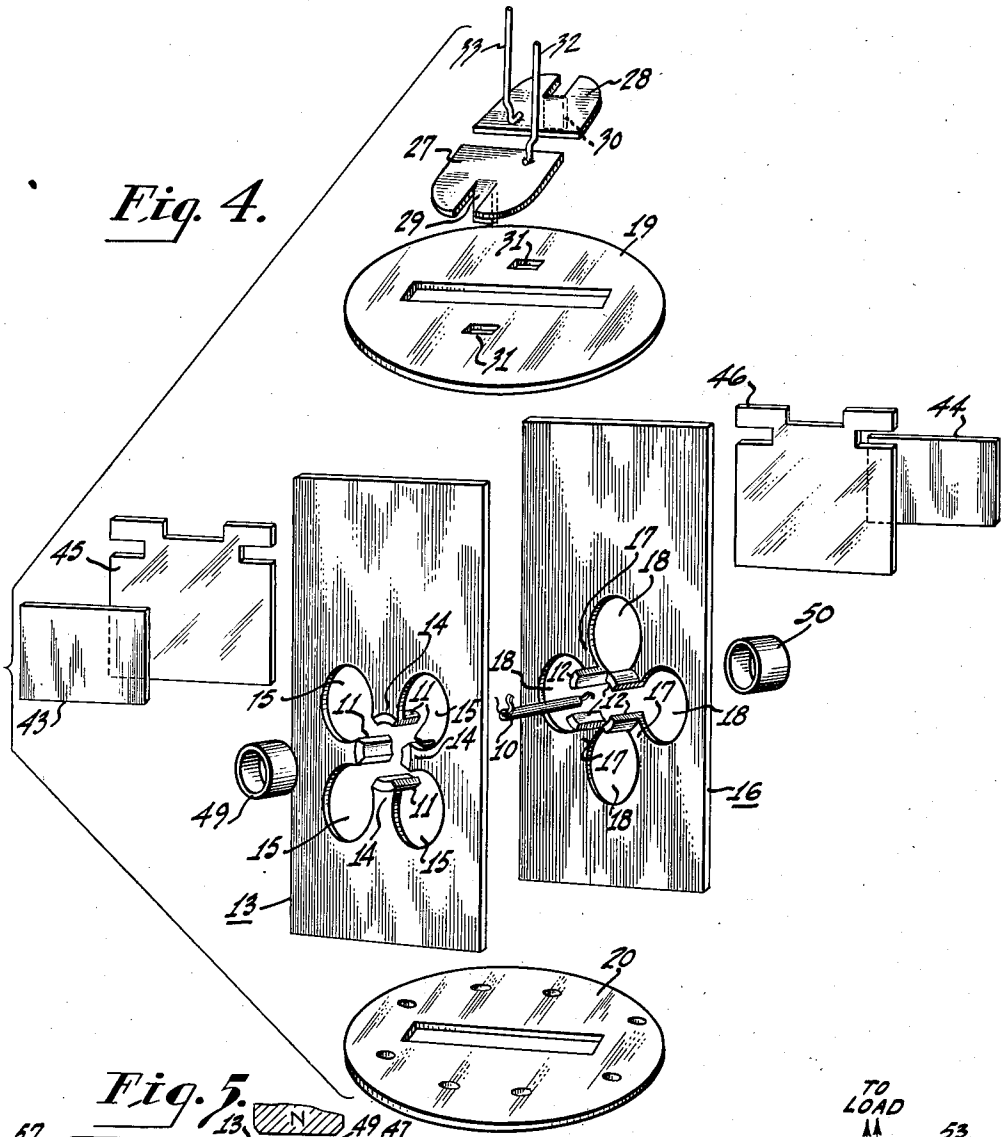
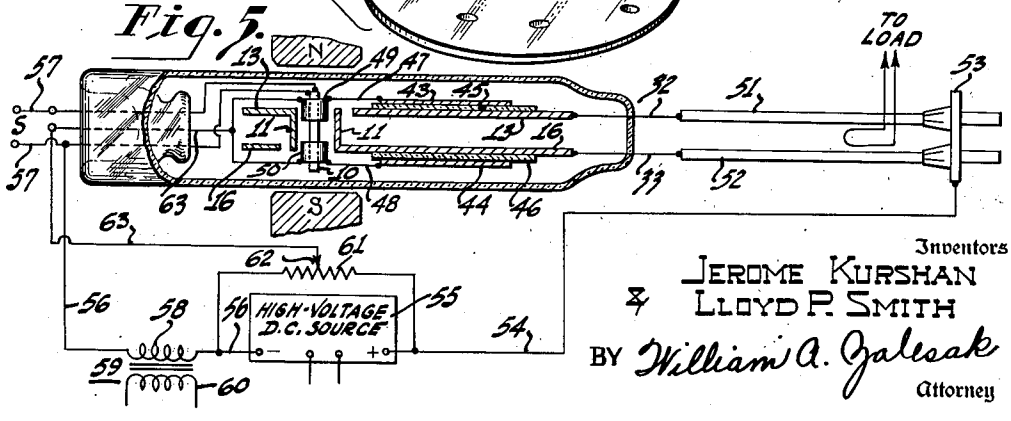


Fig. 5.



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MAGNETRON

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Application October 25, 1947, Serial No. 782,192

17 Claims. (Cl. 315—39)

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This invention relates to magnetrons and particularly concerns magnetrons especially suited for frequency-modulation.

With the usual form of magnetron, the variation of the potential difference between the anode and cathode at modulation frequencies to produce frequency-modulation of the output also produces undesirable and excessive amplitude modulation. In analysis of the operating characteristics of a magnetron, it has been found that for constant anode current, the power output depends upon the intensity of the unidirectional or direct current electric field at or near the anode and that the frequency of the oscillations generated depends upon the manner in which the intensity of the unidirectional or direct current electric field varies with the distance between the anode and cathode.

In accordance with a primary object of the invention, the direct current field intensity near the anode is maintained substantially constant while the direct current electric field distribution between the anode and cathode is varied at modulation frequencies, thus to obtain frequency-modulation of the magnetron output at a substantially constant power level. More specifically, the relation between the power output of a magnetron and frequency of the oscillations generated by it are controlled by a pair of field electrodes, preferably in the form of imperforate cylinders coaxial with the cathode, whose fringe fields extend into the space between the electrodes and whose direct current potential differs from that of the anode by a substantially fixed amount, affording the desired frequency-output characteristic.

The invention further resides in the methods of operation and in the features of construction, combination and arrangement hereinafter disclosed.

For a more detailed understanding of the invention and for illustration of an embodiment thereof, reference is made to the accompanying drawings, in which:

Fig. 1, partly in section, is a front elevational view of a magnetron tube;

Fig. 2 is a plan view in section taken on line 2—2 of Fig. 1;

Fig. 3 is a side elevational view in section taken along line 3—3 of Fig. 1;

Fig. 4 is an exploded view of the electrode assembly shown in Figs. 1–3; and

Fig. 5 is a schematic circuit diagram of a frequency-modulated oscillator utilizing the tube of the preceding figures.

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Referring to the drawings, an elongated, indirectly-heated cathode 10 is disposed axially of a cylindrical cathode space defined by two groups of anode segments 11, 12 disposed in a circular array. As will hereinafter appear, all of the segments of both groups have the same direct current potential, and are all of the same instantaneous modulating-frequency potential. At any particular instant, however, the segments 11 are of one polarity and the intervening segments 12 are of opposite polarity so far as the high-frequency oscillations generated by the tube are concerned.

In the particular form of magnetron shown, which utilizes a tuned circuit externally of the tube envelope, the anode segments 11 extend from the rear face of a metal plate 13 at the tips of teeth or radial bars 14 formed by openings 15 through the plate and equally angularly spaced about the axis of the segment array. Similarly, the anode segments 12 extend from the front face of a metal plate 16 at the tips of teeth 17 formed by circular openings or slots 18 or the like. The openings 15 of plate 13 are so angularly staggered with respect to the openings 18 in plate 16 that when the plates are in their assembled position, the two groups of segments 11—12 interleave to form a cylindrical segmented anode surface.

The plates 13, 16 are positioned within the tube envelope by headers 19, 20 of mica, or equivalent insulating material, having elongated positioning slots through which pass the upper and lower ends of the spaced plates. The plates 13, 16 are held in their proper spaced position at their lower ends by a framework comprising bars 21, 22 respectively welded to the plates 13, 16 and joined at their ends by cross bars 23 of glass, or equivalent insulating material. At their upper ends, the plates 13, 16 are held in proper spaced position by a framework comprising bars 24—25 respectively attached to the plates and joined together by insulating cross bars 26. The anode assembly is held to the upper header 19 by terminal clips 27—28 respectively mechanically and electrically connected to the anode plates 13—16 above the header and having clamping tips 29—30 which extend through openings 31 of the header and are bent to engage its undersurface.

The terminals 27—28 are respectively connected to leads 32, 33 which extend through the tube envelope for connection to an external tuned circuit, such as a parallel line, concentric line or the like, resonant at the frequency of oscillations generated by the magnetron tube.

The pairs of metal rods 34, 35, held to the lower header 20 by clamping clips 38, support the cathode 10 and the leads for the heater which is disposed internally of the cathode. These rods also extend through the header 20 to support the lower frame formed by the bar members 21, 22 and 23. Two pairs of bars 39, 40 extend from the insulating cross bars 26 of the upper frame with their lower ends respectively attached, as by welding, to condenser plates 43, 44, which are insulated from the outer faces of the plates 13, 16 by thin sheets 45, 46 of mica or similar insulating material. A pair of bars 47, 48 are attached as by welding at their upper ends to the condenser plates 43, 44 and respectively attached at their lower ends to a pair of field electrodes 49 and 50. Each of the field electrodes 49, 50 is in the form of an imperforate cylinder of thin sheet metal held in position close to the anode segments 11, 12 and concentric with the cathode 10 by its corresponding support 47 or 48. The field electrodes 49, 50 are positioned closer to the anode segments 11, 12 than to the cathode 10, as illustrated in Fig. 1. The field electrodes 49, 50 extend a substantial distance into the anode-cathode space from the opposite ends thereof and terminate substantially short of one another to leave a substantial intermediate portion of the cathode area directly exposed to the anode segments.

Suitable means, such as the magnets designated N and S in Figs. 3 and 5, are used to provide a constant magnetic field parallel to the axis of the cathode 10 to cause the electrons traveling from the cathode to the anode to follow curved paths in the usual magnetron fashion.

Referring to Fig. 5, the anode leads 32, 33 are connected to the open end of a resonant parallel line formed by bars 51, 52 along which a shorting bar 53 is slidable for tuning purposes. The shorting bar is connected by conductor 54 to the positive terminal of a suitable source 55 of constant high direct current voltage whose negative terminal is connected by conductor 56 to the cathode 10 of the magnetron. The heater leads 57 are connected to a suitable source S of heating current not shown.

In accordance with the present invention, the field electrodes 49, 50 provide means for maintaining the direct current field intensity at the anode substantially constant while the direct current electric field distribution between the anode and the cathode is varied at modulation frequencies. For the moment assuming absence of the field electrodes 49, 50, the oscillations generated by the magnetron may be frequency-modulated by superimposing a modulating signal voltage upon the anode-cathode direct current voltage provided by the source 55; more specifically, the secondary 58 of a modulating transformer 59 may be included in the conductor 56 between the source 55 and the cathode 10 of the tube, and the primary 60 of the transformer connected to a suitable source of modulating signal voltage at audio, video or other frequencies substantially lower than the frequency of oscillation of the magnetron. The resulting frequency-modulation is, however, accompanied by excessive variation of the output at the modulation frequencies.

This undesired variation of the power output, minimized by field electrodes 49, 50 when disposed and energized as herein described, has been found due to variation of the intensity of the direct current electric field at the anode. When

a proper difference is maintained between the direct current potentials of the anode and field electrodes, the direct current electric field at the anode does not vary with the modulation and the power output therefore remains substantially constant. This constancy of the direct current electric field at the anode is believed to be due to fringe fields of the field electrodes 49, 50, which extend into the unobstructed space between the anode and cathode surfaces. The application of the modulating voltage causes the direct current electric field distribution between the anode and cathode to vary with consequent corresponding variation of the frequency of the oscillations generated by the magnetron but because the direct current electric field is maintained substantially constant in the vicinity of the anode, the frequency modulation is not, as in prior magnetrons, accompanied by substantial amplitude-modulation.

As the exact field-electrode potential which affords minimum amplitude-modulation cannot be precisely predicted, there is provided, in shunt to the direct current voltage source 55, a voltage divider 61 whose adjustable contact 62 is connected by lead 63 to the field electrodes 49, 50. It is thus a simple matter, in any particular system, to adjust the positive potential of the field-electrodes until the desired frequency modulation-output characteristic is obtained.

Although the magnetron specifically illustrated is of the type using an external tuned circuit, it shall be understood the invention is applicable to the types of magnetron utilizing resonant cavities opening into the anode-cathode space, for example, the magnetrons may be generally of the construction disclosed in application Serial No. 758,692. It shall further be understood that although the magnetron disclosed herein is one utilizing eight anode segments, the field electrodes may be disposed within the anode-cathode space of a magnetron having a larger or smaller number of anode segments. In all cases, it is desirable that the field electrodes be held at constant high-frequency potential by bypassing them to the outside of the anode plates 13, 16 or equivalent anode block. Although the field electrodes were included primarily to minimize undesired amplitude-modulation, they inherently provide a means of altering the frequency-modulation characteristics of a multi-segment magnetron and may be utilized to improve the frequency-modulation characteristic even at sacrifice of constancy of output.

What is claimed is:

1. A magnetron comprising anode structure defining a cylindrical anode surface of constant diameter, a cathode within said anode structure and extending axially of said anode surface, and a hollow cylindrical imperforate field electrode positioned closer to said anode surface than to said cathode and encircling a substantial part of said cathode within said anode surface and insulated from said anode structure and said cathode, a substantial part of the length of said cathode being directly exposed to said anode structure.

2. A magnetron comprising anode structure defining a cylindrical anode surface, a cathode extending axially of said anode surface, and cylindrical field electrodes positioned closer to said anode surface than to said cathode and encircling opposite end regions of said cathode within said anode surface and insulated from the anode structure and said cathode, a substantial inter-

mediate portion of the cathode area being directly exposed to said anode structure.

3. A magnetron comprising anode structure defining a cylindrical anode surface, a cathode, extending axially of said anode surface, a field electrode interposed between a part of said cathode and said anode surface for controlling the direct current field at said anode surface, and a bypass condenser internally connected between said field electrode and said anode structure.

4. A magnetron comprising segmented anode structure defining a cylindrical anode surface, a cathode extending axially of said surface, a pair of cylindrical field electrodes respectively encircling opposite ends of said cathode and insulated therefrom, and bypass condensers respectively connected internally of the magnetron between said field electrodes and the outer surface of said anode structure.

5. A magnetron comprising a pair of spaced anode members having segments defining a cylindrical anode surface, a cathode extending axially of said anode surface, a pair of cylindrical field electrodes respectively encircling opposite ends of said cathode and insulated therefrom, and bypass condensers within said magnetron, each connected between one of said field electrodes and one of said anode members.

6. A magnetron comprising an anode, a cathode spaced from said anode, means adjacent said anode for providing a constant magnetic field within the space between said anode and said cathode in a direction transverse to the electron path therebetween, a field electrode having a portion thereof interposed between substantial portions of said anode and said cathode, a substantial portion of the length of said cathode being directly exposed to said anode, and a bypass condenser connected between said field electrode and said anode.

7. A magnetron comprising an anode, a cathode spaced from said anode, means adjacent said anode for providing a constant magnetic field within and transverse to the path of electrons between said cathode and said anode, and field electrodes having portions thereof positioned closer to said anode than to said cathode and interposed between the end portions of said cathode and substantial portions of said anode, the intermediate portion of said cathode between said end portions being directly exposed to said anode.

8. A magnetron comprising an anode, a cathode spaced from said anode, means adjacent said anode for providing a constant magnetic field within and transverse to the path of electrons between said cathode and said anode, and imperforate field electrodes having portions thereof positioned closer to said anode than to said cathode and interposed between the end portions of said cathode and substantial portions of said anode, the intermediate portion of said cathode between said end portions being directly exposed to said anode.

9. A magnetron comprising an anode structure defining a cylindrical cathode space of constant diameter, an elongated cathode extending coaxially within said space, means adjacent said anode structure for providing a constant magnetic field within said space parallel to said cathode, and a hollow cylindrical field electrode having a portion thereof positioned closer to said anode than to said cathode and interposed coaxially between substantial portions of said cathode and said anode structure.

10. A magnetron comprising an anode structure defining a cylindrical cathode space of constant diameter, an elongated cathode extending coaxially within said space, means adjacent said anode structure for providing a constant magnetic field within said space parallel to said cathode, and a hollow cylindrical imperforate field electrode having a portion thereof positioned closer to said anode structure than to said cathode and interposed coaxially between substantial portions of said cathode and said anode structure.

11. A magnetron comprising an anode structure defining a cylindrical cathode space, an elongated cathode extending coaxially within said space, means adjacent said anode structure for providing a constant magnetic field within said space parallel to said cathode, and axially-spaced hollow cylindrical field electrodes having parts positioned closer to said anode structure than to said cathode and interposed coaxially between the end portions of said cathode and substantial portions of said anode structure, the intermediate portion of said cathode between said end portions being directly exposed to said anode structure.

12. A magnetron comprising an anode structure defining a cylindrical cathode space, an elongated cathode extending coaxially within said space, means adjacent said anode structure for providing a constant magnetic field within said space parallel to said cathode, and axially-spaced hollow cylindrical imperforate field electrodes having parts positioned closer to said anode structure than to said cathode and interposed coaxially between the end portions of said cathode and substantial portions of said anode structure, the intermediate portion of said cathode between said end portions being directly exposed to said anode structure.

13. An electrical system comprising a magnetron having an anode, a cathode spaced from said anode, and a field electrode having a portion thereof interposed between substantial portions of said cathode and said anode, a source of variable direct current voltage connected to said anode and said cathode, and a source of constant direct current voltage connected to said field electrode and said anode, whereby the direct current electric field at said anode and the power output of said magnetron are maintained substantially constant despite variations in the direct current electric field between said anode and said cathode produced by variations of said variable voltage source.

14. An electrical system comprising a magnetron having an anode, a cathode spaced from said anode, and a field electrode having a portion thereof interposed between substantial portions of said cathode and said anode, a source of variable direct current voltage connected to said anode and said cathode, and a source of constant direct current voltage connected to said field electrode and said anode, whereby the direct current electric field at said anode and the power output of said magnetron are maintained substantially constant despite variations in the direct current electric field between said anode and said cathode produced by variations of said variable voltage source, and a bypass condenser connected between said field electrode and said anode.

15. An electrical system comprising a magnetron having an anode, a cathode spaced from said anode, and a field electrode having a por-

tion thereof interposed between substantial portions of said cathode and said anode, means providing a constant magnetic field within and transverse to the path of electrons between said cathode and said anode, a source of constant voltage and a source of alternating voltage connected in series between said anode and said cathode, and a source of constant voltage connected to said field electrode and said anode to maintain the direct current electric field at said anode and the power output of said magnetron substantially constant despite variations in the direct current electric field between said anode and said cathode.

16. An electrical system comprising a magnetron having an anode, a cathode spaced from said anode, and a field electrode having a portion thereof interposed between substantial portions of said cathode and said anode, means providing a constant magnetic field within and transverse to the path of electrons between said cathode and said anode, a source of variable direct current voltage connected to said anode and said cathode to modulate the frequency of oscillations generated by said magnetron, and a source of constant direct current voltage connected to said field electrode and said anode, whereby the direct current electric field at said anode and the power output of said magnetron are maintained substantially constant despite variations in the direct current electric field between said anode and said cathode produced by variations of said variable voltage source.

17. An electrical system comprising a magnetron having an anode, a cathode spaced from said anode, and a field electrode having a portion thereof interposed betwen substantial portions of said cathode and said anode, means providing a constant magnetic field within and transverse to the path of electrons between said

cathode and said anode, a source of variable direct current voltage connected to said anode and said cathode to modulate the frequency of oscillations generated by said magnetron, and a source of constant direct current voltage connected to said field electrode and said anode, whereby the direct current electric field at said anode and the power output of said magnetron are maintained substantially constant despite variations in the direct current electric field between said anode and said cathode produced by variations of said variable voltage source, and means for adjusting the voltage of said constant voltage source to obtain a desired frequency modulation-output characteristic.

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