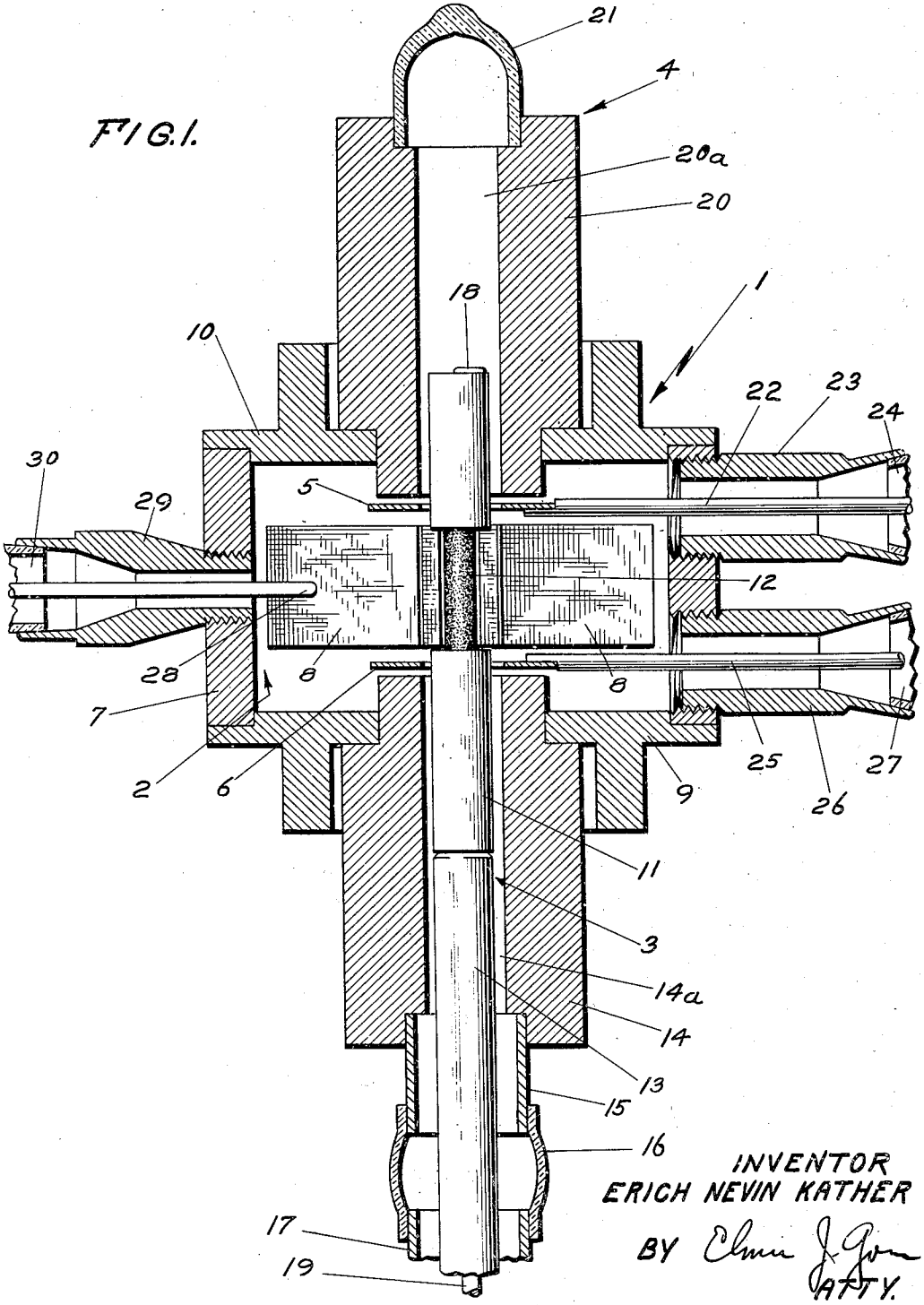
March 1, 1949. E. N. KATHER 2,462,869

ELECTRON DISCHARGE DEVICE

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FIG. 1.



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FIG. 2.

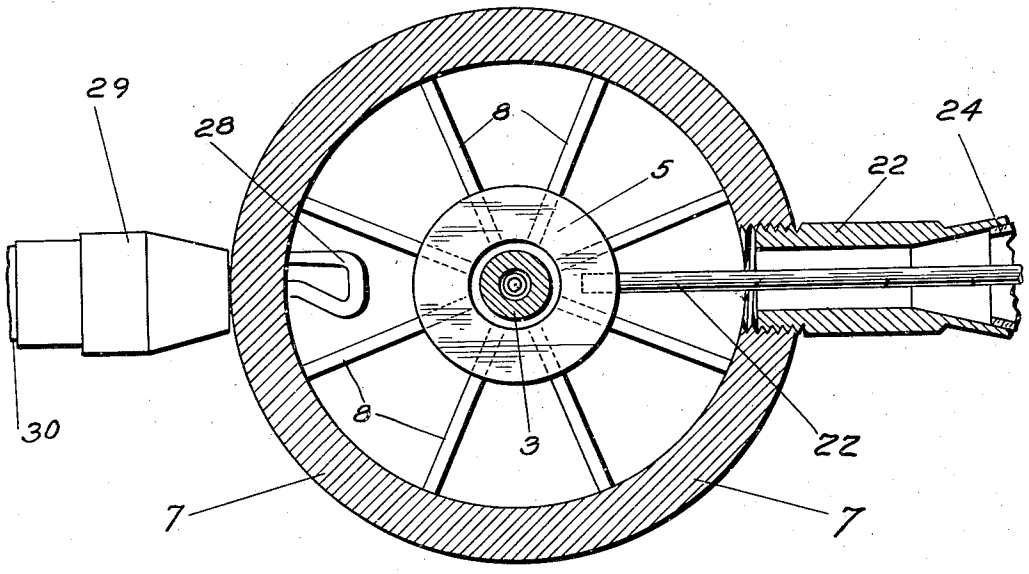


FIG. 3.

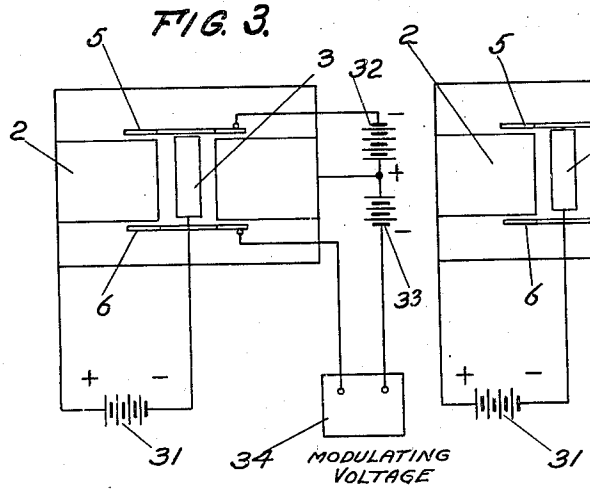
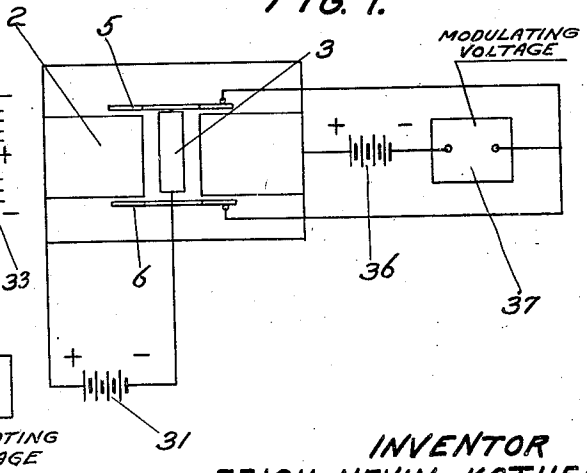


FIG. 4.



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UNITED STATES PATENT OFFICE

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ELECTRON DISCHARGE DEVICE

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Application February 23, 1946, Serial No. 649,615

8 Claims. (Cl. 179—171.5)

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This invention relates to electron-discharge devices, and more particularly to such devices as are known as magnetrons.

This invention is particularly suitable for tuning or frequency modulating magnetrons which are adapted to generate microwaves having a wavelength of the order of several centimeters or less.

An object of this invention is to produce such a device in which the frequency of the oscillations may be modulated over an extremely wide band, for example, 10 megacycles or more.

Another object is to devise such an arrangement in which the frequency modulation is substantially linear with respect to the magnitude of the modulating voltage.

A further object is to devise such an arrangement with substantially no inertia whereby the modulation frequency may effectively utilize the band through which such modulation may be effected.

The foregoing and other objects of this invention will bet best illustrated from the following decription of exemplifications thereof, reference being had to the accompanying drawings wherein:

Fig. 1 is a fragmentary, longitudinal section of an electron-discharge device incorporating the invention;

Fig. 2 is a transverse cross-section taken along the line 2—2 of Fig. 1; and

Figs. 3 and 4 are circuit diagrams representing two typical modulating circuits.

The arrangement as shown in Figs. 1 and 2 illustrates a magnetron indicated generally by the reference numeral 1. This magnetron includes an anode structure 2, a cathode structure 3, a magnetic means 4 for establishing a magnetic field in a direction generally perpendicular to the electron path between said cathode and anode structures, and a pair of modulating electrodes 5 and 6.

The anode structure 2 preferably comprises a cylindrical body 7 made of a highly conductive material, such as copper, and provided with a plurality of anode members in the form of interiorly extending, radially disposed vanes 8. The cylindrical body 7 is closed at its end by plates 9 and 10, the junction between said body and said plates being hermetically sealed as by silver soldering. The cylindrical body 7 is of such diameter and the number, size and relative spacing of the vanes 8 are so chosen that each pair of adjacent vanes, together with that portion of said cylindrical body lying therebetween, define a

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cavity resonator adapted to oscillate in the desired frequency range.

The cathode structure 3, which is coaxial with the anode structure 2, preferably comprises an elongated sleeve 11, conventionally made of nickel or the like, and having a reduced portion 12 which is substantially coextensive with the vertical dimension of the vanes 8 and provided with a highly electron-emissive coating, for example, of the well-known alkaline earth metal oxide type. In order to support the cathode sleeve 11 with respect to the anode member 8, said sleeve may be reduced at its lower end to fit into a tubular conducting member 13 adapted to be supported from a tubular pole piece 14 hermetically sealed into the end plate 9. The pole piece 14 is provided with a bore 14a through which the cathode structure may enter the device. A sleeve 15 of a suitable metal such as "Kovar" is sealed in the lower end of the pole piece 14. A glass sleeve 16 is sealed to the lower end of the sleeve 15 and in turn is sealed to and carries a metal sleeve 17. The lower end of the tubular member 13 is electrically connected to and supported by the sleeve 17 in any desired manner (not shown). The cathode sleeve 11 may be heated by a filament (not shown) connected at one end 18 to said sleeve and at the other end to a lead-in conductor 19 suitably entering said device through a glass seal (not shown) in the lower end of the sleeve 17.

Current may be conveyed to the heating filament by connecting an appropriate source of voltage between the member 17 and the lead-in conductor 19.

Another pole piece 20 is hermetically sealed into the end plate 10. The pole piece 20 is likewise provided with a bore 20a terminating in a tubular member 21 sealed in the upper end thereof. The device is adapted to be evacuated through said tubular member which is then sealed at its upper end. The pole pieces 20 and 14 are fixed, for example, at the opposite ends of a horseshoe magnet (not shown), the two pole pieces and the horseshoe magnet constituting the above-mentioned magnetic means 4 for establishing a magnetic field transverse to the electron path between the cathode and anode structures of the device.

The modulating electrodes 5 and 6 are supported adjacent the upper and lower open ends of the cavity resonators. The surfaces facing these open ends are preferably so constituted as to be good secondary electron emitters. For example, the electrodes 5 and 6 may each be made of a tantalum ring. During the exhaust process, when cathode 12 is heated to a relatively high tempera-

ture, the rings 5 and 6 have deposited on them a film of the oxide coating from the cathode. Such a thin film of oxide deposited on tantalum constitutes a good secondary electron emitter. Of course, it is to be understood that other types of secondary electron emissive surfaces could be substituted for the one just described. Electrode 5 may be supported by a conductor 22 passing out of the device through a pipe 23 threaded and hermetically sealed in the cylindrical body 7. The outer end of the conductor 22 passes through a glass seal 24 carried by the outer end of said pipe 23. Likewise, the electrode 6 is supported by a conductor 25 which passes out through a pipe 26 and a glass sleeve 27 similar to those described in connection with the electrode 5.

When the device is generating oscillations, these oscillations may be let out therefrom by means of a loop 28 introduced into one of the cavity resonators, said loop being supported by a pipe 29 threaded and hermetically sealed in the cylindrical body 7. One end of the loop 28 is connected to the inner end of said pipe and the other end passes out through a glass sleeve 30 supported at the outer end of said pipe.

As illustrated in Fig. 3, the cathode 3 may be maintained at the proper negative potential by a source of such potential illustrated diagrammatically as a battery 31. Pursuant to this invention it is desirable that the electrodes 5 and 6 be biased negatively with respect to the anode structure 2. For this purpose biasing sources of potential illustrated diagrammatically as batteries 32 and 33 may be interposed between the electrodes 5 and 6 and the anode structure 2. In series with one of the sources of biasing potential may be placed a suitable source of modulating voltage 34. The maximum amplitude of this modulating voltage is preferably related to the bias voltage 33 so that the electrode 6 never becomes appreciably positive during operation. In a particular embodiment in which the voltage 31 was about 1200 volts, the voltage 32 about 500 volts, the voltage 33 about 250 volts and the modulation voltage having an amplitude between its maximum positive and negative peaks of about 500 volts, the frequency at which the device oscillated could be varied through a range of about 15 megacycles.

In accordance with my present understanding of the theory of operation of this device, I believe that the operation is substantially as follows. In the space immediately adjacent either of the electrodes 5 and 6 will be found some free electrons, whether due to the emission from the cathode 3 or from some other source. These electrons will be impelled under the voltage existing between the electrode 5, for example, and the anode 2 in a direction toward the lower open ends of the cavity resonators. The device, which under these conditions will be generating oscillations, will have produced between the outer ends of the vanes 8 a transverse, high voltage, high frequency electrical field. Therefore, as the electrons enter this region, they will be subjected to the action of the longitudinal magnetic field and also to the action of said transverse high frequency electrical field. Under these conditions, the electrons will travel in a variable spiral path toward the lower open end of the cavity resonator in which they find themselves. This path will be such as to effectively prevent the electrons from being captured by the surfaces of the vanes 8. As the electrons in a particular cavity emerge from the lower end thereof, those electrons which are in proper phase

relation with respect to the high frequency electrical field will have imparted thereto a considerable acceleration. If there were no electrode such as 6, interposed in their path, these electrons would be quickly captured, for example, by the pole piece 14 or by the cover 9. However, the electrode 6 which is interposed in the path of these electrons will intercept them. The acceleration to which these electrons are subjected by the high frequency electrical field will be sufficient to cause them to liberate large numbers of secondary electrons from the electrode 6. These secondary electrons will be impelled by the bias voltage existing between electrode and the anode structure in a direction to reenter the cavity resonator. Those electrons which are not in proper phase with respect to the high frequency electrical field as they tend to emerge from the lower end of the cavity resonator will be decelerated and will reenter the cavity resonator, thus joining with the secondary electrons emitted from the electrode 6 in their travel through the cavity resonator in an upward direction toward the electrode 5. At the upper end of the anode structure a similar action occurs as the electrons emerge from the cavity resonators, thus producing a large amount of secondary emission from the electrode 5. Under these conditions, an electron multiplying action is created between the electrodes 5 and 6 which results in a rage population of electrons within each of the cavity resonators. The presence of these electrons varies the dielectric constant of the space within each of the cavity resonators, and thus by varying the density of this electron population, the frequency at which the cavity resonator tends to oscillate may be readily controlled. However, the paths of the electrons within each of the cavity resonators is such that substantially no energy is abstracted from the oscillating circuit, thus imparting to the device a relatively high efficiency.

By varying the extent to which the electrons between either or both of the electrodes 5 and 6 and the anode 2 are reflected into the cavity resonators, the density of the electron concentration in the cavity resonators readily may be controlled. Thus, for example, by interposing the modulation voltage 34 in the connection extending to the electrode 6, the frequency modulation described above may be obtained.

Although both of the electrodes 5 and 6 have been described as being electron emissive, in some instances one of these electrodes may be thus constituted, the other electrode serving solely as an electron reflecting member. However, under these conditions, a substantial amount of frequency modulation may likewise be obtained.

Instead of modulating the voltage on but one of the electrodes 5 and 6, various other circuit arrangements may be devised. For example, in Fig. 4 there is illustrated an arrangement in which the voltage on both of these electrodes is modulated. The electrodes 5 and 6 may be connected together and a connection extending from the common lead to the anode structure may include a biasing battery 36 and a source of modulation voltage 37. In this instance likewise the basing battery 36 is so polarized as to tend to maintain the electrodes 5 and 6 negative with respect to the anode structure 2. Such an arrangement likewise produces the desirable frequency modulation.

Although the electrodes 5 and 6 have been indicated as being sources of secondary electrons, other types of electron sources may be utilized,

For example, either one or both of the modulating electrodes may be heated so as to emit electrons thermionically.

Of course it is to be understood that this invention is not limited to the particular details as described above inasmuch as many equivalents will suggenst themselves 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 device comprising a cathode, an anode structure spaced from said cathode and including a pair of anode faces interconnected by a cavity resonator open at both ends, means for maintaining a magnetic field through said cavity in a direction extending between said open ends, a source of electrons facing one of said open ends, and an electron-reflecting electrode facing the other of said open ends.

2. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode and including a pair of anode faces interconnected by a cavity resonator open at both ends, means for maintaining a magnetic field through said cavity in a direction extending between said open ends, and a pair of electrodes facing said open ends, at least one of said electrodes being electron emissive during operation.

3. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode and including a pair of anode faces interconnected by a cavity resonator open at both ends, means for maintaining a magnetic field through said cavity in a direction extending between said open ends, and a pair of electrodes facing said open ends, at least one of said electrodes having a secondary electron emissive surface.

4. An electron-discharge device comprising a cathode, an anode structure spaced from said cathode and including a pair of anode faces interconnected by a cavity resonator open at both ends, means for maintaining a magnetic field through said cavity in a direction extending between said open ends, and a pair of electrodes facing said open ends, both of said electrodes having a secondary electron emissive surface.

5. A frequency modulating oscillator system including an electron-discharge device comprising a cathode, an anode structure spaced from said cathode and including a pair of anode faces interconnected by a cavity resonator open at both ends, means for maintaining a magnetic field through said cavity in a direction extending between said open ends, a pair of electrodes facing said open ends, at least one of said electrodes being electron emissive during operation, means for biasing each of said electrodes negatively with respect to said anode structure, and means for superimposing a modulating signal voltage on at least one of said electrodes.

6. A frequency modulating oscillator system including an electron-discharge device comprising a cathode, an anode structure spaced from said cathode and including a pair of anode faces interconnected by a cavity resonator open at both ends, means for maintaining a magnetic field through said cavity in a direction extending between said open ends, a pair of electrodes facing said open ends, at least one of said electrodes being electron emissive during operation, means for biasing each of said electrodes negatively with respect to said anode structure, and means for superimposing a modulating signal voltage on both of said electrodes.

7. A frequency modulating oscillator system including an electron-discharge device comprising a cathode, an anode structure spaced from said cathode and including a pair of anode faces interconnected by a cavity resonator open at both ends, means for maintaining a magnetic field through said cavity in a direction extending between said open ends, a pair of electrodes facing said open ends, at least one of said electrodes being electron emissive during operation, means for biasing each of said electrodes negatively with respect to said anode structure, and means for superimposing a modulating signal voltage on at least one of said electrodes, the magnitude of the biasing voltage on the last-named electrode being sufficient to maintain said electrode negative during the superimposition of said signal voltage.

8. A frequency modulating oscillator system including an electron-discharge device comprising a cathode, an anode structure spaced from said cathode and including a pair of anode faces interconnected by a cavity resonator open at both ends, means for maintaining a magnetic field through said cavity in a direction extending between said open ends, a pair of electrodes facing said open ends, at least one of said electrodes being electron emissive during operation, means for biasing each of said electrodes negatively with respect to said anode structure, and means for superimposing a modulating signal voltage on both of said electrodes, the magnitude of the biasing voltage on said electrodes being sufficient to maintain said electrodes negative during the superimposition of said signal voltage.

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