July 8, 1947. E. D. McARTHUR 2,423,716

ULTRA HIGH FREQUENCY MAGNETRON OF THE RESONATOR TYPE

Filed March 20, 1943

Fig. 1.

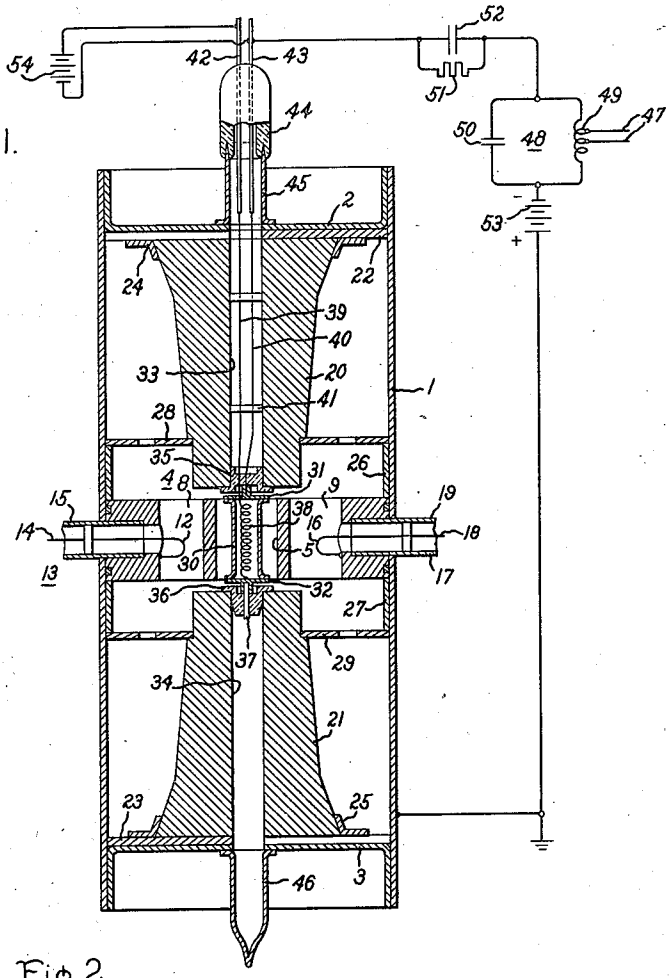
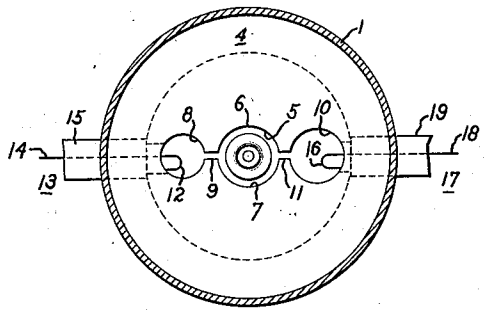


Fig. 2.



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ULTRA HIGH FREQUENCY MAGNETRON OF THE RESONATOR TYPE

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11 Claims. (Cl. 250—36)

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My invention relates to ultra high frequency conversion apparatus and more particularly to ultra high frequency magnetrons of the space resonant type.

It is an object of my invention to provide new and improved ultra high frequency conversion apparatus.

It is another object of my invention to provide a new and improved ultra high frequency electric discharge device of the magnetron type.

It is a further object of my invention to provide a new and improved ultra high frequency magnetron wherein a plurality of superimposed modulating effects act upon the space charge to derive from the magnetron electrical energy at a frequency corresponding to a resultant of the various excitations employed.

It is still another object of my invention to provide a new and improved ultra high frequency magnetron of a construction and arrangement which facilitate frequency conversion of ultra high frequency energy without entailing the use of separate electronic circuits or elements for accomplishing the results.

It is a still further object of my invention to provide new and improved methods of operating an ultra high frequency magnetron.

Briefly stated, in the illustrated embodiment of my invention, I provide a new and improved ultra high frequency electric discharge device of the magnetron type whereby ultra high frequency energy is readily converted. The electric discharge device comprises a metallic or conductive anode structure defining a plurality of space resonant regions or cavities, preferably having different natural frequencies, to produce therebetween electrode sections which serve as anode sections and which cooperate with a centrally positioned cathode. Upon the establishment of an electric field between the cathode and the anode structure and by the use of a magnetic field of proper intensity perpendicular to the electric field, there is imparted to the space charge a rotational motion. The space resonant cavities are excited at different frequencies, thereby modulating the motion of the electrons within the space charge in accordance with a resultant of the excitation frequencies. For example, if two of the space resonant regions are energized at different frequencies, there will be imparted to the electrons of the space charge motions producing frequencies corresponding to the sum and the difference of the excitation frequencies, thereby producing across the anode structure and the cathode of the discharge device potential differences corresponding to the resultant frequencies. Suitably tuned external utilization means, such as an intermediate frequency circuit or amplifier, may be connected to the output terminals of the discharge device for utilization of the resultant frequencies.

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For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims. Fig. 1 of the drawing shows my invention as applied to a magnetron in which the magnetic field is produced by a pair of permanently magnetized pole pieces located within the enclosing envelope for the electrodes, aand Fig. 2 is a plan view of the anode structure which defines the various space resonant cavities.

Referring now to Fig. 1 of the drawing, I have there illustrated my invention as applied to a magnetron of the type generally disclosed and claimed in my copending patent application Serial No. 447,903, filed June 22, 1942, and which is assigned to the assignee of the present application.

The electrodes of the discharge device there illustrated may be enclosed within an elongated cylindrical container, the lateral wall structure of which is provided by a single metal tube 1 which consists of a ferromagnetic material. The ends of the container are closed by flanged members 2 and 3 which are welded or otherwise hermetically sealed to the inner surface of tube 1.

Within the container and approximately at its central region, I provide an anode structure 4 shown in plan view in Fig. 2. The annular anode structure 4 is preferably of disk formation of appreciable longitudinal length and may be constructed of a suitable metal such as copper. Within the anode structure 4 there is provided an enlarged central opening 5 in which a cathode structure described hereinafter is positioned.

As a means for the utilization of ultra high frequency electrical energy and in order to modulate the space charge which is established between a centrally located cathode and the electrode or anode sections 6 and 7, I provide within the anode structure 4 a plurality of annularly or circumferentially positioned space resonant regions. These regions may take the form as illustrated in Fig. 2 in which one cavity comprises a cylindrical opening 8 in communication with the central opening 5 through a radial slot 9, and the other of which comprises a cylindrical opening 10 in communication with the central opening through a radially extending slot 11.

The above described space resonant cavities comprising openings 8 and 10 and slots 9 and 11 are dimensioned to have different natural frequencies. Generally speaking, it may be said that the natural frequency of a space resonant cavity of this character is determined by the distributed capacitance and the distributed inductance thereof, the inductance being constituted primarily by the cylindrical openings and the distributed capacitance being constituted principally by the opposing wall surfaces of the slots.

Electrode means are employed for exciting the respective space resonant cavities or deriving energy therefrom, depending upon the manner of utilization of the electric discharge device. For example, a loop 12 extends into the cylindrical opening 8 and constitutes an extension of an inner conductor of a concentric transmission line 13 comprising an inner coductor 14 and an outer tubular conductor 15. In like manner, the space resonant cavity comprising cylindrical opening 10 may be excited by a loop 16 which constitutes an extension of an inner conductor of a concentric transmission line 17 including an inner conductor 18 and an outer tubular conductor 19.

For the purpose of providing a magnetic field for the discharge device, I provide within the container 1 magnetic pole pieces 20 and 21 which may be tapered and which are directed axially of the container and which extend in close proximity to the upper and lower surfaces of the anode structure 4. Where it is desired to employ permanently magnetized pole pieces, these members may be constructed of a magnetizable material having a high coercive force and a high energy factor, such as alloys of the class including aluminum, nickel and cobalt.

As a means for providing a low reluctance connection between the base extremities of the magnetic pole pieces 20 and 21, these pole pieces may be respectively seated upon relatively thick disk-like members 22 and 23 constructed of a ferromagnetic material such as steel. To secure the pole pieces 20 and 21 to the disk members 22 and 23, use may be made of clamping rings 24 and 25 which are slipped over the pole pieces during the assembly procedure and which are welded to the inner surfaces of disks 22 and 23.

Accurate spacing of the anode structure 4 with respect to the pole faces of pole pieces 20 and 21 may be obtained by the use of spacing rings 26 and 27 which engage the upper and lower surfaces of anode structure 4, and which are also in engagement with a pair of transverse apertured spacing disks 28 and 29 adapted to engage suitable abutments provided by pole pieces 20 and 21.

Within the central opening 5 of anode structure 4, I provide a cathode comprising a flanged sleeve 30 which is preferably coated on the outer surface with an electron emissive material such as barium oxide, and which is provided with end caps 31 and 32 serving to close the ends of the sleeve 30.

In order to position and support the above described cathode structure, magnetic pole pieces 20 and 21 are provided with longitudinally extending channels 33 and 34 which may be of circular cross section. The upper end of the cathode structure may be supported in the desired central position by means of an insulator 35 which closely engages the walls of channels 33, and the lower extremity of the cathode structure may be supported centrally by means of an insulator 36 which is positioned at the upper end of channel 34 and which is provided with a centering pin 37 connected to the lower end cap 32.

Channel 33 in pole piece 20 may also be employed for supplying current to a cathode heating element 38 positioned within the sleeve 30. For example, a pair of conductors 39 and 40, electrically insulated from each other and maintained in spaced relation with respect to the walls of channel 33 by longitudinally spaced insulators 41, serve as a means not only for supplying energy to the heating element 38 but also as a means for obtaining an external connection to the cathode of the discharge device. Conductors 39 and 40 are connected to lead-in conductors 42 and 43, respectively, the latter of which may be employed as the electrical connection to the cathode structure inasmuch as it it connected to the cathode sleeve through the end cap 31.

Lead-in conductors 42 and 43 are positioned in a vitreous seal 44 which, in turn, is sealed to a flanged collar 45 welded to the outer surface of the end member 2. Evacuation of discharge device as a whole may be accomplished through channel 34 which is terminated in a metallic tubulation 46 which is sealed after being evacuated.

Energization of an external utilization circuit 47 may be accomplished by means of a circuit 48, comprising an inductance 49 and a capacitance 50, tuned to an intermediate or resultant frequency derived from the anode structure 4 and the cathode through conductor 40 and lead-in conductor 43. Circuit 48 may be connected to conductor 43 through a circuit comprising a parallel connected resistance 51 and a capacitance 52 which are designed to transmit electrical energy at the intermediate frequency to circuit 48, as well as to effect the the impression of a unidirectional potential across anode structure 4 and a cathode from a suitable source of current such as a battery 51. Energizing current for the cathode heating element may be derived from a battery 54.

Upon application of unidirectional potential between anode structure 4 and cathode sleeve 30, and due to the presence of the longitudinal magnetic field produced by pole pieces 20 and 21, a rotating space charge will be established between the outer surface of cylinder 30 and the anode structure, particularly the anode sections 6 and 7. This motion may be described generally as following a spiral path, the angular velocity of the electrons in the space charge being a function of the magnetic field intensity.

If it be considered that the magnetron is employed for the purpose of converting ultra high frequency energy from one frequency to a second frequency, upon the energization of the space resonant cavities comprising central openings 8 and 10 at different frequencies the electrons constituting the space charge will be controlled or modulated at these different frequencies, the voltages appearing across the slots 9 and 11 at the juncture points with the central opening 5 serving to obtain this effect. That is, the electrons constituting the space charge will undergo variations in velocity corresponding to the modulating frequencies in pursuing their orbital paths.

If one of the space resonant cavities, such as that comprising opening 10, is considered as being energized from a local oscillator at one frequency, and the other space resonant cavity comprising opening 8 is energized at signal frequency, the electrons constituting the space charge will be modulated in accordance with a

resultant electric field giving rise to a modulated current containing the sum and the difference of these two frequencies. Consequently, there will appear between the anode structure 4 and cathode sleeve 30, components of voltage corresponding to the sum and the difference frequencies. The resultant voltages appearing between the anode structure and cathode 30 are utilized for the purpose of energizing an external utilization circuit, such as circuit 47, which is energized through a circuit 48 tuned to a selected resultant or intermediate frequency.

While I have shown and described my invention as applied to a particular form of magnetron, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An ultra high frequency electric discharge device of the magnetron type comprising a cathode and an anode structure having a central opening through which said cathode extends and having in communication therewith a plurality of space resonant cavities, means for establishing a magnetic field which with an electric field applied across said anode structure and said cathode establishes therebetween a rotating space charge, means for exciting one of said cavities at one frequency, and means for exciting another cavity at a different frequency thereby establishing across said cathode and said anode structure a voltage corresponding to a resultant of the above frequencies.

2. An ultra high frequency electric discharge device of the magnetron type comprising a cathode and a disk-type anode structure having a central opening through which said cathode extends and having in communication therewith a plurality of space resonant cavities having different natural frequencies, means for establishing a magnetic field which with an electric field applied across said anode structure and said cathode establishes therebetween a rotating space charge, means for exciting one of said cavities at one frequency, and means for exciting the other cavity at a different frequency thereby establishing across said anode structure and said cathode a voltage corresponding to a resultant of the above mentioned frequencies.

3. An ultra high frequency electric discharge device of the magnetron type comprising a cathode and a disk-like anode structure having a central opening through which said cathode extends and having in communication therewith a plurality of annularly positioned space resonant cavities, means for establishing a magnetic field extending longitudinally through said central opening, means for establishing an electric field between said anode structure and said cathode and which in conjunction with said magnetic field establishes a rotating space charge, means for exciting one of said cavities at one frequency, and means for exciting another cavity at a different frequency thereby producing across said anode structure and said cathode a voltage corresponding to a resultant of the above mentioned frequencies.

4. An ultra high frequency electric discharge device of the magnetron type comprising a cathode and an anode structure having a central opening through which said cathode extends and

having in communication therewith a pair of space resonant cavities having different natural frequencies, means for establishing a magnetic field which with an electric field applied across said anode structure and said cathode establishes therebetween a rotating space charge, means for exiting one of said cavities at one frequency, means for exciting the other cavity at a different frequency, and means connected to said cathode and said anode structure energized in accordance with a resultant of the first mentioned and second mentioned frequencies.

5. An ultra high frequency electric discharge device of the magnetron type comprising a cathode and an anode structure having a central opening through which said cathode extends and having in communication therewith a pair of space resonant cavities having different predetermined natural frequencies, means for establishing a magnetic field which with an electric field applied across said anode structure and said cathode establishes a rotating space charge therebetween, means for exciting one of the cavities at its natural frequency, and means for exciting the other cavity at a different frequency thereby modulating said space charge in accordance with a resultant of said frequencies and producing across said anode structure and said cathode a high frequency voltage corresponding to said resultant frequency.

6. An ultra high frequency electric discharge device of the magnetron type comprising a cylindrical cathode and an annular anode structure having a central opening through which said cathode extends and having in communication there with a pair of space resonant cavities each comprising a cylindrical opening radially displaced from said central opening and in communication therewith through a radial slot, said cavities having different natural frequencies, means for establishing a magnetic field which with an electric field applied across said anode structure and said cathode establishes a rotating space charge therebetween, and means for exciting said cavities at different frequencies thereby modulating the space charge in accordance with a resultant of said frequencies and producing across said anode structure and said cathode a potential difference corresponding to said resultant.

7. Frequency conversion electric discharge apparatus of the space resonant type comprising a plurality of enclosed electrodes including a cathode and an anode structure having a central opening through which said cathode extends and having in communication therewith a pair of space resonant cavities having different natural frequencies, means for establishing a magnetic field which with an electric field applied across said anode structure and said cathode establishes a rotating space charge therebetween, means for exciting said cavities at different frequencies to modulate the space charge in accordance with said frequencies, and means connected to said anode structure and said cathode for utilizing the potential difierence thereacross corresponding to either the sum or difference frequency.

8. Ultra high frequency conversion apparatus of the magnetron type comprising an electric discharge device including a plurality of enclosed electrodes including a cathode and an anode structure having a central opening through which said cathode extends and having in communication therewith a pair of space resonant cavities having different natural frequencies, means for

establishing a magnetic field which with an electric field applied across said anode and said cathode establishes a rotating space charge therebetween, means for exciting said cavities at different frequencies and for modulating the space charge in accordance with said frequencies, and intermediate frequency utilization means connected across said anode structure and said cathode.

9. An ultra high frequency electric discharge device of the magnetron type comprising a cathode and an anode structure having a central opening through which said cathode extends and having in communication therewith a plurality of space resonant cavities having different natural frequencies, means for establishing a magnetic field which with an electric field applied across said anode structure and said cathode establishes therebetween a rotating space charge, externally accessible means coupled with one of said cavities for effecting excitation thereof at one frequency, and a second externally accessible means coupled with another of said cavities for effecting excitation thereof at a different frequency thereby producing across said anode structure and said cathode a high frequency potential difference corresponding to a resultant of the above mentioned frequencies.

10. An electric discharge device of the magnetron type comprising a cathode and an anode structure defining a plurality of space resonant cavities, means for applying a unidirectional potential across said anode structure and said cathode, means for controlling the space discharge between said anode structure and said cathode including means for exciting one of said cavities at one frequency, means for superimposing a modulating effect on said space charge including means for exciting another cavity at a different frequency and means for deriving electrical energy from said cathode and said anode structure at a frequency which is a resultant of the first mentioned and second mentioned frequencies.

11. An ultra high frequency electric discharge device of the magnetron type comprising a cathode and an anode structure having a plurality of space resonant cavities, means for impressing an electric field between said anode structure and said cathode, means for producing a magnetic field in the region between said anode structure and said cathode which is substantially perpendicular to said electric field to produce a rotating space charge between said cathode and said anode structure, means for controlling the space charge including means for exciting one of said cavities at one frequency, and means for superimposing a modulating effect on said space charge by exciting another cavity at a different frequency thereby producing across said cathode and said anode structure a high frequency potential difference corresponding to a resultant of the first mentioned and second mentioned frequencies.

ELMER D. McARTHUR.

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