Sept. 20, 1949. R. N. HALL ET AL 2,482,541

HIGH-FREQUENCY ELECTRICAL APPARATUS

Filed May 12, 1945

Fig. 1.

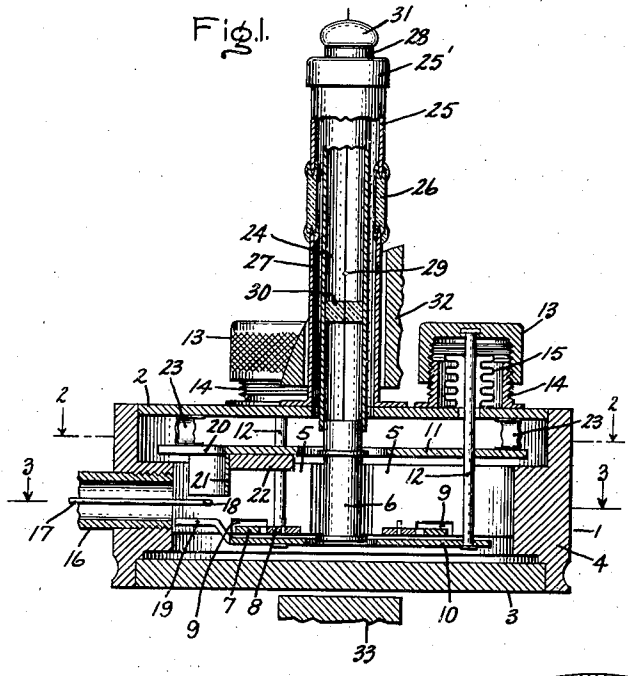


Fig. 2.

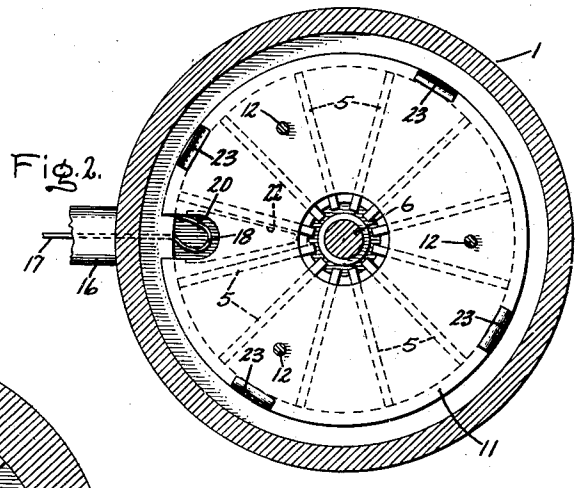
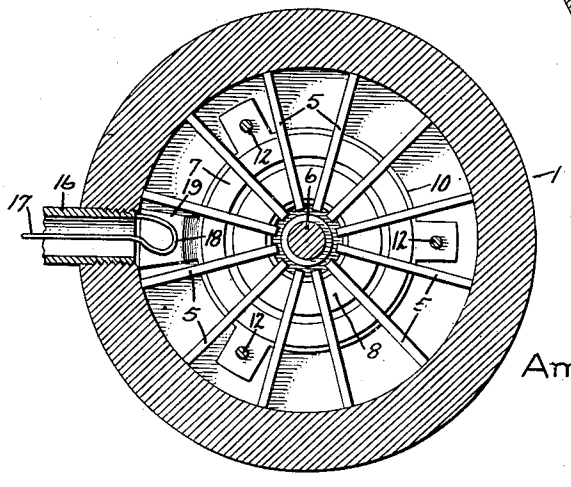


Fig. 3.



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HIGH-FREQUENCY ELECTRICAL APPARATUS

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11 Claims. (Cl. 250—27.5)

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Our invention relates to high frequency apparatus and particularly to improved arrangements for controlling the coupling between a resonant structure and an output circuit. While not limited thereto, our invention is particularly well adapted for controlling the coupling between the resonant circuits of a tunable anode structure of a high frequency magnetron and a coupling loop of an output circuit.

Magnetron constructions employing a resonant anode structure, including an array of tuned circuits arranged about a central opening in which the electrons constituting the space charge of the magnetron are adapted to move, have been widely used as a source of high frequency electric oscillations. It is often desirable to provide means for tuning the resonant anode structure to determine or control the frequency at which the magnetron operates. In the copending Nelson application Serial No. 566,288, filed December 2, 1944, entitled "Electric discharge devices" and assigned to the assignee of the present invention, now matured into Patent 2,424,496, granted July 22, 1947, is described and claimed a tuning arrangement for magnetrons in which a pair of disks, arranged at opposite ends of the anode structure and rigidly coupled together, are provided for simultaneously varying the inductive and capacitive components of reactance of the various tuned circuits of the anode structure. We have found that when operating a magnetron, such as the one described in the above-identified Nelson application, the range of tuning, efficiency and stability of operation may be increased by varying the coupling between the tuned circuits of the anode and the output circuit. In accordance with an important feature of our invention, we provide means for varying the coupling between the tuned circuits of the anode and the output circuit as the operating frequency is adjusted.

It is an object of our invention to provide a new and improved magnetron device.

It is another object of our invention to provide a new and improved tuning arrangement for magnetrons.

It is still another object of our invention to provide new and improved high frequency apparatus including a resonant anode structure and an output circuit in which the effective coupling between the output circuit and the resonant structure is varied with variations in the operating frequency.

In accordance with the illustrated embodiment of our invention, we provide a magnetron including a vane-type resonant anode structure which

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is tuned by a pair of disk-like members of different diameters located on opposite sides of the anode and rigidly secured together so that they move in unison as the magnetron is tuned. One tuning disk is arranged to control predominately the capacitive component of the tuned circuits and the other disk, hereinafter sometimes called L ring, is arranged to control predominately the inductive component of the tuned circuits. As the capacitative tuning element moves closer to the anode structure and the inductive tuning element moves away from the anode structure, the inductance and capacitance are simultaneously increased, thus tuning the anode to a lower operating frequency. In accordance with our invention, we provide a vane extending from the edge of the capacitive tuning element in alignment with the coupling loop of the output circuit to cut off a portion of the flux which would otherwise link the output loop. This vane reduces the effective coupling between the anode and the output circuit as the operating frequency is lowered, with the result that the operation of the device is stabilized. In order to increase the coupling between the output loop and the anode structure as the magnetron is tuned to higher operating frequencies, an opening is provided in the L-ring in alignment with the output coupling loop with the result that flux linking the output circuit is increased at higher operating frequencies resulting in higher efficiency and a wider range of tuning than would otherwise be possible. The desired change in coupling with position of the L-ring is attained by a collar conforming generally with the shape of the output loop and extending into the anode cavity in the direction of the loop. Also, a land on the lower side of the L-ring of less thickness than the collar and conforming to the space between adjacent radial vanes is employed to compensate for the lowered reluctance to magnetic field caused by the presence of the hole in the tuning disk.

Our invention will be better understood by reference to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims. In the drawing, Fig. 1 is an elevational view, partially in section, of a magnetron device embodying our invention; Fig. 2 is a sectional view taken along the line 2—2 of Fig. 1, and Fig. 3 is a sectional view taken along the line 3—3 of Fig. 1.

Referring now to the drawing, our invention has been illustrated as embodied in a magnetron device including a generally cylindrical envelope

1, preferably formed of good conducting material such as copper. The cylinder is closed by a cover plate 2 and a bottom plate 3 which may be joined to the side wall of the envelope in any suitable manner. In the particular embodiment illustrated, the resonant anode structure is formed integrally with the side wall of the envelope and includes a circumferential portion 4 and a plurality of equally spaced radially extending vanes 5 terminating short of the center of the envelope to define a generally cylindrical space within which the cathode 6 of the device is positioned.

In one desired mode of oscillation of the resonant anode structure, the portions of adjacent vanes facing the cathode are displaced 180 electrical degrees. Operation in this mode is enhanced by connecting alternate vanes by conducting members at the ends thereof adjacent the central opening of the anode structure. As shown in the drawing, annular conducting straps 7 and 8 are secured to the lower face of the anode structure concentrically with the central opening in the anode. These straps 7 and 8 are connected with different sets of alternate anode sections and each strap is insulated from the other set of vanes by recesses 9 which provide suitable clearance between the vanes and the straps. The straps 7 and 8 provide a flat surface which cooperates with the capacitive tuning element to vary effectively the capacity of the various circuits of the anode structure. As illustrated in the drawing, the capacitive tuning member is a disk 10, preferably formed of conducting material such as copper. A larger disk 11 is arranged on the opposite side of the anode and connected rigidly with the disk 10 by supporting rods 12 which are adjustably supported from the cover plate 2 by adjusting caps 13. As illustrated in Fig. 1, the cap 13 is threaded on a collar 14 extending upwardly from the cover plate 2, and the supporting rod 12 is rotatably received in the adjusting cap 13. A flexible bellows 15 sealed to the cover plate 2 and to the supporting rod 12 seals the envelope while permitting axial movement of the supporting rod 12. The tuning arrangement just described is in general similar to that described and claimed in the above-identified Nelson application.

An output circuit for extracting energy from the high frequency field produced in the resonant anode structure is provided by a concentric transmission line including an outer conductor 16 threaded into the envelope 1, and a central conductor 17 terminating in a loop 18 in one of the resonant cavities defined by adjacent vanes of the anode structure. It will be understood that the transmission line is hermetically sealed at some point along its length to complete the enclosure for the magnetron device.

In order to modify the coupling between the output loop 18 and the flux in the resonant anode structure as the tuning members 10 and 11 are adjusted in position, we provide a flange or paddle-like extension 19 on the edge of the capacitive tuning disk 10 and extending in alignment with the output loop 18. It will be apparent that this paddle functions to choke off a portion of the flux which would otherwise link the anode structure and the output loop as the disk 10 is moved closer to the anode structure, in this way decreasing the effective coupling with the output as the device is tuned to lower operating frequencies. In order to increase the flux linking the output loop 18 and the effective coupling with the anode structure as the device is

tuned to higher operating frequencies, opening 20 is formed in inductive tuning disk 11 in alignment with the output loop 18 and of the same general shape. While this opening alone has the effect of increasing the coupling, operation of the device is improved by providing a depending flange 21 of the same general shape as the output loop and surrounding the opening 20. This flange terminates at about the plane of the loop 18 when the tuning disk 11 is in its lowest position, that is when the magnetron is tuned to its highest frequency. An extension or land 22 on the lower face of the tuning disk 11, conforming essentially to the space between the vanes bounding the output loop 18 behind the flange 21, further improves the operation of the device as it is tuned to higher operating frequencies. This land is preferably considerably shallower than the flange 21. In order to maintain the tuning assembly of the same high frequency potential as the envelope, a plurality of flexible shorting strips 23 are connected between the tuning disks 11 and the cover plate 2. These strips are flexible enough to permit free movement of the tuning assembly and are effective to prevent the introduction of extraneous frequencies into the system.

The cathode 6 is supported from the cover plate 2 by a hollow supporting tube 24 which is secured to a sleeve 25 by a cap 25'. The sleeve 25 is sealed to the upper end of an insulating sleeve 26, preferably of glass and having its lower end sealed to the upper end of an upstanding sleeve 27 formed on the cover plate 2. The upper end 28 of the tube 24 provides the cathode terminal which may also provide the external connection for one side of the heater element (not shown). The other heater element is positioned centrally of the supporting tube 24 and maintained in insulated relation with respect thereto by a suitable spacing insulator 30. The conductor 29 extends from the upper end of the tube 24 and is sealed thereto by a body of glass 31.

A magnetic field is produced in the space between the cathode 6 and the ends of the vanes 5 by suitable permanent or electromagnetic means (not shown) having pole pieces 32 and 33 located opposite the ends of the cathode 6 and on the exterior of the envelope.

The operation of the embodiment of my invention described above as a source of high frequency electrical oscillations is believed to be generally understood. Briefly, this operation is as follows: Electrons emitted from the surface of the cathode 6 move in the annular space between the cathode and the ends of the radial vanes 5 in curvilinear paths determined by the geometry of the anode structure and the resultant action of mutually perpendicular electric and magnetic fields produced, respectively, by a voltage across the anode and cathode and by the pole pieces 32 and 33. Movement of the electrons excites the anode structure and causes electrical oscillations at a frequency determined by the constants of the mutually coupled circuits formed by the radial vanes. Energy is extracted from the high frequency field produced in the openings through the anode by means of the output loop 18 which is connected with the central conductor of the output transmission line. As the tuning structure is moved downwardly, as viewed in Fig. 1, plate 11, which is the inductive tuning element, moves closer to the anode structure choking off a portion of the high frequency flux which normally passes through the openings of the anode and the capacitive tuning element 10 is moved away from the

straps 7 and 8, thus simultaneously reducing the inductive components of reactance of the tuned circuits of the anode and tuning the device for operation at a higher frequency. In order to increase the coupling between the high frequency of the anode and the output circuit including the loop 18 as the device is tuned to higher frequencies, the opening 20 in the inductive tuning disk is provided in alignment with the output loop 18. This opening allows flux to thread the loop 18 which would otherwise be cut off by the tuning disk. The flange 21 and land 22 are provided to control the change in coupling with operating frequency in such a manner as to maintain efficiency and stability over a wide range of operation. The paddle or vane extension 19 on the capacitive tuning element 10 functions to decrease the coupling between the flux of the anode structure and the output loop as the device is tuned to a lower operating frequency, with the result that the stability of the oscillations is increased.

While we have shown and described a particular embodiment of our invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from our invention in its broader aspects, and we, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of our invention.

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

1. An electric discharge device comprising a space resonant structure adapted to be excited into high frequency oscillation by the space charge of said device, means adjacent said structure for tuning said structure to different operating frequencies, an output element coupled to said structure, and means intercoupling said means and said output element for varying the coupling between said resonant structure and said output element as the operating frequency is varied.

2. An electric discharge device comprising a space resonant structure adapted to be excited into high frequency oscillation by the space charge of said device, means adjacent said structure for tuning said structure to different operating frequencies, an output means including a loop conductor coupled to said structure, and means intercoupling said means and said output means for increasing the coupling between said resonant structure and said output means as the operating frequency is increased.

3. An electric discharge device comprising an anode structure including an array of cavity resonators about a central opening within which the electrons constituting the space charge of the device are adapted to move, a tuning structure mounted adjacent said anode structure for movement with respect to said anode structure for controlling the operating frequency of said device, an output loop positioned in one of said cavity resonators, and means intercoupling said tuning structure and said loop for varying the coupling between the high frequency flux of said anode structure and said output loop as said tuning structure is moved with respect to said anode.

4. An electric discharge device comprising an anode structure including an array of cavity resonators about a central opening within which the electrons constituting the space charge of the device are adapted to move, a tuning structure mounted adjacent said anode structure for movement with respect to said anode structure for

controlling the operating frequency of said device, an output element coupled to said anode structure, and means intercoupling said tuning structure and said output element for varying the coupling between the high frequency flux of said anode structure and said output element as said tuning structure is moved with respect to said anode.

5. An electric discharge device of the magnetron type including an anode having a plurality of openings forming a plurality of coupled cavity resonators, a source of electrons adjacent said anode for exciting said anode into high frequency oscillation, a tuning member adjacent said anode movable with respect to said anode for controlling the operating frequency of said device, an output element coupled to said device including a loop conductor coupled to one of said cavity resonators for coupling with the flux thereof, said tuning member having a recessed portion adjacent to said loop conductor to increase the coupling between said anode and said output element as said device is tuned to higher operating frequencies.

6. An electric discharge device including an anode having a plurality of openings forming a plurality of coupled cavity resonators, a source of electrons adjacent said anode for exciting said anode structure into high frequency oscillation, a tuning member mounted adjacent said anode and movable with respect to said anode for controlling the operating frequency of said device and overlying a portion of each of said openings, an output means including a loop conductor coupled to one of said cavity resonators for coupling with the flux of one of the openings of said anode, said tuning member having an opening in alignment with said loop to maintain the coupling between said anode and said output means as said device is tuned to higher operating frequencies.

7. An electric discharge device including an anode having a plurality of openings forming a plurality of coupled cavity resonators, a source of electrons adjacent said anode for exciting said anode structure into high frequency oscillation, a tuning member mounted adjacent said anode and movable with respect to said anode for controlling the operating frequency of said device and overlying a portion of each of said openings, an output means including a loop conductor coupled to one of said cavity resonators for coupling with the flux of one of the openings of said anode, said tuning member having an opening in alignment with said loop and a curved flange extending from said member into said one of said openings and about said loop to control the flux linking said loop and said anode as said tuning member is moved toward and away from said anode.

8. An electric discharge device of the magnetron type, comprising an anode structure having a plurality of openings therein forming a plurality of coupled cavity resonators, first and second tuning members mounted on opposite sides of said anode and movable with respect thereto for changing the operating frequency of said device, an output element coupled to said device, means supported from said first mentioned tuning member for decreasing the coupling with said output element as said member is moved toward said anode structure, said second tuning member having an opening therein juxtaposed to said output element for increasing the coupling with said output element as said second

tuning member is moved towards said anode structure.

9. An electric discharge device of the magnetron type, comprising an anode structure having a plurality of openings therein forming a plurality of coupled cavity resonators, first and second tuning members mounted on opposite sides of said anode and movable with respect thereto for changing the operating frequency of said device, an output means coupled to said device including a coupling loop, a flange supported from said first mentioned tuning member and in alignment with said loop for decreasing the coupling with said output means as said member is moved toward said anode structure, said second tuning member having an opening juxtaposed to said loop in alignment with said loop for increasing the coupling with said output means as said second tuning member is moved towards said anode structure.

10. An electric discharge device comprising an anode structure having a plurality of spaced openings the walls of which define an array of cavity resonators about a central opening within which the electrons constituting the space charge of the device are adapted to move, a tuning member mounted adjacent said anode structure for movement with respect to said anode structure for controlling the operating frequency of said device and extending over said openings, an output means including a loop positioned in one of said openings, said member having an opening in alignment with said loop, and means extending from said member into the opening in said

anode structure in which said loop is located and conforming generally to the portion of said last mentioned opening not occupied by said loop.

11. An electric discharge device of the magnetron type including an anode having a plurality of openings forming a plurality of coupled cavity resonators, a source of electrons adjacent said anode for exciting said anode into high frequency oscillation, an output means comprising a loop conductor coupled to one of said cavity resonators for coupling with the flux thereof, a tuning member adjacent said anode and moveable with respect thereto for controlling the operating frequency of said device, said tuning member including a portion juxtaposed to said loop, the edge of said portion having an open shape in the vicinity of said loop whereby coupling between said anodes and said output means is increased as said tuning member approaches said anode.

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