Nov. 4, 1952 J. W. McNALL 2,617,079

TUNABLE MAGNETRON

Filed Aug. 8, 1944 2 SHEETS—SHEET 1

Fig. 1.

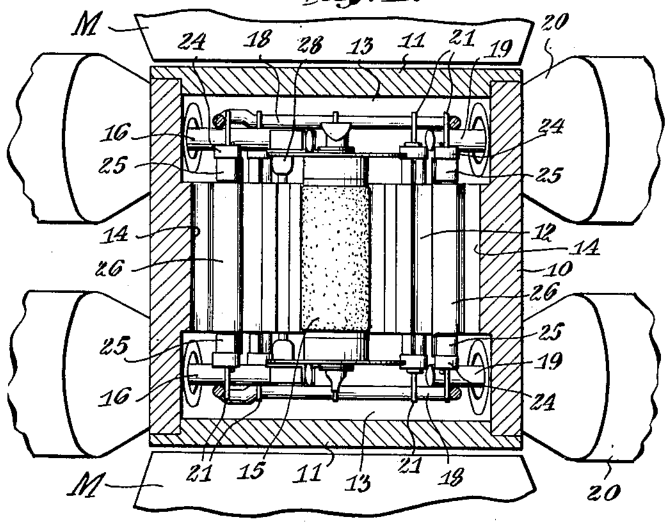

Fig. 3.

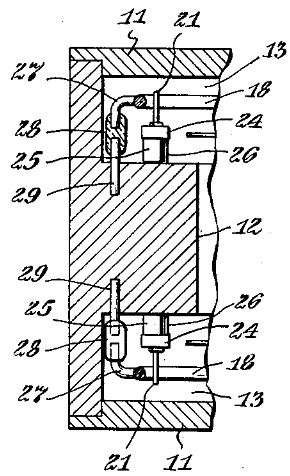

Fig. 2.

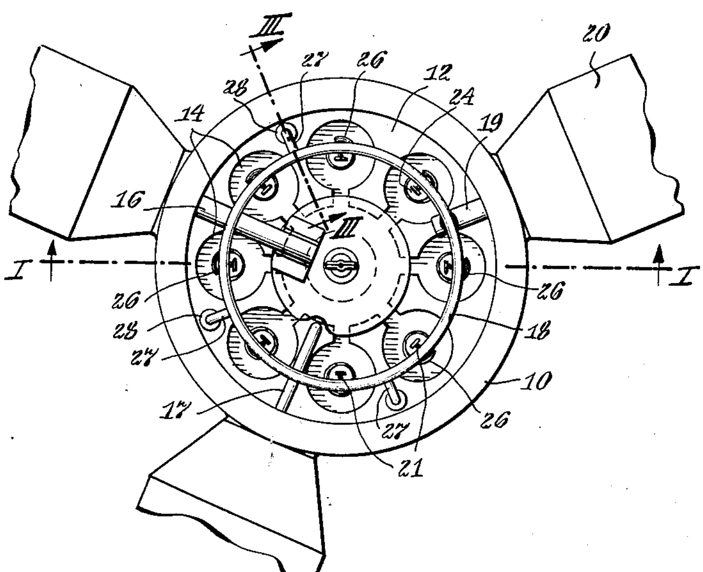

Fig. 4.

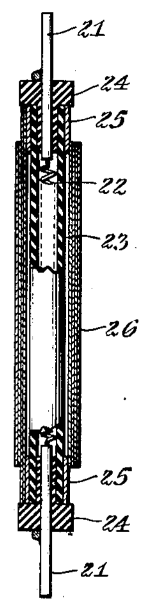

Fig. 5.

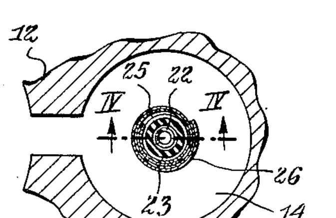

Fig. 6.

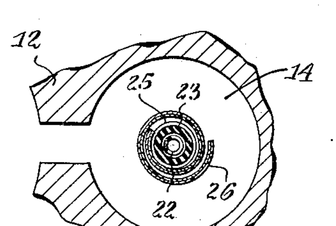

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Fig. 7.

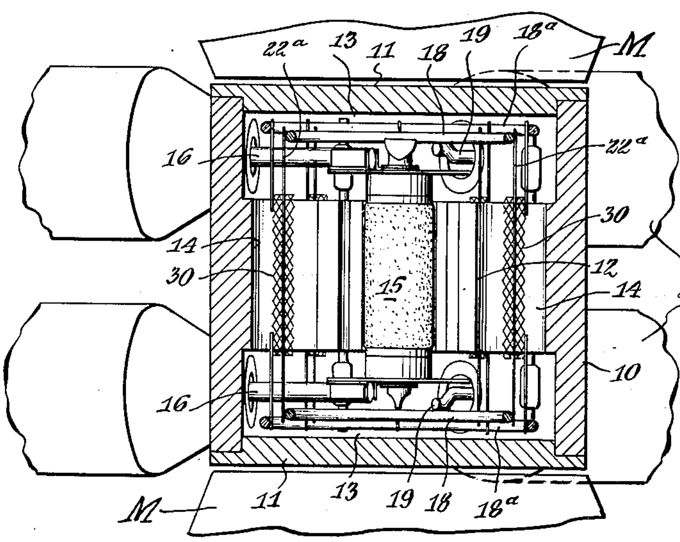


Fig. 9.

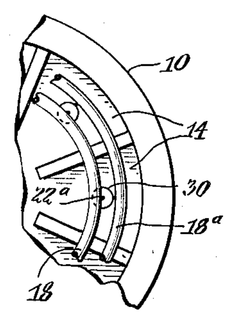
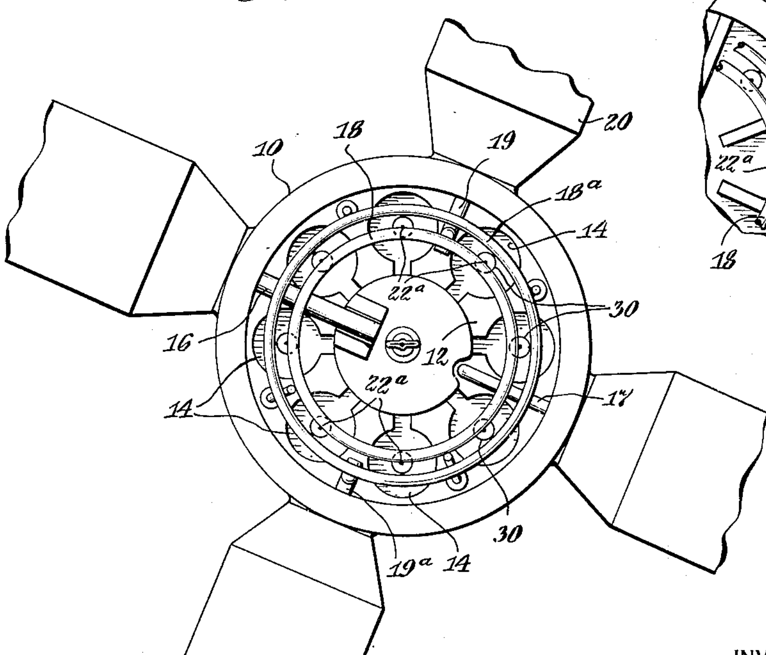


Fig. 8.



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2,617,079

TUNABLE MAGNETRON

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31 Claims. (Cl. 315—40)

This invention relates to magnetrons, and more particularly to tuning means for the same.

A recent development in this art has been termed "Crown of Thorns" as somewhat descriptive of a tuning means for a magnetron, and consisting of a plurality of prongs, one in each of several resonant cavities of a magnetron, and carried from a complete or partial ring at the ends of the cavities so the several prongs may be moved longitudinally and simultaneously in the cavities. The ring is mechanically connected by rod or lever through a flexible part, such as a bellows or diaphragm so as to obtain mechanical control of movement and position of the "Crown of Thorns" within the magnetron. Aside from the mechanical difficulties of sealing, lateral displacement and the like, that structure also has the disadvantage, of enabling the ring to be moved, and of requiring a larger end space in the magnetron with resultant greater spacing apart of the pole pieces of the magnet than in the usual magnetron where no "Crown of Thorns" is employed.

Broadly stated, then, an object of the present invention is to provide a tuning means for a magnetron which will accomplish tuning by a "Crown of Thorns" construction and yet avoid the adverse structural and operational characteristics related above.

Likewise of general nature, the invention contemplates operator control of internal tuning means but without transitional movement of mechanism from exterior to interior of the magnetron.

More in detail, the invention has for an object to provide a movable tuning means within a magnetron while maintaining the prior art dimensional characteristics of the magnetron.

Another object of the invention is to electrically control the functioning of the tuning means from the exterior of the magnetron.

Yet another object of the invention is to accomplish a rigidity of support for the tuning means.

Other objects of the invention will appear to those skilled in the art as the description progresses, both by direct recitation thereof and by inference from the context.

Referring to the accompanying drawings in which like numerals of reference indicate similar parts throughout the several views;

Figure 1 is an axially longitudinal section of a magnetron, as on line I—I of Fig. 2, showing thermally operated tuning means of the present invention therein;

Figure 2 is a plan of the construction of Fig. 1, but with the cover or end plate removed;

Figure 3 is a detail sectional view of a part of the magnetron as on line III—III of Fig. 2, showing ring-supporting means;

Figure 4 is a detail longitudinal sectional view of one of the thermal elements as on line IV—IV of Fig. 5;

Figures 5 and 6 are cross sectional views of a thermal element within a magnetron cavity and showing two positions of the thermally controlled tuning member;

Figure 7 is a sectional view similar to Fig. 1, and showing electronic tuning means for the magnetron;

Figure 8 is a plan of the construction of Fig. 7, but with the cover or end plate removed; and

Figure 9 is a similar plan of a fragmental part of the magnetron showing the invention as applicable to a different shape of cavity of a magnetron from the conventional shape of the preceding figures.

In its general aspects and applicable to all constructions herein shown, the invention provides fixed means within the end spaces of the magnetron, here shown as rings, between which extend a plurality of tuning elements. Each tuning element passes longitudinally through one of the resonant cavities of the magnetron, and is shown coaxial with the cylindrical part of such cavity in the forms using that conventional shape. The invention, however, is not limited to this coaxial relation of cavity and tuning element. Furthermore, while the present showing shows one of of the tuning elements in each resonant cavity, it is within the scope of the invention to utilize the tuning elements in any number of the resonant cavities desired and for range of tuning which the number employed will accomplish.

Referring now specifically to the embodiment of the invention illustrated in the several figures, the reference numeral 10 designates a cylindrical metallic magnetron body, the ends whereof have cover or end plates 11 sealed thereon that the interior may be evacuated. Within and as an integral part of said body is the usual magnetron anode structure 12 of generally cylindrical shape but shorter than the outer part of the body so as to provide end spaces 13 between the anode and said end plates 11. The anode structure is axially hollow to provide a cathode cavity and radiating from this cathode cavity are a plurality of resonant cavities 14, each having in the forms shown in Figures 1 to 8 inclusive, a cylindrical portion parallel to the cathode cavity. The ends of the cathode cavity and the ends of said resonant cavities, in all forms shown, open into the end spaces 13.

A cathode 15 passes axially through the cathode cavity, adequately spaced from the anode and supported as usual from lead-in rods 16 entering the end cavities at the sides thereof. An output loop 17 is situated in one end space, likewise passing out through the side wall of the end space. The size and shape of the magnetron body, the end spaces, anode, cathode and leads above described are preferably all in accordance with prior art practice, in consequence of which the pole pieces M of the magnet (not shown) will have the same relation to the magnetron and its anode as exists in magnetrons as heretofore used.

Describing Figs. 1 to 6 more especially a ring 18 is shown concentrically situated in each end space 13, said ring being conductive and spaced from the anode, end plates, and body wall of the end space. Said ring has a position and diameter substantially locating the ring opposite the ends of the center lines of said cavities, and such that extensions of said center lines intersect the said ring at right angles to the plane of the ring. A lead-in rod 19 entering at one side of the end space, free of contact with the end space wall, is welded or otherwise secured to the ring, and affords physical support thereat for the ring and electrical connection to the exterior of the magnetron. Said lead-in rod is introduced through a hollow housing 20 sealed to the magnetron body and internally sealed with appropriate insulation as usual with lead-in rods of this character.

A cartridge-like tuning element, shown in detail in Figure 4, extends axially through a resonant cavity and provides axially protruding wires 21 at opposite ends, one wire being secured, as by spot welding, to one ring and the opposite wire 21 being secured in like manner to the other ring. The inner ends of said wires 21, within the cartridge-like element, are connected by a heater filament 22. Said filament is surrounded by a sleeve 23 of electrically insulating material, the ends of the sleeve receiving neck portions of insulating end plugs 24 which in turn receive the said wires 21. At the outside of said sleeve 23 next the ends thereof are metallic ferrules 25. Extending from one ferrule to the other and supported thereby is a spirally wound bi-metal thermally responsive tuning member 26. This member will change its diameter under varying heat condition, and thereby effect a change of field condition within the resonant cavity where situated. Preferably the bimetal structure is such that the spiral tuning member tends to unwind or enlarge in diameter with a rise in temperature, as indicated in Figure 6, whereas in normal position under influence of normal tube-operating condition, the bi-metal tends to wind tightly and have a minimum diameter. For tuning purposes the heater filament for the tuning member may have a current applied therethrough from the exterior by way of the lead-in rods 19, rings 18, and wires 21, and the desired degree of heat thereby applied to the said member for expanding it the right amount. As the several heater filaments for the thermal responsive members are in electrical parallel, simultaneous tuning with respect to all cavities may thus be effected.

In order to insure coaxial positioning of all the cartridge-like tuning elements coaxially within their respective cavities, it is preferable to retain the rings 18 in rigid and fixed relationship to the anode. For this purpose, and as shown in Figs. 2 and 3, bracket structures are provided at intervals around the rings. As shown, these bracket structures each comprise a short length of wire 27 butt welded at one end to the outer circumference of the ring, radiating therefrom and, at a short distance from the ring, bent at right angles toward the anode body. The bent end of the bracket wire is embedded in a glass bead 28 which also attaches to another wire 29 the other end of which is embedded in and soldered to the said anode body.

It is likewise feasible to utilize the present invention to obtain field variation in a resonant cavity of a magnetron by electronic means in substitution for the above-described thermo-mechanical means. Illustrative of this modification, Figs. 7 and 8 show two rings 18 and 18^a in each end space, each ring having its own lead-in rods 19 and 19^a and supported rigidly by appropriate insulating brackets.

Filaments 22^a extend from one ring 18 to the other coaxially through the resonant cavities, said filaments in this instance being electron emissive. Around the filaments are cylindrical grids 30 coaxial to the filaments and cavities. The grids are supported from the second ring 18^a in the end space, and by virtue of the lead rod to the grid supporting ring, appropriate electrical bias may be applied to the grids.

It may be here stated that changes in emission from the tuning emissive filament, which is more generically designated a cathode, results in a change in the electron space charge density inside the resonant cavity, thereby affecting the resonant frequency of the cavity and thus changing the frequency of the generated waves from the magnetron. Thus, it is to be understood that the invention contemplates utilization of tuning cathodes as a means operable without inclusion of the grids above-mentioned. However, the provision of grid 30 in the resonant cavity around the tuning cathode permits the space charge density to be varied much more rapidly than can be done by variation of the temperature of the tuning cathode. It is accordingly preferable to utilize said grid 30 and to vary the potential on the grid through the external lead, that variation may be rapidly and smoothly accomplished, if so desired, the arrangement being proficiently applicable to the desired modulating operation. It will be understood that the tuning cathode would be kept negative with respect to the oscillator cavity in consequence of which the wall of the magnetron resonator cavity will act as an anode for the electrons from the tuning cathode, and so that the electrons will be affected by passage through the grid of the tuning means.

I claim:

1. An electron discharge device comprising a cathode and anode, said anode providing cavity resonators, tuning means longitudinally disposed in a cavity resonator and projecting at opposite ends therefrom, and means constituted as a fixed part of said device attached to said projecting ends of and retaining said tuning means against longitudinal displacement in said cavity resonator.

2. An electron discharge device comprising a cathode and an anode around the cathode, and having end spaces at the ends of said anode, said anode having cavity resonators opening into said end spaces, tuning means longitudinally dis-

posed in a cavity resonator and projecting at opposite ends thereof into said end spaces, and means in said end spaces constituted as a fixed part of said device attached to said projecting ends of and supporting said tuning means and retaining the same against longitudinal displacement in said cavity resonator.

3. An electron discharge device comprising a cathode and an anode around the cathode, and having end spaces at the ends of said anode, said anode having cavity resonators opening into said end spaces, tuning means longitudinally disposed in a cavity resonator and projecting at opposite ends thereof into said end spaces, and rings said end spaces supporting said tuning means and retaining the same against longitudinal displacement in said cavity resonator, said anode, cathode and rings having fixed relation to each other.

4. An electron discharge device comprising a cathode and an anode, said anode providing cavity resonators, tuning means in each of a plurality of said cavity resonators, said tuning means each having a filament as part thereof, and means supporting the several filaments of said tuning means and electrically connecting said filaments in parallel.

5. An electron discharge device comprising a cathode and an anode around the cathode, said anode having cavity resonators radiating from the region around the cathode, said cavity resonators having substantially cylindrical portions axially parallel to the cathode, and substantially cylindrical tuning means in one of said cavity resonators coaxial therewith and substantially coextensive with the axial length of said cavity resonator, and said cavity resonator having greater cross sectional area unobstructed than obstructed by said tuning means therein.

6. A tuning means for an electron discharge device comprising a sheet-material member spirally rolled upon itself, and said member being variable in diameter by changing the tightness of rolling of said sheet material, mounting means supporting and holding one longitudinal section of said member fixed, and means in proximity to said member for effecting a change in tightness of rolling of the said material of said member and thereby varying the diameter of the member.

7. A tuning means for an electron discharge device comprising a sheet-material member spirally rolled upon itself, and said member being variable in diameter by changing the tightness of rolling of said sheet material, mounting means supporting and holding one longitudinal section of said member fixed, and thermal means in proximity to said member for effecting a change in tightness of rolling of said material of said member and thereby varying the diameter of the member.

8. An electronic device comprising a cylindrical housing having as part thereof and within the same an anode of less length than the housing, end caps at the ends of the housing enclosing end spaces within the housing between said anode and end caps, said anode having an axial cavity and cavity resonators radiating therefrom, all of said cavities opening at their ends into said end spaces, a cathode in said axial cavity, fixed rings in said end spaces concentric with and in planes normal to the housing axis, and electrically controlled tuning means supported by said rings and extending through a plurality of said cavity resonators.

9. An electronic device comprising a cylindrical housing having as part thereof and within the same an anode of less length than the housing, end caps at the ends of the housing enclosing end spaces within the housing between said anode and end caps, said anode having an axial cavity and cavity resonators radiating therefrom, all of said cavities opening at their ends into said end spaces, a cathode in said axial cavity, fixed rings in said end spaces concentric with and in planes normal to the housing axis, brackets supporting said rings from said anode, and electrically controlled tuning means supported by said rings and extending through a plurality of said cavity resonators.

10. An electronic device comprising an anode having a housing extending beyond ends of the anode, end caps at the ends of the housing enclosing end spaces within the housing between said end caps and the anode, said anode having a central cylindrical cavity the ends whereof open into said end spaces, a cathode coaxial to and extending longitudinally through said central cavity, cavity resonators parallel to said central cavity and opening at their ends into said end spaces, rings in said end spaces concentric to the axis of said central cavity and crossing over the ends of said cavity resonators, and tuning means carried between a pair of rings and extending longitudinally of a cavity resonator, said tuning means being radially expandable at its periphery for tuning purposes.

11. An electronic device comprising an anode having a housing extending beyond the ends of the anode, end caps at the ends of the housing enclosing end spaces within the housing between said end caps and the anode, said anode having a central cylindrical cavity the ends whereof open into said end spaces, a cathode coaxial to and extending longitudinally through said central cavity, cavity resonators parallel to said central cavity and opening at their ends into said end spaces, tuning means extending longitudinally of a cavity resonator and projecting into said end spaces, and means in said end spaces supporting said tuning means at said ends projecting into the end spaces, said tuning means having a bimetal thermally responsive outer member in said resonator adapted to vary the spacing of the said member to the cavity resonator under influence of heat for tuning purposes.

12. An electronic device comprising a cylindrical housing having as part thereof and within the same an anode of less length than the housing, end caps at the ends of the housing enclosing end spaces within the housing between said anode and end caps, said anode having an axial cavity and cavity resonators radiating from the axial cavity, all of said cavity resonators opening at their ends into said end spaces, a cathode in said axial cavity, rings in said end spaces concentric with and in planes normal to the housing axis, brackets supporting said rings from said anode, said brackets having means insulating the rings from the anode, and tuning means supported by said rings and extending through a plurality of said cavity resonators, said tuning means comprising a bimetal thermally responsive outer member and an internal heater therein.

13. An electronic device comprising a cylindrical housing having as part thereof and within the same an anode of less length than the housing, end caps at the ends of the housing enclosing end spaces within the housing between said anode and end caps, said anode having an axial cavity

and cavity resonators radiating from the axial cavity, all of said cavity resonators opening at their ends into said end spaces, a cathode in said axial cavity, rings in said end spaces concentric with and in planes normal to the housing axis, brackets supporting said rings from said anode, said brackets having means insulating the rings from the anode, and tuning means supported by said rings and extending through a plurality of said cavity resonators, said tuning means comprising a heater surrounded by an expandable thermally responsive outer member expansion whereof brings it closer to the wall of the cavity resonator.

14. A magnetron comprising an anode having a central cavity and a plurality of cavity resonators radiating from said central cavity, a first electron-emissive cathode in said central cavity, lead-in connections connected with and for applying operating potentials to said anode and cathode to generate microwave oscillations on said anode, a second electron-emissive cathode in one of said plurality of cavity resonators opposed to a part of said anode for also directing electrons to the anode, and for thereby modifying the said microwave oscillations.

15. A magnetron comprising a first electron-emissive cathode and an anode disposed adjacent said cathode, means connected with and for applying operating potentials to said anode and cathode and thereby obtaining electron flow on paths from the cathode toward said anode to generate microwave oscillations on said anode, a second electron-emissive cathode opposed to another part of said anode for also directing electrons to the anode but to said other part thereof on paths other than the aforesaid paths of electron flow, and for thereby modifying the said microwave oscillations, and means in the path of and for controlling the electrons emitted from said second cathode.

16. A magnetron comprising a first electron-emissive cathode and an anode coaxially disposed adjacent said cathode, means for applying operating potentials to said anode and cathode to generate microwave oscillations on said anode, a plurality of second electron-emissive cathodes distributed in a coaxial series around the first said cathode and opposed to said anode for also directing electrons to the anode, and for thereby modifying the said microwave oscillations, and means around each of said plurality of second cathodes for controlling the electrons emitted therefrom.

17. A magnetron comprising a first electron-emissive cathode and an anode coaxially disposed adjacent said cathode, means for applying operating potentials to said anode and cathode to generate microwave oscillations on said anode, a plurality of second electron-emissive cathodes distributed in a coaxial series around the first said cathode and opposed to said anode for also directing electrons to the anode, and for thereby modifying the said microwave oscillations, all of said second cathodes being connected in parallel, and a lead-in in connection for said plurality of parallel-connected second electron-emissive cathodes.

18. A magnetron comprising an emissive cathode and an anode disposed around the cathode, said anode having cavity resonators therein opening toward the cathode and having partitions directed edgewise toward the cathode and separating successive resonators from each other, means for applying operating potentials to said anode and cathode to generate microwave oscillations on said anode and in said resonators, and means in each of a plurality of said resonators for varying the capacitance thereof and for thereby modifying the said microwave oscillations.

19. A magnetron comprising an emissive cathode and an anode disposed around the cathode, said anode having cavity resonators therein opening toward the cathode and having partitions directed edgewise toward the cathode and separating successive resonators from each other, means for applying operating potentials to said anode and cathode to generate microwave oscillations on said anode and in said resonators, and a plurality of second electron-emissive cathodes of which one is in each said resonator for directing electrons to adjacent partitions for varying capacitance of the resonator and for thereby modifying the said microwave oscillation.

20. A magnetron comprising an emissive cathode and an anode disposed around the cathode, said anode having cavity resonators in a series surrounding and opening radially toward the cathode, said anode having partitions on radii from said cathode directed edgewise toward the cathode and separating the successive resonators of said series from each other, means for applying operating potentials to said anode and cathode to generate microwave oscillations on said anode and in said resonators, and means in each of a plurality of said resonators of said series for varying the capacitance thereof and for thereby modifying the said microwave oscillations, said capacitance-varying means of each resonator being isolated from the others thereof by said partitions.

21. A magnetron having an elongated cathode and an anode around the cathode, said anode having cavity resonators radiating from the region around the cathode and having longitudinal openings into said region parallel to said cathode, each cavity resonator having lateral walls symmetrically disposed on opposite sides of a medial plane longitudinal of the opening and radially of the cathode, tuning means in a cavity resonator substantially coextensive with the length of the resonator and medially between said lateral walls thereof and in said radial plane and in parallelism to said cathode, and a support for said tuning means retaining the same in longitudinally fixed position in its cavity resonator.

22. An electron-discharge device comprising: a cathode; an anode, incorporating a cavity resonator, spaced from said cathode; means, adjacent said anode, for establishing a unidirectional magnetic field in said cavity resonator; and means, incorporated in said device, for projecting a stream of electrons into said cavity resonator to control the resonant frequency of said device.

23. An electron-discharge device comprising: a cathode; an anode, incorporating a cavity resonator, spaced from said cathode; means, adjacent said anode, for establishing a unidirectional magnetic field in said cavity resonator; and means, incorporated in said device, for projecting a stream of electrons into said cavity resonator in a direction transverse to that of said magnetic field to control the resonant frequency of said device.

24. An electron-discharge device comprising: a cathode; an anode, incorporating a cavity resonator, spaced from said cathode; means, adjacent said anode, for establishing a unidirectional magnetic field in said cavity resonator; means,

incorporated in said device, for projecting a stream of electrons into said cavity resonator to control the resonant frequency of said device; and means, coupled to said last-named means, for varying the density of said stream of electrons to frequency modulate said device.

25. An electron-discharge device comprising: a cathode; an anode, incorporating a cavity resonator, spaced from said cathode; means, adjacent said anode, for establishing a unidirectional magnetic field in said cavity resonator; means, incorporated in said device, for projecting a stream of electrons into said cavity resonator in a direction transverse to that of said magnetic field to control the resonant frequency of said device; and means, coupled to said last-named means, for varying the density of said stream of electrons to frequency modulate said device.

26. An electron-discharge device comprising: a cathode; an anode spaced from and surrounding said cathode; said anode including a plurality of radially disposed anode arms each pair of which, together with that portion of said anode lying therebetween, defines a cavity resonator; means, adjacent said anode, for establishing a unidirectional magnetic field through said cavity resonators in a direction transverse to the discharge path between said cathode and said anode; and means, communicating with one of said cavity resonators, for projecting a stream of electrons therein in a direction transverse to that of said magnetic field.

27. An electron-discharge device comprising: a cathode; an anode spaced from and surrounding said cathode; said anode including a plurality of radially disposed anode arms each pair of which, together with that portion of said anode lying therebetween, defines a cavity resonator; means, adjacent said anode, for establishing a unidirectional magnetic field through said cavity resonators in a direction transverse to the discharge path between said cathode and said anode; means, communicating with one of said cavity resonators, for projecting a stream of electrons therein in a direction transverse to that of said magnetic field; and means coupled to said last-named means, for varying the density of said electron stream.

28. An electron-discharge device comprising: a cathode; an anode spaced from and surrounding said cathode; said anode including a plurality of radially disposed anode arms each pair of which, together with that portion of said anode lying therebetween, defines a cavity resonator; means, adjacent said anode, for establishing a unidirectional magnetic field through said cavity resonators in a direction transverse to the discharge path between said cathode and said anode; and an electron gun, carried by said anode and communicating with at least one of said cavity resonators, for projecting a stream of electrons therein a direction transverse to that of said magnetic field.

29. An electron-discharge device comprising: a cathode; an anode spaced from and surrounding said cathode; said anode including a plurality of

radially disposed anode arms each pair of which, together with that portion of said anode lying therebetween, defines a cavity resonator; means, adjacent said anode, for establishing a unidirectional magnetic field through said cavity resonators in a direction transverse to the discharge path between said cathode and said anode; an electron gun, carried by said anode and communicating with one of said cavity resonators, for projecting a stream of electrons therein in a direction transverse to that of said magnetic field; and means coupled to said electron gun, for varying the density of said electron stream.

30. An electron-discharge device comprising: a cathode; an anode spaced from said cathode; said anode including a pair of anode arms which, together with that portion of said anode lying therebetween, defines a cavity resonator; means, adjacent said anode, for establishing a magnetic field through said cavity resonator in a direction transverse to the discharge path between said cathode and said anode; and a source of electrons, communicating with said cavity resonator and adapted to project electrons therein, for altering the resonant frequency thereof.

31. A tunable electron-discharge device comprising: a cathode; an anode structure spaced from said cathode, and incorporating a cavity resonator in which radio-frequency oscillations are adapted to be generated; means adjacent said cavity resonator for establishing a magnetic field therethrough; means, cooperable with the electric-field component of said radio-frequency oscillations, and with said magnetic field, for setting up a space charge in said cavity resonator; and means, coupled between said cavity resonator and said last-named means, for varying the density of said space charge.

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