

[54] **ROTARY TUNER FOR A CIRCULAR ELECTRIC MODE CROSSED FIELD TUBE**

[75] Inventors: **George K. Farney**, Boxwood;
William A. Gerard, Andover, both
of Mass.

[73] Assignee: **Varian Associates**, Palo Alto, Calif.

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331/90

[51] Int. Cl.² **H01J 25/50**

[58] Field of Search **315/39.51, 39.55, 39.57,**
315/39.59, 39.61, 39.77; 331/90

[56] References Cited

UNITED STATES PATENTS

2,851,633 9/1958 Dubois 315/39.55 X
3,343,031 9/1967 Backmark 315/39.55

3,412,285 11/1968 Gerard 315/39.61
3,441,796 4/1969 Cooper 315/39.59 X
3,731,137 5/1973 Foreman 315/39.55

Primary Examiner—Saxfield Chatmon, Jr.

Attorney, Agent, or Firm—Stanley Z. Cole; D. R.
Pressman; Harry E. Aine

[57] ABSTRACT

A coaxial magnetron of the type including a circular electric mode cavity coupled to a vane resonator system is tuned by means of a tuning structure movable in the circular electric mode cavity. The tuning structure includes a pair of arrays of electrically conductive reactive loading elements, such as vanes, reactively loading the resonator. Relative motion is effected between the two arrays of elements to effect a cyclical variation or modulation of the reactive loading on the cavity and thus the output frequency of the tube.

9 Claims, 10 Drawing Figures

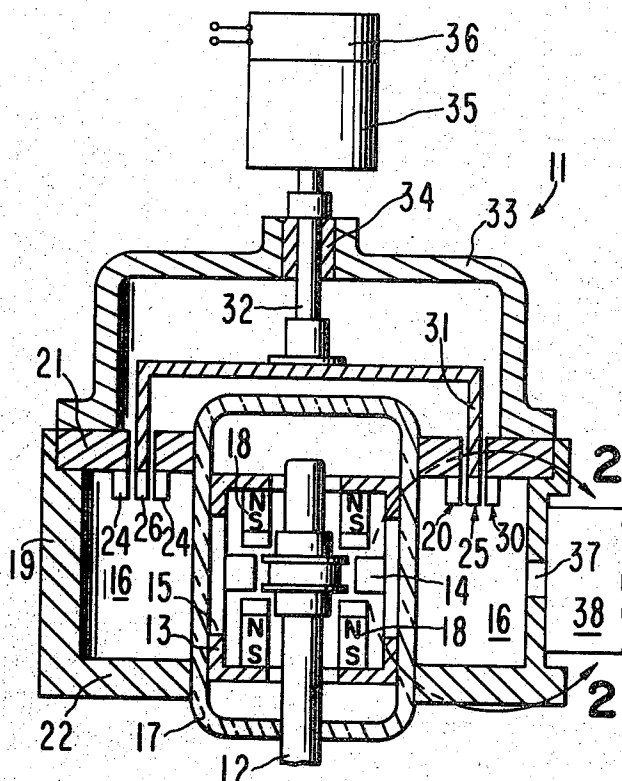


FIG. 1

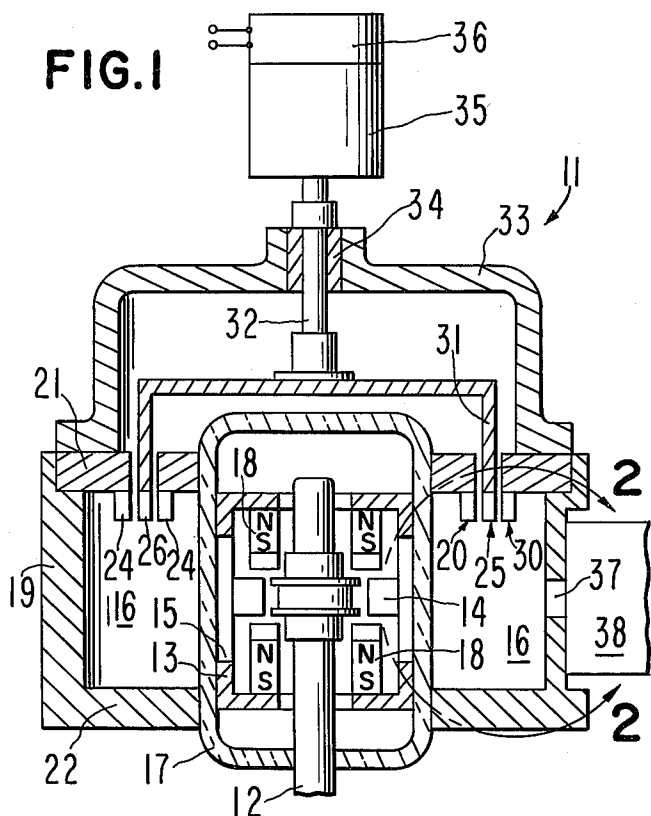


FIG. 2

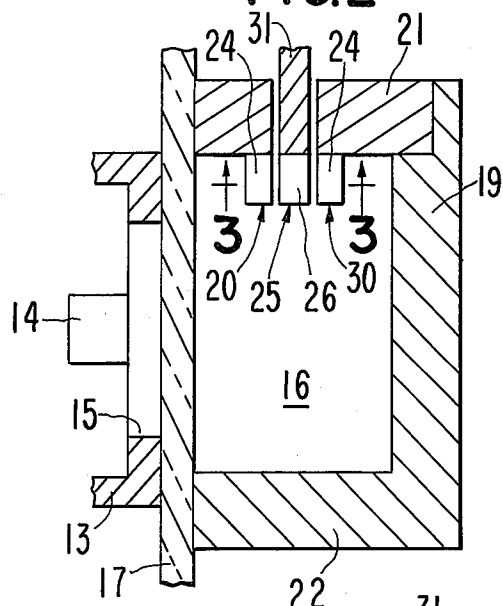


FIG. 3

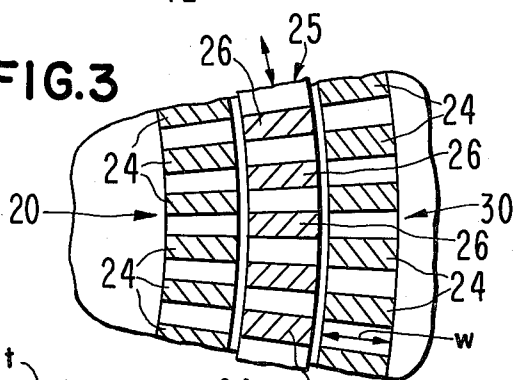


FIG. 4

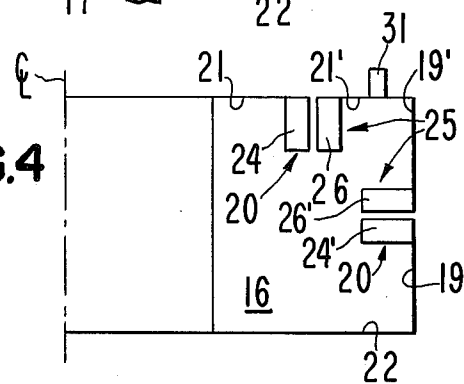


FIG. 5

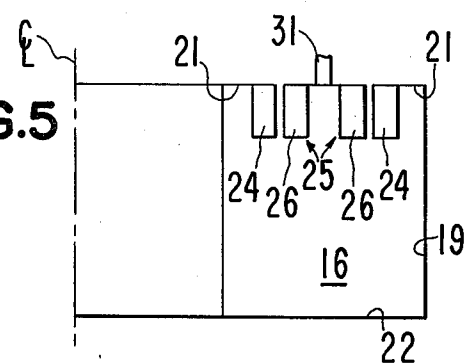


FIG. 6

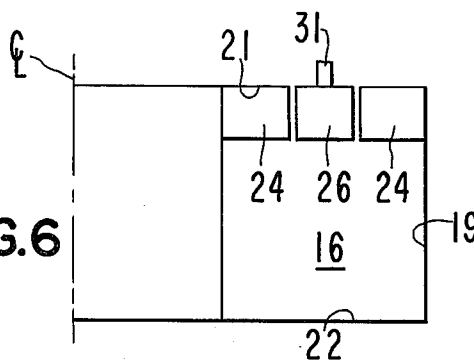


FIG. 7

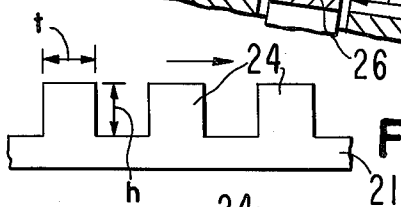


FIG. 8

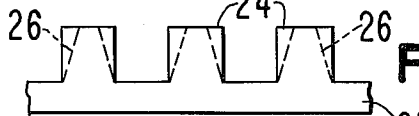


FIG. 9

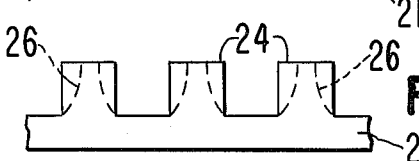
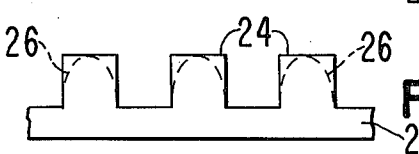


FIG. 10



ROTARY TUNER FOR A CIRCULAR ELECTRIC MODE CROSSED FIELD TUBE

BACKGROUND OF THE INVENTION

The present invention relates in general to frequency agile microwave tubes and more particularly to an improved rotary tuner for coaxial magnetrons.

DESCRIPTION OF THE PRIOR ART

Heretofore, it has been proposed to tune a coaxial magnetron by rotation of a cylindrical dielectric castellated tuning member, in the circular electric mode cavity, relative to a fixed similarly castellated dielectric member, whereby the frequency of the magnetron is modulated due to modifying the electric field within the cavity resonator. Such a tuner is described in U.S. Pat. No. 3,412,285 issued Nov. 19, 1968.

The problem with this prior arrangement is that the castellated cylindrical dielectric tuning structures were centrally disposed in the toroidal shaped coaxial circular electric mode cavity in the high field region thereof. With a substantial amount of dielectric material disposed in the high field region of the circular electric mode cavity the dielectric material substantially resistively loads the cavity, thereby reducing its loaded Q to an unacceptably low value. In addition, the dielectric members serve to concentrate the electric field in the dielectric material such that when the rotating castellated rotor member is rotated out of registration with the castellated stator member, arcing may tend to occur through the gap established between the two members. For these and other reasons the aforescribed tuner has not proven satisfactory in practice.

It is also known from the prior art, relating to vane magnetrons of non-coaxial type, to tune the tube by rotating an apertured metallic cylinder adjacent the back walls of the individual vane resonators. The rotating metallic cylinder was apertured with an array of apertures there being one aperture for each of the respective vane resonators. As the apertured metallic tuning member is rotated, the tuning member presents to the rear wall of the respective vane resonators a solid wall portion followed in succession by an aperture thus effectively varying the position of the back wall of the vane resonator and effecting tuning of the resonator system. While such a tuner results in a cyclical modulation of the output frequency of the tube, this tuner arrangement has certain disadvantages which include instabilities in the output frequency, inability to obtain a tracking output signal for tuning a local oscillator or a receiver, due to such frequency irregularities, and the difficulty of fabricating the tuning structure due to its relatively small size and requirement that it operate within the vacuum envelope of the tube.

Still others have proposed schemes for tuning a coaxial magnetron wherein a circular array of rotatable ceramic paddles were located within the circular electric mode cavity. The paddles were driven in synchronism by a planetary gear arrangement. As each of the paddles turned into a position of alignment with the electric field of the circular electric mode, the tube was tuned to its lowest frequency and conversely when the paddles were turned at right angles to the electric field vector the tube was tuned to its highest frequency.

A significant disadvantage of the rotating dielectric paddles is the relatively large number of rotating parts, gears, and bearings that are required.

It has also been proposed to dither tune a coaxial magnetron by rotating an array of dielectric members adjacent an array of electrically conductive vanes within the circular electric mode cavity of a coaxial magnetron. The rotating dielectric structure modulated the reactive loading effect of the conductive vanes on the circular electric mode of the cavity for modulating the operating frequency of the tube. Such an arrangement is disclosed in copending U.S. Application Ser. No. 461,835 filed Apr. 18, 1974 and assigned to the same assignee as that of the present invention.

In this arrangement, the dielectric tuning structure comprised a slotted dielectric disc or cylinder rotating adjacent the free ends of the vanes with the planar surface of the disc or cylinder being closely spaced to and parallel to the surface generated by the free ends of the vanes. In such a case microwave current tends to be increased or concentrated in the thin annular low impedance space between the rotating dielectric member and the adjacent surfaces of the free ends of the vanes. This concentration of high microwave current in the low impedance space introduces unwanted loss, tending to lower the loaded Q of the cavity, a result which should be avoided if possible.

SUMMARY OF THE PRESENT INVENTION

The principal object of the present invention is the provision of an improved rotary tuner for coaxial magnetrons.

In one feature of the present invention, a cavity resonator as coupled to a microwave interaction structure for stabilizing the operating frequency thereof is tuned by effecting relative movement between a plurality of electrically conductive reactive loading elements coupled to the cavity for reactively loading same and an adjacent plurality of electrically conductive elements, whereby the resonant frequency of the cavity resonator and thus the output frequency of the tube is modulated.

In another feature of the present invention, the cavity being tuned is a circular electric mode cavity of a magnetron which is coupled to the microwave interaction circuit comprising a vane resonator system.

In another feature of the present invention, the electrically conductive reactive loading elements are disposed along one of the walls of the cavity resonator being tuned.

In another feature of the present invention, the tuning structure includes a first array of electrically conductive reactive loading elements coupled to the fields of the resonator and a second array of electrically conductive elements disposed adjacent the array of loading elements for cyclically varying the reactive loading effect of the array of electrically conductive loading elements on the cavity being tuned in response to relative movement between the arrays of first and second tuning elements.

In another feature of the present invention, the tuning structure of a coaxial magnetron includes adjacent first and second similar arrays of electrically conductive reactive loading elements projecting into the coaxial cavity from a wall thereof and including means for effecting relative rotation between the first and second arrays.

In another feature of the present invention, the electrically conductive reactive loading elements of the tuning array which project into the coaxial cavity have heights greater than their widths.

In another feature of the present invention, the tuning structure for a coaxial magnetron includes a pair of similar metallic comb structures disposed in side-by-side relation with their teeth projecting inwardly of the coaxial cavity and including means for effecting relative motion between the adjacent combs.

In another feature of the present invention, the leading and/or trailing edges of teeth of adjacent relative movable tuning combs are shaped to achieve a desired tuning curve.

Other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal sectional view of a coaxial magnetron incorporating features of the present invention,

FIG. 2 is an enlarged view of a portion of the structure of FIG. 1 delineated by line 2—2,

FIG. 3 is a sectional view of the structure of FIG. 2 taken along the line 3—3 in the direction of the arrows,

FIG. 4 is a schematic line diagram view similar to that of FIG. 2 depicting an alternative tuning structure,

FIG. 5 is a view similar to that of FIG. 4 depicting an alternative embodiment of the present invention,

FIG. 6 is a view similar to that of FIG. 4 depicting an alternative embodiment of the present invention, and

FIGS. 7—10 are side views of tuning comb arrays disposed with their teeth in alignment and depicting alternative embodiments of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 there is shown a coaxial magnetron 11 incorporating features of the present invention. The tube 11 includes a cylindrical cathode 12 for emitting a stream of electrons in an annular interaction region defined between the cathode and surrounding cylindrical anode 13 including a circular array of anode vanes 14 projecting inwardly from the cylindrical anode 13 toward the centrally disposed cathode 12 for defining a microwave interaction circuit. A circular array of elongated slots 15 are provided in the cylindrical wall of the anode 13 for providing wave energy communication with alternate vane resonators defined by the region between adjacent vanes 14.

A toroidal shaped cavity resonator 16 is disposed surrounding the anode 13 in electromagnetic field exchanging relation with the vane resonators via the intermediary of the coupling slots 15. Since only alternate vane resonators are directly coupled to the toroidal cavity 16, the π mode of oscillation of the vane resonator system excites the TE_{011} circular electric mode of the toroidal resonator 16. A cylindrical, wave permeable vacuum envelope 17 is disposed surrounding the cylindrical anode 13 such that the electron interaction region between the cathode 12 and the anode resonators 14 may be evacuated by evacuation of the envelope 17 while allowing the external resonator 16 to operate at atmospheric pressure or to be pressurized with a suitable electrically insulative gas, such as SF_6 .

A pair of cylindrical permanent magnet structures 18 are coaxially disposed within the anode 13 in axially spaced relation from the cathode and on opposite sides of the interaction gap between the cathode 12 and the

surrounding vane resonators 14. The permanent magnets 18 are polarized to produce an axially directed magnetic field through the annular interaction region defined between the tips of the vane resonators 14 and the cathode emitter 12.

The toroidal cavity resonator 16 is defined by the region of space bounded by the outside of the cylindrical anode wall 13 and the inside of a cylindrical coaxially disposed radially spaced wall 19. The top and bottom end walls of the resonator 16 are defined by annular electrically conductive plates 21 and 22 joined to the outer side wall 19 and to the vacuum envelope 17.

Referring now to FIGS. 1—3, there is shown a tuning structure 23 for effecting frequency modulation of the output frequency of the tube. More specifically, a pair of radially spaced coaxial arrays 20 and 30 of electrically conductive lands or vanes 24 project inwardly of the resonator 16 from the upper wall 21 thereof to define a stationary array of reactive loading elements coupled to the electromagnetic fields of the excited TE_{011} mode of the resonator 16 for reactively loading the resonator 16. A rotary tuning member 25 is formed by an annular array of electrically conductive vanes 26, as of copper.

In a preferred embodiment, the circumferential extent of the vanes 26 and 24 is the same as the circumferential extent of the space (slot) between adjacent vanes 24 and 26 such that when the angular position of the rotatable tuning member 25 is in the position as shown in FIG. 3, the inductive reactive loading effect of the reactive loading elements 24 is a minimum due to the shorting out of the R.F. field in the slot and therefore the output frequency of the tube is at its highest frequency. However, when the rotatable tuning member 25 is rotated to the position such that the vanes 26 are in circumferential registration with the stationary reactive loading elements (vanes) 24, the reactive loading effect of the loading elements 24 is a maximum on the operating frequency of the cavity 16 such that this relative position corresponds to the lowest frequency of the cavity.

The circular array of axially directed tuning vanes 26 of the tuning member 25 are affixed, as by brazing, to the lower end of a cylindrical electrically conductive actuator 31, as of copper, which passes through an annular slot in the upper wall 21 of the resonator 16. The cylindrical actuator 31 is affixed to an axle 32 (see FIG. 1) which is rotatably supported from a cup-shaped housing 33 via the intermediary of bearing assembly 34. A motor 35 is affixed to the axle 32 for rotatably driving the axle and tuning member 25. An electrical AC generator 36 is coupled to the output shaft of the motor 35 for deriving a time variable output signal which corresponds to the instantaneous frequency deviation of the output frequency of the tube, when the motor has reached operating speed. This time varying signal is employed for tuning the receiver of a radar or the like to the operating frequency of the tube 11 for improved signal-to-noise ratio.

Output microwave energy is extracted from the coaxial resonator 16 via a conventional output coupling iris 37 and waveguide 38 for propagation to a suitable load such as an antenna, not shown. If there are N number of vanes 24 and N number of tuning members 26, the output frequency of the tube will be swept across its tunable band 2N times per revolution of the rotary tuning member 25. Thus, the generator 36 preferably has

the same number of poles as there are reactive loading elements 24.

Referring now to FIG. 4, there is shown an alternative embodiment of the present invention. More specifically, the stationary reactive loading structure 20 includes a second array of such elements 24' extending radially inwardly from the outer side wall 19 of the circular electric mode resonator chamber 16. The rotator tuning assembly 25 includes the circular array of tuning vanes 26 dependent from a portion of the upper wall 21' of the resonator 16 plus a second rotatable array of tuning vanes 26' radially inwardly directed from the outer wall 19 of the resonator 16. The tuning arrays 26 and 26' are coupled together via an upper wall segment 21' and an upper outer side wall segment 19' of the resonator 16. These segments are secured to the lower end of the tuning actuator 31 for rotation therewith. The advantage to the tuning structure of FIG. 4 is that additional reactive loading and tuning is achieved by the addition of the loading and tuning vanes 24' and 26' projecting inwardly from the outer side wall 19 of the resonator 16.

Referring now to FIG. 5, there is shown an alternative embodiment of the present invention which is similar to that previously described with regard to FIGS. 1-3 with the exception that the stator arrays 20 and 30 of vanes 24 are spaced apart by a greater radial distance and the rotator tuning array 25 of vanes 26 includes two such arrays radially spaced one from the other, each being disposed adjacent the corresponding stator array of vanes 24 and 24', respectively.

Referring now to FIG. 6, there is shown an alternative embodiment of the present invention similar to that previously described with regard to FIGS. 1-3 with the exception that the width of the vanes 24 and 26, respectively, has been increased such that substantially the entire upper end wall of the resonator 16 is occupied by the vane arrays.

Referring now to FIG. 7, there is shown, in side elevation, one of the stator arrays of vanes 24. In such an array the vanes 24 have a thickness t , taken in the direction of rotation, and a height h from the inside surface of the wall 21 of the resonator to the free end of the individual vanes 24. In addition, the vanes 24 have a width w as shown in FIG. 3. As the vanes are shown in FIG. 7, the rotator vanes 26 are in registration behind the stator vanes 24, and they have exactly the same shape and dimensions as the stator vanes 24.

In such arrays, it is preferred that the height of the vanes 24 and 26 be less than 1/10th of a free space wavelength and, for increased tuning effect, the vanes 24 and 26 preferably have a width w and thickness t approximately equal to or less than their height h . As the rotator tuning vane array 25 passes the stator reactive loading arrays 20 and 30, the slope of the tuning curve, between the highest and lowest frequency, may not be linear. Accordingly, the shape of the tuning curve can be modified to have any desired shape by shaping the corresponding leading and trailing edges of either or both of the stator and the rotator vanes 24 and 26, as indicated in FIGS. 8-10. FIG. 8 shows a linear taper to the leading and trailing edges of the rotator vanes 26; FIG. 9 shows a concave shape to the leading and trailing edges of the rotator vanes 26; and FIG. 10 shows a convex shape to the leading and trailing edges of the rotator vanes 26.

The gap between the rotator and stator tuning combs occurs at a fixed radius if the vanes are disposed on the end walls 21 and 22 of the resonator 16 and the gap occurs at a fixed axial position if the vanes are disposed on the side wall 19 of the resonator 16. Consequently, the gap is disposed parallel to the direction of all current flow in the desired TE_{01} mode and will not introduce significant undesired R.F. mode conversion with consequent reduction in Q of the cavity 16. This offers a substantial advantage over the previously proposed schemes wherein dielectric comb structures were caused to rotate over the free ends of the stator vane arrays with consequent concentration of high R.F. currents at the tips of the vanes resulting in lowering the Q of the loaded cavity 16.

Thus, it has been shown that the reactive loading members may be disposed along the top wall 21 or along the side wall 19 or, if desired, may be disposed along the bottom wall 22. Furthermore, such reactive loading members 24 and 24' may be located along both the top and bottom walls 21 and 22 as well as along the side wall 19 for effecting greater tuning range.

As thus far described, the rotary tuner 25 is utilized in a coaxial magnetron of the type wherein the stabilizing cavity 16 surrounds the array of coupled vane resonators 14. While this is a preferred embodiment, an alternative embodiment is of the type wherein the vane resonator system 14 surrounds a central circular electric mode resonator. A tube of this latter type is disclosed and claimed in U.S. Pat. No. 3,231,781 issued Jan. 25, 1966 and assigned to the same assignee as the present invention. In such a tube, the top wall of the central resonator could include the array of inwardly directed vanes 24 and the rotatable tuning member 25 would include a similar array of inwardly directed vanes 26.

A tube incorporating the tuner of the present invention provides means for rapidly dithering or sweeping the output frequency of the tube to and fro over a certain band of frequencies.

What is claimed is:

1. A microwave tube comprising:

means for generating a stream of electrons;
microwave circuit means in energy exchanging relation with said stream of electrons for generating electromagnetic energy,

means for coupling said electromagnetic energy to a load;

cavity resonator means coupled to said circuit means for exciting in said cavity a resonance mode affecting the frequency of said electromagnetic energy;
tuner means within said cavity for cyclically varying the resonant frequency of said resonance mode, said tuner means comprising a conductive reactive loading structure, a conductive field perturbing structure, and an axis;

said conductive reactive loading structure comprising an array of vanes disposed on a circle about said axis and aligned along radii of said circle such that the electromagnetic field of said resonance mode couples electromagnetic field in the spaces between said vanes,

said conductive field perturbing structure comprising an array of conductive elements disposed on a circle about said axis adjacent at least one end of said vanes, and

means for producing relative rotation of said reactive loading structure and said field perturbing structure about said axis such that said conductive elements cyclically juxtapose said ends of said vanes and said spaces between said vanes.

2. The apparatus of claim 1 wherein said second plurality of electrically conductive elements comprises a circular array of electrically conductive elements disposed adjacent said first plurality of reactive loading elements for varying the reactive loading effect of said reactive loading elements on said cavity resonator as a function of relative rotary movement of said second electrically conductive elements and said first electrically conductive reactive loading elements.

3. The apparatus of claim 1 wherein said cavity resonator means includes a chamber which is generally a figure of revolution about a cavity axis.

4. The apparatus of claim 3 wherein said chamber is toroidal shaped having a pair of axially spaced coaxially disposed annular conductive end walls and a pair of radially spaced coaxially disposed axially coextensive cylindrical wide walls, and wherein said array of vanes is disposed along at least one of said end and side walls of said cavity resonator means.

5. The apparatus of claim 3 wherein said vanes project inwardly of said toroidal shaped chamber.

6. The apparatus of claim 5 wherein said array of conductive elements of said field perturbing structure is a second array of vanes disposed in side-by-side relation with said vanes of said reactive loading structure.

7. The apparatus of claim 6 wherein the vanes of at least one of said arrays are narrower than 1/10th of a free space wavelength at the operating frequency of the

microwave tube.

8. The apparatus of claim 7 wherein the respective vanes of at least one of said arrays have lengths projecting away from their root portion toward their inner ends thereof which are greater than their respective widths.

9. A coaxial magnetron comprising a cylindrical cathode, a cylindrical anode surrounding said cathode and coaxial therewith, an array of anode members extending radially inward from said anode wall and defining a plurality of anode resonators, an outer coaxial cavity resonator surrounding said anode wall, coupling slots provided in said anode for coupling energy from said anode resonator to said outer coaxial cavity resonator, tuning means provided within said outer coaxial cavity resonator, said tuning means comprising a first tuning member and a second tuning member, and means for providing relative rotational motion of said first and second tuning members to modify the electric field within said cavity resonator and thereby vary the frequency of said coaxial magnetron, and wherein said first of said tuning members comprises an electrically conductive structure having a plurality of electrically conductive vanes disposed on a circle and aligned with radii of said circle for reactively loading said coaxial cavity resonator, and wherein said second tuning member includes a plurality of electrically conductive field perturbing elements coupled with the fields of said coaxial cavity resonator for modifying the reactive loading effect of said vanes on said cavity as a function of the relative rotational motion of said first and second tuning members.

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