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

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[52] **U.S. Cl.** **315/39.61;** 315/39.59; 315/39.77

[51] **Int. Cl.**^{2} **H01J 25/50**

[58] **Field of Search**........... 315/39.51, 39.59, 39.61, 315/39.77

[56] **References Cited**

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Primary Examiner—Saxfield Chatmon, Jr.
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[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 an array of electrically conductive reactive loading elements, such as vanes, reactively loading the resonator and an adjacent array of field perturbing elements. 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.

7 Claims, 7 Drawing Figures

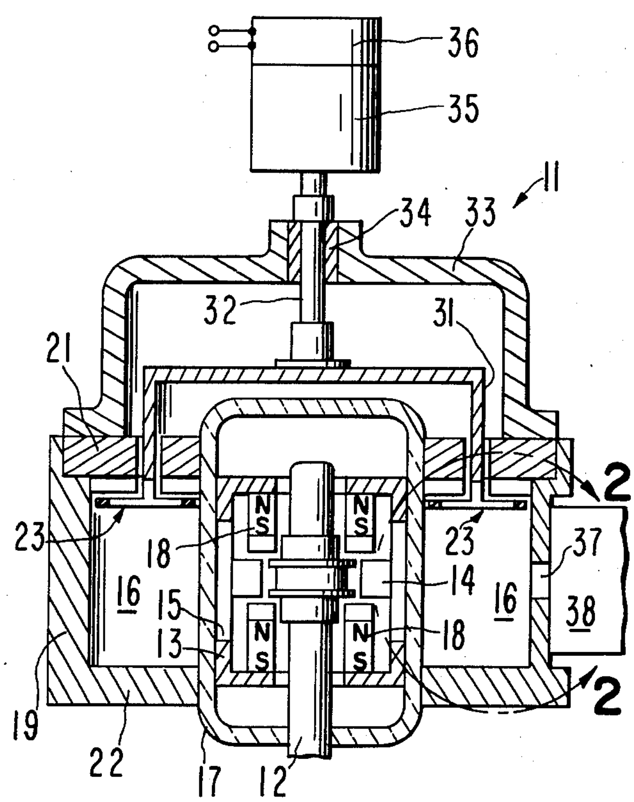


FIG. 1

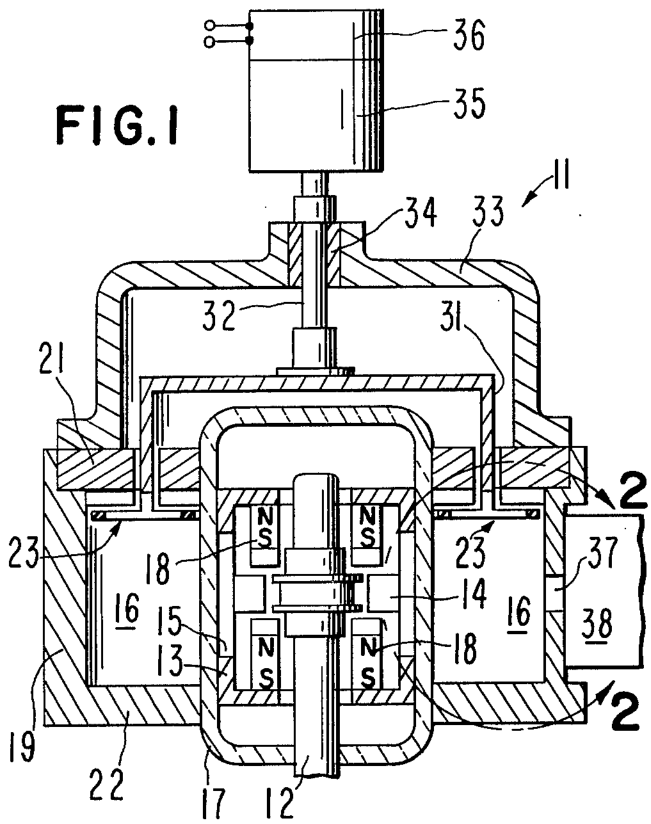


FIG. 2

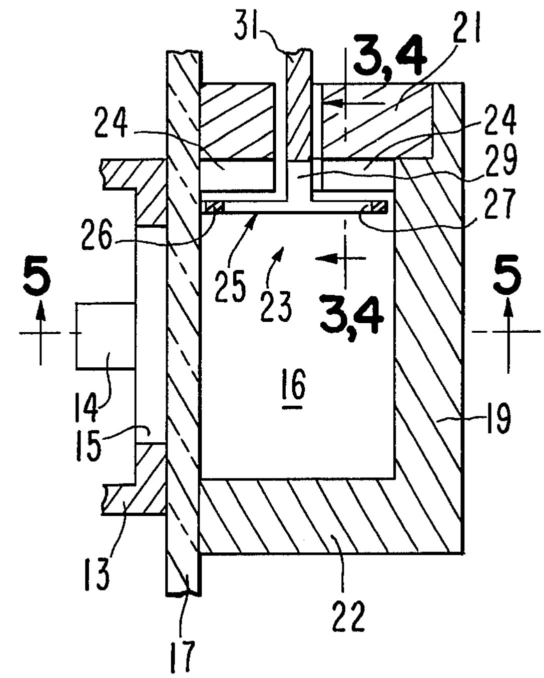


FIG. 3

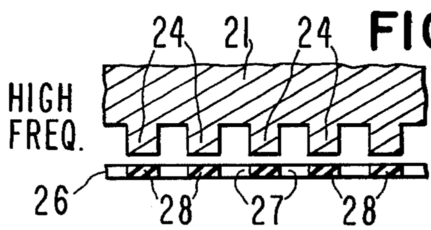


FIG. 4

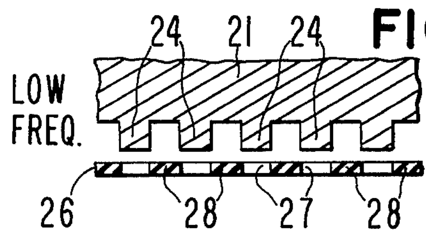


FIG. 5

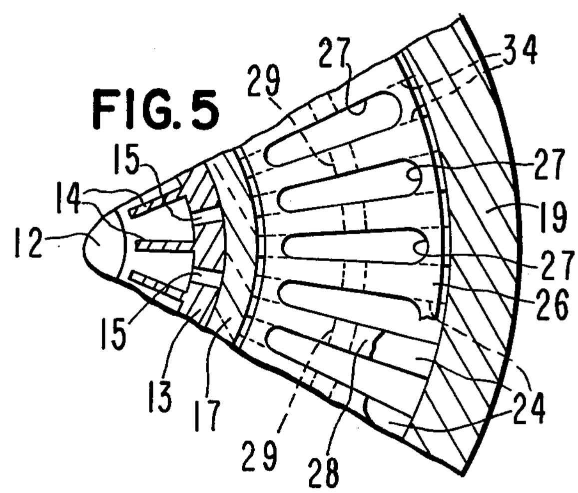


FIG. 6

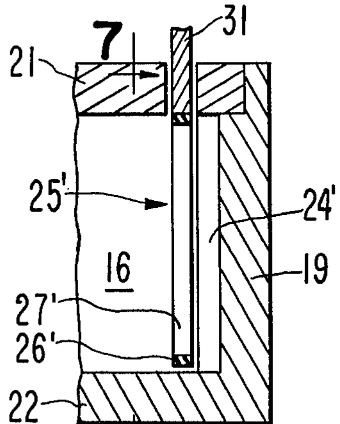
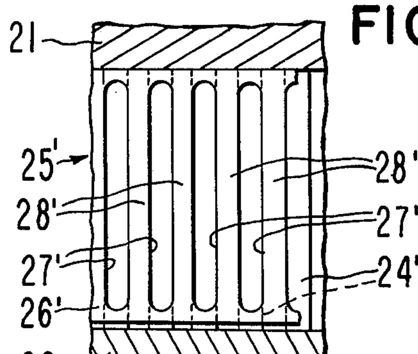


FIG. 7



ROTARY TUNER FOR CIRCULAR ELECTRIC MODE CROSSED FIELD TUBE

RELATED CASES

An improvement of the present invention wherein the relatively movable tuning members are both electrically conductive is disclosed and claimed in copending application Ser. No. 467,317 filed May 6, 1974, assigned to the same assignee as the present invention.

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 or stator 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 permanently 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 aforedescribed 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.

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 electromagnetic field perturbing 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 dielectric field perturbing 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.

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 and showing the dielectric tuning member in a first position,

FIG. 4 is a view similar to that of FIG. 3 depicting the dielectric tuning structure in a second position,

FIG. 5 is a sectional view of the structure of FIG. 2 taken along line 5—5 in the direction of the arrows,

FIG. 6 is a fragmentary detail view of a portion of a structure similar to FIG. 2 and depicting an alternative embodiment of the present invention, and

FIG. 7 is a sectional view of the structure of FIG. 6 taken along line 7—7 in the direction of the arrows.

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 intereaction circuit. A circular array of elongated slots **15** is 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 disposed within the anode **13** in coaxially 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. **1–5,** there is shown a tuning structure **23** for effecting frequency modulation of the output frequency of the tube. More specifically, an array of radially directed electrically conductive lands or vanes **24** are formed in the inside surface of the upper wall **21** of the resonator **16** to define an 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 second rotary tuning member **25** is formed by an annular dielectric plate **26,** as of low loss ceramic such as alumina, beryllia, sapphire, etc. The annular dielectric plate **26** includes an array of apertures **27** with the web portion of the plate which remains between adjacent apertures **27** defining a circular array of field perturbing elements **28.**

In a preferred embodiment, the circumferential extent of the apertures **27** is the same as the circumferential extent of the space (groove) between adjacent vanes **24** 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 and therefore the output frequency of the tube is at its highest frequency. However, when the rotatable field perturbing member **26** is rotated to the position such that the perturbing elements **28** are in registration with the spaces (grooves) between adjacent reactive loading elements **24,** the reactive loading effect of the 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.

A circular array of axially directed dielectric tab portions **29** of the dielectric tuning member **25** are fixed, as by brazing, to the lower end of a cylindrical conductive actuator **31** 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 field perturbing members **28,** 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 FIGS. **6** and **7,** there is shown an alternative embodiment of the present invention. This embodiment is similar to that of FIGS. **1–5** with the exception that the rotating tuning member **25'** comprises a slotted dielectric cylinder **26'** provided with an array of apertures **27'** (slots), the apertures corresponding to the grooves or spaces defined between longitudinally directed lands or vanes **24'** provided in the inside surface of the outer side wall **19** of the cavity **16.** The circular array of longitudinally directed vanes **24'** serves as an array of reactive loading elements for inductively reactively loading the cavity **16.**

The web portion **28',** defined between the adjacent apertures **27',** of the cylindrical dielectric member **26'** serves as an array of field perturbing elements, in the manner as previously described with regard to FIGS. **3** and **4,** for modulating the reactive loading of the cavity **16** in accordance with the relative position of the field perturbing portions **28'** relative to the lands or vanes **24'.** The cylindrical tuning member **25'** is affixed to the metallic cylindrical actuator **31** which in-turn is rotated via the axle **32,** in the manner as described with regard to FIG. **1.**

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 radially directed vanes **24** and the rotatable dielectric plate **25** would include an array of radially directed apertures to define the array of perturbing members **28.**

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. An advantage to the tuner of the present invention is that the dielectric tuning structure **25** is not located in a region of intense electric field and furthermore the amount of dielectric is substantially less than that previously proposed in the aforecited U.S. Pat. No. 3,412,285, because the field is concentrated by the conductive loading elements whereby the loaded Q of the cavity is not reduced below a useable value. Furthermore, the tuner of the present invention employs a much larger number of teeth in the relatively rotatable tuning structures such that the rate at which the rotating tuning member must be turned to achieve a certain modulation frequency is substantially reduced compared with the tuner proposed in the aforecited U.S. Pat. No. 3,412,285. Reducing the speed of the tuner increases bearing life and thus operating life of the tube or, if operated at the same speed, produces a much higher rate of frequency modulation of the output frequency of the tube.

What is claimed is:

1. In a microwave tube;

means for generating a stream of electrons;

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

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 mode of said cavity, said tuner means comprising a conductive reactive loading structure, a 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 electric fields of said mode excite electric fields between adjacent vanes whereby said resonance mode is reactively loaded by said vanes;

said field perturbing structure comprising an array of dielectric elements disposed on a circle about said axis and further disposed to intercept fringing portions of said electric fields between adjacent vanes and,

means for producing relative rotation of said reactive loading structure and said field perturbing structure about said axis to cyclically vary the amount of said fringing field intercepted by said dielectric elements, whereby the resonant frequency of said cavity mode and the frequency of said microwave energy are cyclically varied.

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

3. The apparatus of claim **2** 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 side walls, and wherein said array of vanes is disposed along at least one of said end walls and side walls of said cavity resonator means.

4. The apparatus of claim **2** wherein said chamber is generally cylindrical and has a pair of axially spaced end walls and a cylindrical side wall and wherein said array of vanes is disposed along at least one of said end and side walls.

5. The apparatus of claim **2** wherein said cavity axis coincides with said axis of said tuner.

6. The apparatus of claim **5** wherein said resonance mode has an electric field which is generally circular about said axis of said tuner.

7. A coaxial magnetron comprising a cylindrical cathode, a cylindrical anode surrounding said cathode and coaxial therewith, an array of anode vanes 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 dielectric 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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