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Foreman

[11] **3,731,137**

[45] **May 1, 1973**

[54] **COAXIAL MAGNETRON**

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[73] Assignee: **Raytheon Company**, Lexington, Mass.

[22] Filed: **Feb. 3, 1972**

[21] Appl. No.: **223,250**

[52] **U.S. Cl.** **315/39.77**, 315/39.55, 315/39.61

[51] **Int. Cl.** **H01j 25/50**

[58] **Field of Search**..........315/39.77, 39.55, 315/39.61

[56] **References Cited**

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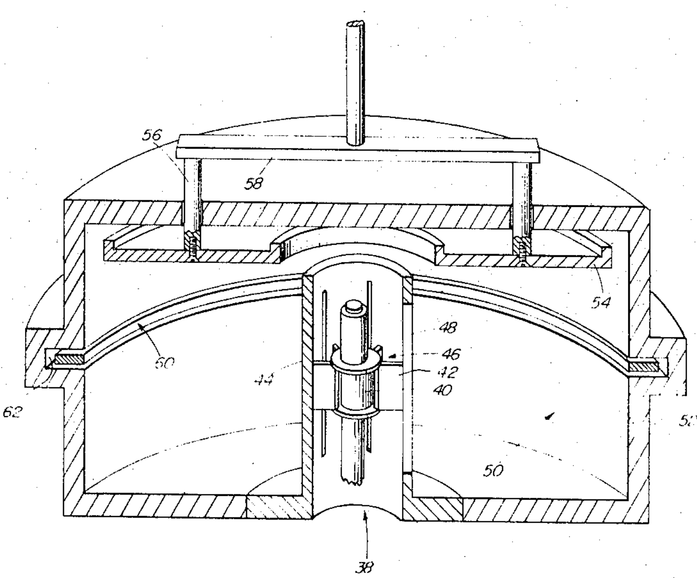
Primary Examiner—Rudolph V. Rollinec
Assistant Examiner—Saxfield Chatmon, Jr.
Attorney—Harold A. Murphy et al.

[57] **ABSTRACT**

A coaxial magnetron having a cylindrical cavity operating in a circular mode is tuned by means circumferentially disposed in the region of maximum electric field intensity. In one embodiment a ring tuner is retained within an annular groove at the midpoint of the outer cavity wall and adapted to be reciprocated in introduce a dissymmetry in the cavity geometry along a path transverse to its axis. The paths of the electric field currents are altered by each excursion of the tuner. Dither tuning of the disclosed structure provides a frequency agility in transmission systems over a portion of the frequency band. Another embodiment provides for the combination with a large plate-type tuner to add a fine tuning capability over a portion of a broad frequency band. Temperature compensation is also attainable by means of the ring tuner arrangement.

12 Claims, 11 Drawing Figures



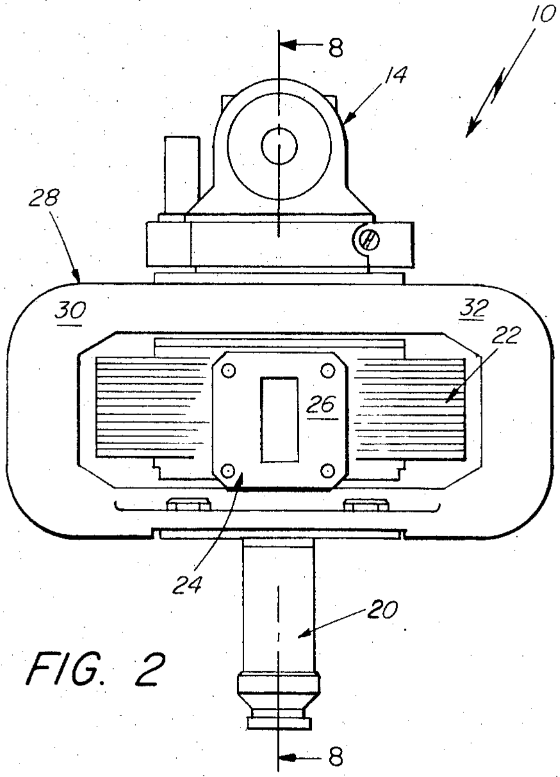


FIG. 2

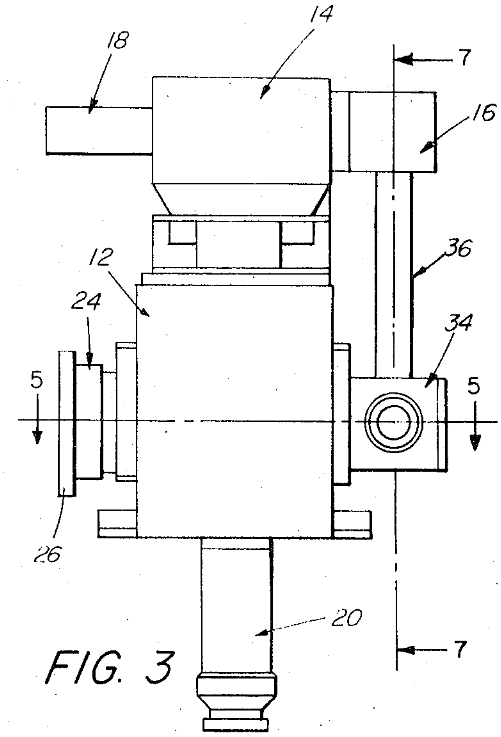


FIG. 3

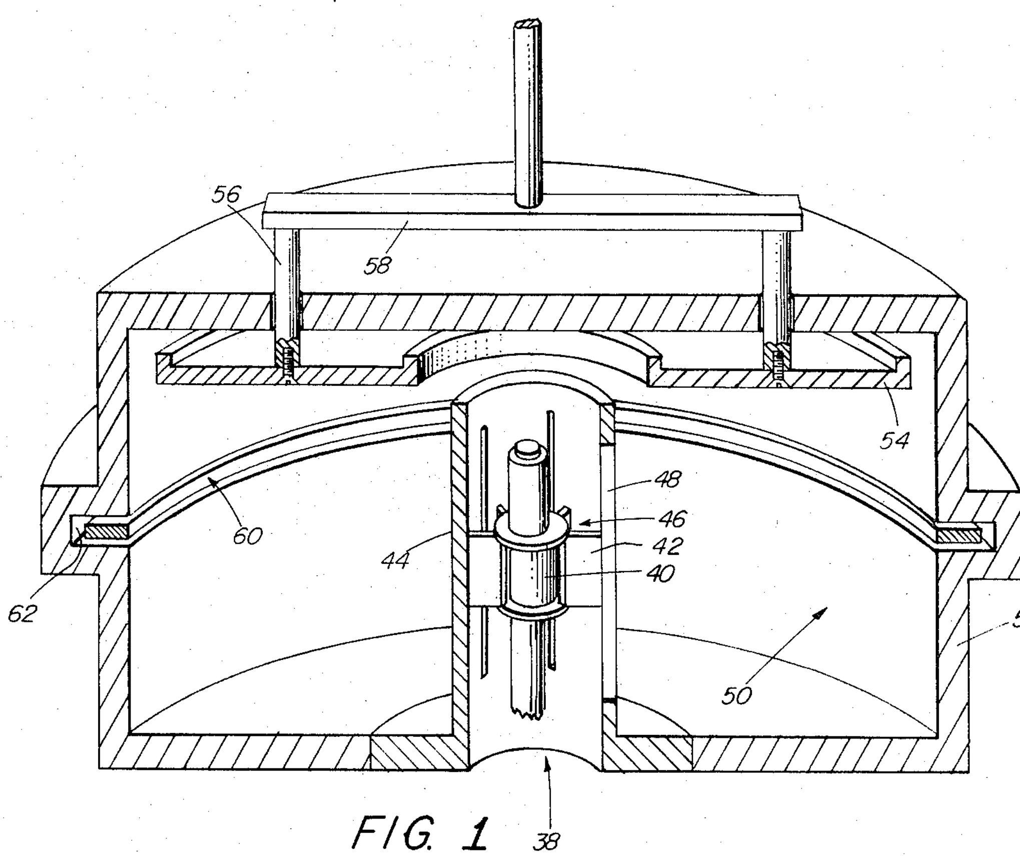


FIG. 1

FIG. 10

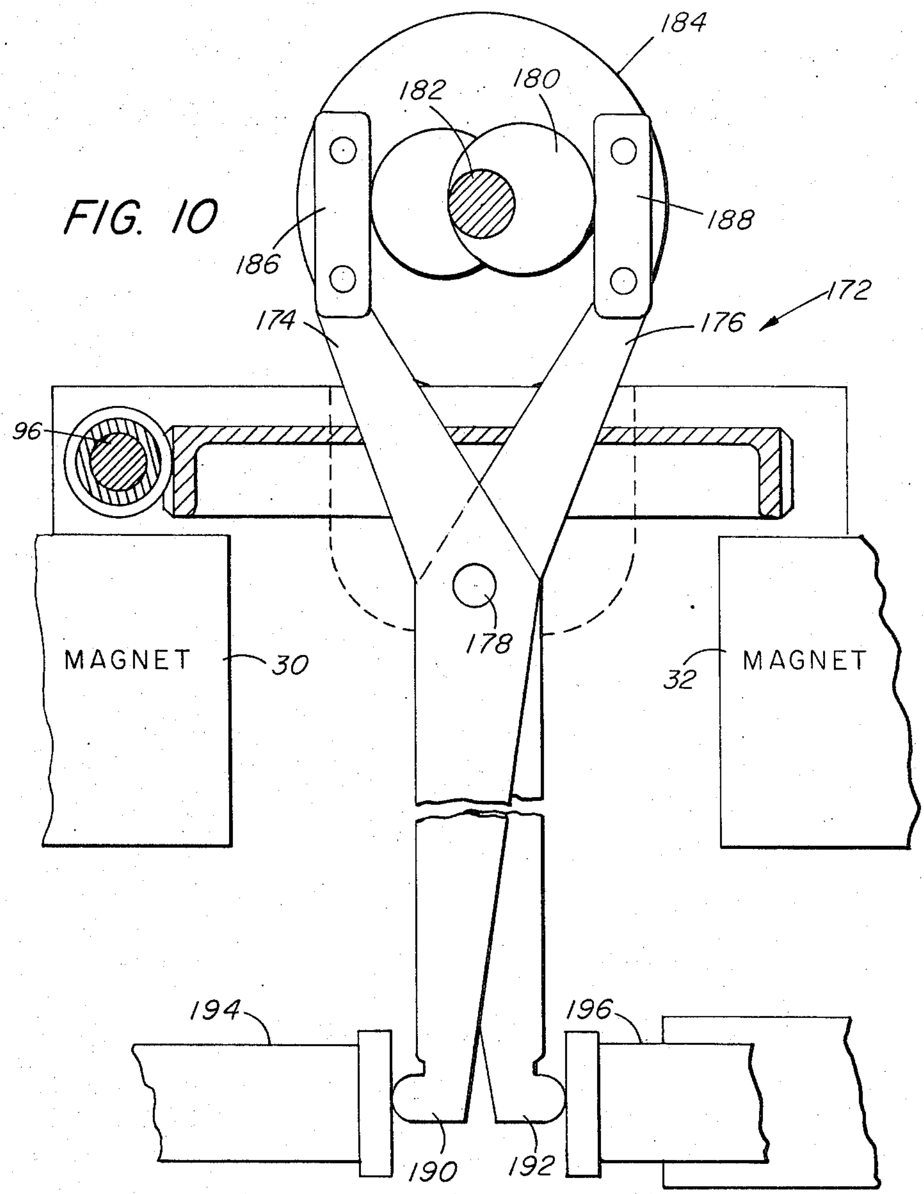
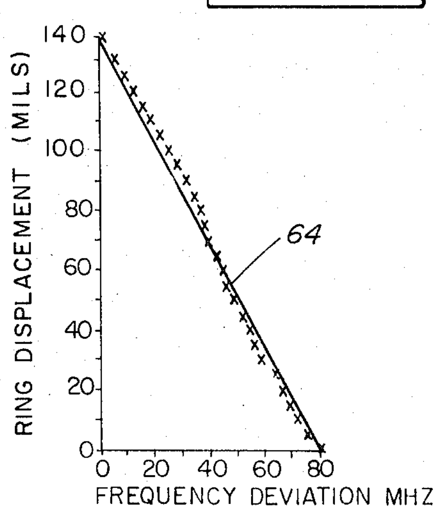

184
182
180
188
186
172
174
176
96
178
MAGNET
30
32
MAGNET
194
196
190
192

FIG. 4


140
120
100
80
60
40
20
0
RING DISPLACEMENT (MILS)
64
0
20
40
60
80
FREQUENCY DEVIATION MHZ

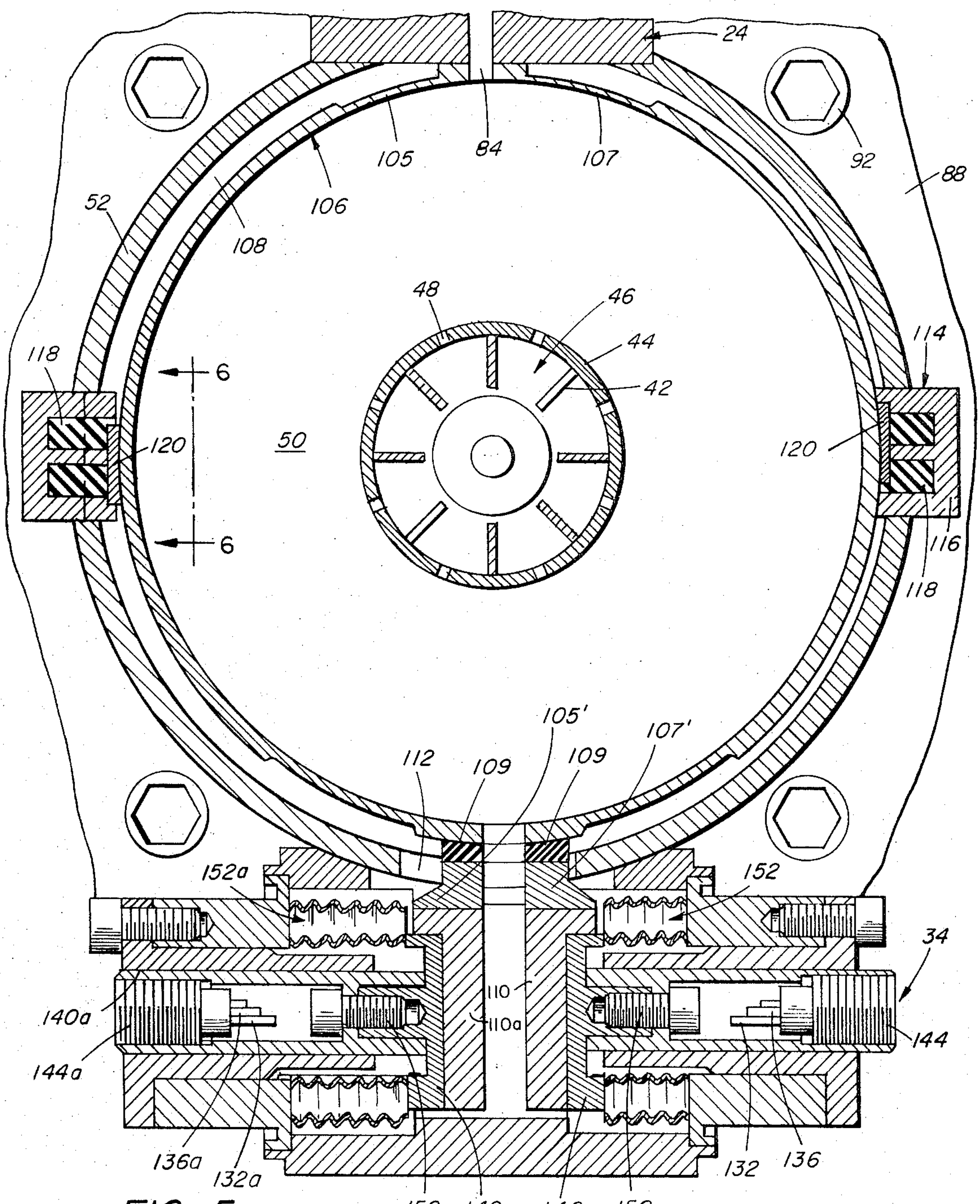


FIG. 5

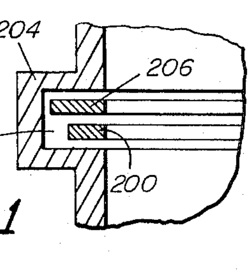


FIG. 11

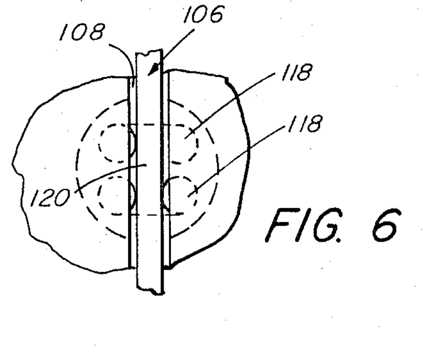


FIG. 6

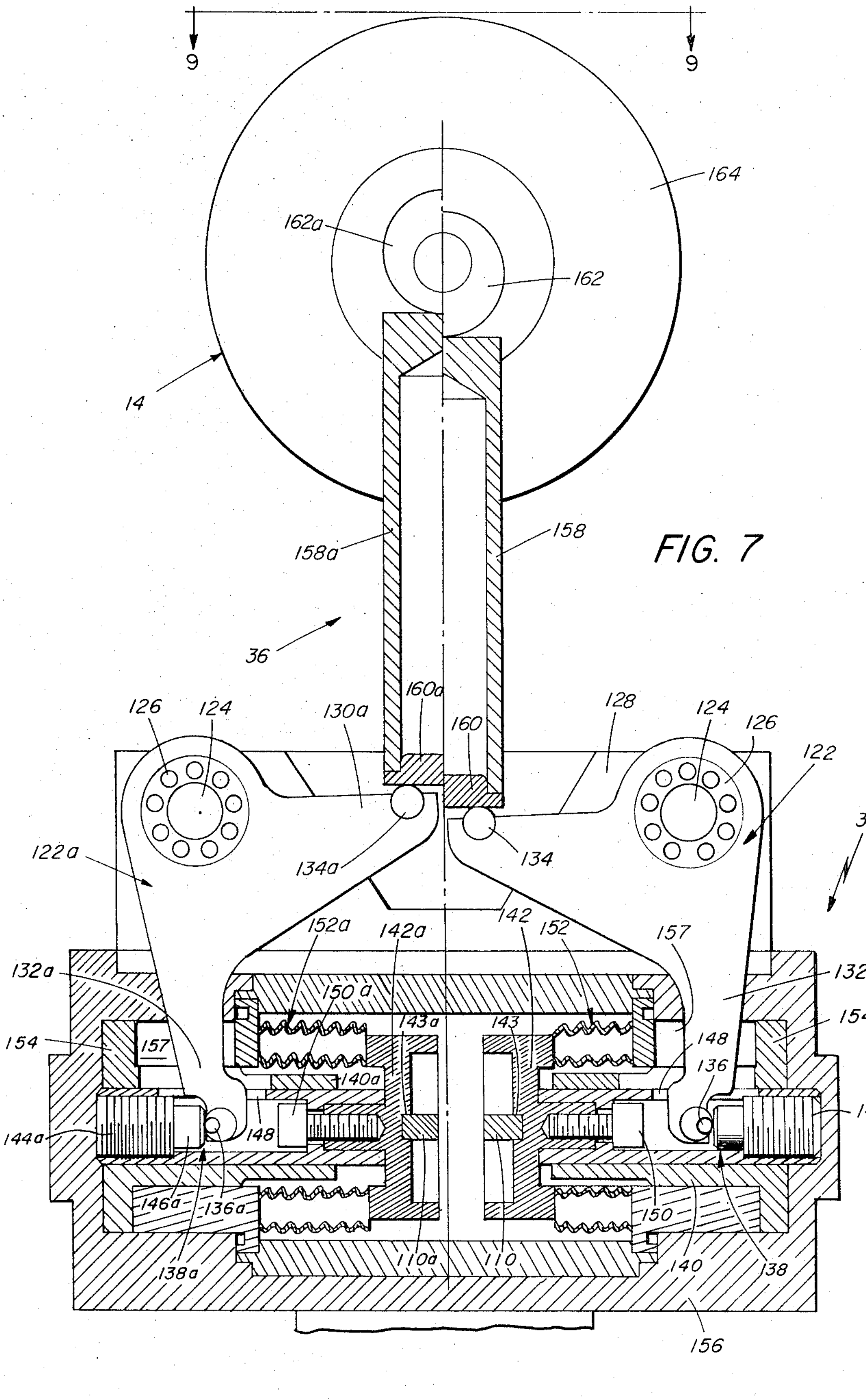
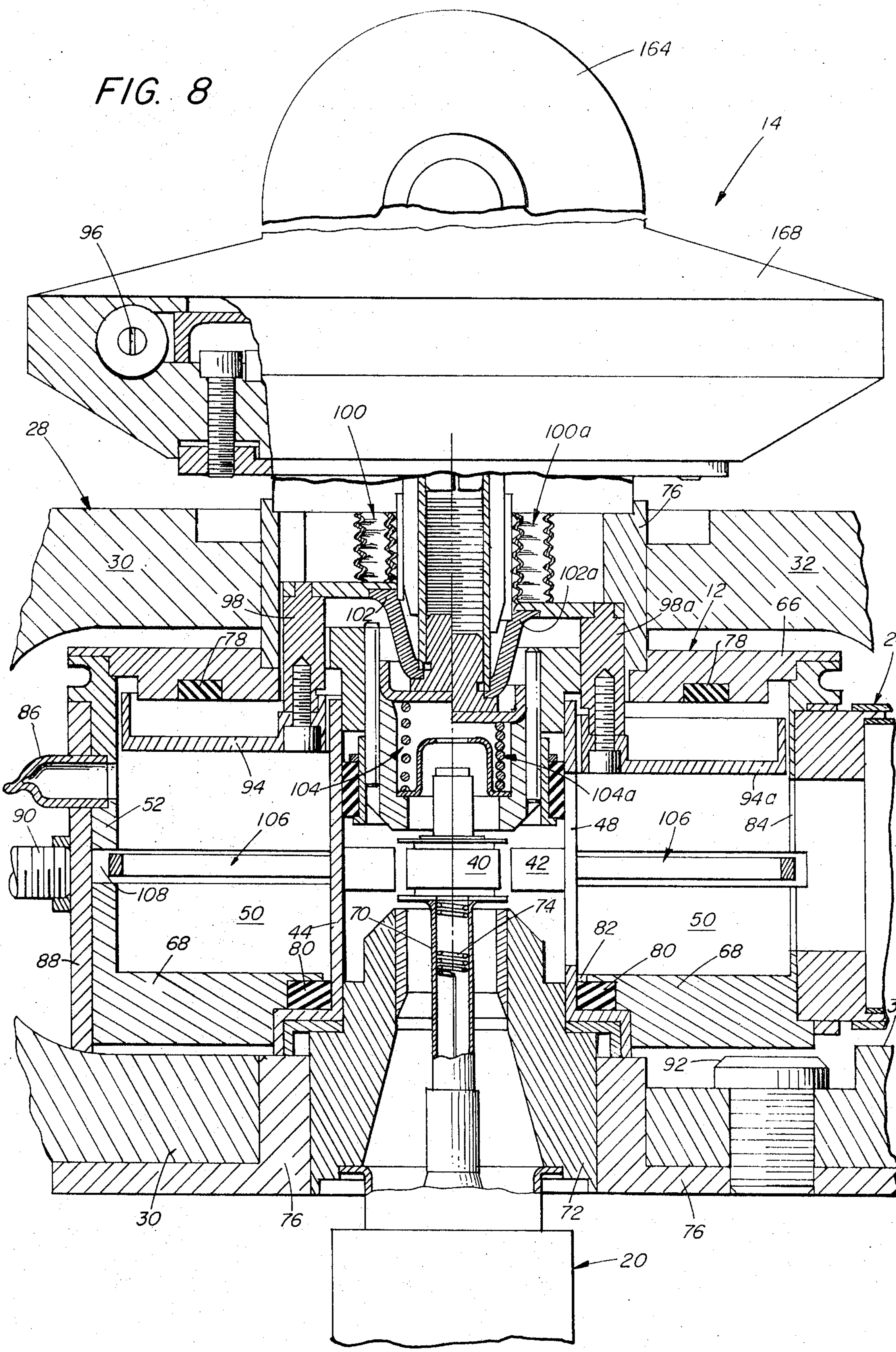

9
9
164
162a
162
14
158a
158
36
160a
160
126
124
130a
128
124
126
122
34
134a
134
122a
152a
142a
142
152
157
132a
150a
132
143a
143
154
154
157
140a
148
136
148
144
144a
146a
136a
150
138a
110a
110
140
138
156

FIG. 7

FIG. 8


164
14
96
168
100
100a
28
76
30
32
102a
98
98a
12
66
102
78
78
24
86
94
104
104a
94a
52
90
106
106
48
84
40
42
108
50
50
70
74
44
82
80
80
68
68
88
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30
76
72
76
20

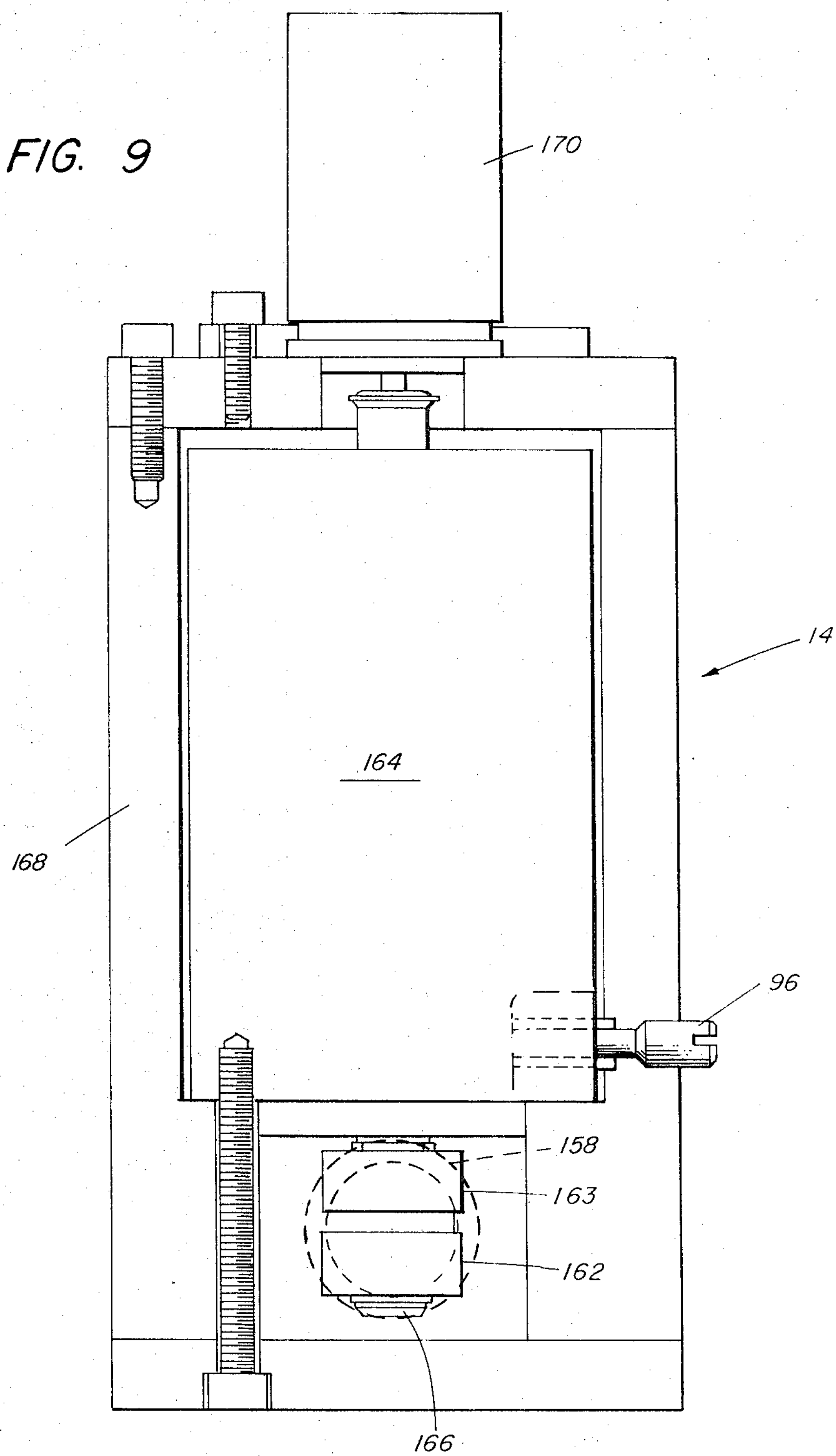

FIG. 9

COAXIAL MAGNETRON

BACKGROUND OF THE INVENTION

The invention relates to crossed field electron discharge devices of the coaxial magnetron type and, in particular, to a tuning structure for such devices.

U.S. Pat. No. 2,854,603 issued Sept. 30, 1958, to R.J. Collier and J. Feinstein discloses a coaxial magnetron device having an inner and an outer resonant system. The inner system comprises a plurality of radially extending vane members extending from an anode wall defining therebetween resonant cavities circumferentially disposed around a central cathode. An outer system is defined by an annular wall member and the cylindrical anode wall to provide an outer circular coaxial cavity resonator. Coaxial magnetrons generally provide for the outer cavity resonator to operate in the TE_{011} circular electric and magnetic mode. Electromagnetic energy is coupled from alternate inner cavity resonators by slots extending within the common anode boundary wall. The inner system generally operates in the pi-mode and the coupling slots together with slot mode absorbing structures are dimensioned to provide for efficient coupling of the respective modes.

In the prior art, such devices have been tuned by an annular plate member which is axially movable within the external cavity resonator. The tuning member effectively forms a movable end wall of the cavity resonator. As it is actuated in a direction towards the opposing end wall member the volume of the cavity is altered. An example of a prior art plate-type tuning structure for coaxial magnetrons is illustrated and described in pending United States patent application entitled "-Coaxial Magnetron Slot Mode Suppressor", filed by Robert J. Foreman, Ser. No. 147,914, filed May 28, 1971, and assigned to the assignee of the present invention.

The large mass of such prior art plate-type tuners makes it difficult to provide rapid tuning over the frequency band or fine tuning over portions of the band. Additionally, in systems requiring frequency agility by rapid dither tuning of the tuning member auxiliary tuning structures are required such as vibrating reed elements of the type disclosed in U.S. Pat. No. 3,087,124, issued Apr. 23, 1963, to Willard M. McLeod, Jr. Spinning type structures have also been disclosed of the type shown in U.S. Pat. No. 3,379,925, issued Apr. 23, 1968, to R.E. Edwards. Both these patents are assigned to the assignee of the present invention. In the coaxial magnetron art, therefore, it is desirable to provide improved tuning structures as well as means for dither tuning which will have linear and reproducible tuning characteristics.

In the circular cavity mode under consideration, namely the TE_{011}, the electric currents are circumferential around the cavity walls while the magnetic fields are transversely disposed in a direction parallel to the axis of the device. The large massive tuning structures vary the distance between the upper and lower end walls of the cavity resonator to reorient the field distributions of both the electric and magnetic fields and thereby provide for the alteration of the resonant frequency. A lightweight tuning structure which avoids the difficulties of the large massive structures and provides for fine, as well as, dither tuning capability is, therefore, desirable for electromagnetic energy propagation devices and systems.

SUMMARY OF THE INVENTION

The present invention provides a coaxial magnetron having an outer cavity resonator with tuning means for varying its dimension in and near the region of maximum electric field intensity when operated in the TE_{011} mode. In one embodiment mechanical means provide for reciprocating motion of split ring tuner structures having at least one end anchored. The deformation of the ring tuner provides a dissymmetry in the cavity geometry with the maximum excursion deforming the substantially circular cavity to have a slightly elliptical configuration. The introduction of conductive tuner material in the cavity alters the path of the electric currents. In an illustrative embodiment a groove housing the tuning structure is provided by an annular wall structure girdling the outer cavity resonator walls. The depth of the groove provides the limits of the tuning structure excursion. The absence of transverse components of current across the groove housing the split tuning ring structures assures a continuance of electrical efficiency with the applicable structure. A tuning range of up to 200 MHz has been demonstrated at different frequency bands with the doubly actuated split ring structures. Multiple tuning structure assemblies will effectively double the tuning range. Linearity and reproducibility of the tuning characteristics over a substantial portion of the frequency tuning band has also been demonstrated. Coupling of dither tuning mechanisms such as a high speed motor-driven eccentric drive and resolver with the disclosed structure will provide for frequency agility in a transmission system.

BRIEF DESCRIPTION OF THE DRAWINGS

Details of illustrative embodiments of the invention will be readily understood after consideration of the following description and reference to the accompanying drawings, wherein:

FIG. 1 is a diagrammatic cross-sectional view of the principal components embodied in the present invention;

FIG. 2 is a front elevational view of a coaxial magnetron embodying the present invention;

FIG. 3 is a side elevational view of the embodiment shown in FIG. 2;

FIG. 4 is a curve illustrating the tuning characteristics of an illustrative embodiment of the invention;

FIG. 5 is a cross-sectional view taken along the line 5—5 in FIG. 3;

FIG. 6 is a cross-sectional view taken along the line 6—6 in FIG. 5;

FIG. 7 is a cross-sectional view taken along the line 7—7 in FIG. 3;

FIG. 8 is a vertical cross-sectional view taken along the line 8—8 in FIG. 2;

FIG. 9 is an elevation viewed in the direction indicated by the line 9—9 in FIG. 7;

FIG. 10 is an elevation view of an alternative mechanical actuating structure for the embodiment of the invention; and

FIG. 11 is a diagrammatic representation in section of an alternative embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. **2** and **3** the illustrative coaxial magnetron **10** comprises an inner and an outer resonant system housed within envelope **12**. A mechanically actuated tuner assembly **14** including motor driven means for action of the tuning structures includes a gear housing **16** and resolver means **18** for readout of the frequency. A cathode support assembly **20** extends coaxially from the envelope **12**. Cooling fins **22** surround the envelope **12** and an output waveguide window assembly **24** for coupling of the electromagnetic energy to the utilization load is also provided. The magnetic field producing means **28** includes substantially C-shaped permanent magnets **30** and **32** which contact inner pole piece members (not visible in these views). The magnetic field extends parallel to the axis of the device and the electric field is oriented transversely thereto to provide for crossed field interaction in the region between the cathode and the anode members. The embodiment of the invention includes mechanical actuating means **34** with intermediate mechanical coupling means for translation of motion from the tuner assembly **14** and gear housing **16** into reciprocal motion of the tuner structure.

The novel concept and the principal components of the invention are diagrammatically illustrated in FIG. **1** which will now be described. The inner resonant system **38** includes a cathode member **40** centrally disposed within an array of circumferentially disposed anode vane elements **42** extending radially from common boundary wall **44**. A plurality of cavity resonators **46** are defined between the anode elements. Alternate slots **48** provide for coupling of the pi-mode generated energy in the inner system to the outer coaxial cavity resonator **50** defined by the common boundary wall **44** and an external cylindrical wall member **52**. The outer cavity resonator system is dimensioned to operate in the TE_{011} mode.

A plate member **54** is axially translated within the cavity resonator **50** to tune the magnetron over a broad frequency band. Suitable mechanical actuating mans, such as rods **56**, are joined by a yoke **58** to suitable drive means. A split ring tuner structure **60** is provided within a groove **62** disposed at a point near the middle of the wall member **52** where the electric field intensity is at the maximum value. The deformation of the ring tuner **60** provides for introduction of a conductive material within the cavity and provides a varying path for the electric currents which, as noted for the TE_{011} mode, are circumferential along the wall **52** of the coaxial cavity resonator **50**. The depth of the groove **62** determines the excursion of the tuner structure. Rapid deformation of the external cavity wall contour in the applicable region results in a dither tuning capability over a substantial portion of the band for frequency agility systems.

An inherent linear tuner characteristic is present as evidenced by FIG. **4**. The displacement of the ring tuner structure has been plotted over a range of 0 to 140 mils. The measured frequencies have been averaged as shown by the solid line **64** to extend over a frequency range of up to 80 MHz for devices operating at X-band. Other embodiments of the invention have been shown to have similar linear tuning ranges over up to 200 MHz at other bands. With motor driven dither actuator means, to be hereinafter described, coupled to the disclosed tuning structure and operated at speeds of up to 12,000 r.p.m.'s an excursion of the tuning range of 200 cycles per minute will result.

Further details of the illustrative embodiment shown in FIGS. **2** and **3** will now be described with reference being directed to FIGS. **5–9**, inclusive. Envelope **12** is defined by annular end wall members **66** and **68** hermetically sealed to outer cylindrical wall member **52**. The anode vane elements **42** are appended to the common anode boundary wall **44** and extend radially inwardly to define therebetween cavity resonators **46** of the inner resonant system.

Cathode **40** is supported axially by the cylindrical support assembly **20** which includes a tubular member **70** and is secured to magnetic inner pole piece member **72**. Electrical leads for energizing cathode heater **74**, as well as the high voltage leads, are introduced through the cathode support assembly **20** to the appropriate anode and cathode members. The previously described magnetic circuit producing means **28** contacts inner pole piece member **72** as well as pole piece adapters **76**.

The outer resonant system includes coaxial cavity resonator **50** defined by the common anode boundary wall **44** and the outer cylindrical wall member **52**. Slots **48** in wall **44** provide for the coupling and locking of the energy between inner and outer resonant systems. Any degenerate energy modes are suppressed by annular lossy member **78** disposed within end wall member **66** and member **80** adjacent to the quarter-wavelength channel choke **82** in end wall member **68**. The external coaxial cavity resonator **50** is coupled through iris **84** and a transformer section to the utilization load by means of output waveguide assembly **24**. An exhaust tubulation **86** in outer wall member **52**, as well as, a mounting and anchor plate **88** together with anchor screw means **90** and **92** comprise the remainder of the coaxial magnetron structure.

An axially translated plate member **94** for broad frequency tuning is actuated by the tuning mechanism **14** including a worm gear arrangement **96** together with post members **98** with a deformable bellows arrangement **100** secured between the tuner mechanism and a movable support member **102**. A slot mode absorber assembly **104** is also axially translated adjacent to the ends of the slots **48** in the manner described in detail in the previously referenced pending United States patent application, Ser. No. 147,914.

The split ring tuner structure **106** is disposed within groove **108** formed in outer wall member **52**. In FIG. **8** the detailed embodiment is shown with the broad tuning plate member **94** in two stages of operation to assist in an understanding of the invention. Components which are involved in movement are shown in the left-hand portion as being at rest. Components shown in the right-hand portion and designated by the suffix "*a*" are in the tuned position.

The tuning structure **106** comprises split ring members **105** and **107** anchored at one end adjacent window assembly **24** to the wall structure of groove **108**. The opposing ends **105'** and **107'** are coupled to actuator means **34** by reciprocating blade members **110** introduced through slot **112** in cavity resonator wall member 52. Intermediate members 109 of an insulating material, such as a dielectric material or ceramics, provide for electrically isolating the ring member from the actuator. In FIG. 5 the right-hand portion of the illustration represents the tuning ring members disposed entirely within groove 108 and, therefore, not perturbing the electric currents in the cavity resonant wall. The left-hand portion represents the tuning ring members in full tuning position extending within the cavity resonator 50. The point of maximum electric field intensity, as previously noted, is approximately at the midpoint of wall 52. The blade members in the position designated 110a, therefore, represent the innermost position as determined by the actuating mechanism. The split tuning ring members anchored at one end upon being deformed have a slight elliptical contour in the essentially circular cavity geometry at the midpoint region. In an exemplary embodiment of the invention the split tuning ring members were fabricated of a rigid metallic material such as, for example, the alloy comprising 10 percent tantalum and 90 percent tungsten. Copper plating preserves the overall electrical circuit efficiencies of the cavity resonator structure. Each of the tuning ring members for an x-band embodiment have a width of 0.050 inches and a height of 0.100 inches.

Ring damping structures 114 are provided approximately 180° apart by housing members 116 each providing two tiers of dielectric rod members 118 adapted to contact opposing sides of tab portions 120. As shown in FIG. 6 the dielectric members 118 support the tab portions and thereby dampen any vibrations for good radial stability in dither tuning applications.

Reciprocating blade members 110 are actuated by means including pivoted cam follower members 122 now to be described with reference being directed to FIG. 7. Each of the members 122 are supported by a central pivot 124 and surrounding ball bearing arrangement 126 secured to a housing member plate 128. A rocker type motion will result with arms 130 and 132 providing a reciprocating motion about the central pivot axis. Each of the arms 130 and 132 carry a cam roller 134 and 136 adapted to contact adjacent bearing surfaces.

Follower member structure 138 includes tubular members 140 having piston type members 142 disposed at the inner end to contact reciprocating blade members 110 disposed within a notch 143. Members 140 are provided with threaded bearing members 144 and are suitably adjusted to attain the desired stroke of the actuating means. An inner bearing surface 146 contacts the cam rollers 136. Slots 148 in tubular members 140 provide for freedom of movement of movable arms 132. Suitable fastening means such as a threaded member 150 secures the piston type member 142 to the inner end of the tubular member. The follower structure is spring loaded by vacuum bellow means 152 which contact piston members 142 and tubular members 154 suitably positioned within the housing 156. Slots 157 again provide for the freedom of movement of the movable arms 132.

Actuation of the ring tuner structures is provided by vertically disposed linear control member 158 carrying on its inner end a bearing surface 160 which contact rollers 134. The outer end contacts eccentrically mounted bearing members 162 which are driven by a motor 164. In FIG. 7 the right-hand portion represents the rest position with the tuning ring members supported wholely within the groove 108. The right-hand portion represents the rest tuning position with the ring members disposed within the groove 108. The linear control member 158 is shown in the downward thrust position and the bellows 152 are compressed. In the left-hand portion or full tuning position the linear control member is in the upward thrust position with the bellows 152 extended to urge the reciprocating blade members 110 to the position within the circular cavity resonator. All the pertinent movable structure, therefore, reflecting the fully tuned position on the left-hand portion of the illustration has again been designated by the suffix "a" to assist in an explanation of the invention. In the exemplary embodiment the tuning range, as described in FIG. 4, was achieved with an actuating means having a stroke of approximately 0.130 inches for each tuning cycle with the ring tuner structures moving transverse to the axis of the cavity resonator.

Referring now to FIG. 9 the top view illustrates motor driven tuner assembly means 14 including eccentric bearing members 162 and 163 mounted on a shaft 166 which is actuated by a motor 164. All the components are supported on a plate member 168. The worm and gear arrangement 96 for driving the broad tuning plate member 94 is supported beneath plate 168 as indicated by the dashed lines in this view. The overall stroke for a linear control member 158, in an exemplary embodiment to cover the described tuning range, was approximately 0.090 inches. Bearing members 162 and 163 are eccentrically mounted on the shaft 166 so that, initially, bearing 162 picks up the linear control member 58 and upon completion of the tuning cycle the inner bearing member 163 contacts this linear control member. The assembly is completed by a resolver means 170 controlled by shaft 166 to provide for direct readout of the fine tuning frequencies over a substantial portion of the tuning range. In present day apparatus a resolver having direct frequency readout is readily available. In this view the position of the linear control member 158 has been shown by dashed lines to indicate the relationship with eccentrically mounted bearing members 162 and 163.

In FIG. 10 alternative actuating means for movement of the split tuning ring members is indicated and will now be described. Yoke arrangement 172 comprising scissors-type arm members 174 and 176 are united by a central pivot member 178. Eccentrically mounted bearing member 180 is mounted on a shaft 182 driven by motor 184. The displacement of bearing member 180 results in reciprocating movement of handles 186 and 188 attached to the outer ends of arms 174 and 176. The inner ends of the reciprocating scissors-type structure 172 provides for reciprocating movement of the inner ends 190 and 192 of the arm members. Piston actuators 194 and 196 suitably spring-loaded as by a bellows arrangement are coupled to the split tuning ring members and upon actuation move these tuning members.

Referring now to FIG. 11 another alternative embodiment of the invention is illustrated. A first tuning ring member 200 having a predetermined dimension is positioned within a groove 202 in cavity resonator wall member 204. A second tuning ring member 206 may also be disposed within the groove **202**. By providing for a wider dimension of the tuning ring **206** the tuning range capability may be doubled. A frequency range, therefore, of up to 400 MHz could be realized over desired frequency bands which is particularly useful in the dither tuning structures for frequency agility systems.

Another application of the disclosed tuning structure resides in automatic temperature compensation over an operating band of frequencies. Generally in resonant cavities different metals are employed having different coefficients of expansion to reduce perturbation of resonant frequencies due to thermal absorption. By providing a suitable liquid in the bellows, the thermal effects on the Q of the cavity can be effectively compensated for by expansion and contraction of the liquid which will move the tuning structure in and out of the cavity interior. Such movement, as herein described, varies the cavity resonance by introducing a dissymmetry in the electrical current bearing surfaces.

In addition to the disclosed material composition of the split tuning ring members, numerous other metals, such as molybdenum, which are capable of withstanding high bake out temperatures may be utilized in the practice of the invention. Numerous other variations, alterations or modifications will also become apparent to those skilled in the art. It is intended, therefore, that the foregoing description of the preferred embodiments be considered in the broadest aspects and not in a limiting sense.

I claim:

1. A crossed field device comprising:
a cathode;
an inner resonant system including a plurality of spaced anode members supported by a common boundary wall and defining therebetween cavity resonators surrounding said cathode to generate electromagnetic energy;
an outer resonant system including a wall member defining with said boundary wall a coaxial cavity resonator adapted to be resonant over a frequency band;
means for producing crossed electric and magnetic fields; and
means for tuning the resonant frequency of said coaxial cavity resonator by introducing a physical dissymmetry in the cavity wall geometry in the region of maximum electric field intensity;
said tuning means being adapted for movement along a path transverse to the axis of said coaxial cavity resonator.

2. The device according to claim **1** wherein said tuning means comprise split ring members having at least one end anchored.

3. The device according to claim **2** wherein said ring members are actuated reciprocally by means coupled to their free ends.

4. The device according to claim **3** wherein said ring members are adapted to be spring-loaded.

5. The device according to claim **3** wherein said ring members are supported at points intermediate the anchored and free ends by stabilizing and vibration damping means.

6. The device according to claim **1** and means including an axially translated tuning member disposed within said coaxial cavity resonator to vary the resonant frequency.

7. A coaxial magnetron comprising:
a cathode;
an anode member having a plurality of radially extending vane elements supported by a common boundary wall and defining therebetween cavity resonators;
an outer cylindrical wall member defining with said boundary wall and opposing end wall members a coaxial cavity resonator adapted to be resonant over a frequency band in a predetermined electric and magnetic field operating mode;
said boundary wall having axially extending slots coupling energy between said anode and coaxial cavity resonators;
means for producing crossed electric and magnetic fields;
means for tuning the resonant frequency of said coaxial cavity by introducing a physical dissymmetry in the outer wall member geometry in the region of maximum electric field intensity;
and means for actuating said tuning means in a direction transverse to the axis of said coaxial resonator.

8. The magnetron according to claim **7** wherein said coaxial cavity resonator is operated in the TE_{011} mode.

9. The magnetron according to claim **7** wherein said tuning means comprise split ring members housed within a groove defined near the midpoint of the axial length of said outer wall member.

10. The magnetron according to claim **9** wherein said split ring members comprise a substantially rigid refractory conductive metallic material.

11. The magnetron according to claim **10** wherein said split ring members are fabricated of a tantalum-tungsten alloy.

12. The magnetron according to claim **7** and a plate member axially translated within said coaxial cavity resonator to vary with one of said end wall members the axial frequency determining dimensions.

* * * * *