

[54] **COAXIAL MAGNETRON SLOT MODE SUPPRESSOR**

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

[58] Field of Search..315/39.67, 39.61, 39.77, 39.51; 333/83 A

2,805,362 9/1957 Kline.....315/39.61

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[57] **ABSTRACT**

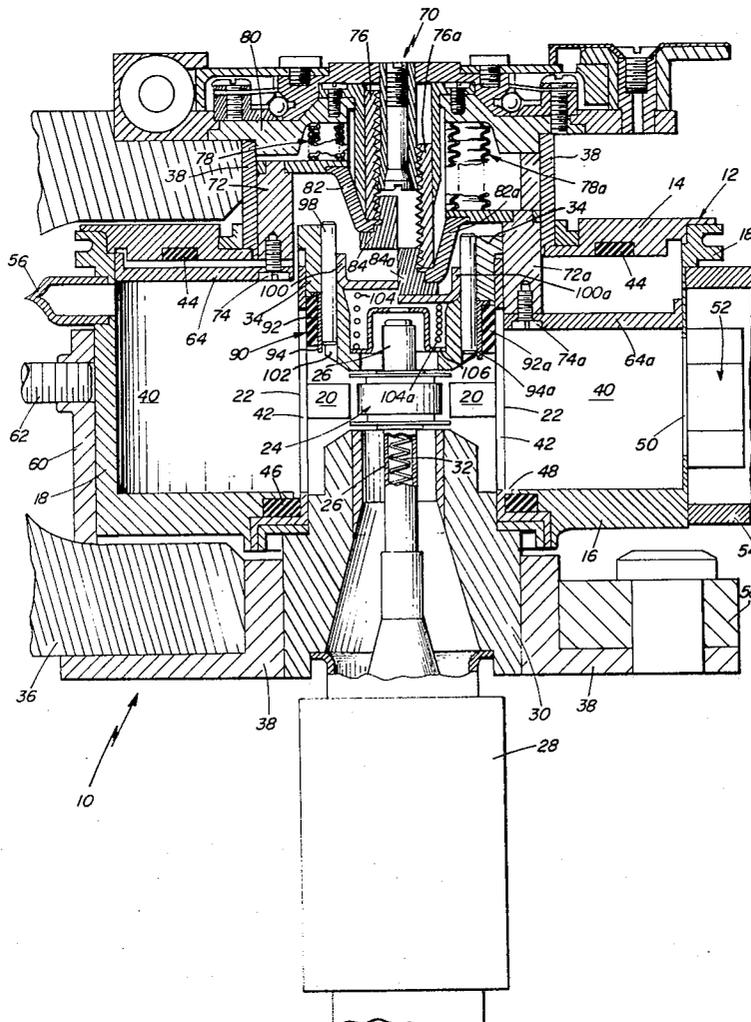
The invention discloses a coaxial cavity magnetron provided with a tunable slot mode absorber adapted to be picked up and moved in consort with the main cavity tuning means. A lossy ceramic ring member is operatively associated with a main tuner mechanism to be actuated and carried a varying distance adjacent to coupling slots in a common boundary wall between two resonant systems. In an embodiment covering a tuning range of 1,100 MHz the slot mode absorber is actuated over a portion of the frequency range approaching the upper limits. Improved starting performance through reduced time jitter due to mode instability renders the applicable device acceptable for short pulse operating conditions. The positioning of the mode suppressor within the slots also presents a lossy structure to the working modes of the device in the region of the tuning means to level power outputs during the tuning excursion.

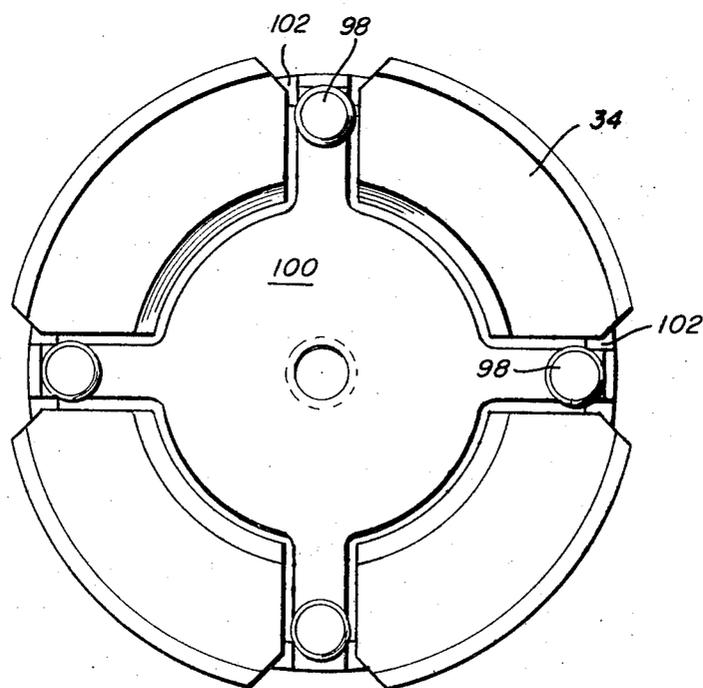
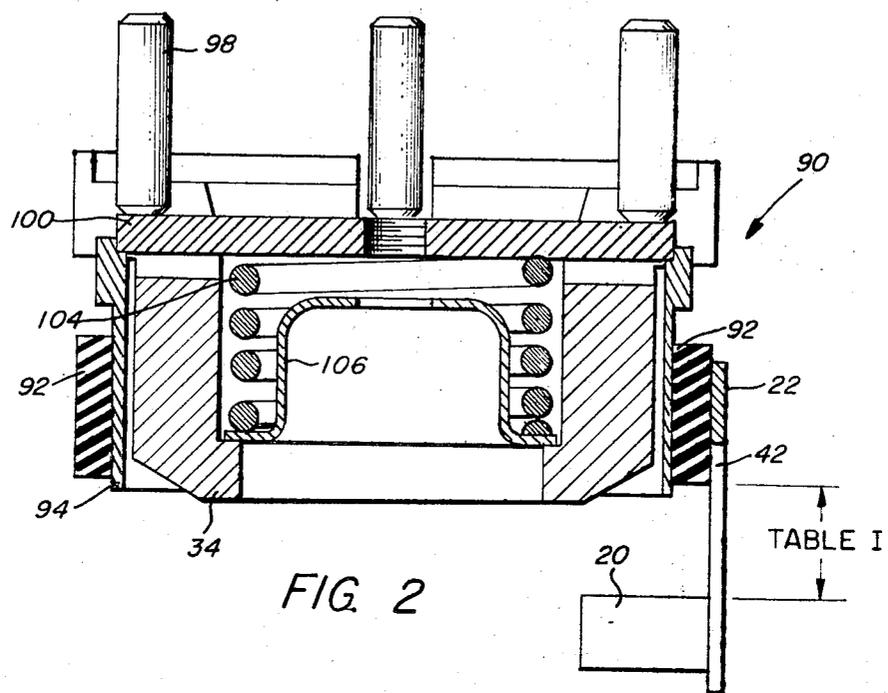
[56] **References Cited**

UNITED STATES PATENTS

3,471,744	10/1969	Pryor.....	315/39.61 X
2,710,945	6/1955	Edson.....	333/83 A
2,877,434	3/1959	Farr et al.....	333/83 A
2,692,977	10/1954	Koppel.....	333/83 A
2,608,673	8/1952	Brown.....	333/83 A
3,479,556	11/1969	Cook.....	315/39.61 X
3,600,629	8/1971	Fenster.....	315/39.61
3,014,152	12/1961	Shelton.....	315/39.61
2,837,694	6/1958	Spencer.....	315/39.51

13 Claims, 7 Drawing Figures





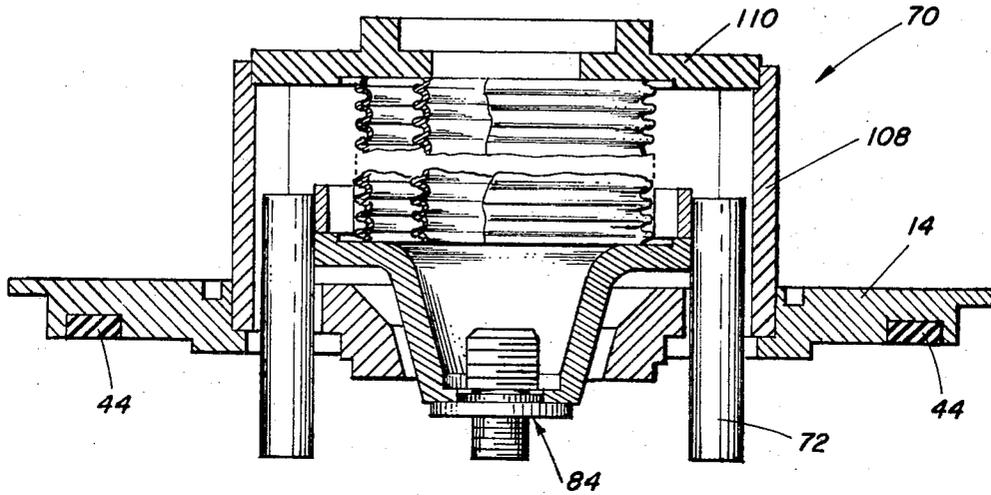


FIG. 4

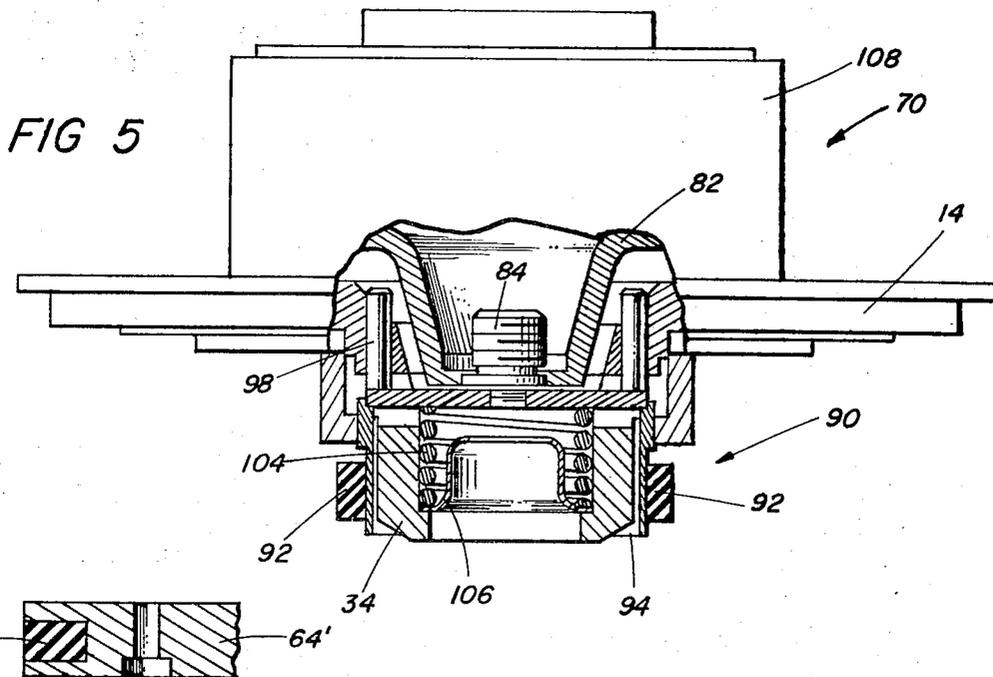


FIG. 6

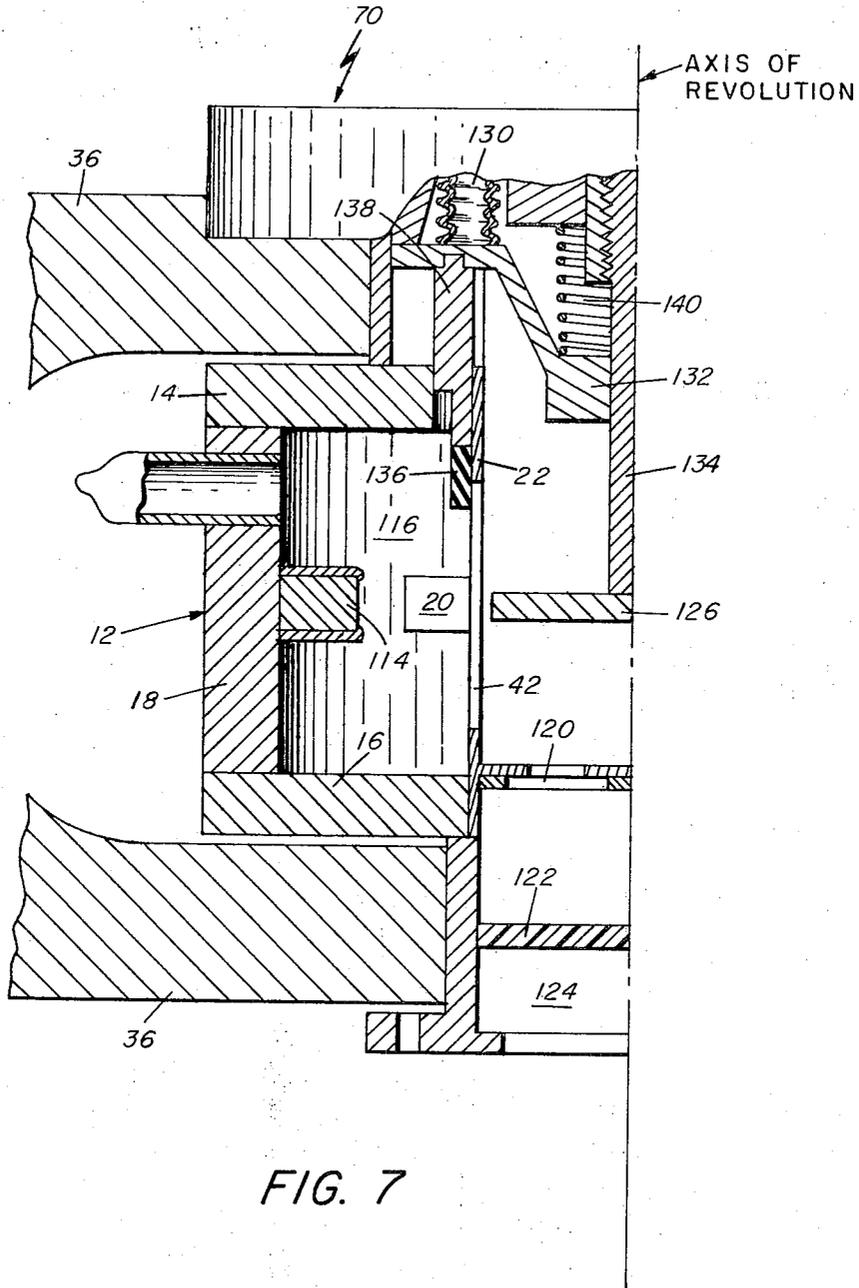


FIG. 7

COAXIAL MAGNETRON SLOT MODE SUPPRESSOR

BACKGROUND OF THE INVENTION

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

In U.S. Pat. No. 2,854,603 issued Sept. 30, 1958 to R. J. Collier and J. Feinstein a coaxial magnetron device comprising an inner and an outer resonant system is described. The inner system includes a plurality of radially extending vane members defining therebetween resonant cavities circumferentially disposed around a central cathode. An outer system is defined by an outer wall and a common cylindrical anode boundary wall to define a coaxial cavity resonator. The outer system is constructed to oscillate in the $TE_{0,1,1}$ mode and the inner system is coupled to alternate cavity resonators by slots extending through the common boundary wall. The inner system is normally designed to operate in the pi-mode and the two systems are locked together by means of the coupling slots.

In accordance with the foregoing slot coupling the systems are locked to a desired working mode of operation affording high frequency stability with large amounts of energy stored in the coaxial cavity resonator. Other modes, however, referred to as "degenerate" modes of the TE or TM designation exist in this coaxial resonator. Suggested suppressors in the prior art have included a quarter wave circular choke provided within an end cover adjacent to and coaxial with the anode wall. The interior of the choke is lined with a lossy material such as iron or carbon to absorb the degenerate modes.

Additionally, with such modes the vane and slot system behaves in a manner analogous to a helix or delay line slow wave structure and energy is propagated in the common boundary wall as a traveling wave. Nearly all the undesired wave energy is stored in the slots. The structure is reentrant and mode instability can result due to oscillation feedback around the anode wall. These oscillations are generally at lower frequencies than the desired operating mode and start at lower values of applied voltage. In short pulse operating conditions these oscillations can start up on the leading edge of the pulse before the required applied voltage level for the desired operating mode. This mode instability leads to a problem of long standing, namely time jitter. The excellent frequency stability, long life and other advantages of coaxial magnetrons have, therefore, not been widely available for short pulse radar systems to cover wide frequency ranges.

In the prior art numerous slot mode absorbers have been suggested to suppress the undesired oscillation modes stored in the anode wall slot system. Typically, such structures include a lossy ring-shaped ceramic member disposed adjacent the ends of the slots coupling the inner and outer resonator systems. In addition to the previously cited patent, another exemplary prior art structure incorporates a mode suppressor ring pinned to a magnetic pole piece adjacent to the slotted anode wall is shown in U.S. Pat. No. 3,169,211 issued Feb. 9, 1965 to J. Drexler et al. In another structure exemplifying the prior art described in U.S. Pat. No. 3,412,284 issued Nov. 19, 1968 to George E. Glenfield a slot mode absorber is provided with an axially

coextensive metallic sleeve bonded in a thermally conductive manner to the ceramic ring to more effectively conduct heat to an adjacent heat sink.

Still another slot mode absorber is disclosed in U.S. Pat. No. 3,231,781 issued Jan. 25, 1966 to M. F. Liscio wherein the annular mode absorber is pinned to the anode structure of an inside-out or reverse magnetron with an internal coaxial $TE_{0,1,1}$ cavity resonator. Another example of the prior art is shown in U.S. Pat. No. 3,471,744 issued Oct. 7, 1969 to G. G. Pryor wherein the slot mode absorber is ring-shaped and formed by a plurality of lossy segments retained within a channel member affixed to the anode wall to provide for thermal expansion.

All of the prior art slot mode absorber structures for either conventional or inside-out coaxial magnetrons are fixed in position adjacent to the ends of the slots. Since such lossy structures which penetrate a portion of the slots have an adverse effect on the circuit efficiency only a 2-4 percent loss is usually tolerated. In tunable coaxial magnetron devices the overall frequency range is limited by the maximum suppression condition to prevent a deterioration of overall performance. The range of such devices has not been measurably improved by the fixed position slot mode absorbers. In addition, the power output over a wide frequency range cannot be maintained at a constant level between the upper and lower limits due to the varying effect of the absorber material relative to the tuning means. A need arises, therefore, for an improved slot mode absorber in coaxial magnetrons to permit greater suppression of undesired modes than has heretofore been possible over broad frequency ranges.

SUMMARY OF THE INVENTION

In accordance with the teachings of the present invention a tunable slot mode absorber is provided for coaxial magnetrons. A unique feature resides in the variable positioning of absorber material, such as a carbonized ceramic within a larger portion of the anode slots over a selected portion of the frequency range. In either configuration with the $TE_{0,1,1}$ coaxial cavity resonator external to the central cathode or internal within the anode common wall the absorber traverses a predetermined region of a tunable band by being picked up to travel in consort with a plunger type tuning assembly. A varying amount of energy absorbing material is thereby exposed within the slots coupling the respective resonant systems.

In an illustrative embodiment the slot mode absorber ring member is spring loaded and a pin-guided mechanical spider structure supported by the tuner magnetic pole piece member is actuated when the main bellows-controlled tuning means reaches a predetermined point approaching the high end of the tuning range. In this position the tuning member is closer to the opposing wall of the coaxial cavity resonator in the region where shunt capacitances tend to terminate RF fields in those modes which have energy stored in the slots. In an X-band device tunable from 8,500 MHz to 9,600 MHz a point at approximately 9,200 MHz was determined to be optimum for actuating movement of the absorber material adjacent to the ends of the slots.

Exemplary of the frequency-dependent variable distance for insertion of the absorber the distance

between the bottom edge of this member and the top of the anode vanes varied up to approximately 0.100 inch closer at the high frequency end than at a fixed position near the lower frequency limit over a range of approximately 400 MHz. The depth of penetration of the lossy material is therefore efficiently maintained to provide for greater suppression of slot modes over wider bandwidths. The effect on mode instability is improved by 4-5:1 over fixed position slot mode absorbers and time jitter readings of less than 5 and 10 nonoseconds are attainable.

In combination with the TE degenerate mode suppression means the new slot mode absorber serves as a power leveling device by presenting losses to the working $TE_{0,1,1}$ mode in the area of the tuning means where power outputs are undesirably high. Further, in combination with absorbing material carried by the tuning means to "overshadow" the slot mode absorbing means the shunt capacitance effect due to the presence of the tuning means in the cavity resonator is overcome. With little additional cost coaxial magnetrons of high mode stability and wide tuning ranges are possible along with the excellent frequency stability and long life.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is a detailed vertical cross-sectional view of the embodiment;

FIG. 2 is an enlarged cross-sectional view of the tuner pole piece assembly including the slot mode absorber;

FIG. 3 is an enlarged end view of the assembly shown in FIG. 2;

FIG. 4 is a cross-sectional view of the tuner actuating mechanism and the slot mode absorber actuating means;

FIG. 5 is a cross-sectional view of the tuner actuating mechanism and the slot mode absorber assembly;

FIG. 6 is a fragmentary cross-sectional view of a tuning ring member incorporating alternate absorber means; and

FIG. 7 is a partial detailed cross-sectional and partial elevational view of an inside-out magnetron embodying the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings the illustrative embodiment in FIG. 1 comprises a coaxial magnetron 10 having an envelope 12 defined by upper and lower annular cover members 14 and 16 hermetically sealed to outer cylindrical wall member 18. A plurality of anode vane elements 20 supported at their base end by common boundary wall 22 extend radially inwardly and define therebetween cavity resonators of the inner resonant system circumferentially disposed about a central cathode emitter 24. The cathode 24 is supported by cylindrical member 26 which is in turn supported at its outer end by tubular member 28. Member 28 is secured to magnetic pole piece member 30. Electric leads for energizing the cathode heater 32 as well as the high voltage leads for applying the electric field potentials to operate the device extend within member 28.

The inner resonant system is designed to operate in the pi-mode of oscillation over the frequency range which is determined by the outer coaxial resonant system.

The magnetron magnetic circuit in addition to the pole piece member 30 includes oppositely disposed inner pole piece member 34 and external C-shaped permanent magnets 36 contacting pole piece adapters 38. Two such external magnets are commonly provided and extend from opposite sides. The magnetic field extends parallel to the axis of the cathode 24 in the interaction region. The electric field also extends transverse to the magnetic field force lines in this region in the manner well known in the art for crossed field devices.

An outer coaxial cavity resonator 40 is defined by cylindrical wall 18 and the common boundary anode wall 22 together with the covers 14 and 16. The dimensions of the cavity resonator 40 are selected to provide resonant frequencies over a predetermined frequency band in the $TE_{0,1,1}$ working mode. Slots 42 in wall 22 permit the coupling and locking of the pi-mode oscillations of the inner system with the $TE_{0,1,1}$ resonant modes in the coaxial cavity 40. The degenerate TE and TM modes are suppressed by an annular lossy member 44 in end cover 14 and member 46 in a quarter wave channel choke section 48 in end cover 16. Such materials as carbonized alumina ceramic, barium titanate, and ferrites may be advantageously employed for suppression members 44 and 46.

Coaxial resonator 40 is coupled through iris 50 and dumb-bell or substantially H-shaped transformer section 52 to a utilization load by means of output waveguide section 54. The waveguide 54 and transformer 52 sections are supported by and inserted within the outer cylindrical wall 18. The remainder of the coaxial magnetron structure comprises cooling fins (not shown), an exhaust tubulation 56 in wall 18, mounting plate 58 to support the device in a system and anchor plate 60 and screw means 62 adjacent wall 18 to secure the C-shaped magnets to the envelope 12.

To tune the generated output energy over the frequency band an axially translated tuning ring 64 is actuated by a tuner mechanism such as a meshing gear and ball bearing structure 70. Post members 72 with screws 74 secure the tuning ring to the threaded tuner shaft 76. A deformable bellows arrangement 78 extends between fixed upper plate member 80 secured to the tuner mechanism and a movable plate and tuner post support member 82 to preserve the vacuum condition within the envelope. The inner portion of member 82 is provided with an adjustable tuner adapter member 84 threadably secured to shaft 76 to couple the absorber pick up means to the tuner mechanism.

The description now proceeds to a discussion of an embodiment of the movable slot mode absorber assembly 90 in accordance with the teachings of the invention with reference being directed to FIGS. 2-5 inclusive. To assist in an understanding of the invention two stages of operation of the assembly 90, namely, the rest position and after pick up by the main tuner mechanism 70, are illustrated in FIG. 1. Those components which are involved in movement are shown in a different position on the right-hand side and have been designated with the suffix *a* after the applicable reference numerals to indicate the tuning position.

Slot mode absorber assembly 90 is movably disposed adjacent to the ends of slots 42. The assembly is supported by inner pole piece member 34 and downward axial displacement results in the introduction of additional lossy material within the upper ends of the slots 42. The slot mode absorber means include a ring-shaped lossy ceramic member 92 carried by sleeve member 94 of a refractory metal, such as molybdenum. The lossy absorbing rind member 92 may, illustratively, be formed from alumina or beryllium oxide material that is porous and is impregnated with carbon formed by firing in a hydrogen atmosphere a coating of a sucrose solution ($C_{12}H_{22}O_{11}$).

Lossy ring member 92 is brazed to sleeve member 94 and the components are supported by a mechanical spider arrangement including pin-guiding members 98 secured to plate member 100 with the pins introduced within passageways 102 in four quadrants of the pole piece member 34. The absorber assembly is maintained under tension by means of a high temperature spring 104 urging against shield member 106. The shield member is in turn affixed and secured to pole piece member 34 adjacent to the end of the cathode assembly 24. The spring forces the absorber assembly upwards to insure proper return to the rest position after a tuning excursion. In an exemplary embodiment a spring member of 10 percent tungsten and 90 percent tantalum alloy metal having a load factor of from 6-10 pounds was employed. At a predetermined point in the tuning band the adapter member 84 contacts plate member 100 and compresses spring 104 thereby carrying absorber member 92 in consort with the main tuning mechanism 70. The lower limit of the axial travel is fixed by member 82 contacting the upper end of pole piece member 34. A varying amount of lossy material to absorb the undesired slot mode energy is thus provided over high end of the tuning band where the tuning ring 64 is closer to end cover 16.

Referring now to FIG. 2 and Table I the operation of the device will be described.

TABLE I

Position of Absorber Relative to Anode Vane

Frequency (MHz)	Distance (inches)
8500	0.225
9220	Absorber pick up point
9600	0.125

In the exemplary embodiment the slot mode absorber at its furthestmost point at the low end of the band is spaced a distance of 0.225 inch from the vane 20. In this application for X-band the pick up point was determined to be 9,220 MHz. Other points may be selected for other frequencies or the entire slot mode absorber assembly can be arranged to be carried by the adapter member 84 to have the lossy material exposed throughout the tuning ring 64 excursion.

Pole piece member 34 is clearly shown in FIG. 3 and the passageways 102 are shown in each of the quadrants to accommodate the guide four pins 98. FIG. 4 illustrates the tuner mechanism 70 with the outer shell member 108 and top cover 110 secured to end cover 14. FIG. 5 shows the complete tuner mechanism coupled with the slot mode absorber assembly 90.

In FIG. 6 an alternative tuning ring member 64' is shown having an annular lossy ring member 112 adjacent to the inner diameter of this member. The disposition of lossy material will assist in leveling the output power even in the working mode by reducing the capacitive effect of the tuning ring member in cavity 40 as it approaches end cover 16 for even greater mode suppression.

Referring to FIG. 7 an alternative embodiment is shown referred to in the art as the "reverse", "inside-out" or "inverted" magnetron. Hermetically sealed envelope 12 includes a common boundary anode wall 22 with the vane elements 20 extending radially outwardly toward a cathode emitter 114. Interaction region 116 provides the π -mode oscillations and is bounded by cover members 14 and 16 and cylindrical wall member 18. Wall 22 encloses an inner coaxial cavity resonator 118 which operates in circular electric modes. Slots 42 permit coupling of the outer π -mode oscillations with the inner resonator 118.

The energy is coupled through an iris and impedance transformer section 120 to a load through window 122 in waveguide 124. Magnets 36 again provide the magnetic field circuit in region 116 for the outer anode-cathode resonator system. A tuning plate 126 tunes the generated output and is axially actuated by a gear mechanism 70 similar to the structure illustrated in FIG. 1. Bellows 130 contacts movable support member 132 secured to a tuner post 134. The lossy slot mode absorber ring 136 is carried by movable member 138 secured to support member 132 to provide for the introduction of the lossy material in a varying amount in the slots 42 during axial excursion of the tuning plate 126. Spring 140 provides the tensioning to insure return of the slot mode absorber assembly to the rest position. The principal variation then in the inside-out embodiment is the inversion of the movable components to suppress the slot modes from one side of wall 22 to the other side.

Other variations include movement of an additional slot mode absorber on the other side of the common boundary wall within the coaxial cavity to overlap and overshadow the absorber ring in the inner resonant system at a predetermined portion of the tuning range. With this additional absorber, the capacitance effect of the tuning ring in terminating RF energy in those modes which have energy stored in the slots at the point of tuner location is further reduced. Still further variations, alternations or modifications in the disclosed structure will become apparent to those skilled in the art. It is intended, therefore, that the foregoing description of the illustrative embodiments be considered in the broadest aspects and not in a limiting sense.

I claim:

1. A crossed field device comprising:

a resonant system including a plurality of spaced anode members supported by a boundary wall defining therebetween a plurality of cavity resonators and a cathode member to generate high frequency oscillations in the pi-mode; means including said boundary wall defining a coaxial cavity adapted to be resonant in a predetermined electric and magnetic field mode;

said boundary wall having a plurality of axially extending slots coupling high frequency energy in said anode-cathode cavity resonators to said coaxial cavity;

means comprising a slot mode absorber assembly including a member of a lossy material movably disposed adjacent to the ends of said coupling slots to suppress energy stored therein capable of generating oscillations in modes other than said resonant mode; and

means for axially translating said assembly over a predetermined tuning range to expose a varying quantity of said lossy material to the energy within said slots.

2. The device according to claim 1 wherein said lossy material member comprises a carbonized ceramic member.

3. The device according to claim 1 wherein said coaxial cavity is external to the anode-cathode resonant system.

4. The device according to claim 1 wherein said coaxial cavity is internal within said anode-cathode resonant system.

5. A crossed field device comprising:
 a resonant system including a plurality of spaced anode vane members supported by a cylindrical boundary wall defining therebetween a plurality of cavity resonators and a cathode member to generate high frequency oscillations in the pi-mode;

means including said boundary wall defining a coaxial cavity adapted to be resonant in a predetermined electric and magnetic field mode over a frequency band;

said boundary wall having a plurality of axially extending slots coupling high frequency energy in said anode-cathode cavity resonators to said coaxial cavity;

means including an axially translated tuning member disposed within said coaxial cavity to vary the resonant frequency;

means comprising a slot mode absorber assembly including a ring-shaped member of a lossy material movably disposed adjacent to the ends of said coupling slots; and

means for moving said lossy material in consort with said cavity tuning means over a portion of said band to expose a varying quantity of said lossy material to energy stored within said slots.

6. The device according to claim 5 wherein said slot mode absorber assembly is carried over the portion of the band approaching the upper limit.

7. A coaxial magnetron comprising:
 an anode member having a plurality of spaced vane members supported by a boundary wall and defining therebetween cavity resonators;
 a cathode member;

means including said boundary wall defining a resonant cavity disposed coaxially to said anode

member;

means for producing transverse electric and magnetic fields;

said boundary wall having a plurality of axially extending slots coupling said cavity resonators and coaxial cavity;

a tunable slot mode absorber assembly having a member of a lossy material movably disposed adjacent to the ends of said slots; and

means for translating said assembly axially to vary the amount of said material exposed within said slots over a predetermined frequency range.

8. A coaxial magnetron according to claim 7 wherein said slot mode absorber assembly is axially translated by a tuner mechanism including spaced pin guiding members.

9. A coaxial magnetron according to claim 7 wherein said lossy material member is maintained under tension by a spring member adapted to return same to a rest position after a tuning excursion.

10. A coaxial magnetron comprising:
 a cylindrical anode member having a plurality of spaced vane members extending radially from a boundary wall and defining therebetween cavity resonators;

a cathode member;

means including said boundary wall defining a resonant cavity disposed coaxially to said anode member;

means for tuning the frequency of said coaxial cavity; means for producing transverse electric and magnetic fields;

said magnetic field producing means including inner pole piece members disposed on opposing sides of said cavity resonators for directing the magnetic field parallel to the axis of said cathode member;

said boundary wall having a plurality of axially extending slots coupling said cavity resonators to said coaxial cavity;

a tunable slot mode absorber assembly having a member of a lossy material movably disposed adjacent to the ends of said slots; and

means supported by one of said pole piece members for translating said assembly in consort with said coaxial cavity tuning means over a portion of said tuning range to expose a varying amount of said material within said slots and absorb energy stored therein.

11. A coaxial magnetron according to claim 10 wherein said absorber assembly is picked up and carried over a predetermined portion of the tuning excursion of said coaxial cavity tuning means.

12. A coaxial magnetron according to claim 10 wherein said coaxial cavity includes end walls with lossy mode absorbing material disposed therein.

13. A coaxial magnetron according to claim 10 wherein said lossy material member is urged upwardly in the rest position by a spring member of a refractory metal.

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