June 7, 1966 W. C. SYLVERNAL 3,255,377

REVERSE MAGNETRON WITH CATHODE SUPPORT STRUCTURE

Filed Aug. 27, 1962 2 Sheets-Sheet 1

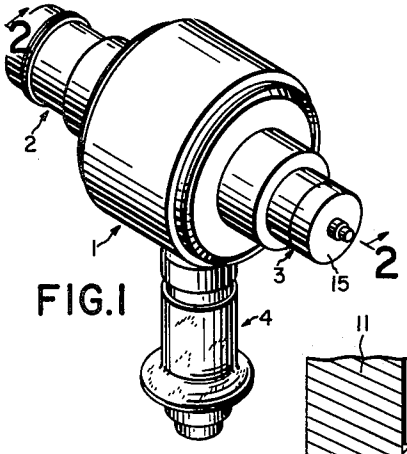
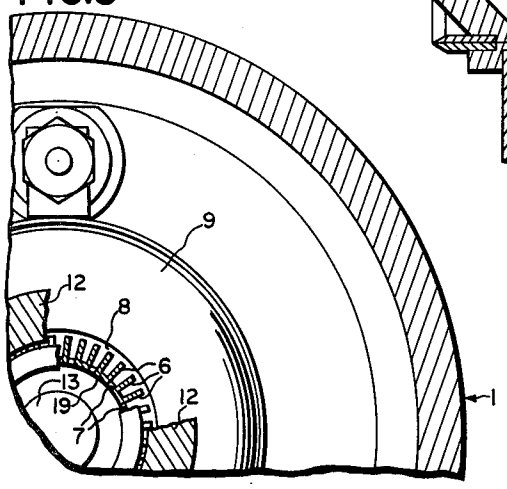


FIG.1

FIG. 2

FIG.3



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FIG.4

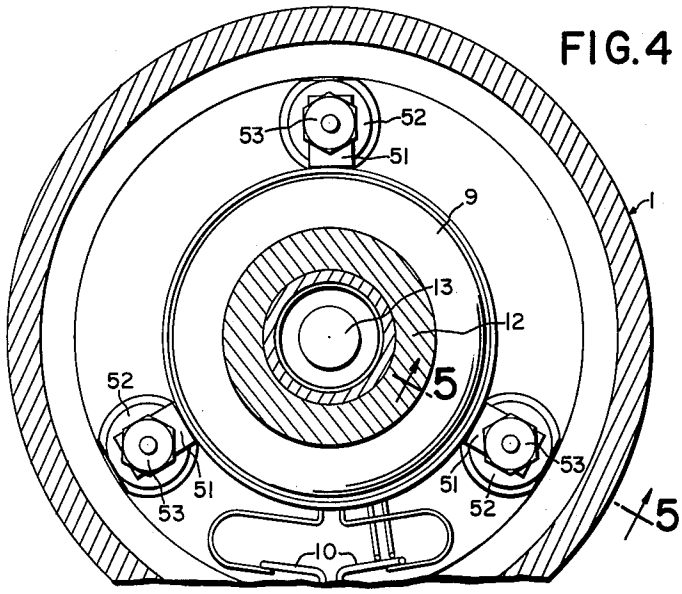


FIG.5

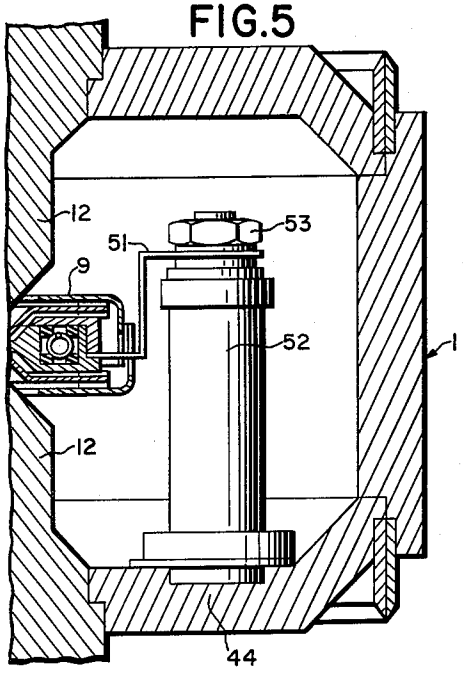
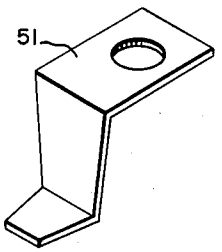


FIG.6



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REVERSE MAGNETRON WITH CATHODE SUPPORT STRUCTURE

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The present invention relates in general to electron discharge devices of the crossed electric and magnetic field type and more specifically to a reverse magnetron useful for generating high power microwave energy at extremely high frequencies such as required in high power, high resolution radars.

A reverse magnetron tube typically comprises a circular electric mode cavity or circular electric mode wave propagating structure surrounded by a circumferential array of outwardly directed vane or cavity resonators coupled to the excited circular electric structure via a circular array of axial slots communicating with alternate anode resonators. The array of anode resonators are surrounded by a magnetron interaction region formed by an annular cathode emitter emitting radially inwardly into the anode, in the presence of a strong axial magnetic field. Rotating spokes of electron space charge interact with the π mode fields of the anode resonators to excite the circular electric mode in the circular electric mode cavity. Since the stored energy of the circular electric mode cavity is much higher than that of the vane resonator circuit, the anode vane resonator system is locked in the π mode to the circular electric cavity mode thereby stabilizing the magnetron. The reverse magnetron structure may be used as an oscillator or as an amplifier and microwave energy is extracted from the circular electric mode wave propagating structure or cavity and fed to a suitable load.

Heretofore a reverse magnetron of the above described type has been built operating at approximately 35 gigacycles and generating a peak power of approximately 150 kilowatts with an average R.F. power of 75 watts. When an attempt was made to achieve this performance on a reproducible basis a severe problem was encountered which prevented attaining these specifications.

The aforementioned problem associated with pushing the power output of the prior art reverse magnetron design to higher power levels is that the ring cathode emitter support failed to assure concentricity with the anode during the relatively large radial thermally produced expansions of the cathode emitter, in use, resulting in failure of the tube.

The reverse magnetron tube of the present invention solves the aforementioned difficulty associated with the prior art tube and provides a 32–35 gigacycle magnetron having a peak power output in the order of 290 kilowatts with average power output of approximately 50 watts while yielding overall efficiencies of approximately 30% and a tunable bandwidth of 12%. This tube represents more than an order of magnitude increase in peak power output with approximately double the previously obtained efficiency while having a long operating life in excess of 2,400 hours.

The principle object of the present invention is to provide an improved high power reverse magnetron tube yielding substantially enhanced peak power with increased efficiency and operating life.

One feature of the present invention is the provision of a cathode support structure wherein a cathode emitter ring is supported from an insulating structure via the intermediary of a spring structure serving to radially position and support said emitting ring with respect to said insulator structure and a concentric anode structure,

thereby permitting relatively large radial motions between said insulator structure and said cathode emitter ring while maintaining concentricity between the anode structure and the cathode structure.

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

FIG. 1 is an outside perspective view of the reverse magnetron tube of the present invention,

FIG. 2 is an enlarged fragmentary view partly broken away and partly in section of the structure of FIG. 1 taken along the line 2—2 in the direction of the arrows,

FIG. 3 is a fragmentary view partly in cross-section and partly broken away of the portion of the structure of FIG. 2 taken along the line 3—3 in the direction of the arrows,

FIG. 4 is a cross-sectional view of the structure of FIG. 2 taken along the line 4—4 in the direction of the arrows,

FIG. 5 is an enlarged cross-sectional view of a portion of the structure of FIG. 4 taken in the direction of the arrows 5—5, and

FIG. 6 is an enlarged perspective view of a portion of the structure of FIG. 5 delineated by line 6—6.

Referring now to FIGS. 1, 2 and 3, character 1 represents the hollow tubular supporting body of the reverse magnetron, as of copper, to which other parts are brazed or otherwise suitably fastened to form a structure capable of being evacuated. On opposite sides of the body 1 in axial alignment there are brazed to the body 1 a tubular output waveguide assembly 2 and tuner assembly 3. Cathode lead-in insulator structure 4 extends outwardly from the main body or section 1 in quadrature with the axially aligned output waveguide and tuner structures 2 and 3, respectively.

The term circular electric mode cavity as used herein is defined to mean a cavity formed, dimensioned, and excited in such a manner as to support at its certain preselected operating frequency a certain circular electric mode, of the general form $TE_{0,m,n}$ to the exclusion of other modes. A circular electric mode cavity typically includes an outer cylindrical side wall and may or may not have an axially directed center conductor.

A circular electric mode cavity 5 is disposed centrally of the anode body 1 on the axis of the tube. In amplifier embodiments of the present invention the circular electric mode cavity 5 is replaced by a circular electric wave propagating wave structure such as, for example, a hollow cylindrical pipe having an input port as well as an output port. A circumferential array of outwardly directed vanes 6 surround the circular electric mode cavity 5 and form an array of anode resonators by the spaces between adjacent vanes 6. Alternate anode resonators are electromagnetically coupled to the circular electric mode cavity 5 via an array of axially directed slots 7 communicating through the common wall between the anode resonators and the circular electric mode cavity 5. A magnetron interaction region 8 surrounds the outer tips of the vanes 6 and is defined by the space inbetween the vanes 6 and surrounding cathode emitter ring 9.

A strong axial magnetic field for the magnetron interaction region 8 is provided by a magnet 11, only partially shown in FIG. 2, enveloping the anode body portion 1 and having a re-entrant internal magnetic gap extending in the axial direction through the magnetron interaction region between the magnetic pole pieces 12 disposed on opposite sides of the anode vanes 6.

Tuning of the tube over its approximate 12% tuning band, centered at approximately 34 gigacycles, is obtained by means of axial translation of a combined cavity

end wall and output coupling plate **13** carried upon the end of an axially directed and positioned rod **14** which is axially translatable via the intermediary of a captured nut **15** and bellows assembly **16**, partially shown.

The negative cathode potential of approximately 23 kv. is applied to the cathode emitter **9** via high voltage lead-in insulator assembly **4**. The cathode **9** uses a low voltage A.C. filament heater and therefore a dual wire cathode lead-in **10** is used.

In operation, the π mode of the magnetron interaction region is locked to the circular electric mode resonator **5** via the intermediary of the coupling slots **7** serving to drive the resonator **5**. An annular slot mode absorber **24**, juxtapositioned the coupling plate end of the slots **7**, suppresses the undesired slot modes. Output energy from the resonator **5** is extracted via the coupling plate **13** and transmitted to the load, not shown, via the intermediary of the circular electric mode output waveguide structure **2** and output wave permeable window **17**.

The tube structure and mode of operation will now be described in greater detail as it specifically relates to each of the before mentioned features of the present invention.

The novel cathode emitter support feature of the present invention can best be seen by further reference to FIGS. 4, 5 and 6. The cathode emitter support structure is characterized by the provision of a plurality of spring fingers serving to support the cathode emitter ring **9** from its outer periphery at spaced apart points. The spring fingers in turn are fixedly secured to the tube body **1** via the intermediary of a plurality of a suitable stand-off insulators.

More specifically, in a preferred embodiment three S-shaped spring fingers **51**, spaced at 120° intervals about the periphery of the cathode emitter **9**, serve to carry the cathode emitter **9** from similar foot portions of the spring fingers **51** as by spot welding or riveting. The outer end portions of the spring fingers **51** are clamped to the end of elongated tubular high voltage cathode to anode stand-off insulators **52** via the intermediary of a plurality of nuts **53** serving to capture the spring finger **51** between the nut **53** and a cap on the hollow cylindrical insulator **52** as of alumina ceramic. The insulator **52** is generally axially directed of the tube apparatus and is fixedly secured, at the end opposite to the spring finger to the transverse header wall **44** of the tube envelope **1**.

In a preferred embodiment all of the spring fingers **51** are made as nearly identical as possible out of relatively thin refractory metal such as, for example, 0.010" thick molybdenum sheet. The spring fingers are also preferably cut from the sheets stock with the metallic grain in each of the fingers being substantially similarly directed to the finger in each instance. Also, the fingers **51** are heat treated for removing residual stresses therein.

During assembly of the tube apparatus the cathode emitter **9** is properly concentrically aligned with respect to the array of anode resonators and then nut **53** is tightened down such as to hold the springs **51** with the established concentricity.

In a typical reverse magnetron tube of the present invention operable at 35 gigacycles and utilizing 120 vane resonators, the cathode emitter ring **9** has an inside diameter of 1.109" with an anode to cathode spacing of 0.012". The anode-cathode concentricity is maintained within ± 0.0005" over a range of radial expansion of 0.003" of the inside diameter of the emitting ring **9** to prevent uneven heating of the anode due to loss of concentricity which would otherwise result in evaporation of the anode, lower efficiency and reduced tube operating life. Cathode supports constructed in the above manner have permitted extension of the operating life of the tube to in excess of 2400 hours.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In a magnetron, a circumferential array of anode resonators, a cathode emitter ring surrounding said anode resonators in radially spaced apart relation, a relatively rigid evacuable tube envelope structure enveloping said anode resonators and said cathode emitter, an anode to cathode insulator for holding off the potential applied to said cathode with respect to that applied to said anode, and a spring structure radially positioning and supporting said emitter ring with respect to said anode resonator array from said tube envelope structure for maintaining concentricity of said anode resonator and said cathode emitter while permitting relative radial motion between said cathode emitter and said envelope structure.

2. In a magnetron, a circularly directed anode structure, a cathode emitter concentrically mounted of said anode structure in radially spaced apart relation, an evacuable tube envelope structure enveloping said anode and cathode, an anode to cathode insulator structure radially outwardly spaced from said cathode emitter ring for holding off the potential applied to said cathode with respect to that applied to said anode, and a plurality of peripherally spaced apart generally axially directed spring fingers connected to said cathode emitter ring for supporting said emitter ring in concentric relationship to said anode structure from said tube envelope structure and for maintaining the concentricity of said anode and cathode structures while permitting relative radial motion between said cathode emitter and said tube envelope.

3. The apparatus according to claim **2** wherein said cathode to anode insulator structure includes a plurality of axially directed cathode insulators and said spring fingers are carried from said envelope structure via the intermediary of said cathode insulators.

4. In a reverse magnetron apparatus, a cylindrical anode wall defining the cylindrical side wall of a circular electric mode cavity resonator, a circumferential array of vanes extending outwardly from one side of said anode wall and defining a plurality of anode resonators, a cathode emitter surrounding said circumferential array of anode resonators, means for producing a magnetic field directed axially of said anode resonators and said cathode emitter in the space between said cathode and anode vanes, a tubular evacuable envelope structure surrounding said cathode emitter and said anode wall, said tubular envelope structure having a pair of axially spaced apart transversely directed headers spaced apart on opposite sides of said cathode emitter with the cathode emitter disposed between said transverse headers, at least three elongated cathode insulators being fixedly carried from one of said transverse headers at circumferentially approximately equally spaced apart positions, said cathode insulators being axially directed of said cathode, and a generally axially directed leaf spring structure interconnecting said cathode emitter and said cathode insulators for positioning and holding said cathode emitter with respect to said tubular envelope structure.

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