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Elfe, Jr.

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[54] **HIGH-IMPEDANCE SLOW-WAVE PROPAGATION CIRCUIT HAVING BAND WIDTH EXTENSION MEANS**

[75] Inventor: **Thomas B. Elfe, Jr.,** Gainesville, Fla.

[73] Assignee: **Sperry Rand Corporation,** Great Neck, N.Y.

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[52] **U.S. Cl.**.....**315/3.5,** 315/3.6, 333/31 A

[51] **Int. Cl.**.....**H01j 25/34**

[58] **Field of Search**.....315/3.5, 3.6, 39.3; 333/31 A

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Primary Examiner—Herman Karl Saalbach
Assistant Examiner—Saxfield Chatmon, Jr.
Attorney—Howard P. Terry

[57] **ABSTRACT**

A slow traveling wave bar and ring high frequency transmission line energy propagation structure for traveling wave tubes is supported by a novel electrically isolating, thermally conducting array of support elements coaxially within a shell having spaced longitudinally extending conductivity perturbations.

5 Claims, 3 Drawing Figures

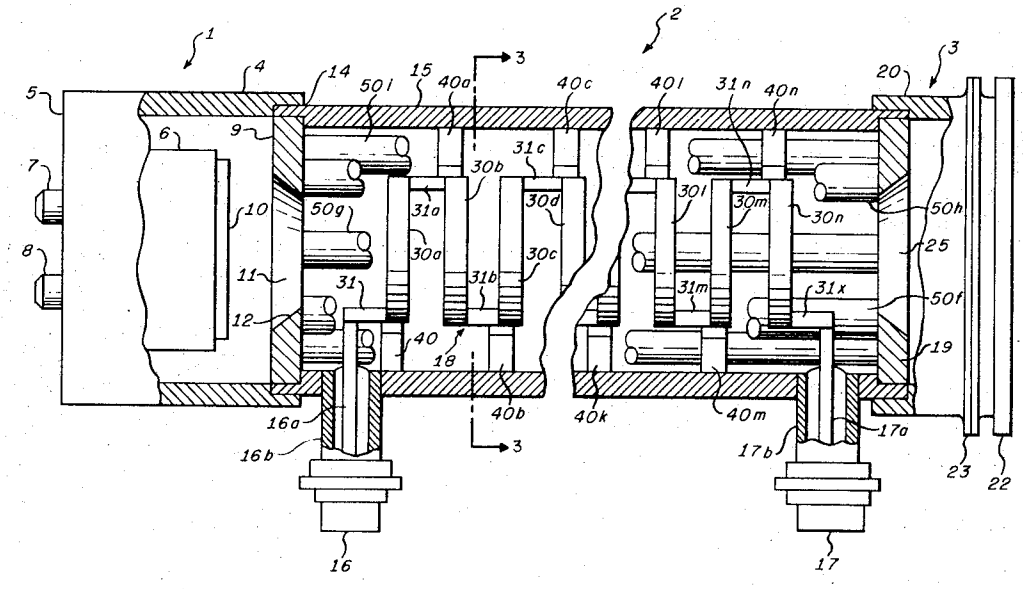
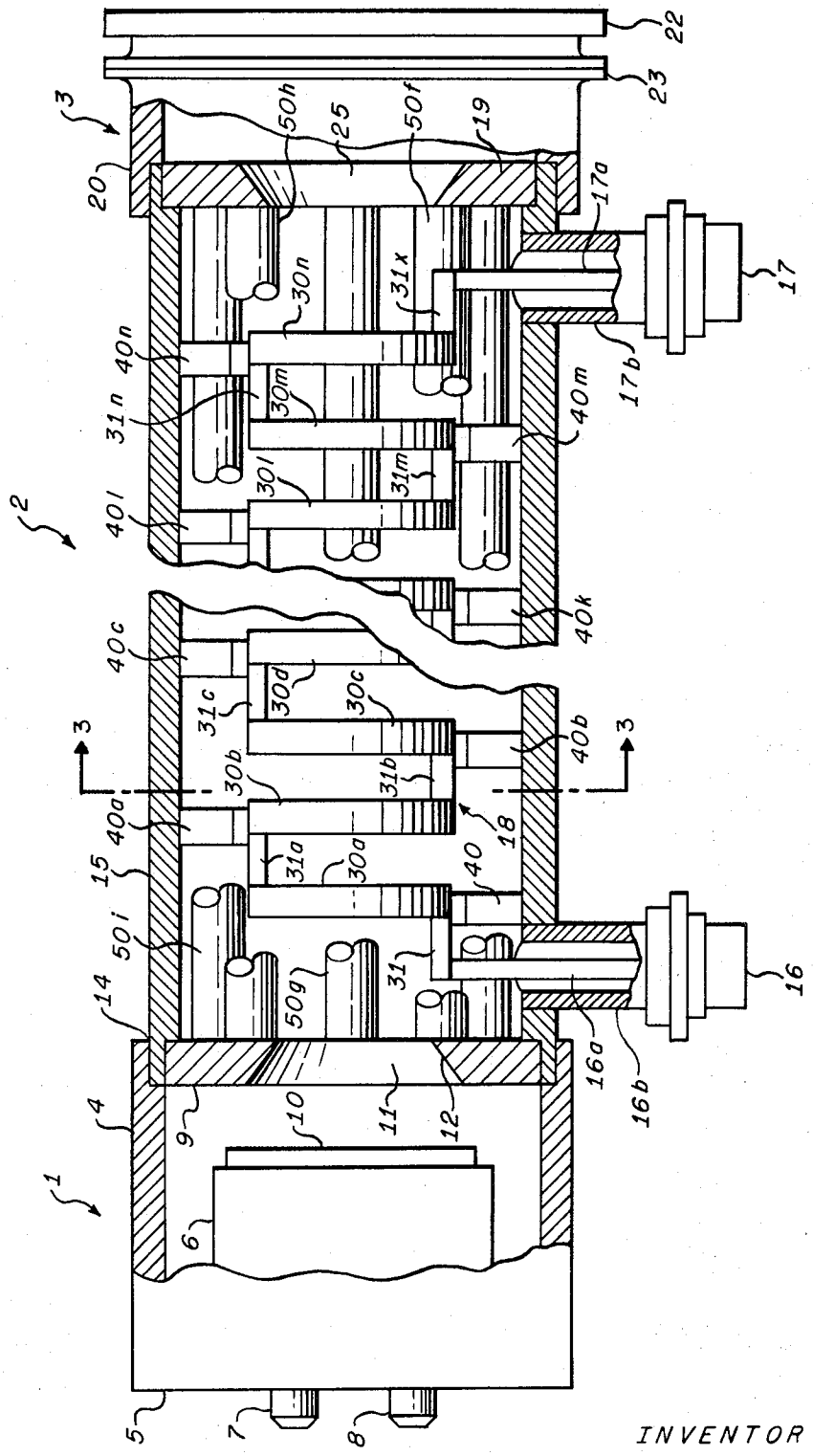


FIG. 1.



INVENTOR
THOMAS B. ELFE JR.
BY
ATTORNEY

FIG. 2.

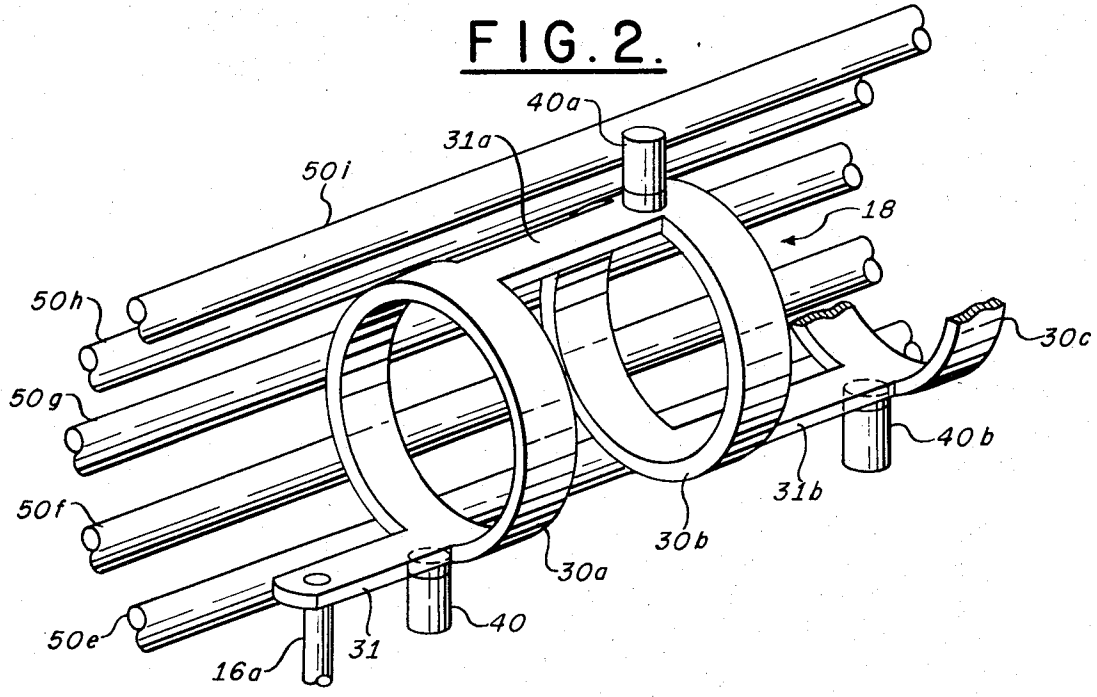
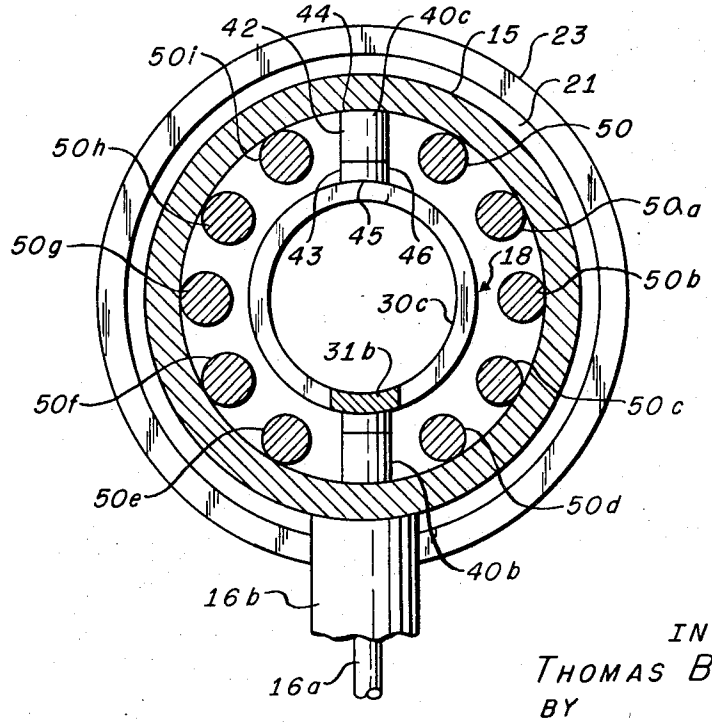


FIG. 3.



INVENTOR
THOMAS B. ELFE JR.
BY
H P Jerry
ATTORNEY

HIGH-IMPEDANCE SLOW-WAVE PROPAGATION CIRCUIT HAVING BAND WIDTH EXTENSION MEANS

The invention herein described was made in the course of or under a contract or subcontract thereunder with the Department of Navy.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention pertains to slow wave propagation structures particularly adapted to use in traveling wave electron beam power amplifiers and oscillators and more particularly concerns ring and bar transmission line structures for traveling wave tubes having desirable impedance characteristics along with relatively low dispersion characteristics over a broad operating frequency band.

2. Description of the Prior Art

Generally, prior art electron beam traveling wave tubes having interaction structures of the ring and bar or derived-helix type have presented relatively narrow band operating characteristics, especially when the slow wave interaction structures have been supported by conventional stub transmission line support elements. When otherwise supported, such devices have been limited as to operating power levels through lack of adequate cooling of the ring and bar structure, and also have generally either been limited in band width by dispersion or have presented unfavorably low impedance characteristics. For these and other reasons, moderate to high power operational levels over relatively broad frequency operating bands have not been readily achieved in compact, light weight traveling wave tubes using conventional bar and ring and analogous slow wave transmission line structures.

SUMMARY OF THE INVENTION

The present invention relates to slow wave transmission line systems particularly adapted to use in moderate to high power traveling wave tubes. In the invention, a slow wave bar and ring type of transmission line is supported by a novel electrically isolating, thermally conducting array of support elements coaxially within a vacuum shell of conductive material for providing relatively high impedance characteristics to the transmission line. The interior surface of the shell is modified with regularly spaced longitudinally extending perturbations for satisfactorily reducing the dispersive characteristics of the transmission line system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a partially cross sectioned view of a vacuum tube embodying the invention.

FIG. 2 is a fragmentary orthogonal view of a central portion of the structure of FIG. 1.

FIG. 3 is a cross section view taken along the line 3—3 of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1, there is illustrated a traveling wave vacuum tube of the high frequency or microwave kind having a cathode assembly 1 for producing a collimated beam of electrons, a high frequency interaction region 2 in which the kinetic energy of the electron beam may be partially converted into very high frequency signals propagating on a slow wave propagation medium, and an electron beam collector assembly 3 wherein the remaining kinetic energy of the electron beam may be converted to heat.

The cathode assembly 1 includes a cylindrical shell 4 forming part of the vacuum envelope of the tube, being further closed by a suitable disk-shaped closure at its end 5. The device at end 5 supports a cathode assembly 6 within the interior of shell 4. Interior connections to the cathode and heater elements (not shown) within cathode assembly 6 are made through conventional electrically conductive pin connectors 7 and 8 projecting through closure 5. An acceleration electrode 9 is positioned within shell 4 opposite closure 5 adjacent the emitting surface 10 of cathode 6, the anode 9 having a central opening 11 and forming in combination with cathode 10 an electron gun assembly for directing the electron beam along the longitudinal axis of the high frequency tube. In the event that a converging electron beam is employed, as in magnetically focused tubes, the aperture 11 in anode 9 may be tapered, as indicated by the taper of annular surface 12.

The vacuum shell 4 and anode 9 are mutually fastened by welding or brazing in the vicinity of annular junction 14 to a further portion of the vacuum envelope of the tube in the form of the extended hollow cylindrical shell 15. Shell 15, as will be further discussed, encloses the novel slow wave propagation structure 18 of the present invention and is penetrated by a high frequency input transmission line system 16 and a high frequency output transmission line system 17 for the respective purpose of supplying high frequency energy to be amplified to a first end of the slow wave propagation transmission line 18 and of abstracting amplified high frequency energy therefrom at its opposite end. The end of hollow cylinder or shell 15 opposite cathode 10 is partially closed by the end wall 19, wall 19 having an aperture 25 through which the electron beam is projected into electron beam collector 3. The apertured wall 19 and a tubular wall 20 form a further extension of the vacuum envelope of the tube and are sealed adjacent annular junction 21 by welding or brazing. The cylindrical tube 20 is closed in a vacuum tight fashion at its end opposite apertured wall 19 by a solid disk 22 which may be sealed to tube 20 at annular junction 23, for example.

The cathode assembly 6 employed in the invention is of generally conventional character and may be selected from one of the types of electron beam forming cathodes which have been employed in various forms in prior art traveling wave tubes or klystrons. The electron beam collector 3, like the cathode 6, may take a conventional form, suitable forms for these elements being discussed, for example, in the U.S. Pat. No. 2,887,608, entitled: "Travelling Wave Tube," filed in the name of Warren D. McBee by the Sperry Rand Corp., and issued May 19, 1959. In magnetically focused forms of the traveling wave tube illustrated in FIG. 1, the apertured anode 9 and the apertured disk 19 may comprise magnetic pole pieces, thus forming part of a magnetic circuit for focusing the high current electron beam generated by cathode assembly 6. The electron beam collector 3, in the instance of relatively high power versions of the vacuum tube of FIG. 1, may

take the form of any of several electron beam collector configurations available in the prior art for dissipating relatively large amounts of unused electron beam energy or for providing more efficient operation of the apparatus by returning a major portion of the unused electron beam energy to the power source. Suitable depressed collector devices for the latter purposes are illustrated, for example, in U.S. Pat. No. 3,173,004, entitled "Depressed Collector Operation of Electron Beam Devices," issued Mar. 2, 1965 to R.J. von Gutfeld and C. C. Wang and assigned to the Sperry Rand Corp.

Referring now particularly to FIGS. **1** to **3**, the novel slow wave propagation structure **18** of the present invention will be described. The slow wave transmission line **18** may be constructed of molybdenum and consists of an extended series of ring shaped-conductors such as rings **30***a*, **30***b*, **30***c*, **30***d*, . . . , **30***l*, **30***m*, and **30***n*. The various rings **30***a* to **30***n* are substantially similar and are substantially equally spaced along the axis of the novel traveling wave tube so that they may be in energy exchanging relation with an electron beam projected along the axis of the tube. The several conductive rings **30***a* to **30***n* are joined by diametrically opposed or staggered conductive bars **31***a*, **31***b*, . . . , **31***n*. Thus, it is seen that the first conductive ring **30***a* is joined by a conductive bar **31***a* to the next succeeding ring **30***b*. In turn, ring **30***b* is joined by a bar **31***b* placed 180° from bar **31***a* to the third conductive ring **30***c*. Ring **30***c* is in turn joined by a conducting bar **31***c* aligned with bar **31***a* and therefore spaced 180° from bar **31***b*. The configuration, generally called a derived-helix propagation structure, continues in this manner with alternate bars joining rings at one annular location and other intermediate bars connecting rings 180° from the locations of the first set of bars.

Bar **31** at the input side of ring **30***a* is coupled conductively to the inner conductor **16***a* of the coaxial transmission line **16**, its outer conductor **16***b* being brazed or welded in vacuum tight fashion in an aperture in vacuum shell **15**. In a similar manner, the last ring **30***n* of the assembly of rings is joined to a bar **31***x* projecting toward the collector **3** of the tube, bar **31***x* being conductively joined to the inner conductor **17***a* of the output transmission line **17**. Outer conductor **17***b* is sealed in vacuum tight manner in a second aperture in the vacuum shell **15**.

It is thus seen that the ring and bar slow wave transmission line system **18** is partly supported within the envelope shell **15** by coaxial line conductors **16***a* and **17***a*. However, the major support for the slow wave transmission line system **18** is provided by the several novel stub support elements **40***a*, **40***b*, **40***c*, . . . , **40***k*, **40***l*, **40***m*, **40***n* found in two substantially regular arrays lying on diametrically opposite sides of slow wave line **18**. Elements **40***a* through **40***n* perform additional important electrical and other functions, since they electrically and thermally cooperate as parts of the transmission line system, as will be seen.

As is shown particularly in FIG. **3**, for example, each such stub support element consists of pairs of abutting collinear rods, such as the rods **42** and **43** which form the support element **40***c*, for example. The rod **42** consists of a material such as copper highly conductive for high frequency currents. On the other hand, the relatively short rod **43** preferably consists of a material having electrical insulating properties, but which is never the less a good heat conductor. The materials of rods **42** and **43** are such that a butt seal may be made by a conventional method between the two rods at junction **46**, while one end of the metal rod **42** is sealed in a conventional manner at face **44** to the inner surface of vacuum envelope shell **15**. Likewise, the electrically insulating, thermally conducting rod **43** is sealed in a conventional manner at face **45** extending partly over bar **31***e* and partly over ring **30***d*. Thus, the seal at face **45** is beneficially located in a region of low amplitude high-frequency electric field. Each stub support in the arrays of supports is similarly constructed, each being associated with its particular ring and bar.

Flow of heat from the several rings of the transmission line **18** is enabled by the novel configuration, while the transmission line system **18** is also electrically isolated thereby from other parts of the tube. Improved heat conduction from line **18** is provided by the use of aluminum oxide, of beryllium oxide, or of diamond as the material for the short rods, such as short rod **45**, and the support arrangement also yields a beneficially higher characteristic impedance than prevails in conventional narrow-band stub supported transmission line systems which do not employ the short electrically insulating rods. Both beryllium oxide and aluminum oxide ceramics are found to be readily sealable to metallic materials, such as to copper rods suitable for use as rod **42**.

The transmission line system is completed and the somewhat dispersive nature of the stub supported line **18** is beneficially compensated in the following manner. Referring to FIGS. **1**, **2**, and **3**, a regular circular array of longitudinally extending rods or wires **50** to **50***i*, which may be made of materials such as copper or a copper plated metal, is welded, brazed, or otherwise fastened to the inner surface of vacuum shell **15**. The individual rods or wires, such as rod **50***g*, may be of any convenient cross section, such as circular, and each such rod will generally extend so as to run adjacent to the full extent of transmission line **18**. The desired loading effect of the rod or wire array brings about reduction of the dispersive characteristics of line **18**, the rods forcing or guiding high frequency fields and thus guiding the high frequency currents normally flowing on the inner surface of shell **15** so that they flow mainly in parallel relation with the axis of the tube, rather than circumferentially. Other types of regularly spaced lineal perturbations in the inner surface of shell **15** are found to produce the desired effect, including longitudinal slots or grooves or other discontinuities formed in the inner wall surface of shell **15**. While the exact mechanism of operation of such loading devices is not necessarily precisely established, their use leads to the achievement of greatly improved operating band widths for the novel stub supported, slow wave transmission line system of the present invention.

It will be appreciated by those skilled in the art that the dimensions and proportions illustrated in the several figures have been chosen in the interest of making the drawings clear, and do not necessarily represent values that would be selected in actual practice. It will further be appreciated that the novel transmission line system including the dispersion correction arrange-

ment may be used in a variety of types of traveling wave tube devices, including amplifiers and oscillators. It will also be readily appreciated that an internal attenuator system of conventional design may be employed in such tubes when used as amplifiers. A conventional attenuator may readily be employed, such as one in the form of one or more longitudinal dielectric rods located between circuit **18** and the shell **15** and coated along at least a part of their lengths with a thin layer of carbon. Accordingly, for the sake of simplifying the drawings, no internal attenuation means has been illustrated. Other conventional elements, such as a conventional sever in line **18**, may also be employed where desired.

According to the invention, traveling wave tube designs with slow wave propagation lines having desirably high characteristic impedances may readily be achieved in designs also permitting improved operating band widths. Moderate to high power operation is readily obtained by using the invention, since conduction of heat from the transmission line is improved, permitting longer life operation at a given high frequency output power level. Employment of the invention permits the manufacturer successfully to build shorter, lighter weight traveling wave tubes efficiently generating higher power outputs than is possible with known comparable configurations.

While the invention has been described in its preferred embodiments, it is to be understood that the words which have been used are words of description rather than of limitation and that changes within the purview of the appended claims may be made without departure from the true scope and spirit of the invention in its broader aspects.

I claim:

1. A traveling wave tube comprising

cathode means for projecting an electron beam along a predetermined path,

electron beam collector means

circuit means interposed between said cathode means and said collector means along said electron beam path for forming derived helix slow wave propagation circuit means in high frequency energy exchanging relation with said electron beam,

transmission line means for coupling high frequency energy into and out of said slow wave propagation circuit means,

hollow tubular shell means having a circularly cylindric inner high frequency current conducting surface surrounding said derived helix slow wave propagation circuit means in substantially coaxial relation therewith,

electrically insulating, thermally conducting means for supporting said slow wave propagation circuit means from said circularly cylindric inner high frequency conducting surface, and

spaced lineal perturbation means comprising an array of high frequency current guiding means fixed upon said circularly cylindric inner high frequency conducting surface for inhibiting circumferential flow of high frequency currents upon said circularly cylindric inner high frequency conducting surface for decreasing the dispersive characteristics of said traveling wave tube, each said current guiding means comprising rod means lying in substantially parallel relation with said electron beam path.

2. Apparatus as described in claim **1** wherein said electrically insulating, thermally conducting means comprises at least one array of individual rods with axes lying substantially in a diametral plane of said traveling wave tube,

said rods each being bonded at one end to said slow wave propagation structure in respective regions of low amplitude high-frequency electric field.

3. Apparatus as described in claim **2** wherein said rods comprise in abutting relation at least a major portion of high frequency current conducting material and a minor portion of thermally conducting, electrically insulating material.

4. Apparatus as described in claim **3** wherein:

said major portion of high frequency current conducting material is bonded to said circularly cylindric inner high frequency conducting surface of said shell means, and

said minor portion of thermally conducting, electrically insulating material is bonded to said slow wave propagation circuit means.

5. Apparatus as described in claim **4** wherein said thermally conducting, electrically insulating material comprises beryllium oxide.

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