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IMPEDANCE MATCHING STRUCTURE FOR SLOW WAVE DEVICE OF MICROWAVE TUBE

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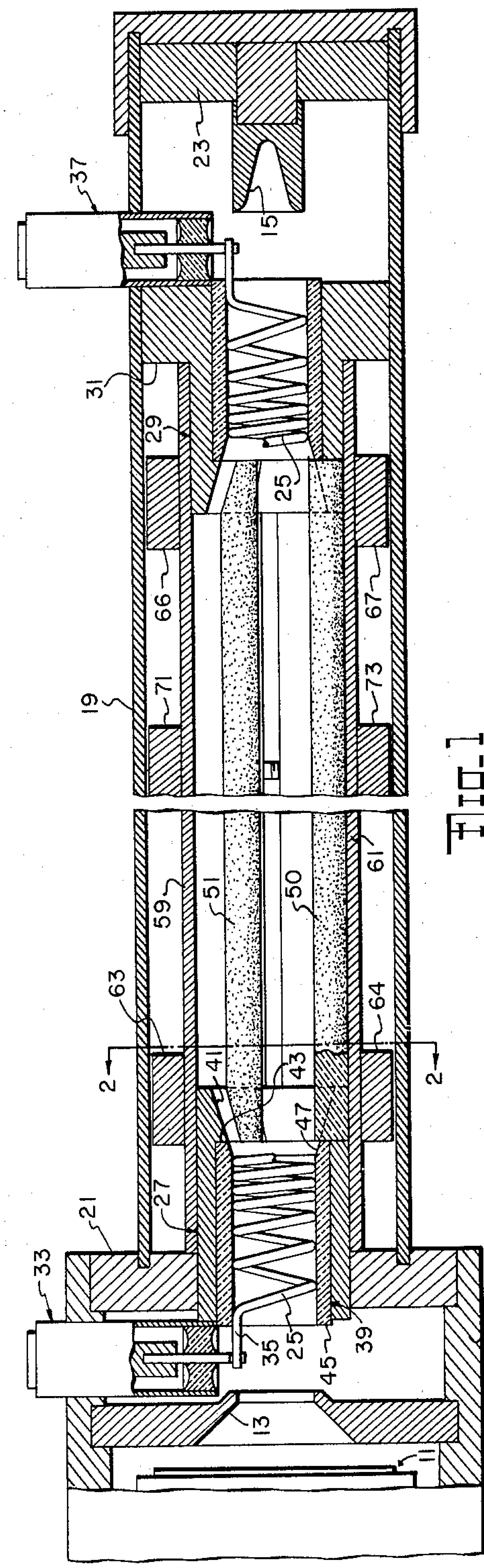

FIG_1

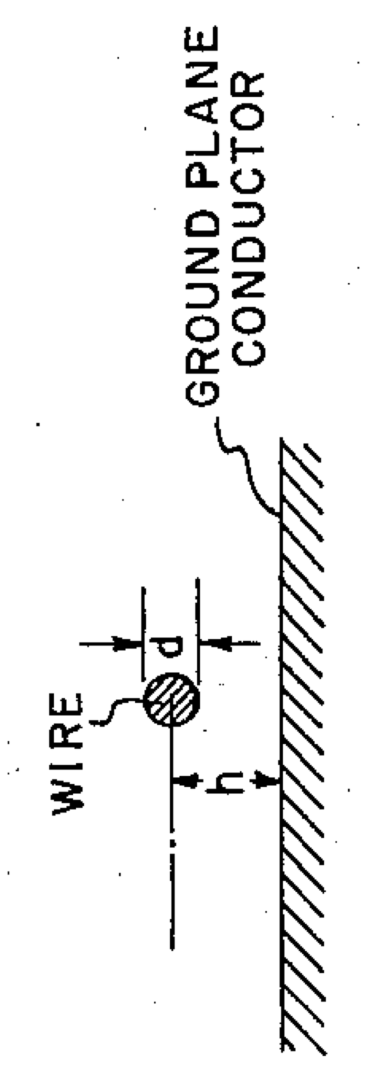

FIG_3

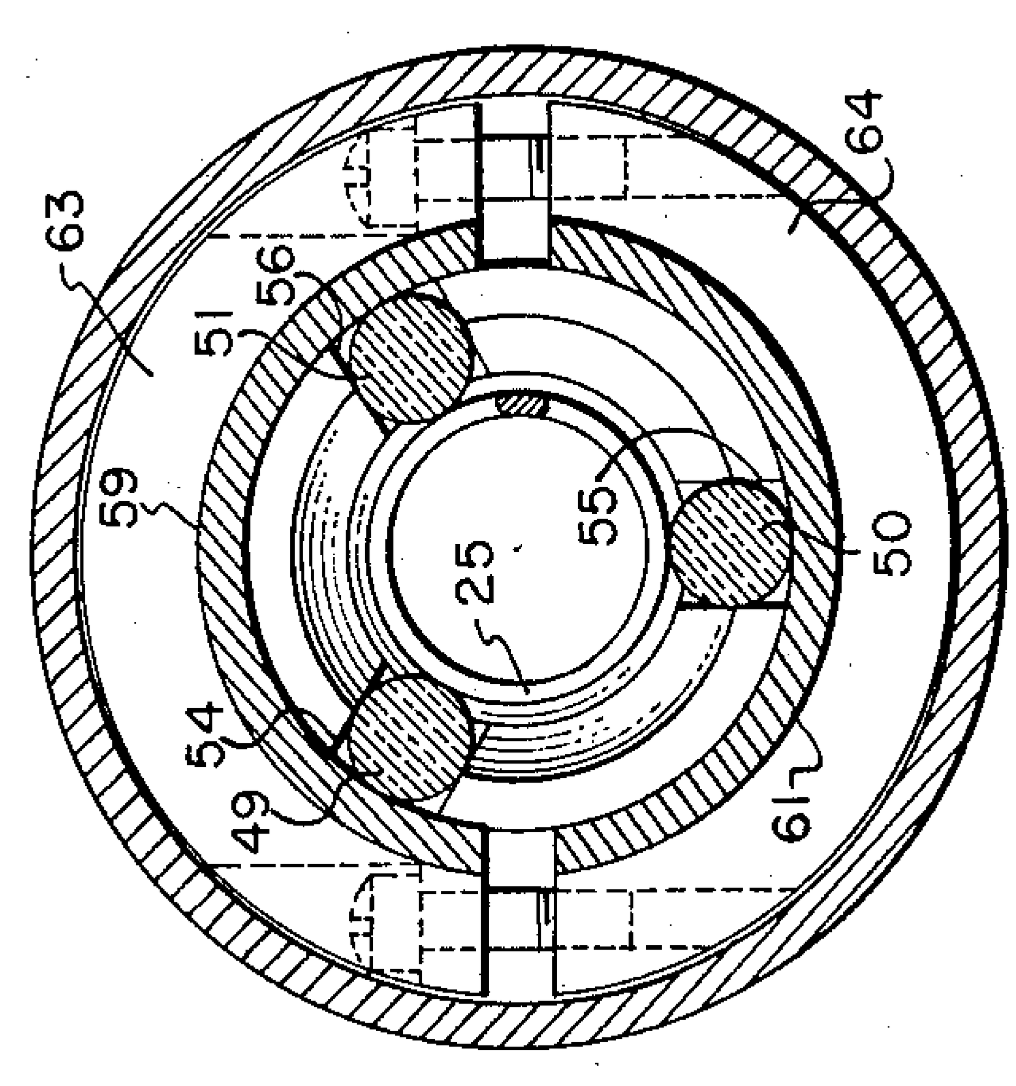

FIG_2

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IMPEDANCE MATCHING STRUCTURE FOR SLOW WAVE DEVICE OF MICROWAVE TUBE

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This invention relates to microwave tubes utilizing a slow wave device for guiding electromagnetic energy for interaction with an electron beam, and it is particularly concerned with apparatus for supporting the slow wave device and matching it to a microwave transmission line.

A slow wave device such as the helix of a travelling wave tube is generally matched to a coaxial line having a lower impedance than the helix. Sometimes this is done by a horn having a throat portion and a flared mouth portion. The horn surrounds an end section of the helix and is connected to the outer conductor of the coaxial line. The inner conductor of the coaxial line is connected to an end of the helix within the throat portion of the horn. The throat portion and the part of the helix therewithin form a wire-above-ground-plane transmission line whose impedance equals that of the coaxial line. The flared mouth portion of the horn matches this impedance to the higher impedance of the helix beyond the horn.

A fifty ohm coaxial line is generally connected to the helix of a travelling wave tube. If the wire forming the helix has a diameter of the order of .020 inch, for example, and the dielectric constant of the medium between the helix and horn is substantially equal to 1, the spacing between the helix and the throat portion of the horn must be of the order of .004 inch to provide a transmission line impedance of the order of 50 ohms. It has heretofore been extremely difficult to attain and accurately maintain such a close spacing. Even if the required spacing were provided, short circuits might occur between the horn and helix, particularly if the travelling wave tube is subjected to mechanical shock and vibration.

Therefore, it is an object of the invention to provide a novel structure for supporting a slow wave device of a microwave tube, and for matching this device to an external transmission line.

It is another object of the invention to provide a helix to transmission line matching structure wherein the helix is more readily supported in accurate spaced relationship with a horn of the matching structure than in previously known devices.

It is a further object to provide such a structure wherein the helix is ruggedly supported within the horn.

It is another object to provide a practical structure utilizing a horn for matching the impedance of a helix whose wire has a diameter of the order of a few hundredths of an inch, to the impedance of a coaxial line whose impedance is of the order of fifty ohms.

It is yet a further object to provide a structure as aforedescribed that minimizes the possibility of the occurrence of short circuits between the helix and horn.

Generally the foregoing objects are attained by supporting an end section of the helix within a horn having a throat portion joined to a flared mouth portion by an inward step. A sleeve of insulating material having a high dielectric constant is fitted around the helix within the throat portion for maintaining an accurate spacing between the helix and the throat portion. A plurality of dielectric rods extend along the outside of the helix for supporting the helix within the mouth portion. One end of the sleeve and a group of ends of the dielectric rods lie adjacent each other at the step between the throat and mouth portions of the horn, this step enhancing the impedance match provided by the structure. The details of the invention will become more apparent from the following description and accompanying drawings wherein:

Fig. 1 is a sectional view showing a travelling wave tube having input and output matching sections in accordance with the present invention;

Fig. 2 is a cross sectional view of the tube shown in Fig. 1, taken along the line 2—2; and

Fig. 3 is a diagram for explaining how part of the matching section is designed electrically.

Referring now to Fig. 1, a travelling wave tube is shown having a cathode-focussing electrode subassembly 11, and anode 13 and a collector 15. The anode and the cathode-focussing electrode subassembly are coaxially supported along the longitudinal axis of the tube by a metallic cup-like element 17 forming part of a vacuum envelope for the tube. The collector 15 is coaxially supported along this axis by a metallic cylinder 19 forming a further part of the vacuum envelope.

An apertured plate 21 extends across one end of the cup-like element 17 for supporting the cylinder 19 in coaxial relationship with the anode 13. Plate 21 forms part of the vacuum envelope of the tube, and may be of highly magnetically permeable material for providing an input pole piece of a magnet arrangement for ensuring that the diameter of the electron stream is maintained constant throughout the slow wave propagating structure of the tube. A plate 23 at the collector end of the tube constitutes an output pole piece for the magnet arrangement, not shown.

A wire helix 25 is coaxially supported along the axis of the tube between the anode 13 and the collector 15. A conductive horn 27 encircles one end section of the helix at the input end of the tube. The horn 27 passes through an aperture in plate 21 for support in coaxial relationship with the axis of the tube. A conductive horn 29 encircles the other end of the helix at the output end of the tube. Horn 29 is provided with a flange 31 for coaxial support within cylinder 19.

An input coaxial line 33 passes into the tube through an aperture through the cylindrical wall of element 17, the coaxial line 33 being supported by element 17 at right angles with the axis of the tube. The outer conductor of the coaxial line is connected to the end of horn 27 as illustrated in Fig. 1. A short linear extension 35 of the helix wire connects the inner conductor of coaxial line 33 directly to the end turn of the helix.

An output coaxial line 37 passes into the tube through an aperture provided in the cylindrical wall of the tube envelope 19. Coaxial line 37 is also supported at right angles with the tube axis and is connected to the output ends of the helix 25 and horn 29 as illustrated. The coaxial line 37 might instead pass out of the tube along an axis parallel to the tube axis, provided a suitable right angle coaxial line bend is employed.

The input horn 27 has a throat portion 39 of constant inner diameter and a flared mouth portion 41 of tapered inner diameter. The throat and mouth portions of the horn are joined by an inward step 43 at right angles with the axis of the tube.

A dielectric sleeve 45 is fitted around the end section of the helix 25 within the mouth portion 39 of the horn. The sleeve 45 maintains this section of the helix in rigid, coaxially spaced relationship with the inner surface of the throat portion 39. The sleeve 45 preferably has a high dielectric constant. One end of the inner surface of sleeve **45** is tapered for providing a smooth transition to the flared mouth portion **41** of the horn **27**. The output horn **29** is substantially the same as the horn **27**, so will not be described in detail.

The intermediate region of the helix **25** is supported by a plurality of dielectric rods **49**, **50** and **51** extending longitudinally along the outside of the helix between horns **27** and **29**. These rods may be of the same dielectric material as that of sleeve **43**. The diameters of rods **49**—**51** are equal to each other.

The ends of the rods **49**—**51** are positioned within suitable slots in the mouth portions of the horns **27** and **29** so as to be disposed in 120 degree relationship with each other around the helix. The slots in the horn **27** are indicated by the numerals **54**, **55** and **56** in Fig. 2.

The helix **25** and the rods **49**—**51** are confined within a longitudinally split cylinder having two halves **59** and **61** of conductive material. This cylinder is provided for clamping the rods in firm engagement with the helix, and for coaxially positioning the helix and rods subassembly along the axis of the tube. The ends of the cylinder are supported by the horns **27** and **29**, respectively. A pair of semicircular members **63** and **64** clamp one end of the cylinder to the horn **27**. A further pair of semicircular members **66** and **67** clamp the other end of the split cylinder to the horn **29**.

One or more intermediate pairs of clamps such as **71** and **73** are also provided about the split cylinder for further ensuring that the dielectric rods are pressed firmly against the helix. If intermediate regions along the rods **49**—**51** are coated with attenuating material, as is often the case for a travelling wave amplifier, clamps **71** and **73** ensure that the split cylinder presses these intermediate attenuating regions into close contact with the helix **25**.

The aforedescribed tube is operated as a conventional travelling wave amplifier. The electron stream, which is produced by the cathode-focussing electrode subassembly **11** and the anode **13**, is directed through the helix **25** for interaction with microwave energy travelling along the helix. The microwave energy supplied to the helix from coaxial line **33** is amplified by interaction with the electron stream. After amplification, it is transferred to the output coaxial line **37**. The horn matching structures **27** and **29** ensure that there is a substantially reflectionless transfer of microwave energy to and from the helix over a wide frequency band.

It should be apparent that the ends of the helix are supported ruggedly within the horn matching structures. Therefore, mechanical shock or vibration of the tube is unlikely to produce a short circuit between the helix and either one of the horns. This is the case even if the helix has a small wire diameter, which requires that the spaces between the helix and the inner surfaces of the horns be small.

In order to more fully understand the construction and operation of the horn matching sections, the input matching section will now be described in further detail. First, the turns of helix **25** and the inner surface of the throat portion **39** of the horn **27** constitute a wire-above-ground-plane transmission line. Its impedance should equal the characteristic impedance of coaxial line **33**. Generally, this impedance is 50 ohms for a standard coaxial line.

The impedance of a wire-above-ground-plane transmission line is given by the equation

$$Z=\frac{60}{\sqrt{\epsilon}}\cos h^{-1}\frac{2h}{d}$$

where h is the spacing between the wire and a ground plane conductor, ϵ is the dielectric constant of a medium in which it is assumed that the wire is embedded, and d is the diameter of the wire. Fig. 3 is a schematic diagram for illustrating how the equation is applied.

If the above equation is applied to the wire-above-ground-plane transmission line of the input matching structure in Fig. 1, for example, the impedance of this transmission line can only be approximated, using the dielectric constant of sleeve **45** as ϵ. This is the case since the helix wire is not actually embedded in the sleeve **45**. For a given impedance, therefore, the thickness of sleeve **45** and the spacing between the helix **25** and the throat portion **39** of the horn is required to be slightly smaller than determined by the above equation.

The exact spacing for attaining a wire-above-ground-plane transmission line impedance equal to that of input coaxial line **33** is determined empirically, after obtaining the approximate spacing from the above equation. In one design of a tube where the diameter of the wire of helix **25** is .020 inch, the sleeve **45** having a dielectric constant of approximately 9, the thickness of sleeve **45** is .030 inch. This provides a wire-above-ground-plane impedance that is substantially 50 ohms.

The first few turns of the helix are stretched apart as indicated in Fig. 1 for enhancing the transfer of microwave energy from the straight wire extension **35** to the helix **25**. The microwave energy travelling along the helix **25** within the horn throat portion **39** is primarily in a wire-above-ground-plane transmission line mode. The electric field vectors of this mode extend between the helix wire and the inner surface of the throat portion **39** of the horn. Since the wire-above-ground-plane transmission line impedance substantially equals the impedance of coaxial line **33**, microwave energy is efficiently transferred from the coaxial line **33** to the helix **25**.

Generally, it would be desirable if the wire-above-ground-plane transmission line impedance at the input end of the horn mouth portion **41** be approximately equal to the transmission line impedance along the horn throat portion. However, the dielectric medium between the helix and horn within the horn mouth portion is constituted principally by a vacuum, whereas the medium between the helix and the throat portion of the horn is provided by sleeve **45**. Sleeve **45** preferably has a much higher dielectric constant than the vacuum. Therefore, the impedance of the helix at the input end of the horn mouth portion is higher than the impedance of the helix within the horn throat portion.

The step **43** is provided for reducing the impedance discontinuity effected by the change from one dielectric medium to another. Step **43** brings the inner surface of the smaller end of the horn mouth portion **41** into closer physical relationship with the helix **25** than the inner surface of the horn throat portion **39**. The magnitude of the step is limited by the minimum spacing that might be required to be maintained between the helix **25** and the inner surface of the horn at this point. In tubes where the diameter of the wire of helix **25** is of the order of .020 inch, it is impractical to extend the step **43** close enough to the helix **25** for attaining a transmission line impedance of 50 ohms. Therefore, the impedance at the input end of the horn mouth portion **41** will be slightly higher for a tube having such a small wire diameter.

The end of the sleeve **45** is tapered at **47** for providing a smooth impedance transition from the 50 ohm wire-above-ground-plane transmission line impedance to the slightly higher impedance at the input end of the horn mouth portion **41**. The optimum length and angle of the taper **47** are best determined empirically.

The mouth portion **41** of the horn is flared for gradually changing the mode of energy travelling along the wire-above-ground-plane transmission line to a helix mode wherein the electric vectors of the energy extend primarily between the adjacent turns of the helix. At the same time, the impedance of the helix **25** is gradually increased along the horn mouth portion to a much higher value at the output end of the horn. Although the taper of the horn is illustrated as being linear, it could instead be along an exponential curve.

The axial length of the mouth portion **41** of the horn is not critical, except that it should be above some minimum length for energy at the lowest frequency of operation for the tube. This minimum length is best determined empirically since it is difficult to determine the wavelength of energy within the horn mouth portion 41.

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

What is claimed is:

1. A travelling wave tube comprising a helix, means for producing and directing a stream of electrons through said helix, a horn enveloping one end of said helix, said horn having a throat portion of constant diameter and a flared mouth portion, a dielectric sleeve fitting around the helix within the throat portion of said horn, the outer surface of said sleeve being in contact with the inner surface of said throat portion along the length of said throat portion, one end of said sleeve being at the junction between the throat and the mouth portions of the horn, and a step along the inner surface of said horn at said junction for making the impedances of said helix on opposite sides of said junction approximately equal.

2. The combination as set forth in claim 1, wherein the thickness of said dielectric sleeve is tapered in the vicinity of said step.

3. The combination as set forth in claim 2, further including a plurality of dielectric rods disposed around said helix beyond the mouth portion of said horn, said rods extending into said mouth portion for support of said helix therewithin, the ends of said rods being at the step between the throat and mouth portions of said horn.

4. In combination, a slow wave device for microwave energy having one of its ends surrounded by a tubular horn, said horn having a throat portion of constant diameter and a flared mouth portion, a dielectric sleeve fitting around said slow wave device within the throat portion of said horn for supporting said device in coaxially spaced relationship with said throat portion, the outer surface of said sleeve being in contact with the inner surface of said throat portion along the length of said throat portion and a plurality of dielectric rods extending from one end of said sleeve along the outside of said slow wave device for further supporting said device in coaxially spaced relationship with the mouth portion of said horn.

5. The combination as set forth in claim 4, wherein said throat portion is joined to said mouth portion by an inward step toward the axis of said horn, one of the ends of said sleeve and the ends of said dielectric rods adjacent said sleeve being located in the vicinity of said step.

6. The combination as set forth in claim 5, wherein the thickness of said dielectric sleeve is tapered at said one end thereof for providing an impedance transition from the throat portion to the mouth portions of said horn.

7. The combination as set forth in claim 6, wherein the inner surface of said dielectric sleeve is tapered at said one end for substantially matching the taper of the inner surface of the flared mouth portion of said horn.

8. In a travelling wave tube, the combination of a helix whose ends are encircled by first and second conductive horns, respectively, each horn having a throat portion of constant inner diameter and a flared mouth portion, the inner surface of said throat portion being joined to the inner surface of the smaller end of said mouth portion by a step toward said helix, a plurality of dielectric rods extending longitudinally along the outside of said helix for supporting the helix in coaxially spaced relationship with the mouth portions of said horns, respectively, opposite ends of said rods being at the steps between the throat and flared mouth portions of said horns, respectively, means for rigidly supporting said rods relative to said horns, and first and second dielectric sleeves fitting around opposite ends of said helix within the throat portions of said first and second horns, respectively, for supporting the ends of said helix in coaxially spaced relationship with the throat portions of said horns, the outer surfaces of said sleeves being in contact with the inner surfaces of the throat portions of said horns along the lengths of said throat portions, one of the ends of each sleeve being at the step between the throat and mouth portion of each horn.

9. The combination as set forth in claim 8, wherein the step between the throat and mouth portion of each horn is substantially at right angles with the longitudinal axis of each horn.

10. The combination as set forth in claim 9, wherein the inner surface of each dielectric sleeve at the step between the throat and mouth portion of each horn is tapered for effecting a smooth impedance transition from the throat to the mouth portion of each horn.

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