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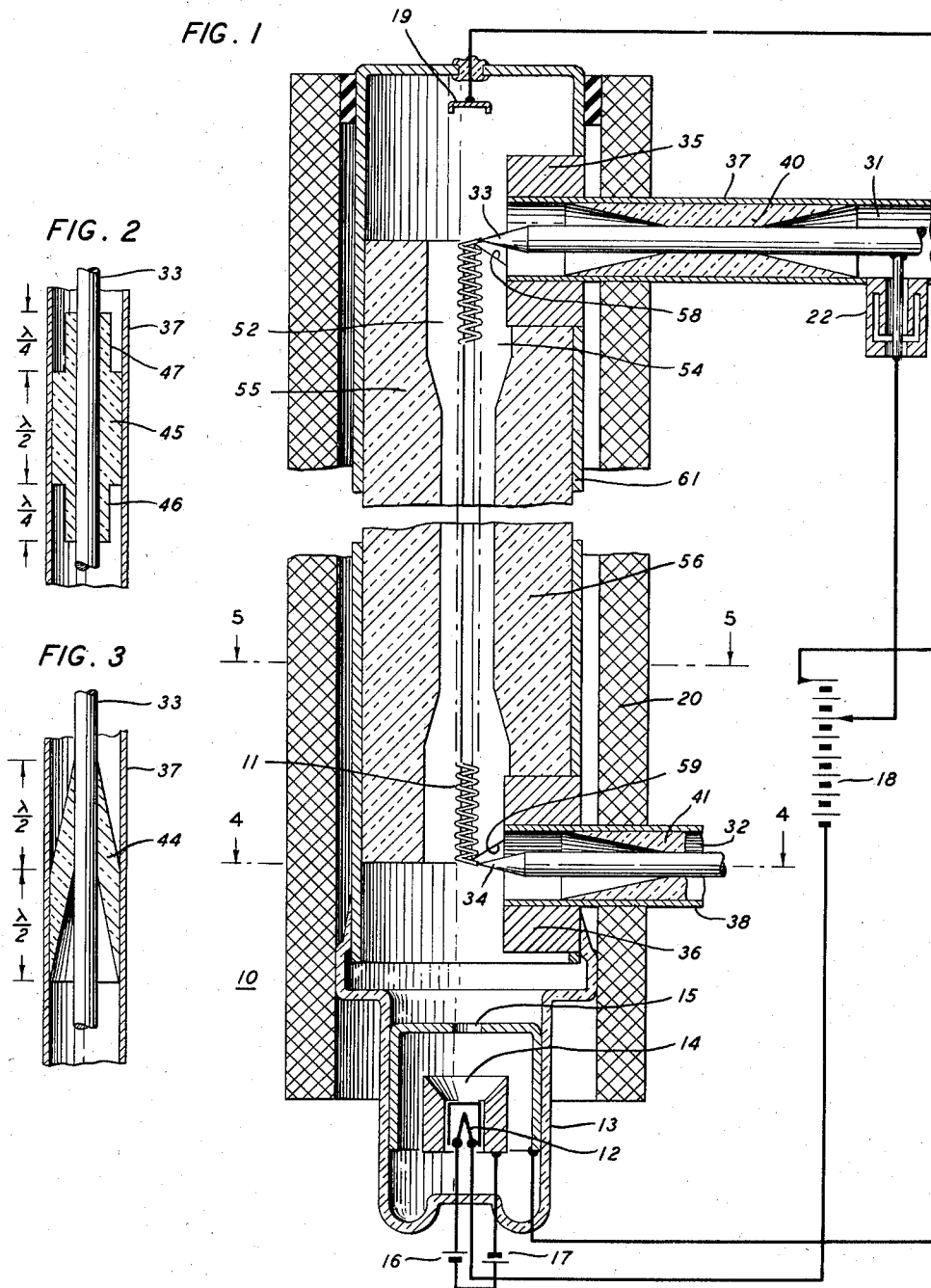
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2,863,085

TRAVELING WAVE TUBE STRUCTURE

Filed Dec. 11, 1952

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 4

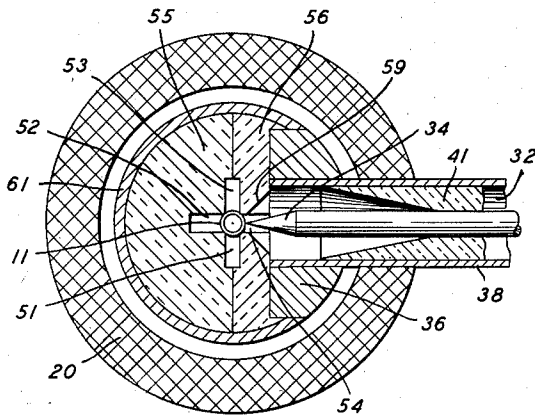


FIG. 5

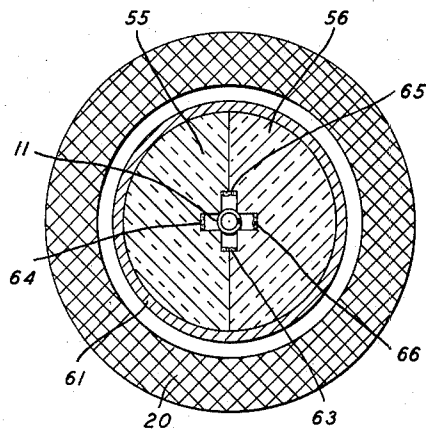


FIG. 6

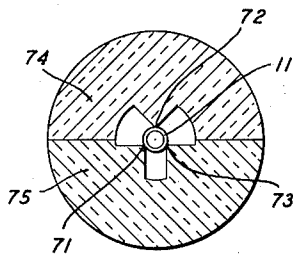


FIG. 7

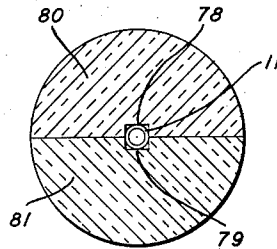


FIG. 8

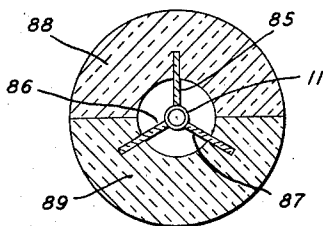
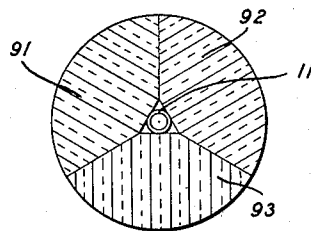


FIG. 9



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1

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TRAVELING WAVE TUBE STRUCTURE

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This invention relates to electronic devices of the type in which there is cumulative interaction between an electron stream and a high frequency electric field associated with a slow wave transmission path. More specifically, by way of example, this invention is concerned with coupling and mounting arrangements for helices employed in electronic tubes of the traveling wave tube type, particularly in those adapted to operate in the millimeter wavelength region.

In this exceedingly high frequency region, the conducting helix of the slow wave transmission path must have a small diameter and many turns to the inch for optimum operating conditions and thus must be made from very small diameter wire, such as, for example, one or two thousandths of an inch thick. With the minute dimensions involved, conventional methods of matching to input and output lines become impractical. For example, when the entire helix is only 10–20 mils in diameter and the wire is proportionately smaller, the practice of tapering the helix for broad band coupling becomes practically impossible from the standpoint of obtaining consistent or reproducible results. Despite this lack of suitable high frequency coupling structure in the prior art, quality impedance matches are important for broad band operation to minimize tube instability and reduce signal degradation.

An important object of the invention, therefore, is to couple input and output members to a slow wave transmission path in a traveling wave tube or the like, over a broad frequency band at shorter-than-centimeter wavelengths.

Another object is to provide a simple helix support having good electrical qualities for use in tubes of the traveling wave type.

Still another object is to secure frequency selective attenuation and/or noise cancellation along the length of the slow wave transmission path.

In accordance with the invention, a structurally reproducible impedance match between a helix and a coaxial connecting line is attained by using, as the line, one having the end of its center conductor tapered over a fraction of the operating wavelength and directly connected to the helix. The present device is to be distinguished, however, from known traveling wave tube coaxial inputs in which the helix and the coaxial input line have different characteristic impedances, and in which either the helix or the center conductor of the coaxial line is gradually tapered over several operating wavelengths. In an important aspect of applicant's invention, the helix and coaxial line have substantially the same impedance and are connected by the tapered center conductor of the coaxial line, with the taper being less than a quarter of the operating wavelength to reduce capacitive loading of the end turns of the helix without altering the characteristic impedance match.

A feature of the invention resides in a simple helix mounting, made up of elongated dielectric elements which surround the helix and make line contact therewith, with the assembly being contained by a cylindrical envelope.

2

In addition, the elongated dielectric supporting elements may be slotted to a varying depth for noise cancellation, and the sides and/or bottoms of the slots may be coated with a lossy material to provide a suitable frequency selective loss characteristic along the length of the helix.

Other features and advantages will be apparent from the following description of certain embodiments of the principles of the invention which are shown in the drawings.

In the drawings:

Fig. 1 is a longitudinal cross-section of a traveling wave tube employing helix couplings in accordance with the invention;

Figs. 2 and 3 show alternative coaxial bead structures which may be used with the device of Fig. 1;

Fig. 4 is a cross-sectional view of Fig. 1 taken in a plane through line 4—4 of that figure;

Fig. 5 is a cross-section of Fig. 1 taken in a plane through line 5—5 of Fig. 1; and

Figs. 6 through 9 show alternative helix supporting arrangements.

Referring more particularly to the drawings, Fig. 1 shows, by way of example and for purposes of illustration, a traveling wave tube 10 comprising an evacuated envelope 13, 61 including therein a cathode 12 and a collector 19 forming an electron stream therebetween, and a helical slow wave transmission path 11 in coupling relation with the electron stream and having input and output lines 31 and 32 coupled to its ends. Before proceeding with the detailed description of the tube, it is considered desirable to emphasize the high frequency for which it is adapted and the resultant small size of the tube, with the full length of the tube being only about three inches, as contrasted with usual traveling wave tube lengths of 18 inches or more. This miniaturization of the entire tube and, more particularly, the minute size of the helix 11 forming a part thereof create a number of problems which have been solved by the structure of the present invention. Features of this structure, such as the coupling between the tiny helix 11 and the external coaxial lines 31 and 32, the location of high frequency loss material to get the proper loss at each point along the helix, and the mounting of the helix, will all be covered hereinafter.

Proceeding to a consideration of the usual electron stream-forming electrodes and the helix 11, the cathode 12 is located at one end of the envelope 13, and has the usual focussing electrode 14 and accelerating electrode or gun anode 15 associated therewith. Heater and bias voltages are supplied to the cathode and focussing electrode by suitable voltage sources 16 and 17, respectively. The voltage source 18 provides suitable accelerating and anode voltages to the above-noted accelerating electrode 15, helix 11, and to the collector 19. The helix voltage is normally approximately equal to the accelerating voltage but, for focussing purposes, may be adjusted to a somewhat higher or lower value. It is supplied to the helix through the center conductor 33 or 34 of either of the connecting coaxial lines 31 or 32, the connection to the coaxial line being made by the quarter wavelength stub 22. A longitudinal magnetic field for focussing the electron beam is provided by any suitable means such as the electromagnetic coil 20. A large electromagnet with a horseshoe yoke, having the gun anode and the collector made of magnetic material and serving as pole pieces, may also be used to provide this longitudinal field.

The helix 11 must be of small dimensions for operation at less-than-centimeter wavelengths. By way of example, for operation at between 5 and 6 millimeters wavelength, the dimensions of a suitable helix having approximately four turns per wavelength can be:

Wire diameter.....	mils.....	2
Internal diameter of helix.....	do.....	1.5

Turns per inch-----	300
Pitch of helix-----mils--	3.33
Wire diameter/pitch-----	0.6
Length of helix-----inches--	1.5

The foregoing dimensions and other particular dimensions which will be presented hereinafter represent the size of one illustrative tube, and are given by way of example and not of limitation. The characteristic transverse impedance of the helix at the above noted wavelength is approximately 72 ohms, as calculated from the curve on page 40 of J. R. Pierce's book, "Traveling Wave Tubes," D. Van Nostrand Company, Inc., 1950. The same curve indicates that this characteristic impedance does not vary rapidly with frequency.

In order to couple this minute helix to input and output lines at 5 to 6 millimeters (0.2 inch) wavelength, conventional traveling wave tube practices were found inapplicable. For example, it would be impractical to taper the turn spacing of a helix having an internal diameter of only 0.015 inch and wire only 0.002 inch thick. The glass envelope thickness required for mechanical strength is a fraction of a wavelength, and makes it difficult to match the helix to a tunable external cavity. A cavity within the evacuated envelope would be possible but could not be tuned or adjusted conveniently after assembly.

An exemplary solution to this coupling problem is shown in Fig. 1 and in the cross-sectional view of Fig. 4, taken in a plane through line 4—4 of Fig. 1. Coaxial lines 31 and 32, having the same characteristic impedance as the helix, form the input and output connections of the tube. To match the 72 ohm characteristic impedance of the helix a ratio between the outer diameter of the inner conductor and the inside diameter of the outer conductor of approximately 1:3 is required; the particular inner and outer diametral dimensions selected are about 18 and 53 mils, respectively. Although it might have been anticipated that the helix and the coaxial lines of the same impedance would be well matched with almost any connecting structure, this was not found to be the case, and a number of matching structures were found to have high standing wave ratios of from 5 to 12 decibels. The structures at each end of the helix as shown in Fig. 1, however, with the sharply tapered central conductors 33 and 34 extending radially outwardly from the helix, and the enlarged end portions 35 and 36 secured to the outer conductors 37 and 38 of the coaxial line, have a standing wave ratio only slightly greater than one decibel over the greater portion of a frequency band equal to ten percent of the operating frequency, and an acceptable standing wave ratio over a much broader frequency band. The length of the taper from the full diameter of the inner conductor of the coaxial line to the point where its diameter corresponds to that of the helix wire is less than a quarter wavelength; for example, the selected taper length is 35 mils, as contrasted with a quarter wavelength in free space of approximately 53 mils, at the operating frequency. The enlarged outer conductor of the coaxial line encloses the center conductor for approximately one half the longitudinal extent of the taper and then extends outward radially from the center of the coaxial line with its radial thickness being approximately 44 mils.

The considerations which govern the selection of the particular coupling structure are (1) the desirability of coupling the helix and coaxial line, both of which have the same characteristic impedance, as closely as possible, and (2) the avoidance of excessive capacitive loading in the coupling structure. The low standing wave ratio mentioned above is believed to be attributable in part to the low capacitance of the connections to each end of the helix by the radially extending sharply tapered center conductors of the coaxial lines. In addition to the good electrical properties of this coupling structure, it also has the advantage of manufacturing reproducibility, and

eliminates the need for unwinding or tapering any turns of the delicate helix.

Also shown in Fig. 1 are the internally tapered dielectric beads 40 and 41 which support the central conductor of the coaxial line and provide practically reflectionless seals for the evacuated envelope. This type of tapered bead has a taper of substantially one half wavelength at each end, which provides a transition having minimum reflection for a short taper. The internal taper is used with refractory beads (quartz, glass, etc.) to avoid the chipping which was found to occur at the thin edge adjacent the tiny central conductor, when an external taper was used. External tapers may also be used and have the advantage for non-refractory beads that the taper may be readily machined. The internal-external tapered bead 44 shown in Fig. 3 still retains the optimum half wavelength taper length and is somewhat shorter in length than the two other types mentioned above. The dielectric bead 45 of Fig. 2 employs quarter wavelength matching transformer sections 46 and 47 to match the characteristic impedances of the central portion of the bead to that of the open coaxial line, and may also be substituted for the beads shown at 40 and 41 in Fig. 1.

As shown in Figs. 4 and 5, the helix 11 is supported by line contact with the inwardly projecting corners of the cruciform aperture formed by the slots 51, 52, 53 and 54 in the two semicylindrical dielectric elements 55, 56. As shown at 58, 59 of Fig. 1 and at 59 in Fig. 4, the dielectric element 56 is cut away at each end to permit access for the end of the coaxial line and still support the delicate helix 11. The two semicylindrical dielectric elements are held in the assembled position by the cylindrical conducting shield 61, which is also part of the tube envelope. Although the dimensions of this shield are not critical, it is desirable to hold its diameter to a minimum to suppress electromagnetic oscillations which might otherwise be excited in the conductively bounded cavity which it forms.

As illustrated in Fig. 5, high frequency loss material such as aquadag may be applied to the bottoms and/or along the sides of one or more of the grooves at 63, 64, 65 and 66 in order to prevent oscillation. Inasmuch as the field associated with lower frequency signals extends outwardly from the helix a greater distance than the field of the desired higher frequency signals, the loss material applied to the bottom of the grooves increases the attenuation at lower frequencies where oscillation is more likely to occur without substantially increasing the attenuation at the operating frequency. In addition, by varying the depth of one or more of the grooves along their lengths, as shown in Fig. 1, the effective attenuation of all frequencies will be altered. This will avoid the necessity for varying the amount of loss material along the length of the helix, as a uniform coating of loss material in slots of varying depth will provide the desired variation in attenuation. It may be noted that this variation in depth is substantial, and that it may exceed the 2:1 ratio shown in Fig. 1 when greater differences in attenuation are desired.

The structure shown in the present device would also be suitable for noise cancellation, based on the principles set forth in C. F. Quate's application, Serial No. 220,416, filed April 11, 1951. One method of noise cancellation developed in the above-mentioned application involves the retardation of the signals traveling along the helix over a portion of its length by the use of an annular ring of dielectric material encircling the helix. The same retardation may be accomplished in the instant device by reducing the depth of the slots in the supporting dielectric material over a predetermined distance.

The operation of the traveling wave tube 10 as shown in Figs. 1, 4 and 5 as an amplifier in the forward, or electron flow, direction will be described to illustrate one mode of operation. A weak high frequency signal is

applied to the coaxial line 32 and is transmitted through the bead 41, across the tapered coupling 34 to the lower end of the helical slow wave transmission path 11. With the longitudinal velocity of the electric field associated with this input signal arranged to be approximately equal to the electron stream velocity, there will be an interaction between the field and the electron stream with some of the electrons being slowed down and others speeded up. As these electrons traverse the length of the helix they become bunched and the electric field associated with the groups of bunched electrons is transferred back to the helix, resulting in an amplified signal at the output end of the helix 11.

Improvement in the operation of the tube has been effected, in accordance with the invention, by providing low loss coupling structures 33, 35 and 34, 36. By using the practically reflectionless dielectric supporting beads 40, 41 as a vacuum seal, as well as the above-noted coupling structure, full benefit from the amplification of the tube may be obtained. The frequency selective loss material which may be placed on the bottom of the slots 52 and 54 in the dielectric supporting elements 55 and 56 also improves the operation of the device by suppressing lower frequencies. This feature is particularly useful when the device is used as an amplifier through the prevention of oscillations at lower frequencies at which the net gain might substantially exceed the feedback loss, without substantially reducing the amplification at the desired higher frequencies. As mentioned hereinabove, variation of the slot depth, as illustrated in Fig. 1 for slots 54 and 55, may be employed to improve the operation of the tube either through noise reduction and/or selective attenuation along the length of the helix.

Figs. 6 to 9, which illustrate alternative dielectric helix supporting elements, may be provided with suitable high frequency loss material, but are not as well adapted to the varying slot depth arrangement as the embodiment of Figs. 4 and 5. In the device of Fig. 6, for example, the helix 11 makes line contact at three spaced points 71, 72 and 73 with the generally semicylindrical dielectric supporting elements 74 and 75. In the embodiment of Fig. 7, the two matching slots 78 and 79 in the dielectric elements 80 and 81 form a substantially square aperture with the helix 11 frictionally supported by contact with the walls thereof. In the arrangement shown in Fig. 8, the helix 11 is supported by three evenly spaced radial dielectric strips 85, 86 and 87 extending inwardly from a generally circular aperture in the dielectric supporting elements 88 and 89, the strips being secured in slots in these elements. Fig. 9 illustrates a simple triangular supporting aperture for the helix 11 which is formed by chamfering the sharp corner of the three segment-shaped dielectric elements 91, 92 and 93. Of these five types of dielectric supports, the types with reentrant apertures, and surfaces which are spaced from and facing the helix, such as shown in Figs. 6 and 8, as well as in the device of Figs. 4 and 5, are preferred because of the line contact with helix and the convenient surfaces for applying high frequency loss material.

Summarizing the features of the present invention, applicant has provided a novel structure for use in tubes of the traveling wave type at very short wavelengths by the use of an improved helix output coupling arrangement, and a novel multifunction helix supporting structure. It is further noted that, although the electron tube as described in the present application is especially suitable for use at very short wavelengths, it is also valuable at lower frequencies, particularly where broad frequency bands are desired.

It is to be understood that the above-described arrangements are merely illustrative of the principles of the invention. Other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In combination, electrode means for forming an electron stream, a helical slow wave transmission structure paralleling said electron stream, elongated slotted dielectric elements supporting said structure, the slots being of varying depth and being relatively shallower near the center than at the ends of said transmission structure, said dielectric elements together forming a supporting structure having a cruciform central aperture, with the helix supported on the inwardly projecting edges of the dielectric members, and a coating of high frequency loss material located on the surfaces of the slots farthest removed from the center of said aperture.

2. In an electron tube of the traveling wave type adapted for operation at less-than-centimeter wavelengths, means for forming an electron stream, a helical slow wave transmission structure having a predetermined characteristic impedance in coupling proximity to said electron stream, longitudinal dielectric elements having slots of varying depth supporting said structure on the edges of said slots, and coaxial input and output lines having substantially the same characteristic impedance as said transmission structure coupled to the ends of said structure, the center conductors of said coaxial lines being sharply tapered over a distance which is a fraction of the operating wavelength at the ends which are connected to said slow wave transmission structure.

3. A device as defined in claim 2 wherein one surface of at least one of said slots is coated with high frequency loss material.

4. In an electron tube of the traveling wave type adapted for operation at less than centimeter wavelengths, means for forming an electron stream, a helical slow wave transmission structure having a predetermined characteristic impedance in coupling proximity to said electron stream, longitudinal dielectric elements having slots of varying depths supporting said structure on the edges of said slots, coaxial input and output lines having substantially the same characteristic impedance as said transmission structure coupled to the ends of said structure, the center conductors of said coaxial lines being sharply tapered over a distance which is a fraction of the operating wavelength at the ends which are connected to said slow wave transmission structure, and coaxial dielectric beads located in said coaxial lines adjacent said tube to support said center conductor and provide a low loss vacuum seal for said tube.

5. In combination, electrode means for forming an electron stream, a helical slow wave transmission structure paralleling said electron stream, and a dielectric structure for supporting said helix, said structure including a reentrant aperture and having at least one edge in contact with said helix throughout the greater portion of the length of said helix, the entire width of said edge being substantially less than the radius of said helix, and said dielectric structure having at least one surface out of contact with and facing said helix.

6. A combination as defined in claim 5 wherein said supporting structure includes at least one thin vane of dielectric material having one edge in contact with said helix.

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