

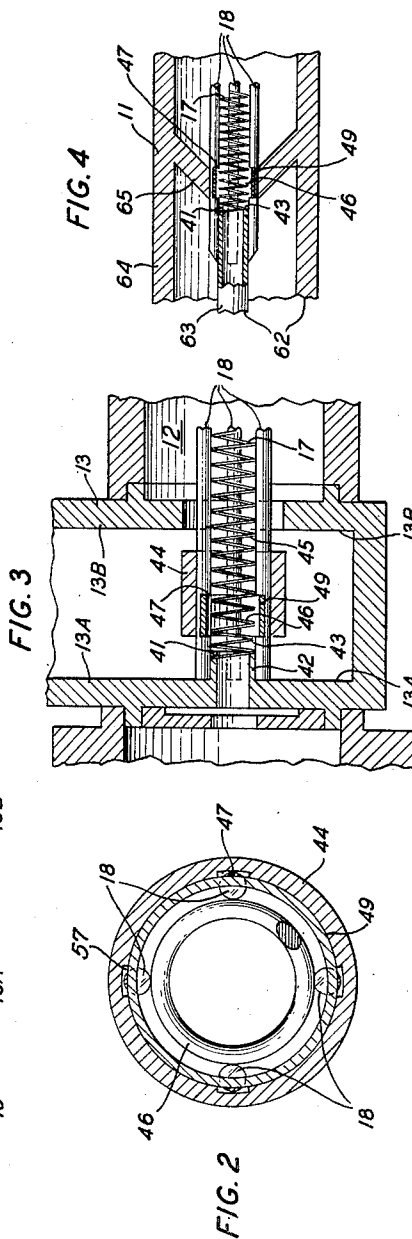
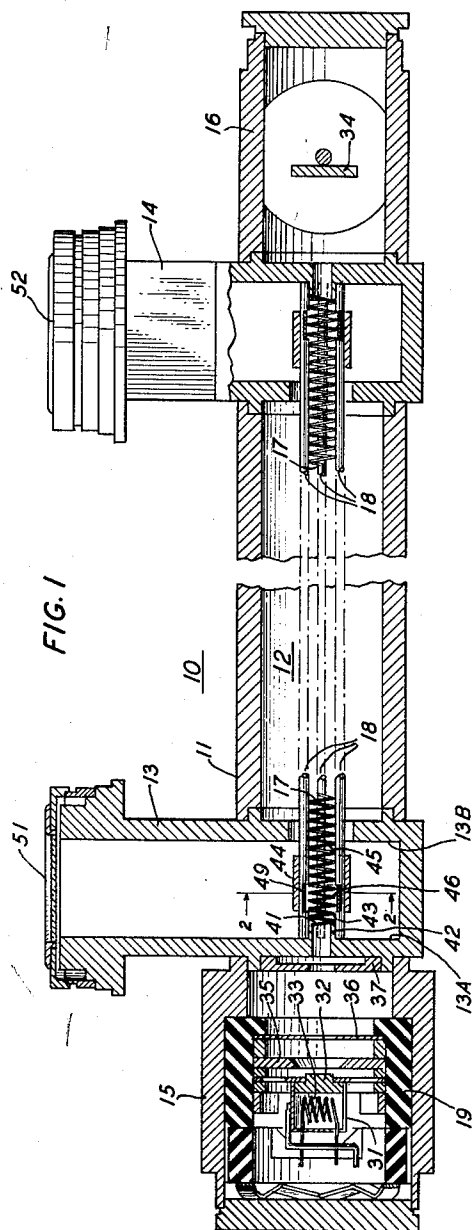
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HELIX COUPLING ARRANGEMENTS

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HELIX COUPLING ARRANGEMENTS

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This invention relates to microwave transducers, and more particularly to arrangements for energy transfers between helical wave guiding structures, for example, of the kind characteristic of helix-type traveling wave tubes, and alternative forms of wave guiding structures, such as hollow wave guides and coaxial lines.

For purposes of illustration, it will be convenient to discuss the present invention with particular reference to energy transfers to and from the wave guiding structures of helix-type traveling wave tubes, although the applicability of the principles of the present invention to analogous arrangements is not intended to be precluded thereby. In such traveling wave tubes, a wave circuit comprising an elongated helical conductor propagates radio frequency signal waves therethrough at axial velocities slower than the velocity of light and an electron stream is projected in the direction of wave propagation through the electric field set up by the wave circuit. By proper adjustment of the relative velocities of the propagated wave and the electron stream, the wave and the stream can be made to interact in a cumulative fashion whereby amplification of the wave is realized. In such tubes, it is important to secure over the broad frequency range in which the tube operates accurate impedance matches between the helix wave circuit and the signal input and output circuits which are coupled in energy exchange relationship thereto for introducing input signals and deriving amplified outputs, respectively. If mismatches are here present, components of the radio frequency waves tend to be reflected back and forth along the helix wave circuit. Such components generally make for signal degradation and, in some cases, may result in tube instability. Additionally, for efficiency of operation, it is important that the coupling provided between the helix circuit and the input and output circuits be high and substantially uniform over the entire operating frequency range.

An object of the present invention is to facilitate the energy transfer to and from wave circuits which comprise helical conductors.

A related object is to improve the impedance match in helix-type traveling wave tubes between the helix wave circuit and the signal input and output circuits which are coupled in energy exchange relation therewith.

In the copending application Serial No. 270,721, filed on February 8, 1952, for J. R. Pierce, there are described arrangements for coupling helix circuits to other suitable forms of wave transmission circuits. In each of these arrangements, the electric field coupling between the helix and such other transmission circuit is confined to a short portion of the helix and an impedance transformer is utilized for reducing the helix impedance at the short coupling portion. The present invention relates to modifications which facilitate the design and fabrication of such coupling arrangements in traveling wave tubes.

In particular, it is advantageous to provide a supporting structure which maintains the helix rigid and in accurate alignment and also permits the positioning of the impedance transformer sufficiently close to the helix.

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The present invention is directed toward such a structure and particularly to one which additionally serves to support whatever field confining elements there may be desired to supplement the action of the impedance transformer as described in the above-mentioned Pierce application.

In accordance with the present invention, the helix is supported in field coupling relation along a short coupling portion with another form of wave transmission circuit, for example, a hollow wave guide, by means of a plurality of dielectric rods which are spaced apart and extend longitudinally in contact with the helix to furnish support therefor. Each of these rods is notched or slotted along a region thereof adjacent the portion of the helix which follows the coupling portion thereof, and a conductive member is passed through these notches or slots and around the helix for transforming the helix impedance at the coupling portion. In this way, there is achieved a rugged structure which is relatively easy to construct and assemble in a traveling wave tube.

The invention will be better understood from the following more detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1 shows in longitudinal cross section a typical helix type traveling wave tube wherein is embodied an illustrative coupling arrangement in accordance with the invention;

Fig. 2 is a cross sectional view taken along the line 2—2 of Fig. 1 which illustrates the relative positioning of the various elements of the coupling arrangement;

Fig. 3 represents an enlargement of the coupling arrangement of the tube shown in Fig. 1; and

Fig. 4 shows an illustrative arrangement for coupling a helix to a coaxial line in accordance with the invention.

For purposes of exposition, it has been thought undesirable to draw the various figures to scale, since it has been found advantageous to exaggerate the size of some of the elements which figure most prominently in the coupling arrangement which is the basis of this invention.

With reference now to the drawings, the helix type traveling wave tube 10 shown by way of example in Fig. 1 is constructed primarily of a non-magnetic material, which, for increased ruggedness and to minimize need of shielding, can be a metal (e. g. copper). In general, to avoid distortion of the strong magnetic field used to collimate and focus the electron beam, it is advantageous that the use of magnetic materials in the tube structure be kept at a minimum. Envelope 11 includes, as integral parts thereof, a cylindrical elongated central chamber 12, signal input and output circuit connections which comprise the hollow wave guides 13 and 14, respectively, an electron gun housing 15, and a target housing 16. Substantially coaxial with this chamber 12 and extending at its two ends into the input and output wave guides 13 and 14, which are suitably apertured therefor, there is disposed the helix 17 which serves as the slow wave circuit along which electromagnetic waves are transmitted between the input and output connections. The helix is supported by a series of dielectric ceramic rods 18 which are spaced apart around the periphery of the helix and extend parallel to the helix axis in contact with the outer surface of the helix along the length thereof. The walls of the guides can be notched for maintaining the rods rigidly in position therebetween. The input and output rectangular wave guides 13 and 14 are of conventional rectangular cross section and their long dimensions are normal to the plane of the drawing. In this way, when transverse electric waves are propagating in the wave guides 13 and 14, the axis of the helix 17 will be parallel to the electric fields within the wave guides.

An electron gun 19 situated in the electron gun housing 15 and a collector electrode 34 in the target housing 16

in target relationship with the electron gun serve as the termini of the electron stream. The electron gun is of a standard design and comprises a heater compartment 31, of which the face nearest the central chamber 12 includes a circular disk 32 which is perpendicular to and concentric with a continuation of the axis of the helix. This disk is activated and serves as a cathode when heated. A heating coil 33 is provided within the compartment 31 and is supplied with heating current from a suitable potential source by way of leads (not shown) brought out through a glass vacuum seal.

At the opposite end of the tube envelope within the housing 16, there is positioned the target electrode 34 which, generally though not necessarily, is maintained at a positive potential with respect to the cathode 32 by means of suitable potentials applied by way of leads (not shown) brought out through a glass seal. When heated, the cathode 32 emits electrons which are directed through the input wave guide 13 which is suitably apertured for their passage therethrough, down the central chamber 12 flowing close past the helix 17, and through the output wave guide 14, also suitably apertured, to the collector 34. Along this path and perpendicular thereto, there is first disposed the field shaping electrode 35 which comprises an annular disk through whose orifice the electron stream passes. Further along the electron path is positioned a control electrode 36 which is also an apertured disk through which the electrons flow. The potential on this grid can be varied to control the intensity of the electron stream. Still further along the path is the accelerating electrode 37 which also is annular for the flow of electrons therethrough. Its potential is maintained positive with respect to the cathode by a suitable voltage source. In practice, it is generally convenient to maintain this electrode, the tube envelope and the helix at ground potential and, accordingly, the cathode 32 at a potential negative to ground. The accelerating potentials are chosen to impart an electron velocity substantially equal to the axial wave velocity along the helix. A magnetic coil (not shown) is disposed around the exterior of the tube for producing a longitudinal magnetic field parallel to the axis of the helix for reducing radial components of electron velocity and focussing the stream into a well defined cylindrical beam, preferably hollow, coaxial with the helix.

In order to keep the interior of the tube envelope evacuated, the wave guides 13 and 14 are sealed off with cover glasses 51 and 52, respectively, which are made vacuum tight, and the central chamber is provided with an exhausting tubulation which however has not been shown here.

The description hitherto has been of a typical helix traveling wave tube and many variations thereof are equally suitable for the purposes of the invention. In particular the tube envelope can be of a glass or similar non-conductive material, in which case the elongated central portion thereof is supported between two suitably apertured wave guides so that the helix ends extend into the wave guides for electromagnetic coupling thereto in accordance with principles familiar to workers in this art.

As has been indicated above, the invention is directed to improving the match between the helix and the wave guides to which it is coupled. As is described in the copending Pierce application to which reference has been made above, it is found advantageous in coupling a helix to a wave guide to confine the coupling therebetween to a short end portion of the helix, generally less than half a wavelength long, and to provide an impedance transformation for reducing the helix impedance at this coupling region.

With particular reference now to the arrangement for coupling the helix 17 to the input wave guide, which is shown in an enlarged view in Fig. 3 and in cross section in Fig. 2, the end 41 of the helix extends into the wave

guide and is connected to the cylindrical conductive post 42 which extends from the guide wall 13A.

It is advantageous that the pitch of the helix remain uniform up to the point of connection. To this end, a portion of the end of the conductive post 42 is beveled in a pitch corresponding to that desired for the helix and the end 41 of the helix is fitted flush with this beveled portion and the connection is made there. As a result, there is effected between the conductive post 42 and the helix 17 a smooth transition, and more importantly, one that can be reproduced quite exactly in a convenient fashion. Alternatively, the helix end can be integral with a cylinder formed by brazing together a plurality of closely spaced turns of the conductor. The field coupling is confined to a suitably short portion 43 of helix by means of an apertured conductive member 44 which surrounds the intermediate portion of the helix in the wave guide, leaving exposed to the wave guide field only the coupling portion 43 and a somewhat longer end portion 45. This longer exposed portion 45 is unimportant from a coupling standpoint, being made too long for the wave guide field to have an appreciable effect. The conductive member 44 is suitably positioned and dimensioned so that the energy incident thereon is used to propagate a wave along the helix in the direction of electron flow. Additionally, to secure the impedance transforming effect desired, there is provided a hollow cylindrical or ring member 49, for forming a quarter wave impedance transformer. The general principles of such quarter wave impedance transformers are more fully described on page 188 in the *Radio Engineer's Handbook* by F. E. Terman, published by McGraw-Hill Book Company, New York (1943). In practice, it has been found desirable to position this transformer section 49 to surround as closely as possible the quarter wavelength helix portion 46 following the coupling portion 43. To this end, each of the dielectric rods 18 which serves to support the helix is cut away to form a slot or notch 47 along its inner surface adjacent the helix portion, and the member 49 is passed therethrough around but spaced apart from the helix portion. Moreover, it has been found convenient to support the conductive member 44 around the dielectric rods 18, in contact with portions of the ring member 49 so that the two may be maintained at the same potential level. A longitudinal slot 57 is provided on the inner surface of the outer ring member 44 to accommodate each of the four rods 18 as shown in the transverse cross-sectional view of Fig. 2, so that in the longitudinal cross-sectional planes shown in Figs. 1 and 3 the members 44 and 49 are not shown to be in contact. As clearly appears in Fig. 2, however, members 44 and 49 are in contact at all points not included in the four slots 57.

At the output end of the tube shown in Fig. 1, the helix 17 is coupled to the wave guide 14 in an analogous fashion, so that for the sake of brevity, a description thereof is being omitted.

It is, of course, possible to utilize a coupling arrangement of the kind described at only one of the two ends of the helix circuit in conjunction with some other suitable form of coupling arrangement at the other end.

Moreover, the basic arrangement described can be modified in various ways. It may be desirable in special instances to eliminate the field confining member 44 and employ only the impedance transformer member 49. Alternatively, the field confining member 44 can take a variety of forms. For example, it may be desirable in other instances to extend the field confining member from the wave guide wall 13B, in which case it may also be desirable to vary the geometry of this end portion of the wave guide for example, to decrease in this region this short dimension of the wave guide for forming a flat end portion.

These principles described can be applied to arrangements for coupling a helix to a coaxial line form of wave transmission circuit. By way of example Fig. 4 shows

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an arrangement in which the helical conductor 17 is in an energy exchange relation with the coaxial terminal 62 which comprises an inner cylindrical conductor 63 enclosed by a hollow outer cylindrical conductor 64. The inner conductor 63 can be solid or, as is advantageous for the traveling wave tube application shown, tubular for passage therethrough of an electron stream. In such application the outer conductor 64 can be integral with the envelope of the tube. The helix is maintained coaxial with the inner and outer conductors by means of a series of dielectric support rods 18 extending longitudinally along the surface of the helix and spaced apart therearound. One end 41 of the helix is connected to an end of the inner conductor 63, preferably in the manner described above to provide a smooth easily reproduced transition from the inner conductor 63 to the helix. The field coupling region between the helix and the coaxial line is formed by extending a projection or base member 65 from the outer conductor 64 towards the inner conductor for forming a gap therebetween in which the electric field resulting from a wave propagating along the coaxial line has a large component in the direction of the helix axis. This axial component is reinforced and stray capacitance reduced by having the projection extend obliquely as shown towards the inner conductor. The coupling gap between the inner and outer conductors is adjusted so that the coupling portion 43 of helix in this gap is less than one half a wavelength. Additionally, as above, an annular conductive member 49 surrounds the quarter wavelength of helix 46 following the coupling 43 and each of the support rods has that portion of its inner surface opposite this quarter wavelength of helix notched in a slot 47 for passage therethrough of the ring member 49 which serves as the impedance transformer.

It is to be understood that the above-described embodiments are merely illustrative of the general principles of the invention. In particular various other modifications of the arrangements shown in the above-identified Pierce application, can be devised by a worker in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In an electronic device, input and output wave guiding circuits, a helix wave transmission circuit extending between the input and output wave guiding circuits, one end region thereof in field coupling relation with the input circuit and the other end region thereof in field coupling relation with the output circuit, a plurality of dielectric support members extending longitudinally along the surface of said helix and spaced apart around the helix periphery, each of said support members slotted along two portions of its inner surface adjacent to portions of the helix following the two coupling end regions, and means at each coupling region for matching the helix impedance to the associated wave guiding circuit comprising a conductive ring member closely surrounding but spaced apart from the helix and passing through the slots in the support members.

2. In an electronic device, means forming and defining a path of electron flow, a helix along said path for guiding electromagnetic waves for interaction with the electron flow, a wave transmission circuit in energy exchange relation with an end portion of said helix, a plurality of dielectric rods extending longitudinally along said path and spaced apart around the periphery of said helix for supporting the helix along said path, each of said dielectric rods being notched along a portion of its surface adjacent a portion of helix following said end portion of the helix, and a conductive ring member passing through the notches closely surrounding but spaced apart from the helix.

3. An electronic device according to claim 2 which includes a field confining member surrounding a portion of the helix following the end portion and passing around the dielectric rods, which is at the potential of the conductive ring member.

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4. In an electronic device, input and output hollow wave guides, a helix wave transmission circuit having one end extending in the input wave guide for coupling thereto and the other end extending in the output wave guide for coupling thereto, a plurality of dielectric rods extending along the outer surface of said helix spaced apart around the helix periphery for supporting the helix between the two wave guides, each of said rods slotted along portions of its inner surface adjacent to portions of the helix extending within the two wave guides, and means within each wave guide for matching the helix impedance to the wave guide impedance comprising a conductive ring member closely surrounding but apart from the helix passing through the slots in the dielectric rods, and a field confining conductive element within each wave guide surrounding the helix and the dielectric rods.

5. In an electronic device, a helical conductor, a hollow wave guide apertured in a side wall for admittance of one end of said helical conductor, a conductive post extending from a side wall of said wave guide to which is connected said end of the helical conductor, a plurality of dielectric rods spaced apart around and in contact with the helical conductor for its support within the wave guide, each of said rods having a portion of its inner surface slotted, and a conductive annular member passing through the slots in the dielectric rods and closely surrounding a portion of the helical conductor in the wave guide.

6. An electronic device according to claim 5 which includes an apertured conductive field confining element in the wave guide passing around the dielectric rods for surrounding a portion of the helical conductor and in contact with said conductive annular member.

7. In an electronic device, a helical conductor, a hollow wave guide apertured in a side wall for admittance of one end of said helical conductor, a conductive post extending into said wave guide to which is connected said end of the helical conductor, a plurality of dielectric support rods spaced around and in contact with the outer surface of the helical conductor, each of said support rods being spaced apart along a portion of its inner surface from said helical conductor for forming slots therebetween, and a conductive member in said wave guide comprising an annular member passing through said slots for closely surrounding a portion of the helical conductor.

8. In an electronic device according to claim 7 which further includes in the hollow wave guide an apertured element surrounding the dielectric rods and at the potential of said annular member.

9. In an electronic device, a helix, a hollow wave guide apertured in a side wall for admittance of one end of said helix, a conductive post extending into said wave guide to which is connected said end of the helix, the portion of the end of said conductive post to which the connection is made being beveled to the pitch of the helix, conductive means for confining the coupling between the helix and the wave guide to an end portion of the helix, a plurality of dielectric support rods spaced around and in contact with the outer surface of the helix, each of said support rods being spaced apart along a portion of its inner surface from the portion of the helix following said coupling end portion for forming slots therebetween, and a conductive member disposed to pass through said slots for surrounding the portion of the helix following said coupling end portion.

10. In a transmission system, a helix, a plurality of dielectric support members extending along in contact with the helix surface, each of said members slotted along a portion of their inner surface for providing therealong a separation from said helix, and means in an energy exchange relation with said helix including an outer hollow member comprising a portion of the outer conductor of a coaxial terminal and having a conductive projection with an aperture therein which includes an annular element for closely surrounding the helix passing

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through the separation formed between the helix and support members, and an inner member comprising a portion of the inner conductor of said coaxial terminal, one end of the helix being connected to said inner member.

11. In a wave transmission system, a helix, a wave guiding structure in energy exchange relation with said helix including an outer hollow member comprising a portion of the outer conductor of a coaxial terminal and an inner member comprising a portion of the inner conductor of said coaxial terminal, the helix being connected at one end to said inner member, a lateral member extending from said outer member towards said inner member apertured for passage of the helix therethrough for forming therebetween a coupling gap in which extends an end portion of the helix, a plurality of dielectric support rods spaced around and in contact with the major portion of the outer surface of the helix but spaced apart from a portion of the helix following the coupling end portion for forming slots therebetween, and a conductive member passing through said slots for surrounding a portion of said helix.

12. In electronic apparatus, a helix, a wave guiding structure in energy exchange relation with said helix

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including an outer hollow member comprising a portion of the outer conductor of a coaxial terminal and an inner member comprising a portion of the inner conductor of said coaxial terminal, the helix being connected at one end to said inner member, a plurality of dielectric support rods spaced apart around the helix, each notched, and a lateral member extending from the outer conductor of the coaxial terminal comprising a ring member passing through the notches in the dielectric rods for closely surrounding a portion of the helix following the connected end of the helix for transforming the helix impedance and a field confining member passing around the dielectric rods.

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