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APPARATUS FOR COUPLING A HELICAL CONDUCTOR TO A MICROWAVE FIELD

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Fig. 1.

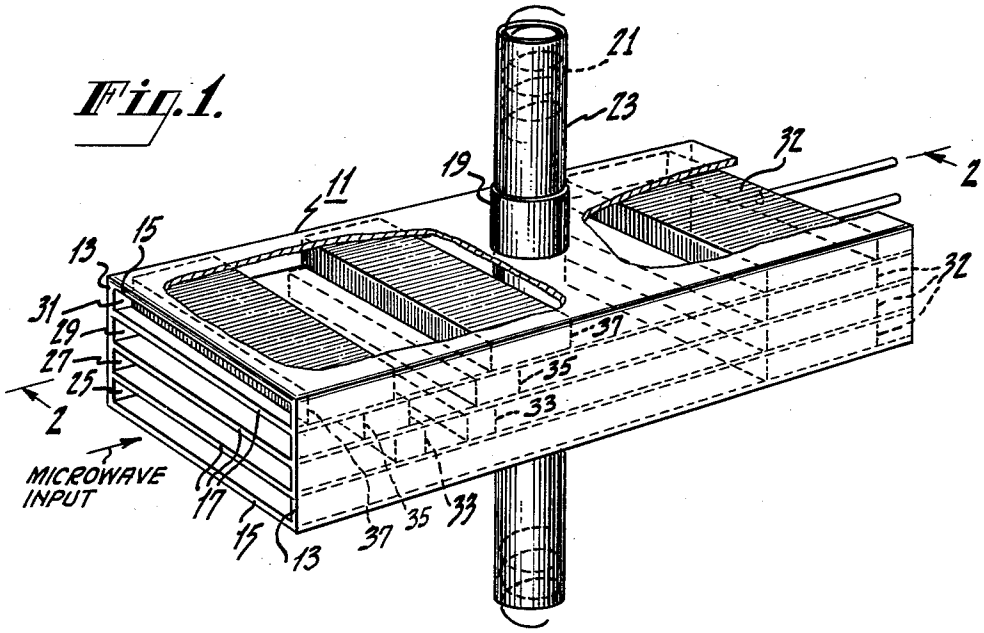
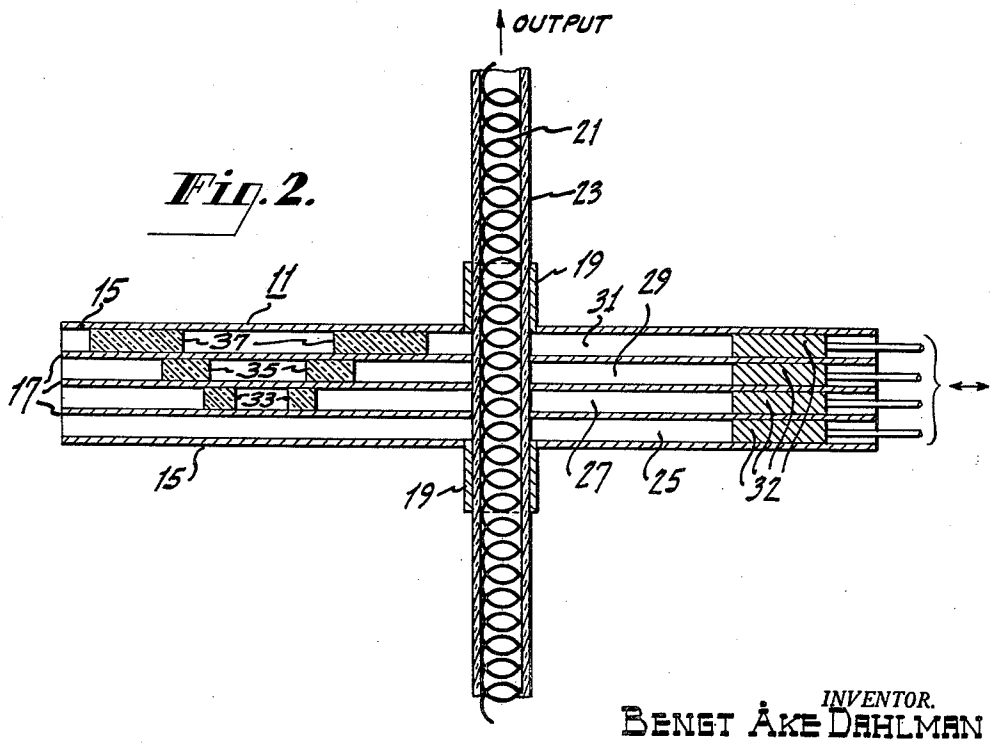


Fig. 2.



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APPARATUS FOR COUPLING A HELICAL CONDUCTOR TO A MICROWAVE FIELD

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The terminal fifteen years of the term of the patent to be granted has been disclaimed

11 Claims. (Cl. 333—21)

This invention relates generally to coupling a helical conductor to a guided microwave electromagnetic field. More particularly, the invention relates to novel structure for coupling a helix, for example, of the type employed in traveling-wave-tubes, to an electromagnetic field propagated within a microwave transmission line.

Heretofore, one of the most common methods of coupling the helix in a traveling-wave-tube to a hollowpipe waveguide has been to connect a small antenna to the end of the helix. The antenna is arranged so that it is parallel to the electric field in the waveguide and thus couples to the microwave field. However, this method of coupling, while having certain advantages, has the principal disadvantage that the axial position of the helix in the waveguide is very critical. Rather limited axial movement of the helix causes the voltage standing-wave ratio, as seen from the waveguide, to increase appreciably.

An object of the present invention is to provide improved means for coupling a helix to a guided electromagnetic field.

Another object of the invention is to provide improved means for coupling a helical conductor of the type employed in a traveling-wave-tube to an electromagnetic field propagated within a hollowpipe waveguide.

Another object of the invention is to provide a directive microwave coupling between a hollowpipe waveguide and a helix.

A further object of the invention is to provide a microwave coupling of the type mentioned above wherein the electrical effect of axial movement of the helix with respect to the waveguide is not critical.

Briefly in accordance with a typical embodiment of the invention, a rectangular hollowpipe waveguide is divided by walls normal to the electric axis into a plurality of wide flat sub-guides. The waveguide is adapted to receive a portion of the helix with the helix oriented so that its longitudinal axis is normal to the broad walls of the waveguide. Each sub-guide couples to a different section of the helix with a phase delay that varies linearly along the helix. By suitably adjusting the phase delay in each sub-guide, the coupling between the waveguide and helix is directive. With a directive coupling the importance of the impedance conditions at that part of the helix which does not carry any power decreases. Since the helix is uniform this means that the coupling structure is relatively insensitive to movement of the helix with respect to the electric axis of the waveguide. That is, the axial position of the helix in the waveguide is not critical.

The invention will be described in greater detail with reference to the accompanying drawing in which:

Figure 1 is a perspective view of a preferred embodiment of the invention in which a helix couples to a microwave field propagated in a hollowpipe waveguide; and

Figure 2 is a front sectional view of the structure of Figure 1 taken along section line 2—2.

Similar reference characters are applied to similar elements throughout the drawing.

Referring to Figures 1 and 2, a rectangular hollowpipe waveguide **11** includes narrow walls **13, 13** and broad walls **15, 15**. The waveguide **11** is divided into a plurality of sub-guides by thin metal sheets **17**. The sheets **17** are arranged so that they are parallel to the broad walls **15, 15** and are normal to the electric field vectors of the energy pattern propagated within the waveguide **11**.

The waveguide **11** includes collars **19, 19** spaced from the input end of the waveguide. These collars **19, 19** preferably extend from each of the broad walls **15, 15** of the waveguide **11** and are located approximately midway between the narrow walls **13, 13**. The broad walls **15, 15** and the metal sheets **17** each include aligned apertures having diameters substantially the same as the inside diameters of the collars **19, 19** and in registry therewith. The apertured waveguide structure and collars thus are adapted to receive a slow wave structure such as the helix **21**. The helix **21** may be supported prior to its insertion in the waveguide **11** by some convenient means such as a glass tube **23**. The tube **23**, in addition to providing support for the helix **21**, affords the additional advantage, after insertion, of insulating the helix from the waveguide and from the collars **19, 19**.

The method by which microwave energy is directionally transferred from the waveguide **11** to the helix is as follows. The waveguide **11**, in the example illustrated, is divided into four sub-guides **25, 27, 29**, and **31**. Microwave energy is coupled to the input end of the waveguide **11** and is simultaneously propagated in all sub-guides. The coupling device is tuned by means of metallic tuning pistons **32** which are longitudinally movable in each sub-guide. Sub-guide **25**, most remotely spaced from the output end of the helix **21**, couples to the portion of the helix adjacent thereto. Under such circumstances the energy thus transferred from the sub-guide **25** to the helix **21** propagates bi-directionally along the helix. The next adjacent sub-guide **27** includes a pair of spaced phase delay members **33, 33** comprising, for example, dielectric materials such as polystyrene or polytetrafluoroethylene (the latter being sold commercially under the trade-name "Teflon.")

The total thickness of the members **33, 33** is chosen such that the phase delay of microwave energy propagated in sub-guide **27**, with respect to the energy propagated in sub-guide **25**, is substantially equal to the phase delay of microwave energy traveling from a given point on the portion of the helix adjacent sub-guide **25** to a corresponding point on the portion of the helix adjacent sub-guide **27**. Since the two phase delays are made equal the energy transferred to the helix **21** from sub-guide **27** and propagated in one direction along the helix **21** "reinforces" the energy transferred to the helix from sub-guide **25**. The energy propagated in the reverse direction along the helix **21** is decreased. The coupling thus is directional, that is, a substantial amount of coupled energy is propagated along the helix in the direction of the sub-guide having the greater phase delay. Only a negligible amount of energy is propagated along the helix **21** in the opposite direction.

Sub-guides **27** and **29** similarly include spaced phase delay members **35, 35** and **37, 37**, respectively. The overall thickness of the phase delay members in each of these sub-guides is made greater than that in the immediately preceding sub-guide so that the change in phase delay from one sub-guide to the next is constant. That is, the phase delay in sub-guide **29** is greater than that in sub-guide **27** and the phase delay in sub-guide **31** is greater than that in sub-guide **29**. With the above cou-

pling arrangement each sub-guide contributes to the directional propagation feature of the invention.

In a typical embodiment of coupling structure in accordance with the invention, the cross-sectional dimensions of the waveguide **11** are 1½" x ¾". The waveguide **11** is divided into four sub-guides, as indicated herein. A 4.5 turn per inch helix is wound on a 0.094" mandrel using 0.080" wire. The constant change in phase delay between successive sub-guides is selected and adjusted by means of the phase delay members **33, 35, 37** to be $\pi/2$ radians. With the operative ends of the tuning pistons spaced 1.73" from the axis of the helix, a directivity of 10–16 decibels is obtainable within the frequency band from 6400–6700 megacycles.

While the phase delay members in each sub-grade have been shown and described as pairs of spaced members, i. e., **33, 33** and **35, 35** and **37, 37**, it is pointed out that the two members in each sub-guide may be replaced by a single member, if desired, to provide the necessary phase delay. The use of pairs of spaced members is preferred, however, or the members may be tapered as shown in E. G. Linder Patent 2,430,130, to reduce undesired reflections.

What is claimed is:

1. A directive microwave energy coupling arrangement comprising, a rectangular hollowpipe waveguide for propagating said microwave energy, a plurality of metallic plates for dividing said waveguide into a plurality of sub-guides, said plates being arranged normal to the electric vector of the electromagnetic field pattern of said microwave energy, phase delay means in each but one of said sub-guides for differently delaying the phase of microwave energy coupled therethrough, the phase delay in any one sub-guide differing from the phase delay in an adjacent sub-guide by a constant amount, and a conductive helix having a portion of its length arranged in an energy transfer relationship with said sub-guides, the pitch of said helix portion being related to the constant difference in phase delay between said sub-guides.

2. A coupling arrangement as claimed in claim 1 wherein said phase delay means in each but one of said sub-guides comprises a pair of spaced phase delay members.

3. A coupling arrangement as claimed in claim 2 wherein said delay members comprise dielectric members.

4. A coupling arrangement as claimed in claim 1 including means for tuning said divided waveguide.

5. A coupling arrangement as claimed in claim 4 wherein said tuning means comprises a tuning piston for each of said sub-guides.

6. A directive microwave energy coupling arrangement comprising, a rectangular hollowpipe waveguide having broad and narrow walls, a plurality of flat metallic plates parallel to said broad walls for dividing said waveguide into a plurality of sub-guides, phase delay means in each but one of said sub-guides for differently delaying the phase of microwave energy coupled therethrough, the phase delay in any one sub-guide differing from the phase delay in an adjacent sub-guide by a constant amount, and a conductive helix having its longitudinal axis normal to said broad walls and a portion of its length arranged in an energy transfer relationship with said sub-guides, the pitch of said helix portion being related to the constant difference in phase delay between said sub-guides.

7. A coupling arrangement as claimed in claim 6 wherein said broad walls and said metallic plates include aligned apertures in registry with each other and said helix extends therethrough.

8. A coupling arrangement as claimed in claim 6 including a glass tube positioned intermediate said helix and said waveguide.

9. A directive microwave energy coupling arrangement comprising, a rectangular hollow-pipe waveguide for propagating said microwave energy, a plurality of metallic plates for dividing said waveguide into a plurality of sub-guides, said plates being arranged normal to the electric vector of the electromagnetic field pattern of said microwave energy, phase delay means in said sub-guides for differently delaying the phase of microwave energy coupled therethrough, and a conductive helix having a portion of its length arranged in an energy transfer relationship with said sub-guides, the pitch of said helix portion being related to the differences in phase delay between said sub-guides.

10. A directive microwave energy coupling arrangement comprising a hollow pipe waveguide for propagating said microwave energy, means for dividing said waveguide into a plurality of sub-guides, delay means in said sub-guides for delaying the microwave energy coupled therethrough by different amounts, and a conductive helix having a portion of its length arranged in an energy transfer relationship with said sub-guides, the structure of said helix portion being related to the differences in delay between said sub-guides.

11. A directive microwave energy coupling arrangement comprising, a rectangular hollowpipe waveguide for propagating said microwave energy, a plurality of metallic plates for dividing said waveguide into a plurality of sub-guides, said plates being arranged normal to the electric vector of the electromagnetic field pattern of said microwave energy, phase delay means in each but one of said sub-guides for differently delaying the phase of microwave energy coupled therethrough, and a conductive helix having a portion of its length arranged in an energy transfer relationship with said sub-guides, the pitch of said helix portion being related to the differences in phase delay between said sub-guides.

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