

June 21, 1949.

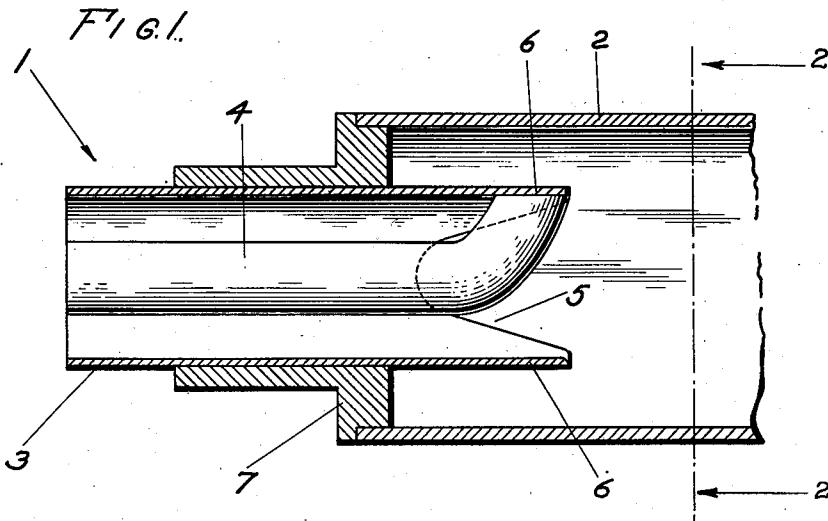
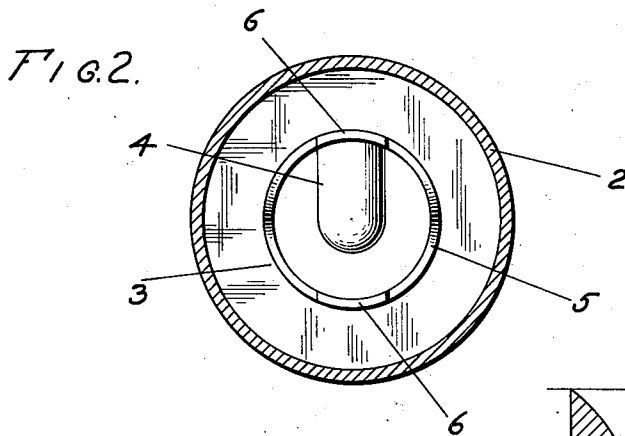
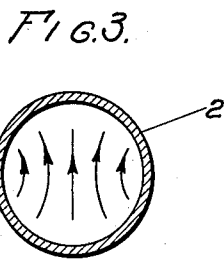
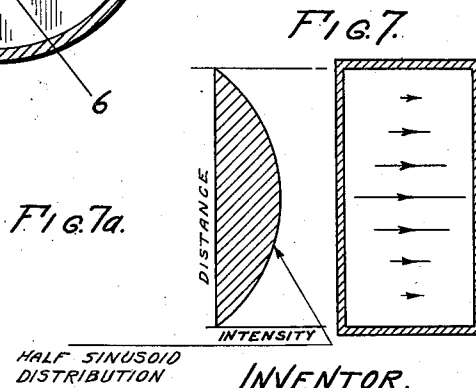
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COUPLING SYSTEM FOR WAVE GUIDES

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2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 4.

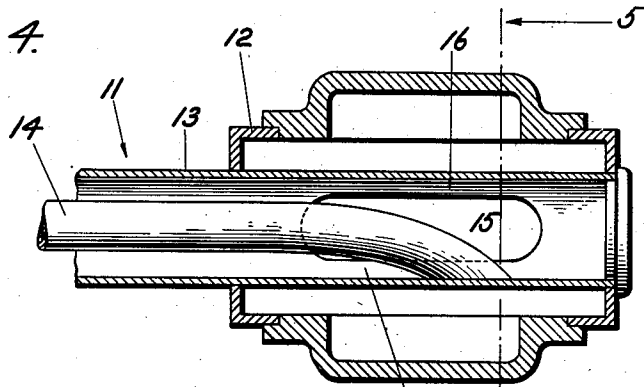


FIG. 5.

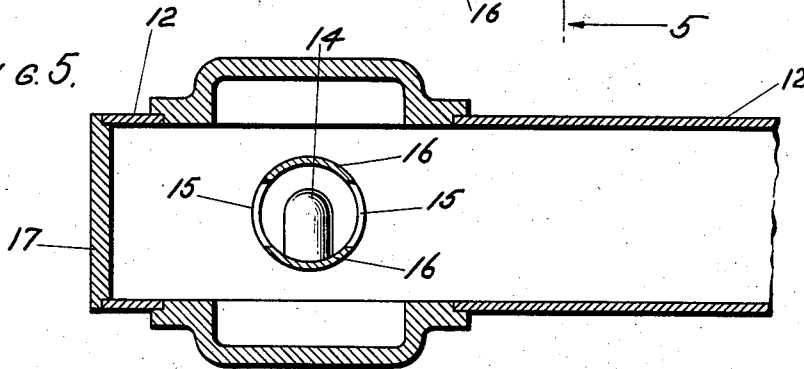
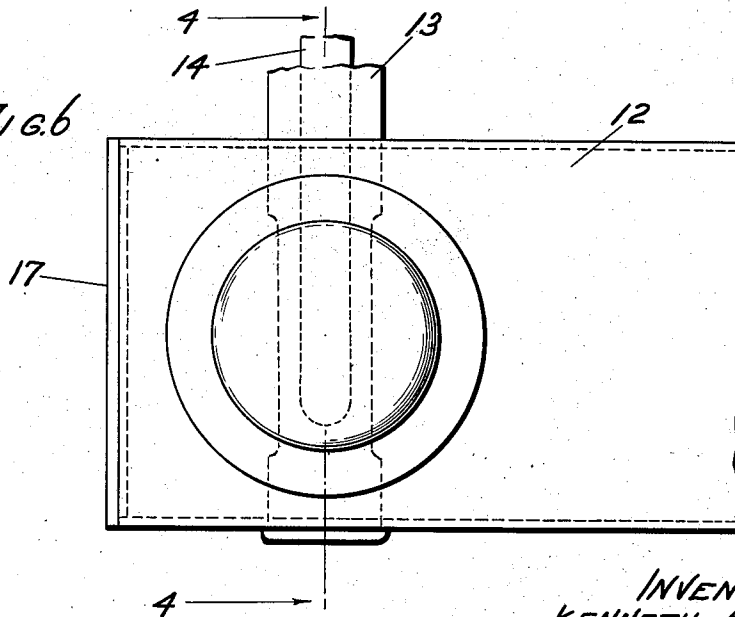


FIG. 6.



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COUPLING SYSTEM FOR WAVE GUIDES

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12 Claims. (Cl. 178-44)

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This invention relates to guided electromagnetic wave transmission systems, and more particularly to a transition device for coupling a coaxial conductor transmission line and a hollow wave guide.

In coupling a coaxial line to a dielectric wave guide, it is desirable to convert the wave form from one most suitable for propagation in the coaxial line to a form suitable for the geometry of the dielectric wave guide, whatever its configuration may be. Conversely a wave passing through the system in the reverse direction should be converted from the type most desirable for transmission through the guide to a type suitable for transmission in the coaxial line.

It is among the objects of the invention to provide a device by which electromagnetic waves of one type, under propagation in a guided wave transmission system, may be modified or reshaped so that after conversion they will be propagated as waves of a predetermined type.

In coupling the coaxial line and a hollow wave guide, it is generally essential that the concentric line be joined to the wave guide in a predetermined direction. For example, in coupling a concentric line to a rectangular wave guide, it has heretofore been generally necessary to couple to the hollow wave guide at some predetermined position on the wide dimension of the guide. If for structural reasons inherent in the transmission system the concentric line must approach the hollow wave guide from a different side, such for example as from the narrow side thereof, then a series of transmission line sections disposed at proper angles must be introduced in the system in order that the concentric line may enter the wave guide from the proper direction. Not only is the additional bulk and weight due to such bends or angles objectionable, but they also introduce additional mechanical complications in a system where it is desired to rotate one section of the transmission line relative to another, as in the case where the direction of propagation from an antenna system is to be varied. Furthermore, such bends necessarily increase the electrical losses in the system.

It is a further object of the invention to provide a device of the type described in the foregoing for effecting the desired transition between the concentric line and the hollow wave guide in a simple direct manner without the introduction of complex bends or angles into the concentric line as it approaches the guide.

A further object of the invention is to provide a device of the type described which is suitable

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for the transmission of waves of relatively high energy.

The invention will be described as a transition device from the principal wave in a coaxial transmission line to the TE 1, 1 mode in a hollow cylindrical wave guide, and to the TE 0, 1 mode in a rectangular guide, but should not be construed as limited to any particular mode. Also it will be understood that the invention may be utilized in transmission lines of less common shapes.

The foregoing and other objects of the invention will be best understood from the following detailed description, reference being had to the accompanying drawings wherein:

Fig. 1 is a section through one form of my novel transition device;

Fig. 2 is a section taken on the line 2-2 of Fig. 1;

Fig. 3 is a diagrammatic view illustrating the mode of operation of the form of the invention shown in Figs. 1 and 2;

Fig. 4 is a section through another embodiment of the invention and is taken on the line 4-4 of Fig. 6;

Fig. 5 is a section taken on the line 5-5 of Fig. 4;

Fig. 6 is a plan view of the form of the invention shown in Figs. 4 and 5;

Fig. 7 diagrammatically illustrates the mode of operation of the form of the invention shown in Figs. 4, 5 and 6; and

Fig. 7a shows diagrammatically the field distribution corresponding to Fig. 7.

Referring to the drawings, and first to Figs. 1-3 thereof, the transition device in this instance includes a coaxial conductor transmission line 1 and a cylindrical wave guide 2. The coaxial line 1 comprises an outer tubular conductor 3 and an inner conductor 4 which is positioned centrally in the outer conductor except at the end thereof where the conductor 4 is bent to contact the conductor 3 to the inner surface of which the conductor 4 is soldered or otherwise secured to provide good electrical connection therewith.

The coaxial line 1 projects into the wave guide 2 at the approximate electrical center thereof. In this instance the wave guide is cylindrical and the coaxial line 1 projects into the wave guide 2 in such manner that the electrical center of the radiating elements hereafter described extends into the round wave guide for a distance approximately equal to one-quarter of the length of the waves which the system is adapted to transmit. The outer conductor 3 is provided with a pair of diametrically opposed slots 5 which extend from

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the end thereof within the wave guide 2 for a distance approximately equal to one-quarter of the length of the waves on the transmission line. Since a substantial portion of the walls of the tube 3 are cut away in forming the slots 5, a pair of opposed tongues 6 is provided by the remaining material of the tube 3, and it is to one of these tongues that the conductor 4 is secured to provide a good electrical connection between the outer tubular conductor 3 and the inner conductor 4. A reflecting plug 7 closes the end of the wave guide 2 and is provided with a central opening through which the outer tubular conductor 3 extends.

Guided wave transmission lines of the type described in the foregoing are usually designed to carry electromagnetic waves of approximately a predetermined wave length which may be represented by λ . If the length of the slot 5, as indicated in Fig. 1, is made approximately equal to

$$\frac{\lambda}{4}$$

a circuit which is resonant at the predetermined wave length λ is provided by the slots 5, which resonant circuit has points of high potential at the tip ends of the tongues 6. The slots 5 may be designated as one-quarter wave length slots and may be said to be excited at the frequency corresponding to the predetermined wave length λ . Waves are propagated in both directions in the wave guide 2, that in the direction of the reflecting plate 7 being reflected so that it combines in proper phase with the wave traveling in the desired direction.

In order that the reflected waves combine in proper phase with the oppositely directed waves, the distance between the reflecting plate 7 and the electrical center of the radiating slots 5 should be

$$\frac{\lambda}{4}$$

The term electrical center means point, or small area, or small volume from which, viewed from a point several wave lengths away, the electromagnetic energy appears to emanate. However, since the portion of the coaxial line which projects into the wave guide 2 alters the electrical characteristics of the portion of the guide so traversed, the actual distance that the coaxial line 1 projects into the wave guide 2 in order that the reflected and direct waves combine in proper phase differs from the theoretical. It will therefore be understood that when referring to distances in terms of wave length herein, the apparent electrical distance is meant, not necessarily the linear distance.

In the operation of this form of invention, when the coaxial line is working in the principal mode, a potential difference varying with time is impressed across each of the slots 5. These slots 5 are excited with points of high potential occurring at the ends of the tongues 6. Since the depth of each slot is electrically equal to

$$\frac{\lambda}{4}$$

the distance between the points of high potential as taken along the slots is equal to

$$\frac{\lambda}{2}$$

A circuit is therefore provided by each slot which is resonant at the frequency corresponding to λ ,

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where λ is the length of the wave upon the line 1. A wave is propagated in guide 2 in both directions from the points of high potential at the ends of the tongues 6 corresponding to the wave form shown in Fig. 3 in which the curved arrows indicate lines of electrical intensity. The wave propagated in the direction of the reflecting plates 7 is reflected back and combines in proper phase with the waves propagated in the opposite direction.

The above described form of the invention functions efficiently as a transition device at relatively high power. I have found that the limit of power-handling capacity is usually evidenced by the formation of corona at the ends of tongues 6. To avoid this difficulty and increase the power-handling capacity and yet retain the advantages possessed by the form of the invention previously described, the coupling may be modified in the manner illustrated in Figs. 4-6.

In this form of the invention the coaxial conductor transmission line 11 has its outer tubular conductor 13 projecting transversely through a hollow wave guide 12. In this instance the hollow wave guide 12 is rectangular in transverse section and the coaxial line 11 enters the wave guide through one of the narrower walls thereof and extends to the opposite wall. Slots 15 in the outer conductor 13 extend longitudinally of the portion of said conductor enclosed within the wave guide 12, and the inner conductor 14 of the coaxial line 11 is bent to contact the inner wall of the outer tubular conductor 13 at a point intermediate the length of the slots 15. The portions of the tubular conductor 13 remaining after the slots 15 have been cut therein provide two opposed conductive strips 16 to one of which the central conductor 14 is electrically connected. In this case the length of the slots 15 is made approximately equal to one-half of the length of the waves on the transmission line and it will be observed that a conductive path is provided between the two strips 16 around each end of the slots 15 by the material of the tube 13.

The operation of this form of the invention is similar to the operation of the form previously described except that the length of the slots 15 is made approximately equal to

$$\frac{\lambda}{2}$$

The points of high potential occur at the mid point of the length of the slots. The distance between the points of high potential as taken along the slots is equal to

$$\frac{\lambda}{2}$$

in either direction. When the coaxial line is working in the principal mode, the slots 15 are excited as in the previously described form. A circuit is provided in each direction by each of the slots 15 from one of the high potential points to the other, which circuits are resonant at the frequency corresponding to λ . A wave is propagated in the guide 12 in both directions corresponding to the form shown in Fig. 7 where the lines indicate the distribution of electrical intensity. The reflecting plate 17, which is used when propagation is desired only in one direction, is positioned so that the reflected waves combine in proper phase with the direct waves. The distribution of the electric field in the rectangular guide is indicated in Fig. 7a in which the ordinates represent corresponding points along the long dimension of the wave guide, and the ab-

scissas represent the relative intensity of the field. This form of distribution is recognized as the most favorable form for the rectangular guide. In this form of the invention wave forms of a higher order or mode may be obtained by changing the number and/or position of the slots 15.

It will be apparent that the resonant circuit provided by the slots in the outer conductor of the coaxial transmission line in either of the forms shown need not necessarily be formed in the manner shown by cutting slots in the outer conductor and connecting the inner conductor to one of the strips of material of the outer conductor remaining after the slotting operation. For example, the tongues 6, of the form shown in Figs. 1 and 2, may be formed of separate strips of conductive material attached to the enclosed end of the outer conductor, the inner conductor being connected as before to one of said strips. Similarly, the strips 16 of the form shown in Figs. 3, 4 and 5 may be formed separately from the outer conductor 13 and connected thereto in any desired manner, as by soldering, to provide the pair of diametrically opposed strips.

There has been herein described two embodiments of the invention. Many other embodiments, within the scope of the appended claims, will be apparent to those skilled in the art from a consideration of the forms shown and the teachings herein.

What is claimed is:

1. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow wave guide, said outer conductor extending into said wave guide and having slots in the side walls thereof within said wave guide dividing a portion of said outer conductor into conductive strips, said inner conductor being connected to said outer conductor at one of said strips.

2. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow wave guide, said outer conductor extending into said wave guide and having opposed slots in the side walls thereof within said wave guide dividing a portion of said outer conductor into a pair of conductive strips, the length of said slots being substantially equal to one-quarter of the length of the waves on said transmission line.

3. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow wave guide, said outer conductor extending into said wave guide and having slots in the side walls thereof within said wave guide dividing a portion of said outer conductor into conductive strips, the length of said slots being substantially equal to one-half of the length of the waves on said transmission line.

4. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow cylindrical wave guide, said outer conductor extending into said wave guide at the approximate electrical center thereof and having a pair of diametrically opposed slots in the side walls thereof within said wave guide dividing a portion of said outer conductor into a pair of conductive strips, said inner conductor being connected to said outer conductor at one of said strips.

5. A coupling system comprising a coaxial conductor transmission line having an outer con-

ductor surrounding an inner conductor, a hollow wave guide, said outer conductor extending into said wave guide and having slots in the side walls thereof within said wave guide dividing a portion of said outer conductor into conductive strips, said inner conductor being connected to said outer conductor at one of said strips, the length of said slots being substantially equal to one-quarter of the length of the waves on said transmission line.

6. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow wave guide, said outer conductor extending into said wave guide and having slots in the side walls thereof within said wave guide dividing a portion of said outer conductor into conductive strips, said inner conductor being connected to said outer conductor at one of said strips, the length of said slots being substantially equal to one-half of the length of the waves on said transmission line.

7. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow wave guide, said outer conductor extending into said wave guide and having a pair of diametrically opposed slots in the side walls thereof within said wave guide dividing a portion of said outer conductor into a pair of conductive strips providing a circuit resonant to the frequency of the electromagnetic waves on said system, said wave guide having a closed and spaced from the high potential points of said resonant circuit at a distance substantially equal to one-quarter of the length of the waves on said system.

8. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow rectangular wave guide, said outer conductor extending into said wave through the narrow side thereof, and having a pair of diametrically opposed slots in the side walls thereof within said wave guide dividing a portion of said outer conductor into a pair of conductive strips.

9. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow rectangular wave guide, said outer conductor extending into said wave guide through the narrow side thereof and having a pair of diametrically opposed slots in the side walls thereof within said wave guide dividing a portion of said outer conductor into a pair of conductive strips, said inner conductor being connected to said outer conductor at one of said strips.

10. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow wave guide, said outer conductor extending into said wave guide and having a pair of diametrically opposed slots in the side walls thereof within said wave guide dividing a portion of said outer conductor into a pair of conductive strips connected together at each end by said outer conductor, said inner conductor being connected to said outer conductor at one of said strips.

11. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow wave guide, said outer conductor extending into said wave guide and having a pair of diametrically opposed slots in the side walls thereof within said wave guide dividing a portion of said outer conductor into a pair of conductive strips,

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said inner conductor being connected to said outer conductor at one of said strips.

12. A coupling system comprising a coaxial conductor transmission line having an outer conductor surrounding an inner conductor, a hollow wave guide, said outer conductor having a portion projecting into said wave guide, said portion of said outer conductor having an opening within said wave guide, the dimensions of said opening being correlated to the frequency of the electromagnetic waves on said transmission line to form a circuit at said opening resonant to said frequency, said central conductor being electrically connected to said outer conductor at a point within said portion of said outer conductor enclosed by said wave guide, said wave guide having a closed end spaced from the high potential points of said resonant circuit at a distance substantially equal to one-half of the length of the waves on said system.

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Certificate of Correction

Patent No. 2,474,137.

June 21, 1949.

KENNETH A. YOUNG

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 6, line 33, claim 7, for "closed and" read *closed end*; line 41, claim 8, after the word "wave" insert *guide*;

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 22nd day of November, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.