

Aug. 9, 1966

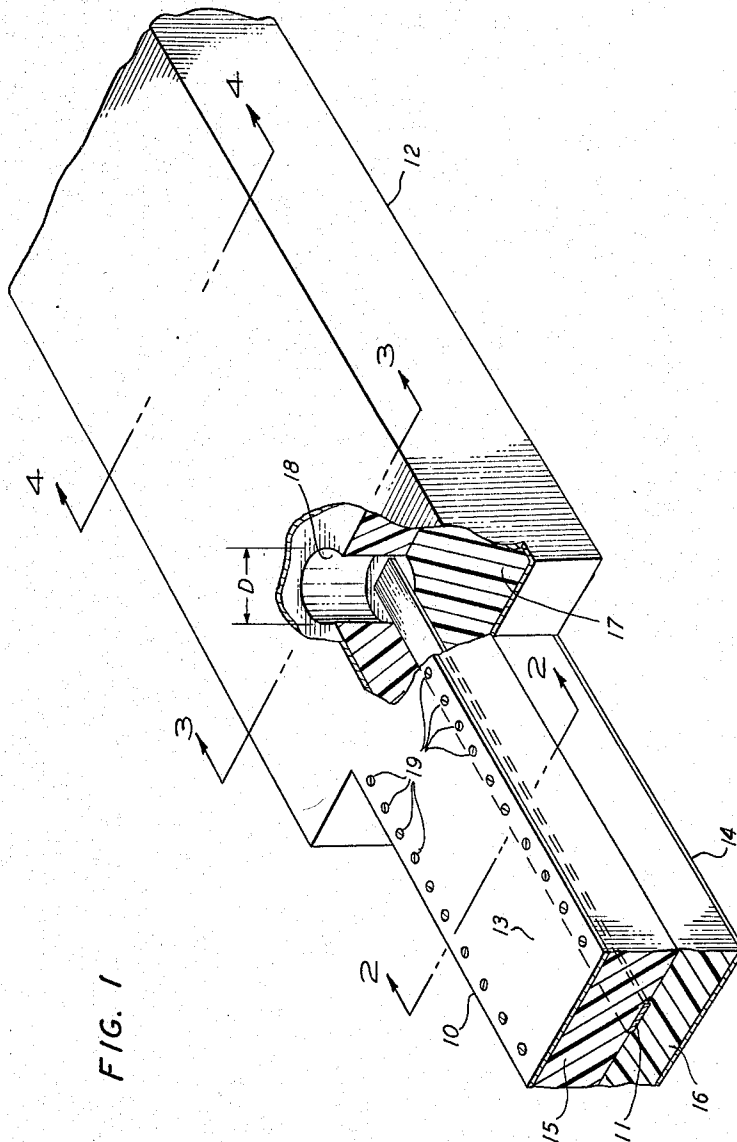
JOJI HAMASAKI

3,265,995

TRANSMISSION LINE TO WAVEGUIDE JUNCTION

Filed March 18, 1964

4 Sheets-Sheet 1



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FIG. 2

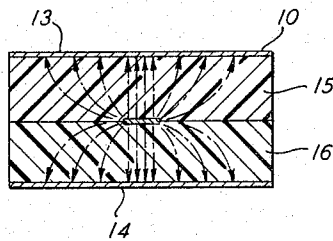


FIG. 3

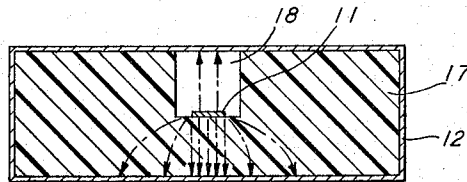
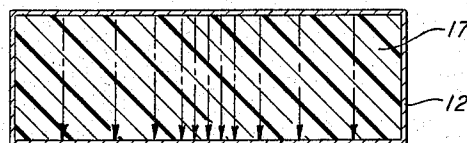


FIG. 4



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FIG. 5

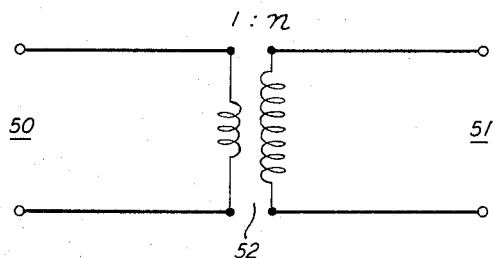
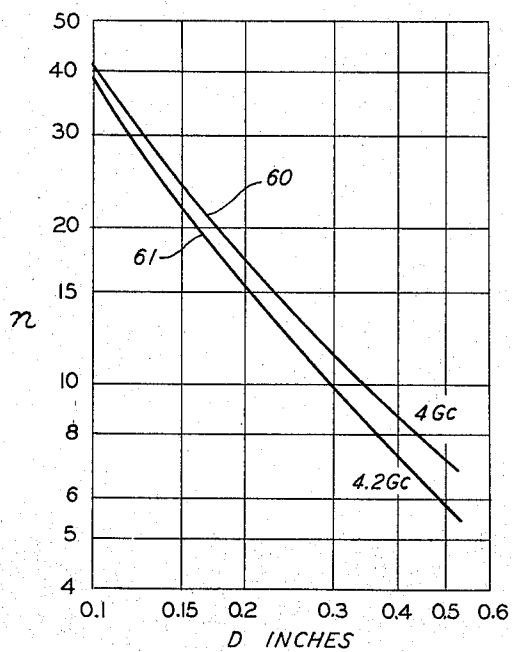


FIG. 6



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FIG. 7

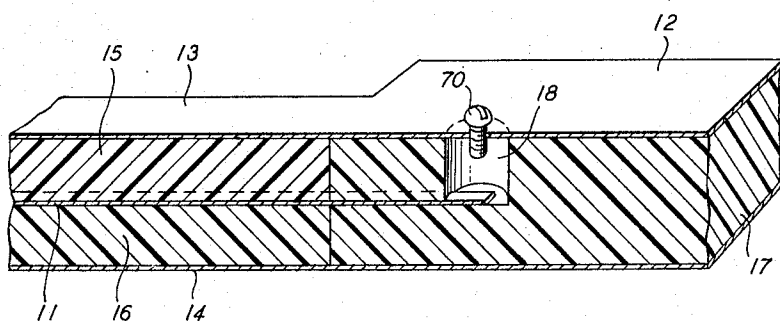
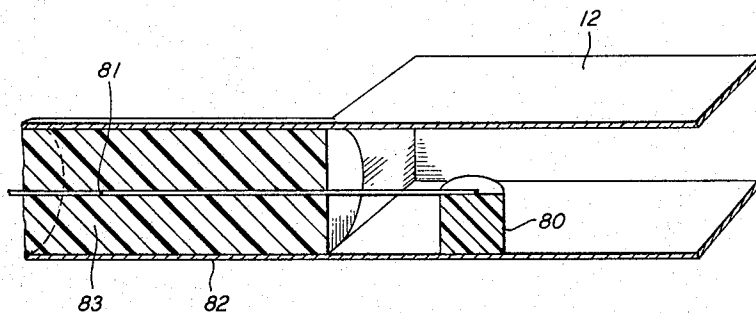


FIG. 8



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TRANSMISSION LINE TO WAVEGUIDE JUNCTION

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6 Claims. (Cl. 333-21)

This invention relates to electromagnetic wave transmission devices and more particularly to devices for coupling strip or coaxial transmission lines to waveguides.

It is frequently desirable in electrical systems to utilize electromagnetic wave transmission lines of diverse types. For example, the energy generated by many microwave devices is most readily transmitted therefrom by a probe which is easily extended to form the inner conductor of a coaxial transmission line. With such devices it may be necessary to transfer the microwave energy between the coaxial transmission line and a waveguide. Similarly, it is often desirable to couple energy from a hollow or dielectric-filled cavity to a strip transmission line. In other cases, waveguides have proven to be the most efficient means for propagating wave energy over an extended transmission path and means are needed to couple the energy into and out of such structures at their terminals.

In all such systems it is necessary to have convenient means for transferring the energy from one type of transmission medium to another. These coupling means must provide a sound electrical and mechanical junction for the two transmission lines and present minimal reflection of, and attenuation to, the propagating wave energy. Various types of coupling means meeting these requirements are well known in the art. For example, several methods of coupling coaxial transmission lines and waveguides are illustrated in "Principles and Applications of Waveguide Transmission," G. C. Southworth, D. Van Nostrand Co., Inc., N.Y., 1950, pages 352-356.

With the recent upsurge in the use of strip transmission lines, however, many of the prior art techniques have proven unsatisfactory in particular application. Specifically, one may wish to couple wave energy propagating in the TEM wavemode in a strip transmission line to the dominant TE₁₀ wavemode in a rectangular waveguide. In accordance with the prior art techniques this may be done by coupling the electric or magnetic fields of the wavemodes. The magnetic coupling method generally requires a loop in the inner conductor of the strip line which is grounded to the waveguide wall and is, therefore, not readily susceptible to adjustments.

The electric field method, on the other hand, requires that the center conductor of the strip line be extended as a probe into the waveguide in a transverse direction. It is obvious that if the strip transmission line and the waveguide are colinear, the magnetic coupling scheme must be used and its nonadjustable feature tolerated; alternatively, if the adjustable feature of the electric coupling scheme is desired, additional mechanical means must be provided so that the center conductor extends transverse to the waveguide.

It is an object of the present invention to provide a coupler for colinear transmission lines of diverse type.

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It is a further object of the present invention to provide strip transmission line or coaxial transmission line-to-waveguide coupling which is easily adjustable.

In accordance with the present invention these objects are accomplished by what may be termed "capacitance" coupling. In a preferred embodiment a strip transmission line propagating electromagnetic wave energy in the TEM wavemode is colinearly disposed with and abuts against a section of dielectric-filled rectangular waveguide. The center conductor of the strip transmission line protrudes solely in the longitudinal direction a short distance into the waveguide. At the end of this extended center conductor, a small region of different dielectric material extends between the conductor and one of the waveguide walls. The dielectric constant of this small region is selected so that it is greater than or less than that of the dielectric material filling the remainder of the guide. Due to the difference in dielectric constants of the two materials, asymmetrical displacement currents and a corresponding asymmetrical electric field distribution are established in the guide. The resulting asymmetrical electric field has components common to components of the wave energy in the rectangular waveguide and coupling is thereby achieved.

By providing a conductive or dielectric tuning screw between the waveguide wall and extended center conductor, the capacitance can be varied, thereby varying the degree of coupling between the strip transmission line and waveguide.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a pictorial view, partially broken away, of one embodiment of the present invention;

FIGS. 2, 3 and 4 are cross-sectional views of the embodiment of FIG. 1 showing the electric field distribution patterns therein;

FIG. 5 is a lumped parameter equivalent circuit of the embodiment of FIG. 1;

FIG. 6 is a graphical representation of the coupling characteristic of the embodiment of FIG. 1;

FIG. 7 is another embodiment of the present invention utilizing an adjustable tuning screw; and

FIG. 8 is a third illustrative embodiment of the present invention, showing a coaxial line-to-waveguide coupler.

Referring more specifically to the drawings, FIG. 1 is a pictorial representation, partially broken away, of a preferred embodiment of the present invention. A strip transmission line 10 having a flat, ribbon-like center conductor 11 abuts against a colinear section of rectangular waveguide 12. Center conductor 11 is separated from conductive ground planes 13 and 14 by layers 15 and 16 of dielectric material. Center conductor 11 extends longitudinally a short distance past the abutting junction into waveguide 12. Although this distance is not critical, it should be noted that center conductor 11 should extend into waveguide 12 a distance at least as great as the radius of coupling hole 18 described hereinafter. Typically, this distance can vary from a small fraction of a wavelength to several wavelengths of the energy propagated through the structure.

In this embodiment, waveguide 12 is filled with a dielectric material 17 having a dielectric constant substantially the same as that of dielectric layers 15 and 16. The dielectric material utilized may be any relatively low loss dielectric material known in the art. Materials known commercially as "Teflon" or "Tellite" are suitable for this purpose. A circular coupling hole 18, having a diameter D, is formed through dielectric material 17 between one of the broad walls of guide 12 and center conductor 11 in the region of its extended end. Although in the embodiment of FIG. 1 this coupling hole is circular and air filled, in general, it can be of any cross-sectional geometry and can also be filled with any low loss dielectric material having a dielectric constant different than that of material 17. For most practical applications the dielectric constant of the material filling coupling hole 18 should be at least 50 percent greater than, or, in the illustrative embodiment of FIG. 1, less than that of dielectric material 17.

Also shown in FIG. 1 are screws or bolts 19 which function to hold the sandwich-like strip transmission line together and also to minimize radiation from center conductor 11.

The operation of the embodiment of FIG. 1 can be explained with reference to the cross-sectional drawings of FIGS. 2, 3 and 4.

FIG. 2 is a cross-sectional view of strip transmission line 10 showing the electric field lines of the TEM wave energy propagating therein. As is evident from the drawing, the electric field lines are symmetrically disposed about the interface between dielectric layers 15 and 16.

FIG. 3 is a cross-sectional view of the embodiment of FIG. 1 taken through the transverse section including coupling hole 18. Due to the fact that the air filled hole has a lower dielectric constant than dielectric material 17, asymmetrical displacement currents and an asymmetrical field distribution result. The electric field lines, shown as broken lines in the drawing, are more concentrated between center conductor 11 and the bottom wall of waveguide 12 than in the region of coupling hole 18. The electric field lines therefore have substantial components transverse to guide 12 in the center region thereof.

Referring now to the cross-sectional view of FIG. 4, the electric field lines of the TE_{10} wavemode in guide 12 are seen to have a somewhat similar distribution. That is, the electric field is uniform across the narrow dimension of guide 12, whereas its magnitude varies in a sinusoidal manner across the broad dimension thereof. The electric field lines are seen to be concentrated in the center region of waveguide 12.

It is well known that two electromagnetic waves can be coupled by orienting the fields so that the two waves have some common field component. Comparing the electric field components of FIG. 3 with those of FIG. 4, it is seen that this condition is met. The asymmetrical electric field distribution produced in the presence of coupling hole 18 therefore enables the TEM wave energy of strip transmission line 10 to be coupled to the TE_{10} wave energy of guide 12.

The performance of the embodiment of FIG. 1 can be readily explained by considering the equivalent lumped parameter network of FIG. 5. In this circuit, transmission lines 50 and 51 represent strip transmission line 10 and waveguide 12 of FIG. 1, respectively. The coupling between the two transmission lines is represented by the ideal transformer 62 having a 1:n turns ratio.

FIG. 6 is a graphical representation of the relative coupling between a strip transmission line and a dielectric-filled waveguide expressed as a function of the coupling hole diameter D. This graph was obtained by power measurements on an experimental embodiment similar to the embodiment of FIG. 1. The experimental structure was designed for operation at a frequency of four kilomegacycles per second (referred to hereinafter as gigacycles per second, or gc.) the width of conductor 11 was 0.185 inch and the spacing between center con-

ductor 11 and ground planes 13 and 14 was 0.121 inch. The narrow and broad dimensions of guide 12 were 0.242 inch and 1.372 inches respectively. Center conductor 11 extended a distance of 0.450 inch inside waveguide 12. The dielectric material used in the strip transmission line and waveguide is commercially known as "Tellite" and has a dielectric constant of approximately 2.32 at the frequency of operation.

Returning to the graph of FIG. 6, curve 60 represents the degree of coupling of the device at a frequency of 4.0 gc., in terms of the turns ratio, n, of the equivalent circuit of FIG. 5 plotted as a function of the diameter, D, of coupling hole 18. Similarly, curve 61 represents the same parameters measured at a frequency of 4.2 gc. From this graph it is seen that the degree of coupling expressed in terms of n varies inversely with the coupling diameter D. Furthermore, this relationship is substantially linear over the range of values measured (i.e., from $D=0.1$ inch to $D=0.5$ inch).

FIG. 7 is a cross-sectional pictorial representation of another embodiment of the present invention providing an adjustable coupling. This embodiment is similar to the embodiment of FIG. 1 and for this reason like numerals have been carried over from FIG. 1 to represent like structural elements. The only difference between this embodiment and that of FIG. 1 is that an adjustable tuning screw 70 is provided in a tapped hole through the wall of guide 12. Screws 70 enters guide 12 in the region of coupling hole 18 adjacent the extended end of center conductor 11. By turning screw 70 so that it penetrates further into guide 12 the degree of coupling is decreased. By moving screw 70 out of guide 12 the degree of coupling is increased. In practice, screw 70 can be fabricated either of conductive or dielectric material. It should be noted, however, that a dielectric tuning screw has a lesser effect in varying the coupling coefficient than does a conductive tuning screw.

FIG. 8 is a cross-sectional pictorial representation of yet another embodiment of the present invention. Again similarity dictates that like numerals be carried over from FIG. 1 to represent like structural elements. In the embodiment of FIG. 8 strip transmission line 10 has been replaced by a coaxial transmission line having an inner conductor 81 and outer conductor 82 separated by dielectric material 83. In addition, waveguide 12 is filled with air rather than dielectric material 17 and coupling hole 18 has been replaced by dielectric cylinder 80. The operation of this embodiment is substantially identical to that of FIG. 1. As with the embodiment of FIG. 7, means, such as a dielectric or conductive tuning screw, can be provided to vary the degree of coupling.

It is understood that the above-described arrangements are merely illustrative of the application of the present invention. It is obvious that by applicable design techniques other arrangements including those utilizing other than circular coupling holes and dielectric cylinders and utilizing other forms of transmission lines may be devised by those skilled in the art without departing from the spirit and scope of the present invention.

What is claimed is:

1. In combination, a section of two-conductor transmission line, a section of conductively bounded rectangular waveguide, means for coupling electromagnetic wave energy from one of said sections to the other of said sections, said means comprising a solely longitudinal extension of one conductor of said two-conductor transmission line section into said waveguide section, a region having a first dielectric constant extending between said longitudinally extended conductor and one of the broad walls of said waveguide section, the remainder of said waveguide section having a dielectric constant different than said first dielectric constant.

2. The combination according to claim 1 wherein said two-conductor transmission line comprises a strip transmission line.

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3. The combination according to claim 1 wherein said two-conductor transmission line comprises a coaxial transmission line.

4. The combination according to claim 1 wherein said coupling means comprises, in addition, a conductive tuning screw extending through one of said waveguide walls adjacent said extended conductor. 5

5. The combination according to claim 1 wherein said coupling means comprises, in addition, a dielectric tuning screw extending through one of said waveguide walls adjacent said extended conductor. 10

6. The combination according to claim 1 wherein said dielectric constant of the remainder of said waveguide section differs from said first dielectric constant by at least 50 percent. 15

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