April 11, 1961 L. J. RUEGER 2,979,676

WAVEGUIDE TO MICROSTRIP TRANSITION STRUCTURE

Filed Oct. 30, 1957 2 Sheets-Sheet 1

FIG. 1

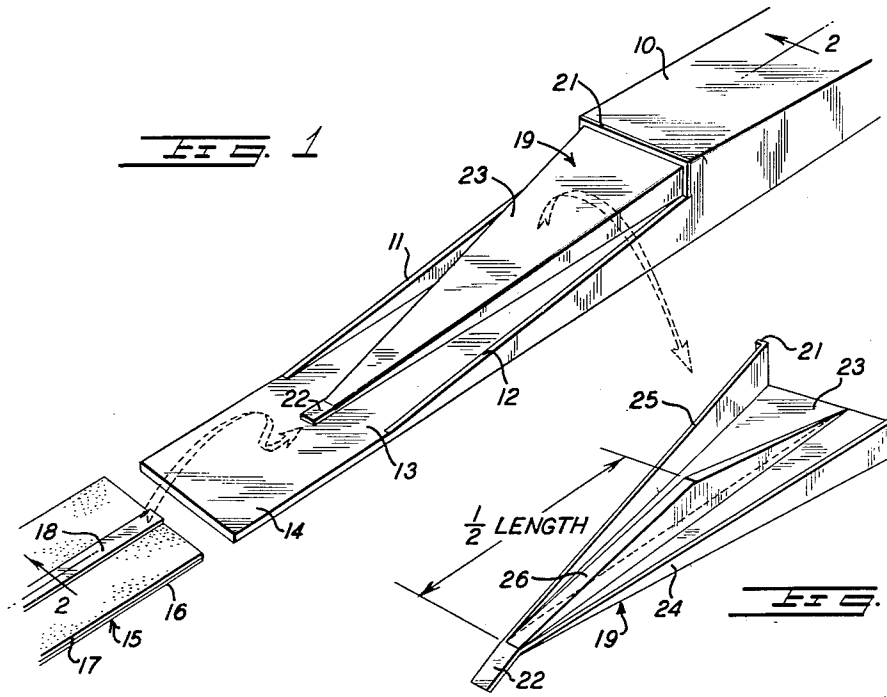


FIG. 3

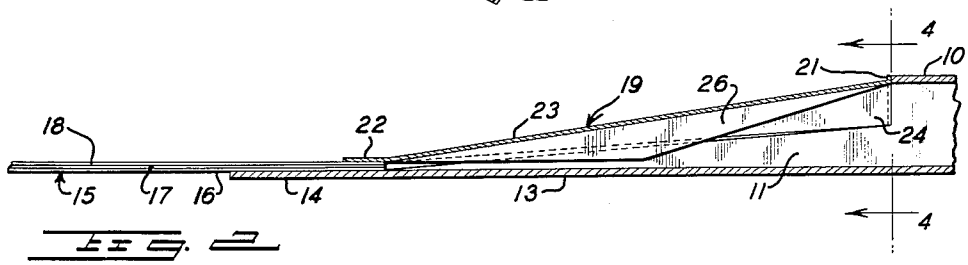


FIG. 2

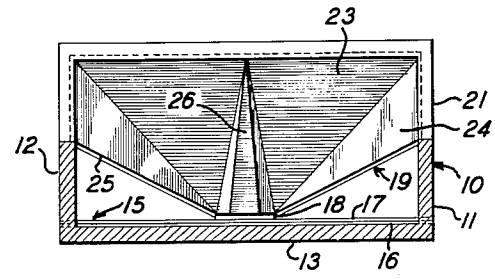


FIG. 4

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WAVEGUIDE TO MICROSTRIP TRANSITION STRUCTURE

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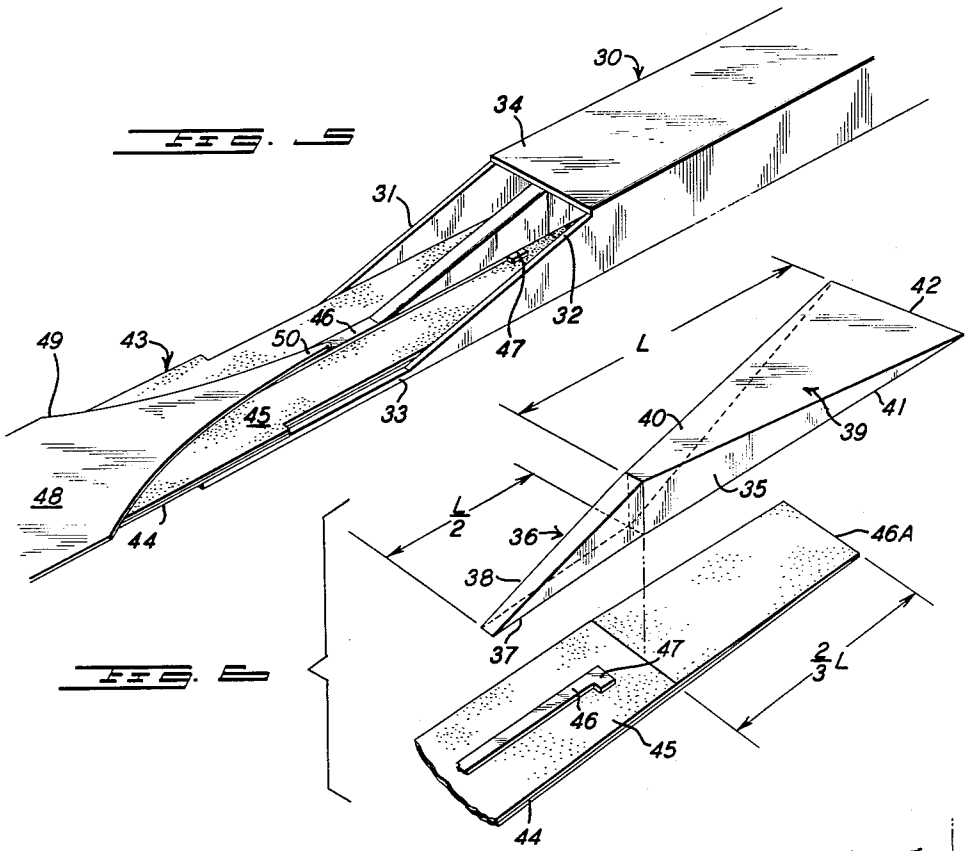


FIG. 5

FIG. 6

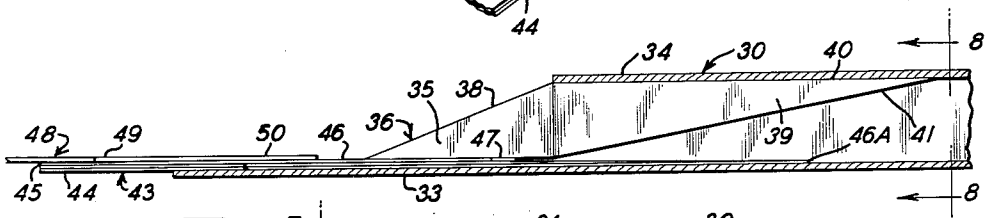


FIG. 7

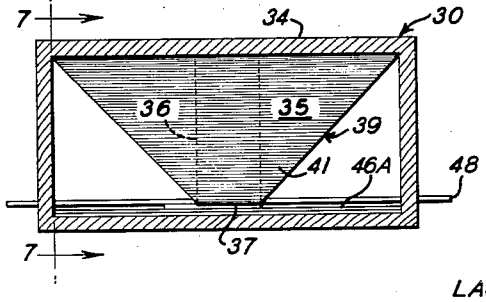


FIG. 8

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WAVEGUIDE TO MICROSTRIP TRANSITION STRUCTURE

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3 Claims. (Cl. 333—34)

The present invention relates generally to microwave energy transfer apparatus; more particularly it relates to an improved transition structure for transferring microwave energy from a conventional waveguide to a strip type transmission line of the kind used in printed circuit techniques.

Recent developments in printed circuit techniques have included the introduction of strip type transmission lines which comprise flat, narrow conductors etched or otherwise suitably fixed on printed circuit boards. These transmission lines, sometimes known as "microstrip" lines, are particularly advantageous in use because of their light weight and the small space and volume they occupy; specifically, they find useful application in guided missile circuits, proximity fuzes and aircraft radar. "Microstrip" lines, however, are limited in their power handling capabilities, whereas conventional waveguides are not nearly so limited. In radar, high and low power circuits are often located in physically close proximity and require mutual coupling. To take advantage of the above-mentioned meritorious features of strip type transmission lines, the transition structure constituting the present invention was developed. By its use very complex low power radar circuits can be coupled to high power equipment. Specifically, phased array antenna feeds can be built, of small physical size, for low power use and easily coupled to high power amplifiers with minimum volume expended in waveguide transmission lines.

One of the problems inherent in the use of printed circuits, however, is that of coupling strip transmission lines to conventional waveguides in such a manner that voltage standing wave ratios, with resultant undesirable radiation, will be reduced to minimum values. Such couplings may be effected by the use of transition devices which accomplish the desired effect in gradual steps. However, such devices are of impractical size and therefore are not adaptable for use, say, in missile systems.

One object of the present invention, therefore, is to provide a transition structure which will couple a conventional waveguide to a strip transmission line with minimum losses as a result of the coupling structure.

As another object, the invention provides a transition structure that is compact and which, therefore, will be particularly useful in missile applications and airborne radar.

Other objects of the invention, not pointed out hereinabove, will become evident as the description proceeds.

In the drawings:

Fig. 1 is a perspective view showing one embodiment of the improved transition structure, a section of strip transmission line being shown confronting but out of engagement with the waveguide section;

Fig. 2 is a section on the line 2—2 of Fig. 1, but with the "microstrip" section in operative position on the waveguide section;

Fig. 3 is an enlarged fragmentary perspective view of the transition element, inverted to show the impedance matching fin employed;

Fig. 4 is a transverse section on the line 4—4 of Fig. 2;

Fig. 5 is a perspective view showing a modification of the invention;

Fig. 6 is an exploded detail perspective particularly showing the transition element and matching stub employed in the modification of Fig. 5;

Fig. 7 is a longitudinal section of the embodiment of Fig. 5; and

Fig. 8 is a transverse section on the line 8—8 of Fig. 7.

The solution of the problem of building a successful waveguide to conductor strip ("microstrip") transition structure requires that two functions be satisfied, namely, the phase velocities must be transformed and the field patterns must be transformed. These two functions can be realized in a single transition but only with a performance compromise or with a structure of excessive length (greater than 5 wavelengths), or with a structure having surfaces which are not simple geometric planes. The term "single transition," as used above, excludes a series of adjoining transitions each made up of simple geometric planes. The transition structures constituting the present invention are each approximately two wavelengths long and are combinations of transition structures each including simple geometric planes.

Referring to the drawings in detail, and first to Figs. 1 through 4 thereof, a portion of rectangular waveguide is shown generally at **10**. The open end of the waveguide **10** is cut away to provide inclined side walls **11** and **12** and an extended flat bottom wall **13**. As best seen in Fig. 1, the side walls **11** and **12** extend from points medially of the height of waveguide toward the bottom wall **13** and merge therewith at points in spaced relation to the end of said wall thereby to form an extension **14**.

An end portion of a conductor strip is shown at **15**, said strip comprising a base or ground plane conductor **16**, a dielectric member **17** and a conductor element **18**. For clarity the conductor strip **15** is shown, in Fig. 1, confronting the extension **14**; in Fig. 2 said strip is shown in operative position overlying said extension. The base conductor **16** and the dielectric member are conveniently of the same width as the extension **14** whereas the conductor element **18** will be of a width determined by the frequency of the microwave energy it is desired to conduct. For frequencies of the order of 6000 mc., the base conductor **16** is 1½ inches wide and 0.0014 inch thick; the dielectric member **17** is 1½ inches wide and 0.058 inch thick; the conductor element **18** is 0.0014 inch thick and 0.150 inch wide.

To effect an electrical coupling between the waveguide **10** and the conductor strip **15** a transition element is provided. The transition element is shown generally at **19** and is seen, inverted to show detail, in Fig. 3. The element **19** comprises a trough-like body formed of copper or other suitable material and tapered in width and height from a relatively wide end, having a flange **21**, to a relatively narrow end, terminating in a terminal member **22**, said terminal member being of the same width as the conductor element **18**. The body includes a flat wall **23** and tapered side walls **24** and **25**. A matching fin **26** extends throughout the length of the body medially of its width, and is soldered or otherwise suitably secured to the under side of the wall **23**. The matching fin is of generally triangular shape and is tapered in thickness toward its rear end, that is, toward the relatively wide end of said body, one end of the fin terminating at the rear edge of the body and the other end terminating adjacent the base of the terminal member **22**.

The transition element **19** is mounted in operative position as shown in Figs. 1 and 2, that is, with the flange **21** in engagement with the edge of the waveguide **10** above the rear extremities of the side walls **11** and **12**. The

body of the transition element 19 extends forwardly between the side walls and in gradually increasing spaced relation thereto, so that the base of the terminal member 22 lies in substantially the same transverse plane as the forward extremities of the side walls 11 and 12. When assembled, as shown in Fig. 2, the terminal member 22 overlies the free end portion of the conductor element and makes electrical contact therewith, and the base or ground plane conductor lies upon the extension 14.

The principle of operation of the invention resides in transforming the upper half of the waveguide 10 by conformal mapping into one conductor, i.e., the conductor element 18, of the conductor strip 15 while at the same time transforming the lower half of the said waveguide 10 (also by conformal mapping) into the other conductor of the strip 15 (the base or ground plane conductor 16). This transformation is effected by the transition element 19, that is, the field patterns and phase velocities are transformed by the gradually narrowed body of the element 19. The side walls 24 and 25 mainly act as shields, tending to minimize radiation from the sides of the element 19; the matching fin 26 serves to confine the microwave energy to the center of the element for conduction to the conductor element 18.

In the modification of the invention illustrated in Figs. 5, 6, 7 and 8 radiation from spurious modes set up by waveguide to conductor strip transition are confined and attenuated during the field pattern shaping process. A portion of the waveguide is shown at 30. The waveguide 30 includes inclined side walls 31 and 32, a flat bottom wall 33 and a top wall 34. Fitted within the open end of the waveguide 30 medially of the width thereof is a transition element comprising a matching fin 35. The fin 35 is best seen in Fig. 6. It comprises a forward section 36 of triangular shape and uniform width, the width being the same as that of the conductor element (0.150"), to be described hereinafter. The section 36 includes a flat bottom wall 37 and an inclined top wall 38. The fin 35 also includes a rear section 39 which is formed integral with the section 36 and which has a flat top wall 40 of a width gradually increasing from its point of connection to the forward section to its rear extremity, the rear extremity being of the same width as the top wall 34 (inside dimension) of the waveguide 30. The bottom wall 41 of the section 39 is inclined upwardly toward its rear end and meets the top wall at its rearmost extremity to define a sharp end edge 42.

As best seen in Figs. 5 and 7, the matching fin 35 is fitted in the open end of the waveguide 30 with the forward section 36 parallel to the inclined side walls 31 and 32 and the rear section disposed within the waveguide with the flat top wall 40 in engagement with the inner surface of the top wall 34. As best seen in Figs. 7 and 8, the flat bottom wall 37 is spaced above the upper surface of the bottom wall 33 of the waveguide a distance substantially equal to the thickness of the entire conductor strip.

A portion of the conductor strip is shown at 43. The conductor strip comprises a base or ground plane conductor 44, a dielectric member 45 and a conductor element 46. The conductor 44 and the member 45 are of a width conveniently to cover the bottom wall 33 and to fit between the side walls 31 and 32. The dielectric member 45 and the conductor 44 are thinned toward their free ends to form a knife edge 46A. The conductor element 46 is mounted medially of the width of the conductor strip and, for frequencies of the order of 6000 mc., is 0.150" wide and 0.0014" thick. At its free end the conductor element carries a laterally extending matching stub 47. For test purposes a line termination element (load) 48 may be laid on the element 46. The forward end of the element 48 is provided with side edges 49 which are curved toward each other to define a narrow tip 50. The edges 49 adjacent the tip are so shaped that they will lie tangent to the straight side edges of the conductor element 46, thereby to provide smooth coupling between said element 46 and the line termination element 48.

Experiments have revealed that the modification shown in Figs. 5 through 8, described hereinabove, is superior in operation to the first-described modification. More specifically, in the modification just described radiation from spurious modes, set up by the transition, are confined and attenuated during the field pattern shaping process by the extension of the waveguide walls (the inclined side walls 31 and 32), and by the attachment of the matching fin 35 to the top wall 34 of the waveguide 30. The thinned dielectric member 45, which extends from the conductor element 46 and terminates in the knife edge 46A, permits an effective transition of the phase velocities between the conductor strip 43 and the waveguide. As will be obvious, the knife-edge termination of the conductor strip 43 may be used to advantage in the modification illustrated in Figs. 1–4.

Of the above described embodiments, that shown in Figs. 5, 6, 7 and 8 provides the most gradual phase velocity transformation. As will be observed, all of the embodiments utilize plane surfaces for ease of construction. Ideally, the transition elements could be made to include ogee-curved surfaces tangent at their termini to provide better matching, but with a sacrifice of ease of construction.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In apparatus for conducting electrical energy between a waveguide and a conductor strip, a waveguide section having an open end and top, bottom and side walls, said bottom wall being projected to define an extension and the side walls having extended portions inclined from said side walls to the surface of the extension, a matching fin mounted between the extended portions, said matching fin including a forward section extending between the side walls and a rear section mounted within the waveguide section, said conductor strip having a conductor member overlying the extension, a dielectric member overlying the conductor member, and a conductor element on the dielectric member and electrically coupled to the fin, said fin reducing the phase velocity of waves moving from the waveguide section to the strip for providing a coupling between the waveguide and the conductor strip and the extended portions of said walls cooperating with the fin for confining and attenuating any spurious modes set up by the transition.

2. Transition structure as defined in claim 1 wherein said conductor element includes a laterally extending matching stub.

3. In apparatus for conducting electrical energy between a waveguide and a conductor strip, a waveguide section having an open end and top, bottom and side walls, said bottom wall being projected to define an extension and the side walls having extended portions inclined from said side walls to the surface of the extension, said conductor strip having a conductor member overlying the extension, a dielectric member overlying the conductor member, and a conductor element on the dielectric member, a matching fin, and means mounting the matching fin between the extended portions of the side walls and electrically coupling it to the conductor element, said means comprising a transition element having one portion connected to the waveguide and a terminal portion connected to the conductor element, said transition element being tapered in width toward said terminal element and having tapered side walls, said first-mentioned side walls and the side walls of the transition ele-

ment confining and attenuating any spurious modes set up by the transition.

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