

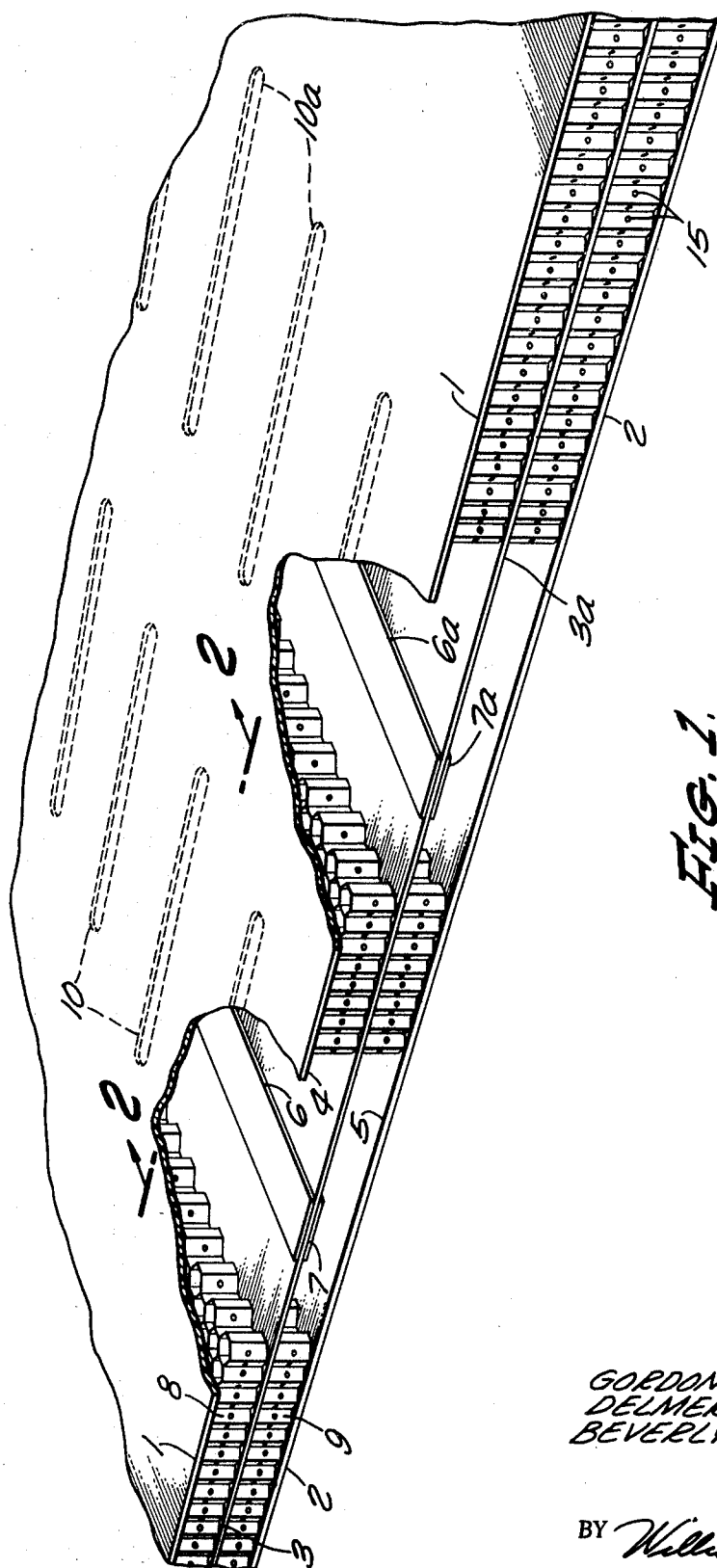
June 30, 1970

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MICROWAVE STRIP TRANSMISSION LINE ADAPTED
FOR INTEGRAL SLOT ANTENNA

3,518,688

Original Filed Nov. 22, 1965

2 Sheets-Sheet 1



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GORDON R. STAYBOLT
DELMER L. THOMAS
BEVERLY J. TODD
INVENTORS.

BY *William T. O'Neil*

AGENT

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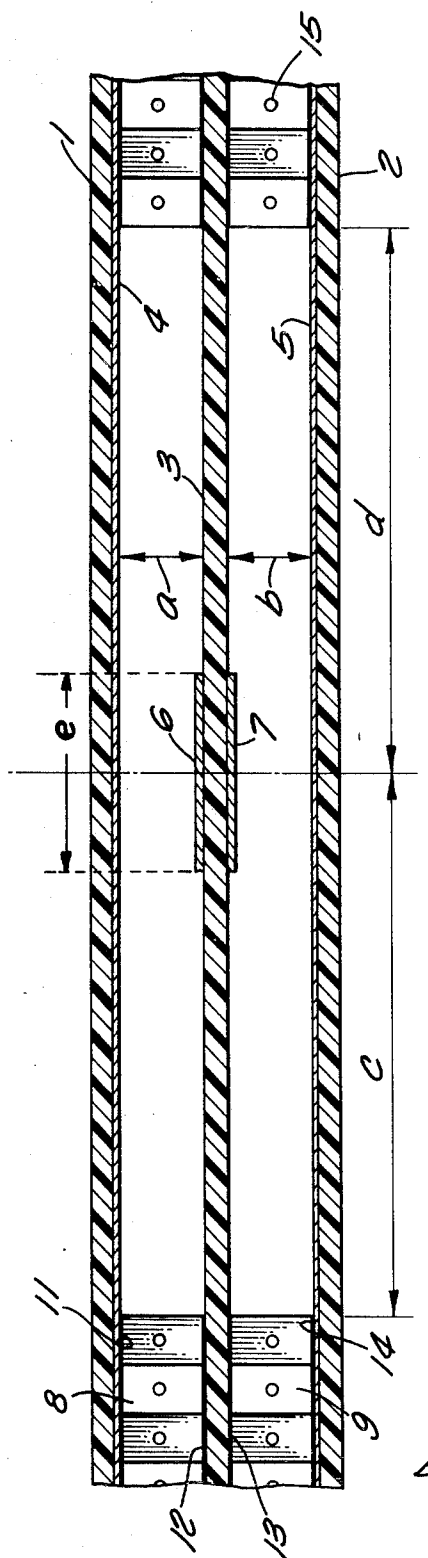
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FIG. 2.



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DELMER L. THOMAS
BEVERLY J. TODD
INVENTORS.

BY *William T. O'Neil*
AGENT

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Gordon R. Stayboldt, Los Angeles, Delmer L. Thomas, Westminster, and Beverly J. Todd, Chatsworth, Calif., assignors to International Telephone and Telegraph Corporation, New York, N.Y., a corporation of Maryland

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3 Claims

ABSTRACT OF THE DISCLOSURE

This disclosure describes an improved microwave strip transmission line. The line is mechanically rugged, readily sealed, and inexpensive compared to prior art strip lines of comparable electrical and environmental performance. Copper clad plastic sheets are used as outer sheets with their copper layers facing internally. Non-conductive honey-comb provides the separation material internally, thereby placing most of the internal electrical field in air. A single or double center strip is supported on an additional parallel plastic sheet by said honey-comb material symmetrically between the outer sheets. Acting as a transimmission line, the device can be an antenna array with its own transimmission line feed by merely etching appropriately located slots in one or both of said outer copper layers. The outer plastic sheets remain closed as sealed "windows" over the slots.

This invention relates to microwave strip transmission lines utilizing TEM mode propagation.

More particularly, this invention relates to an improved microwave strip transmission line which combines efficiency and low loss operation with mechanical ruggedness.

In the prior art, a number of transmission line designs utilizing TEM mode propagation in a configuration including a relatively thin flat center conductor or an etched foil center conductor between ground planes have been designed. A single conductor over a ground plane usually spaced by solid dielectric (sometimes referred to as microstrip) is well known as is the use of a center conductor evenly spaced between two ground planes normally called strip transmission line. Microstrip frequently employs very high grade dielectric materials such as Teflon impregnated fiberglass in order to minimize the dielectric loss encountered. In configurations where a center conductor is spaced between two ground planes, some designs have made use of solid dielectric materials enveloping the center conductor and filling the interior space between the two ground planes. Other designs have made use of dielectric posts or spacers between the two ground planes in order to obtain the advantage of having a mostly air dielectric between the two ground planes.

All such prior art lines are constructed in a manner which makes the maintenance of the line impedance uniform over the line length a difficult task. The solid dielectric lines are disturbed by the dielectric constant tolerance and the thickness tolerance, which is a larger percentage of the line spacing, while the air dielectric lines are disturbed by the electrical discontinuities represented by dielectric support posts.

In describing the present invention, it will be observed that important advantages accrue to the method of construction employed. Not the last of these advantages is the fact that a strip transmission line constructed in accordance with the present invention exhibits handling

ability and loss factors comparable to a 100% air space strip transmission line. Moreover, greater uniformity of line characteristic impedance over longer line lengths than achieved in conventional designs for an equal fabrication cost is achieved by virtue of precise spacing and the practical elimination of electrical discontinuities afforded by the present invention. These and other advantages accruing to the structure of the present invention are achieved in a mechanical structure which provides a very much higher strength-to-weight ratio than achieved in prior art structures.

In describing the present invention drawings are provided as follows:

FIG. 1 is a pictorial drawing with cutaways illustrating an embodiment with two strip transmission lines in parallel each with radiating slots for the implementation of an antenna array integral with the transmission line structure.

FIG. 2 shows a cross-sectional view of one of the transmission line sections, exaggerated in size for clarity.

Referring now to FIG. 1, it will be noted that three continuous sheets or panels, 1, 2, and 3, extend throughout the structure of the device. These panels are preferably fiberglass or some other high strength plastic material. Panels 1 and 2 have one surface coated with a thin layer of conductive metal such as copper. Panel 3 is of the same material except that at the beginning of the fabrication process a panel having both surfaces clad in the thin conductive material is used. This copper clad plastic sheet material is well known and commonly used in etched circuit applications. Since the copper clad sides of panels 1 and 2 are the surfaces which are internal to the completed structure, the dielectric constant and loss characteristic of the plastic panel material is not important in the case of panels 1 and 2, since it will be seen that the plastic material of panels 1 and 2 is not subjected to the electromagnetic field of the transmission line. In the case of panel 3 however, it is desirable that the plastic material used be one which exhibits comparatively low loss and has physical properties desirable for the application, including strength in thin section and bondability. A suitable material for panel 3 is copper clad epoxy glass. Thus, from the standpoint of economy, panels 1 and 2 may be of lower grade than is desirable for panel 3.

As a first step in fabrication, all of the metal coating from both sides of panel 3 is etched away except the strips 6 and 7, and 6a and 7a. Panels 1 and 2 have their metal coatings continuous on the insides except in the areas where slots are etched through the copper layer to provide radiators.

At this point in the description it is desirable to refer also to FIG. 2. Here the said ground planes constituting the metal cladding on panels 1 and 2, are shown at 4 and 5, respectively. In the sectional view constituting FIG. 2, the cross-section of a typical strip transmission line will be readily recognized. Although only one of the two transmission lines illustrated in FIG. 1 is shown in the sectional view of FIG. 2, corresponding to the line associated with the center conductor strips 6 and 7, it will be understood that the structure is substantially identical in the other section of FIG. 1 corresponding to the center strip conductors 6a and 7a. Dimensionally, the spacings a and b are equal. Dimensions c and d are also equal to each other. In a typical transmission line design for a 50 ohm characteristic impedance, the approximate dimensions a and b were each 0.25 inch., dimensions c and d were each 1.0 inch, and the center conductor strips 6 and 7 were 0.50 inch (dimension e). It should be noted that the use of a dual center conductor as at 6 and 7 assures the electrical symmetry of the line and thus its impedance

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uniformity. The use of thin metal clad dielectric panels, especially panel 3, and a large center conductor to ground plane spacing relative to the dielectric thickness of panel 3 permits the use of relatively low cost materials, for example, the previously mentioned copper clad epoxy glass, without introducing high power losses and also minimizes the effect of dielectric thickness variation on the line impedance. Moreover, the placing of the metal foil ground planes on the inside of panels 1 and 2, minimizes the possibility of physical damage due to rough handling, and reduces the total thickness of dielectric material in the electromagnetic field of the line, thus reducing the effects of dielectric constant, loss tangent and thickness tolerance on the line parameters. Precise spacing of the center conductors is achieved by the use of a plastic impregnated fiber glass honeycomb material 8 and 9. Such honeycomb material is particularly adaptable to being economically cut to a precise height as a spacer material. The use of such a honeycomb material has the advantage of high strength in the plane where strength is most needed while obtaining a low dielectric constant, low loss and high strength-to-weight ratio. The comparatively large volume of air contained in the honeycomb structure is a significant factor in respect to these dielectric loss factors. It is to be further noted that the line parameters are selected in the typical design (i.e., dimensions *a*, *b*, *c*, and *d*) so that the field between the ground planes 4 and 5 is comparatively small where the honeycomb edges lie, thereby to hold dielectric loss and dielectric constant discontinuities low.

The fiberglass honeycomb material, before nylon impregnation, and before installation, is readily folded (flat-tened) in a direction normal to the axes of the cells. This facilitates the pre-drilling of holes of which 15 is typical, such that in the final assembly, entrapped air may be purged from the line or if the line is to be completely sealed, dry gas pressurization can be provided. The provision of these air relief holes is of course possible by means of other well-known processes. The accurate thickness sizing of the honeycomb may be accomplished in a flat milling operation, for example, and at the same time multiple saw cuts could be provided to produce the same result as provided by the aforementioned drilled holes.

In the final steps of assembly, the honeycomb material is firmly cemented to the panels 1, 2 and 3. A desirable method of accomplishing this bonding operation includes the use of a very thin epoxy film adhesive in sheet form laid in as shown at 11, 12, 13 and 14 in FIG. 2. In this way the entire line can be bonded into a rigid unit in a thermal press, such that the said film adhesives are thermally set and complete and uniform adhesion through the structure is achieved. Adhesive spraying is, of course, also adaptable to this operation with the final cure being accomplished in a thermal press.

The final assembly of the strip transmission line in accordance with FIG. 1 will be seen to be adaptable to a number of substantially parallel strip transmission lines and a corresponding plurality of radiating slots, such as 10 and 10a, for the instrumentation of a multiple antenna array. Slots 10 and 10a may be duplicated, as a design matter, on the opposite sandwich face.

Radio frequency shielding around the exposed edges is, of course, possible. One suitable means includes addition of a conductive mesh over the exposed ends in electrical contact with the ground planes. The use of fiberglass and epoxy resin wet layup techniques would then provide a dust and gas tight enclosure over the mesh about the sandwich ends. The excitation and termination of the strip transmission line or lines in parallel is a matter of well-known microwave technique and does not constitute a part of the present invention.

The entire sandwich may be supported by clamping members along the edges of the sandwich since the structural strength provided is substantial. It will also be evident that a completed sandwich line structure in accord-

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ance with FIG. 1 would present the appearance of a simple plastic structural panel with no radiating elements visible from the outside. The radiating slots of which 10 and 10a are typical would not be visible from the outside since they are only etched through the internal ground plane material and not through the fiberglass panel itself.

Additional advantages of the present invention will be evident to those skilled in the art in view of the foregoing description. It will be evident, for example, that the entire structure is capable of operating in very adverse environments, since it is readily sealed and pressurized and is mechanically rugged.

Although radiating slots are shown, the entire structure is adaptable to a straight transmission line application without radiating elements.

Although not illustrated, a conductive barrier or wall from ground plane—to ground plane may be required on either side of each strip line when the radiating slots 10 and 10a are employed on only one face of the sandwich. This is because of the tendency for undesired waveguide type (spurious in this situation) moding resulting from such an asymmetrical line loading. If required, the barrier wall could easily take the form of a thin metal or metal foil barrier placed between breaks in the honeycomb and center sheet, or the entire sandwich structure can be divided into individual sandwich sections with shielded sides in accordance with a method hereinbefore described. No such need arises when the 10 and 10a slots are duplicated on both sides of the sandwich or in the event the structure is constructed as a transmission line only without radiator slots. Normally, the spacing between the strip transmission lines of FIG. 1 is such that the electromagnetic fields are greatly diminished at a point half way between strip transmission line sections and accordingly interaction is therefore minimal.

Economy of construction has also been accomplished in that the use of solid dielectric materials with their difficult bonding problems, has been avoided.

Modifications falling within the scope of the present invention will suggest themselves to those skilled in the art and accordingly it is not intended that the scope of the present invention be limited by the drawings or by the description, which are illustrative only.

We claim:

1. An electromagnetic strip transmission line adapted for inclusion of radiating slots comprising:

- first and second parallel panels of non-conductive material forming an interior space between said panels;
- a sheet of metallic coating on the interior surface of each of said panels, said sheets being arranged to face and run substantially parallel to each other, thereby forming a pair of ground planes;
- a third panel of non-conductive material parallel to said first and second panels and located so as to be substantially equidistant between said first and second panels within said interior space;
- a pair of conductive strips substantially equal in width and thickness and substantially parallel to said ground planes, said strips being located on opposite surfaces of said third panel, thereby to form an electrically symmetrical strip type transmission line; means comprising a layer of dielectric honeycomb material with cell axes substantially normal to said panels, filling said interior space between said first and third and also between said second and third panels except for a space adjacent to said strips for a distance on either side of said strips in which the electromagnetic field between said ground planes remain in excess of a predetermined strength; and bonding means for firmly cementing said sandwich material to said first, second and third sheets, thereby to form a rigid structure.

2. The invention set forth in claim 1 further defined in that the walls of said honeycomb material are perfo-

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rated to afford gas flow therethrough and thereby to avoid gas entrapment during evacuation.

3. The invention defined in claim 1 in which at least one of said ground planes is slotted at least through the thickness of said metallic coating thereby to form at least one slot of dimension and placement so as to radiate energy therefrom, thereby to provide an integral antenna for which said strip transmission line provides the feed.

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HERMAN KARL SAALBACH, Primary Examiner

15 W. H. PUNTER, Assistant Examiner

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