Nov. 17, 1964 R. M. WILLIAMS 3,157,847

MULTILAYERED WAVEGUIDE CIRCUITRY FORMED BY STACKING PLATES HAVING SURFACE GROOVES

Filed July 11, 1961 4 Sheets-Sheet 1

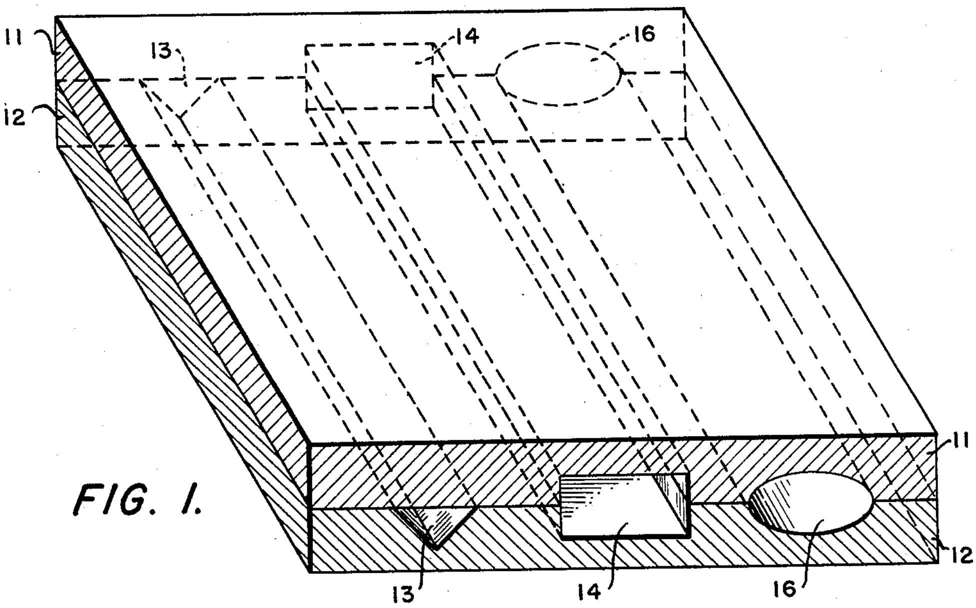

FIG. 1.

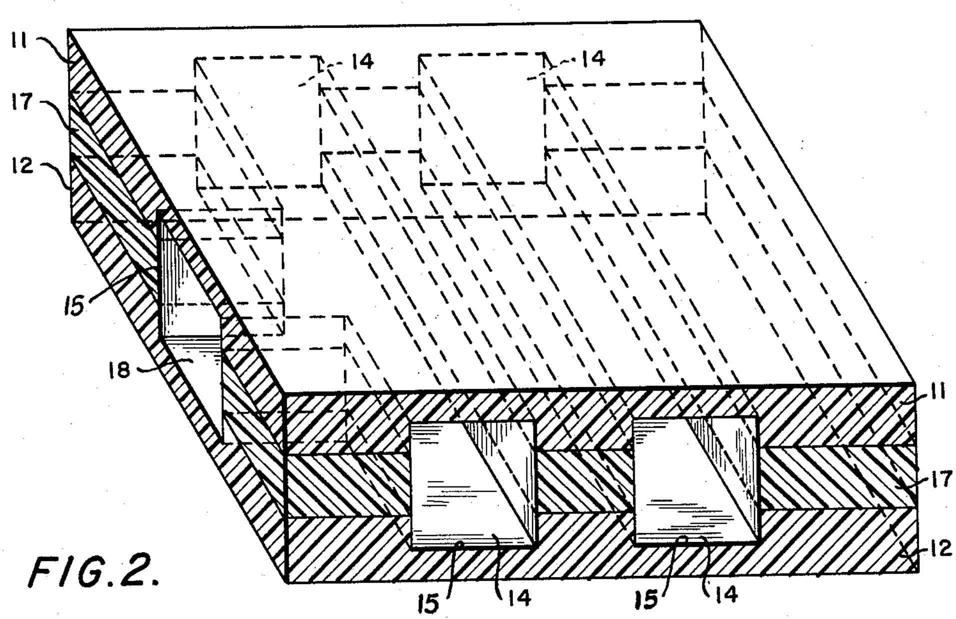

FIG. 2.

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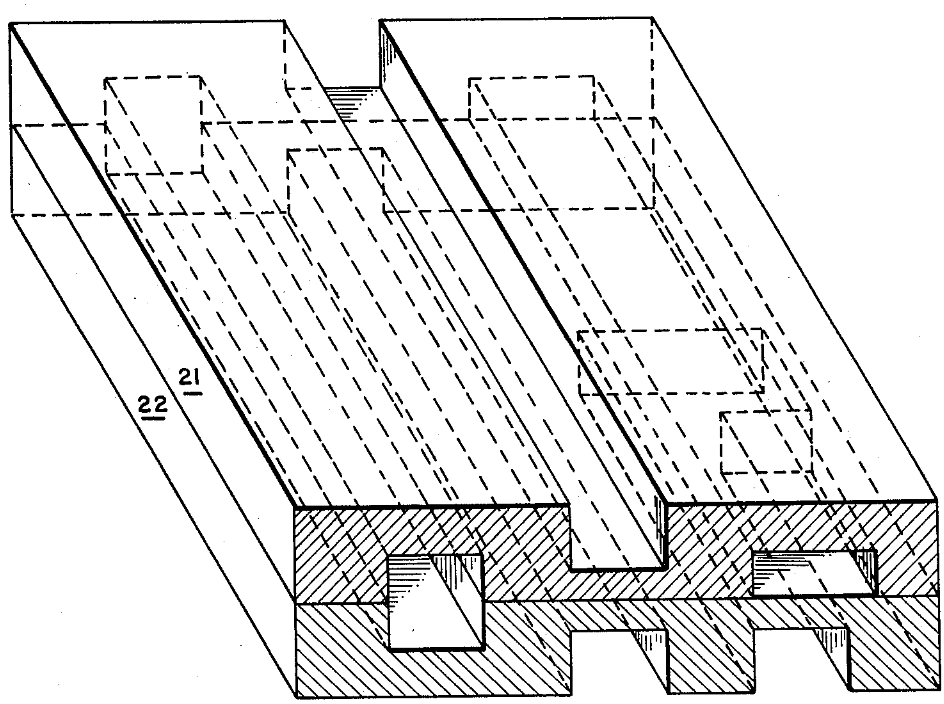
FIG. 3.



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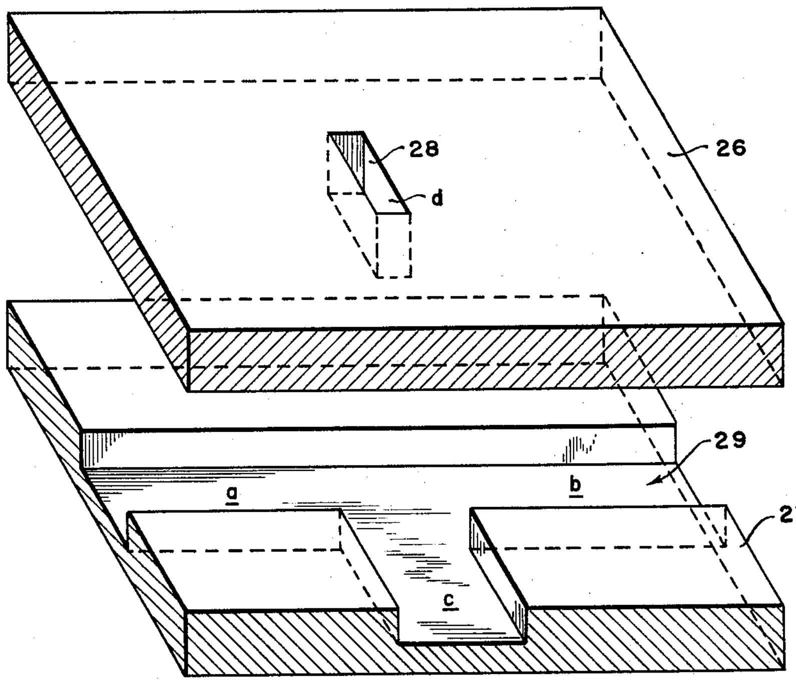

FIG. 4.

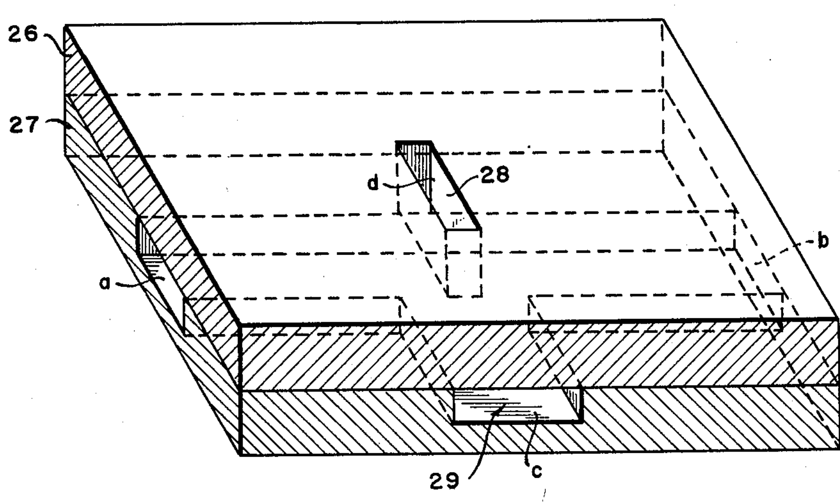

FIG. 5.

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MULTILAYERED WAVEGUIDE CIRCUITRY FORMED BY STACKING PLATES HAVING SURFACE GROOVES

Filed July 11, 1961 4 Sheets-Sheet 4

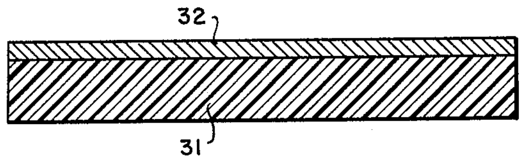

FIG. 6.

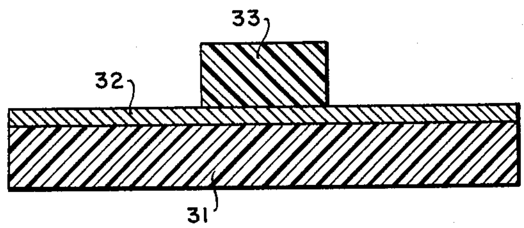

FIG. 7.

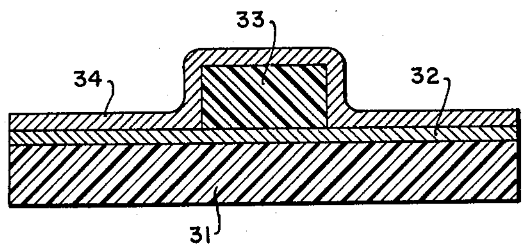

FIG. 8.

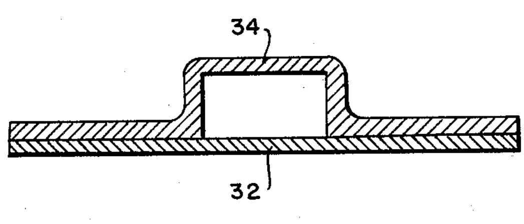

FIG. 9.

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United States Patent Office

3,157,847

Patented Nov. 17, 1964

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3,157,847
MULTILAYERED WAVEGUIDE CIRCUITRY FORMED BY STACKING PLATES HAVING SURFACE GROOVES

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Filed July 11, 1961, Ser. No. 123,320
1 Claim. (Cl. 333—95)

The present invention relates to microwave circuitry and more particularly to waveguide construction of microwave circuits.

At the present time, large amounts of research and development time and money are being used to explore new electronic equipment which can operate in frequency bands in the electromagnetic spectrum above about three hundred megacycles per second and extending possibly to 300 to 500 kilomegacycles per second, or as commonly termed, "microwave frequencies." In the microwave frequency range, hollow pipes, known as waveguides, instead of the familiar solid conductors and transmission lines used in lower frequency applications, are used to transmit electrical energy.

Waveguides, in general, are hollow pipes of various configurations with walls being made of continuous sheets or surfaces of highly conductive material, usually metal, or alternatively the waveguide may consist of hollow dielectric tubes, either of the type known as the "Gobau Line" or that known simply as dielectric waveguide, depending on the relative areas of the dielectric and the opening through it. Particularly with the higher frequencies of the microwave range, any discontinuity in the guide produces a reactive load, inductive or capacitive, depending on the particular character of the discontinuity. Elimination of the dicontinuities can be met with waveguide only if the walls are perfectly smooth, flat, and straight, which of course is a physical impossibility. Waveguides, therefore, must necessarily be a compromise between electrical performance and mechanical feasibility; otherwise the cost of manufacturing and installing waveguides becomes too great to be practical. Since the cost of having each waveguide circuit made to order is often excessive, waveguide heretofore has been manufactured in sections and connected together by conventional coupling means with inherent discontinuities in the surface of the guide at each joint. Furthermore these guides, of necessity, are heavy and expensive to manufacture and occupy a large volume of space in use.

Accordingly, it is an object of the present invention to provide a waveguide which will allow a substantial reduction of undesirable discontinuities and the undesirable wave propagation modes which such discontinuities inherently generate.

Another object is the provision of waveguide circuit components which allow waveguide circuit construction which is simpler and more compact than prior art circuits and which can be constructed economically.

A further object is the provision of a method of construction of waveguide circuits which is adaptable to mass production.

In accordance with the invention there is provided a waveguide system made up of the interchangeable modular components of various shapes which are designed to be stacked in virtually any desired configuration to furnish a single waveguide or plurality of waveguides as a single compact unit. The method set forth herein enables entire waveguide circuits of highly flexible design along with associated waveguide components to be simply, compactly, and economically constructed by techniques which are easily adaptable to mass production. Additionally in most applications a substantial reduction in the number of waveguide connections with their attendant discontinuities is usually possible.

2

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings in which like reference numerals designate like or corresponding parts throughout the several figures and wherein:

FIG. 1 is a view in perspective of an embodiment of the invention forming straight waveguides of three different cross-sectional shapes;

FIG. 2 is a view in perspective of another embodiment of the invention wherein flat dielectric sections are utilized to vary one dimension of the waveguide cross-section;

FIG. 3 is a view in perspective of still another embodiment of the invention in which sections are arranged for multiple stacking;

FIG. 4 is an exploded view in perspective of a waveguide hybrid junction or "magic tee" made in accordance with the present invention;

FIG. 5 is a perspective view of an assembled hybrid junction or "magic tee" made up of the elements of FIG. 4; and FIGS. 6–9 illustrate the series of steps used in a method of making a waveguide circuit in accordance with the instant invention.

Referring now to the drawings there is shown in each figure a section of a multiple waveguide circuit made in accordance with this invention. The various shapes are shown for illustrative purposes only and it will be realized by those skilled in the art that any number of waveguides of any desired cross-sectional shape or shapes may be formed in like manner.

As shown in FIG. 1, there are provided a first component section or blank 11 and a second component section or blank 12 which may be of a metal which is a good electrical conductor or alternatively may be of dielectric material having waveguide coated with metal. Each of the component sections 11 and 12 is basically a flat plate in which a plurality of grooves of any desired cross-section are provided. As shown in the figure, matching grooves are provided in the two plates to provide triangular 13, rectangular 14, and elliptical 16 waveguides when the two plates 11 and 12 are fitted together. These sections may be formed by chemical etching and milling, photo-etching, mechanical milling, casting, moulding, stamping, pressing, sintering of metal powders, or any other conventional method depending on the materials of which the sections are composed. It will be realized that in order to guide an electromagnetic wave the walls of the waveguide structure must be conductive and must be smooth to prevent undesirable wave modes from being generated by surface discontinuities. Therefore, when dielectric materials are used for the plates and a conductive type guide surface is desired, a thin conductive coating is applied to the surfaces of the plates which will form the guides when the plates are fitted together. This coating may be applied by any conventional means such as plating, painting or the like. Plating, polishing, painting, or other conventional techniques may also be utilized with other materials where the finished surface does not have the required smoothness. It will be realized that some of the manufacturing processes enumerated above will not form sharp corners, but the approximate shape which can be obtained will still be capable of guiding an electromagnetic wave.

Referring to FIG. 2, there is shown the aforementioned alternative arrangement employing sections or blanks made of dielectric material instead of metal. The waveguide transmission paths provided by the desired slots in the sections or blanks are coated, painted or plated with an electrically conducting material 15 such as a metal.

Thus, with metal-coated slots, wave propagation characteristics therein are substantially the same as in the slots of the metal blanks shown in FIG. 1.

Further, there is shown in FIG. 2 an embodiment of the invention wherein flat plate sections 17 are interposed between sections 11 and 12. A stacking arrangement of this type is desirable, for example, when the process for forming slots 14 could not be used to provide deep slots. It will be realized that any number of plates, depending upon the configuration desired, may be interposed between the slotted sections 11 and 12. The plates may be fastened together by any conventional means such as welding, soldering, or the use of screws or tapered pins.

The embodiment as shown in FIG. 2 also shows an example of how the invention may be utilized to provide waveguide coupling devices. Slots 18 are provided in the inner surfaces of sections 11 and 12 at right angles to one of the slots 14. In this manner, a shunt tee junction is formed. It will be realized that other waveguide coupling devices can be formed in a similar manner.

FIG. 3 shows diagrammatically how a series of sections 21, 22, may be utilized to provide a multiplicity of waveguide circuits by stacking. Any number of plates may be stacked to provide any desired number of circuits.

FIGS. 4 and 5 illustrate the application of the invention to multiplane coupling. In this embodiment of the invention, a pair of plates 26 and 27 are stacked to form a hybrid junction or as commonly known, a "magic tee" waveguide bridge. As may be seen in FIG. 4, plate 26 is provided with a rectangular slot 28 perpendicular to the major faces of the plate and designed to interact with the T-shaped slot 29 of section 27. This type of device is commonly used as an impedance bridge to check waveguide components for mismatch. As is evident from the symmetry of the waveguide sections of the device, if a signal is supplied to leg *c*, no output will appear on leg *d* if legs *a* and *b* are terminated by equal impedances; however, if the impedances of legs *a* and *b* are unequal, an output signal will be obtained on leg *d*.

Referring now to FIGS. 6–9, there is illustrated another method of making a waveguide circuit in accordance with the instant invention. The manufacture, of even straight sections, of waveguide for use at frequencies near 100 to 300 kilomegacycles becomes very difficult since the dimensions of rectangular guide opening become approximately equal to 0.1 inch by 0.05 inch. The method shown in FIGS. 6–9 eliminates the difficulties encountered in manufacturing waveguides in accordance with prior art techniques. As shown in FIG. 6, a section of a flat plate of dielectric material 31 is first provided as a base and as flat electrically conductive coating 32 is applied to the base, the pattern of the desired waveguide circuit is then laid out on the coating 32 (FIG. 7) by providing dielectric strips 33 having external dimensions equal to the desired internal dimensions of the waveguide opening. Then, an electrically conductive metal layer 34 is placed over the form (FIG. 8) by evaporating, spraying, or any other conventional technique. Dielectric strips 33 act as forms for producing the desired waveguide circuit. At the points where metal layers 32 and 34 are in contact, a bond is formed between them, thus effectively forming a one piece metallic waveguide circuit structure. If desired, the dielectric portions may then be removed (FIG. 9) by melting or etching, for example, and the one piece waveguide circuit is left. It will be obvious to those skilled in the art that if a metallic plate is used as a base in place of dielectric plate 31, no additional metallic coating such as 32 would be necessary and the first coating

step could be eliminated. However, it may be desirable in many applications to maintain greater rigidity during the manufacturing process combined with lightness of weight in use, in which case the dielectric backing during manufacturing is generally preferable.

It will be realized by those skilled in the art that the invention as described may be applied to waveguide circuits of virtually any shape and may be used to provide conventional type coupling devices either in one plane or between adjacent planes by stacking. Waveguide cavities, transitions, antennas, power splitters and other components can also be derived by use of the techniques described above.

Therefore, by utilization of the present invention, entire waveguide circuits of highly flexible design may be simply, compactly, and economically constructed by mass production techniques and a substantial reduction in the number of waveguide connections with their attendant discontinuities is made possible.

Obviously many other 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 claim, the invention may be practiced otherwise than as specifically described.

What is claimed is:

A wave guide module comprising:

at least three flat faced elements in stacked relation;

a first of said elements having at least one groove in each of the opposite flat faces thereof, the surfaces of said grooves and at least a portion of said flat faces being of an electrically conductive material;

a second of said elements having at least one groove in at least one of the opposed flat faces thereof said second of said elements having the surface of said grooves and of portions of said flat faces of an electrically conductive material;

said first element mounted with one of its flat faces adjacent one of the flat faces of said second element in said stack with said electrically conductive surfaces of the one in registry with at least one of of grooves in the other element to form wave guide sections;

a third of said elements having electrically conductive portions on the flat surfaces thereof and mounted in said stack with one first surface thereof adjacent the other flat surface of said first element and with at least one of said electrically conductive portions in registry with at least one of the grooves in said first element, whereby a wave guide module containing a plurality of wave guide sections is assembled.

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