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3,135,935

TRANSMISSION LINE AND METHOD OF MAKING

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FIG. 1

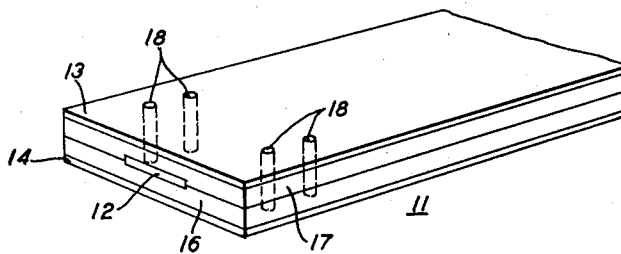


FIG. 2

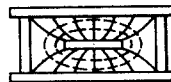


FIG. 3

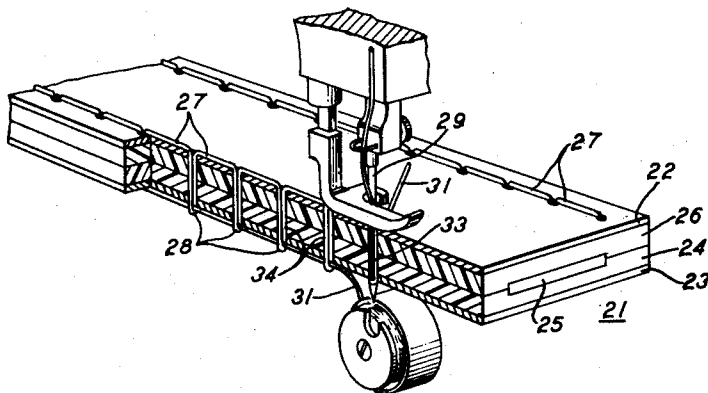
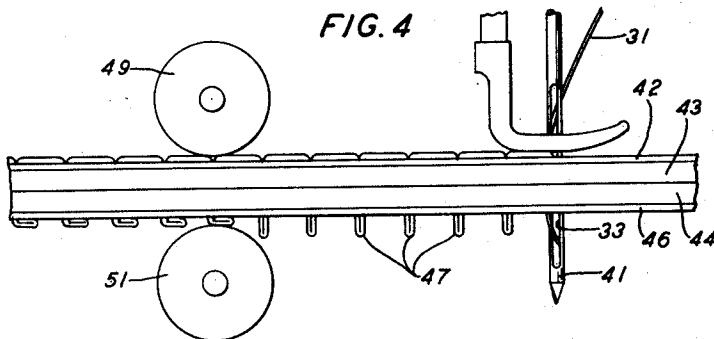


FIG. 4



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3,135,935 TRANSMISSION LINE AND METHOD OF MAKING

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This invention relates to electrical transmission lines and more particularly to transmission lines that are used in high frequency communication systems.

At the present time the two most common types of microwave transmission lines which are used in communication systems are the coaxial cable and the waveguide. Both of these types of transmission lines suffer from certain faults. In the case of coaxial cables, they are exceedingly difficult to manufacture and, although they lend themselves to use over extended distances, the cost of manufacture becomes high when great distances are to be spanned. Waveguides, on the other hand, do not lend themselves to use over extended distances, and, because of the close tolerances required, are even more difficult or expensive to manufacture than the coaxial cable. However, the waveguide permits the use of higher and higher frequencies surpassing the frequency capabilities of the coaxial cable.

As an alternative to both waveguides and coaxial cables, printed circuit techniques have been utilized to make what is commonly referred to in the art as strip transmission line, which consists actually of two planar outer conducting members commonly referred to as ground planes and an inner member which is the actual conducting member spaced between the two outer members. The space between the two ground planes is commonly filled with dielectric. This dielectric serves the function of holding the inner conducting member in proper spaced relationship to the ground planes.

The strip transmission lines most commonly used consist of such a center conductor between two planar ground planes. A conventional way of providing an electrical connection to the two ground planes to suppress unwanted modes, and also of holding the entire assembly together, is by rivets or screws. These rivets, in order that a proper wave transmission circuit for the TEM mode may be formed, must be spaced very close together as, for example, approximately $\frac{1}{10}$ of a wavelength or less, so that radiation from the circuit can be avoided and the desired mode transmitted. Obviously, a problem arises as higher and higher frequencies are to be transmitted inasmuch as the rivets, in order to have the necessary strength, must have a certain minimum diameter. Thus, typically, the rivets are .080 inch in diameter and cannot be conveniently spaced closer than about .150 inch between centers. Obviously, this represents a serious limitation for higher and higher frequency transmission.

In addition to the foregoing the lateral spacing of the rivets should be something less than $\frac{1}{2}$ a wavelength and preferably less than $\frac{1}{4}$ of a wavelength to avoid conversion from the desired TEM mode of transmission to a waveguide mode. This requirement of less than $\frac{1}{4}$ of a wavelength results from the fact that the typical rivets or fasteners which are spaced $\frac{1}{10}$ of a wavelength apart along the line are inductive and that the waveguide thus obtained corresponds to a solid waveguide of wider dimensions.

If, for example, it is desired to operate the circuit at 12 kilomegacycles where the wavelength in the dielectric is approximately 1.67 centimeters for a dielectric constant (ϵ) of 2.25, then the fastener spacing should be equal to or less than .167 centimeter which is equal to

approximately .066 inch along the line. Obviously, the minimum limits set forth in the foregoing for the use of rivets or screws prevent their use in such an arrangement.

In addition, in the manufacture of such a transmission line it is necessary to drill numerous holes for the rivets and to fasten the rivets in place. It can be appreciated that, at especially high microwave frequencies, such a technique is quite inefficient because of the small rivet spacing.

It is an object of the present invention to transmit microwave frequencies in a strip-type transmission line which has a higher frequency limit than is obtainable in present lines of this type.

It is another object of this invention to produce a strip-type transmission line for use at high microwave frequencies by a method which does not entail drilling holes and inserting and fastening individual rivets or pins therein.

These and other objects of the present invention are achieved in an illustrative embodiment wherein a transmission line comprising first and second thin parallel planar conducting ground planes are separated from each other by a suitable dielectric material. Within the dielectric material and parallel with the ground planes and equally spaced from each is a center planar conductor, which is narrower than the ground planes. In order that the desired TEM mode be propagated in the transmission line, the ground planes are electrically connected together by conductive means passing through the insulation.

It is a feature of the present invention that the conductive means connecting the ground planes together comprises a continuous conducting thread stitched to said ground planes through the dielectric material, there being such a continuous member on each side of the center conducting member.

With such an arrangement, it is possible to space the vertical portions of the stitches quite closely together, much more so than heretofore achievable through the use of rivets or individual connectors, and thus much higher frequency operation is possible.

It is another feature of the present invention that the stitching is performed by more or less conventional sewing machine techniques using, for example, the type of machine used in sewing shoes together. Such a technique eliminates the necessity of drilling holes in the transmission line as required in prior art techniques and permits every adjustment and insures uniformity of the spacing between the stitches.

These and other objects and features of the present invention will be readily apparent from the following description, taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a perspective view of a strip transmission line of the prior art;

FIG. 2 is a cross section of the line of FIG. 1 showing the field configuration of the desired TEM mode;

FIG. 3 is a perspective view of one illustrative embodiment of the invention, and

FIG. 4 is a side view of another illustrative embodiment of the invention.

Turning now to FIG. 1, there is shown a conventional type strip transmission line 11 comprising a planar center conductor 12 lying in a plane parallel to and preferably equally spaced from a pair of parallel planar ground planes 13 and 14 of conducting material. Ground planes 13 and 14 are held in spaced relationship by a pair of longitudinally extending dielectric members 16 and 17 which also serve as a support for conducting member 12. Dielectric members 16 and 17 are of a material preferably of low dielectric loss, and, in general, are glued together at their juncture to assist in holding the assembly together.

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It is not necessary that there be two dielectric members, it being possible to use a single member filling the entire space and in which conductor 12 is buried.

As thus far described, transmission line 11 is capable of transmitting electromagnetic energy. However, in addition to transmitting energy in the desired TEM mode, it also tends to generate spurious unwanted modes. A further drawback to such a line is that it tends to radiate energy out of the unbounded sides of the line, and it also is subject to having unwanted energy radiated into it. In order to remedy these defects, and additionally to aid in holding the structure together, an array of spaced conducting rivets or pins 18 extends along the line on either side of the center conductor and electrically connects the two ground planes 13 and 14 together. When these pins are spaced longitudinally and transversely less than one-half a wavelength apart, spurious modes and radiation of energy are effectively eliminated, and the structural strength of the line is increased. The desired TEM mode, as depicted in FIG. 2, then contains substantially all of the energy being propagated in the line.

As pointed out in the foregoing, such a transmission line as just described has certain inherent frequency limitations. As the desired frequency of operation increases, both the radiation problem and spurious mode generating problem become more acute. It therefore becomes necessary to space the rivets or pins 18 quite close together in the longitudinal direction, such as, for example, approximately $\frac{1}{10}\lambda_e$, where λ_e is the wavelength in a medium of dielectric constant ϵ . Thus efforts to space the pins, which must have a certain minimum diameter for structural strength, so close together represent an almost impossible construction problem, inasmuch as individual holes must be drilled for each pin. In addition, the speed and ease of fabrication which make such a line so desirable are negated, the cost and difficulty of fabrication becoming prohibitive.

In FIG. 3, there is shown an arrangement embodying the principles of the present invention wherein a strip transmission line 21 is produced which suffers from substantially none of the defects of the type of line depicted in FIG. 1. As in the line 11 of FIG. 1, line 21 comprises a pair of parallel, planar ground planes 22 and 23 of thin conducting material such as copper, held in proper spaced relationship by a pair of dielectric members 24 and 26, which also serve to support a center conducting member 25 in proper parallel, planar relationship with members 22 and 23. In accordance with the principles of the invention, however, the pins or rivets 18 of the device of FIG. 1 are replaced by a continuous conducting thread 27 which is stitched through the ground plane 22, dielectric members 24 and 26, and ground plane 23, making electrical contact with both ground planes. In FIG. 3, there is depicted an arrangement for creating a lock stitch, wherein the loops 28 formed by the lock stitch needle 29 loop around a bobbin strand 31 preferably of conductive material, thereby assuring good electrical connection between the ground planes 22 and 23. Inasmuch as conducting thread or wire 27 undergoes fairly rough manipulation during the sewing operation, it should be any one of a member of suitable high conducting materials of good flexibility and tensile strength. In practice, copper has been found to work well, but other materials may be more suitable. For example, aluminum, nickel, copper coated steel, or various alloys may be used equally as well. Bobbin wire 31 does not have to possess these properties in the same degree, other than that of high conductivity. In addition, the needle 32 may be modified by lengthening the grooves 33 on either side to protect the wire 27 during passage through the line. The needle should, of course, be as sharp as possible to enable easy penetration of the ground planes.

It can readily be appreciated that with the arrangement

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of FIG. 3, the vertical stitches, which function in the manner of the pins or rivets 18 of the line of FIG. 1, can be located in place quite rapidly, do not require a tedious drilling of holes, and may be spaced quite close together by a simple adjustment of the sewing machine. With such an arrangement, it has been possible to construct lines where the longitudinal spacing between members 34 is well within the required $\frac{1}{10}\lambda_e$, even at very high microwave frequencies. The lateral spacing between stitches or conductive members 27 should be less than $\frac{1}{2}\lambda_e$ and preferably less than $\frac{1}{4}\lambda_e$. This latter dimension stems from the fact that members 34 are inductive and the transmission line thus created corresponds to a waveguide of wider dimensions. Thus the $\frac{1}{4}\lambda_e$ spacing effectively suppresses the spurious waveguide modes which might be set up with a greater spacing. It can readily be appreciated that such a spacing can easily be maintained with the arrangement of FIG. 3 without the necessity of complicated drill jigs or fixtures.

In FIG. 4 there is depicted a second method of creating a stitched transmission line, wherein instead of a lock stitch, a simple loop stitch is utilized. In the arrangement of FIG. 4, the sewing needle 41 pierces ground plane 42, dielectrics 43 and 44, and ground plane 46, and forms simple loops 47 of conductive thread 48. A pair of pressure rollers 49 and 51 are arranged to follow the needle 41 and press the loops 47 flat against ground plane 46, thereby insuring good electrical contact between the loops 47 and ground plane 46. The flattened loops may then be glued or soldered in place, although this last step while desirable is not strictly necessary.

From the foregoing it can readily be seen that utilizing the principles of the present invention, a simple strip-type transmission line of very high frequency capability is produced in an economical, simple, and rapid manner.

While only two methods of making the transmission line have been disclosed, other methods may occur to workers in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A high frequency electrical transmission line comprising first and second planar thin outer conducting members lying in spaced parallel planes, a third thin planar conducting member in the space between said first and second members, means for maintaining said third planar conducting member in fixed parallel insulating relationship with said first and second members, said means comprising dielectric material in the space between said first and second members, and means for forming non-radiating side walls for said transmission line comprising a thin continuous conducting thread on each side of said third planar member, each of said threads being stitched to said first and second members through said dielectric material.

2. A high frequency electrical transmission line as claimed in claim 1 wherein the transverse spacing between stitching in the dielectric material is less than $\frac{1}{4}\lambda_e$, where λ_e is the wavelength of the electrical energy propagating in said transmission line.

3. A high frequency electrical transmission line as claimed in claim 1 wherein each of said thin continuous conducting threads passes through said dielectric and is looped about a thin continuous conducting thread in electrical contact with one of said planar outer members.

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