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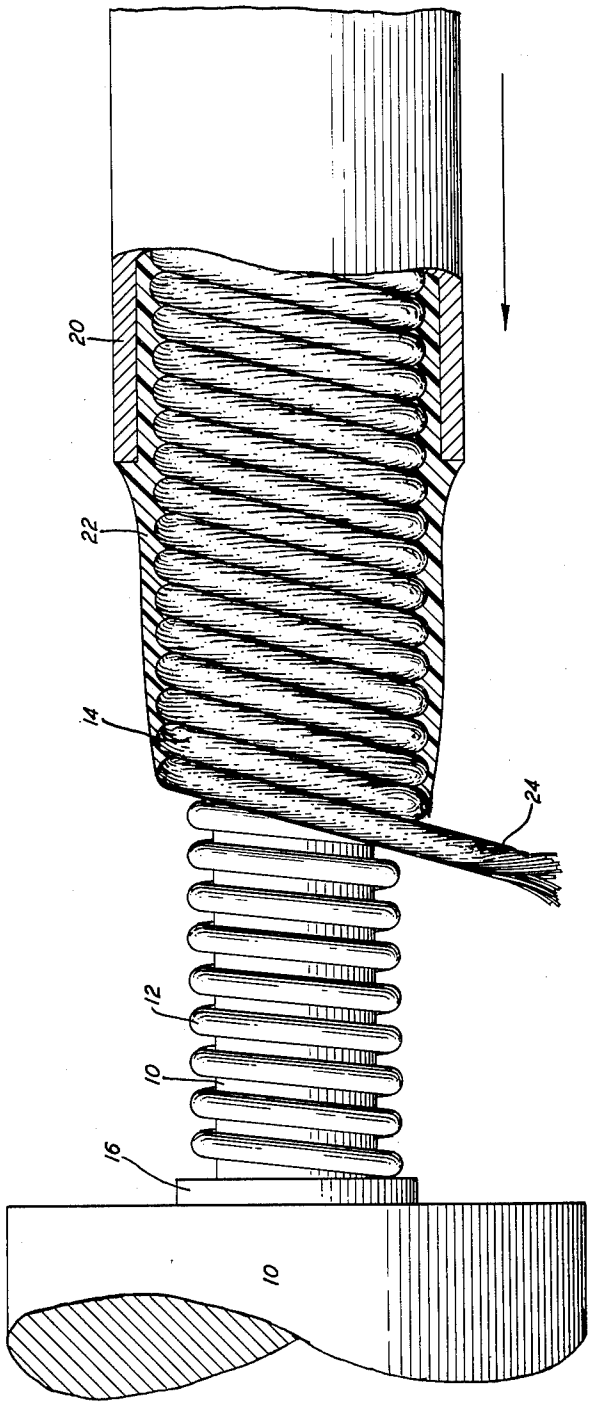

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METHOD FOR CONSTRUCTING A WAVE GUIDE

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This invention relates to a method for constructing a wave guide, and more particularly, to a method for constructing a helical wave guide having a rigid steel pipe as a protective sheath.

It is known that a closely wound helical conductor of diameter gerater than 1.2 free space wavelengths is a transmission medium that is suitable for propagating a properly excited circular electric TE_{01} mode. It has been shown that such a medium greatly minimizes the inherent tendency of this mode to degenerate into spurious modes as a result of the substantially different phase constants provided for the several modes. The helical conductor is surrounded by a jacket of electrically dissipative material which introduces a large difference in the attenuation constants presented to the spurious modes and the TE_{01} mode. By virtue of this difference in attenuation constants, which is independent of the differences in phase constants, degeneration is further reduced.

Since this type of wave guide is desirable because of its advantage of substantially pure mode transmission, the most economical construction technique resulting in the best mechanical and electrical characteristics is desired. In this respect, it has been realized that there are many advantages in having a conductive metallic material for a protective sheath. As disclosed in the United States Patent 2,848,695, granted J. R. Pierce on August 19, 1958, and the United States Patent 2,848,696, granted S. E. Miller on August 19, 1958, the outside protective sheath may be wound of overlapping, thin strips or may be made of a woven braid thereby forming a non-corrosive metallic shield. As further disclosed, the metallic shield serves to protect the line from outside mechanical influences such as weather, moisture, and insects and from electrical influences such as stray radiation from adjacent transmission lines and lightning.

Other methods have been considered for fabricating a helical transmission line with an outer protective sheath of metallic material which exhibits more rigidity than the lines resulting from the two methods disclosed in the above-mentioned patents. For example, several methods of using a solid pipe as opposed to braided metal or overlapped, thin strips of metal have been attempted. One method is to cut the length of pipe longitudinally in half and then to insert the helical conductor and its associated jackets in one half and to cover with the other half. This method is cumbersome, expensive and much rigidity is lost because of the cut.

Another method is to provide a longitudinal seam and then to spring the pipe open and insert the helical conductor. The pipe is then allowed to return to its original position. Here again there are disadvantages as this method will only work with relatively short sections, the line produced is not watertight, and rigidity is lost.

Another possible method is to push the helical conductor and its associated jackets into a rigid steel pipe. If the steel pipe is made small enough to give necessary support to the helix, then it is substantially impossible to insert the helix into the steel pipe without desetroying the helix. On the other hand, if the steel pipe is made large enough so that the helix and associated jackets will enter into the steel pipe, the void remaining between the pipe and the jackets of the helix is obviously undesirable for many reasons. This problem may be solved in some cases by filling the void with a plastic forced into the void under pressure at one end either with or without a counterforce of suction at the other end. However, this solution is expensive and will work satisfactorily only on short sections of line.

It is therefore an object of the present invention to provide a method for constructing a helical wave guide with a rigid steel pipe as a protective sheath.

In accordance with the present invention, both the inside of a pipe of slightly enlarged diameter and the outside of the helix jacket are coated with an uncured thermosetting synthetic resin, such as epoxy, and the helix is inserted in the pipe with the resin on the two surfaces serving as the lubricant. As a result of this method of assembly, the resin simultaneously serves as a filler and upon curing as an adhesive sealing the two assembled parts into a unitary wave guiding structure.

This and other objects, the nature of the present invention, and its various features and advantages, will appear more fully upon consideration of the single drawing which shows the fabrication of a wave guide as an illustrative embodiment of the present invention, and the detailed description thereof.

Referring to the drawing, a view illustrating the construction of a section of transmission line is shown as an illustrative embodiment of the present invention. A mandrel 10 of suitable length and of exactly the cross-section desired for the inner surface of the finished line is cleaned and then coated with a suitable mold release. The mandrel 10 is rotated and the insulated conductor 12 is closely wound thereon with a left-hand thread. The reason for the preferred left-hand thread will hereinafter become apparent. Conductor 12 may either be solid or stranded and may comprise copper alone or a base metal, such as iron or steel, plated with a highly conductive metal, such as copper or silver. The dimensions and characteristics of the conductor 12 in this embodiment are similar to or the same as the specific characteristics and dimensions disclosed in United States Patent 2,848,696, granted S. E. Miller on August 19, 1958, or United States Patent 2,848,695, granted J. R. Pierce on August 19, 1958. Around this conductor 12 is wound a lossy jacket 14 composed of lossy roving 24 coated with uncured epoxy 22, a fluid plastic. This roving 24 is composed of many threads or continuous filaments of glass that are loosely twisted to form a structure similar to yarn. This roving is impregnated or coated with carbon, a lossy material, and then brought in contact with uncured or wet epoxy 22. As the roving 24 is wound around the helix 12, the excess epoxy 22 forms a layer on the outside of the roving 24, as shown pictorially in the drawing. The thickness of the lossy jacket 14 is in accordance with the thickness specified in the copending application of H. G. Unger, Serial No. 770,841, filed October 30, 1958, now U.S. Patent 2,950,454, issued August 23, 1960.

The jacket 14 of spiraled roving coated with uncured epoxy has its ends secured by wrapping them around anchors at each end of the mandrel 10, as represented by anchor 16. These anchored ends secure the structure so the steel pipe 20 may be longitudinally pushed, in the direction of the arrow shown, over an anchored end to provide the outer steel jacket.

Several plastic materials have been found suitable for practicing the invention. The embodiment disclosed employs a suitable commercially available epoxy resin of the type that may be catalytically cured to form a thermosetting polymer.

For example, a suitable catalyst is usually either an amine, amide, or a combination of both. It is preferred that a fast enough catalyst be employed that the exothermic heat aids in producing the cure. However, it has been found that the reaction may be hastened without undesirable shrinkage if the exothermic cure is also

accompanied by moderate external heat. Specifically, 20 parts per 100 by weight of the curing agent metaphenylene diamine has proven satisfactory. Alternatively, one of the several less expensive thermoplastic polyester resins may be employed.

In general, in practicing this portion of the invention the techniques and materials used are similar to those known to the art and used in other glass reinforced plastics. Reference is made for alternative plastic materials to the text, "Glass Reinforced Plastics," by Phillip Morgan, published in the United States by Philosophical Library, Incorporated.

The inside of the steel pipe **20** also contains uncured epoxy which may be identical to the epoxy around the roving **24**, to act as a wetting agent for the steel. The excess epoxy **22** and the epoxy inside of the steel pipe **20** combine to act as a lubricant between the jacket **14** and the pipe **20**, thereby facilitating the insertion of the helix into the steel pipe. The epoxy **22** also acts as a filler and binder in the structure and in its cured state becomes a homogeneous adhesive between the lossy jacket **14** and the steel pipe **20**.

With the steel jacket **20** in place, the unit is placed in an oven for curing. The mandrel **10** is left in place during the curing process so the structure may be rotated at all times. This continuous rotation results in a uniform ratio of resin-to-glass throughout the jackets, thereby minimizing ellipticity which would result from unequal shrinkage.

This structure is reasonably inexpensive to fabricate and has the mechanical advantages of being anhygroscopic, having a high bending strength or rigidity, and being vacuum-tight. This structure also has the electrical advantages of affording lightning protection and affording protection from stray radiation. This structure has the further advantage that threads may be cut into the steel jacket for joining sections. Furthermore, it permits accurate facing on the end of the structure which insures axial alignment. The reason for winding the helix with a left-hand thread is to permit conventional rotation for the facing and threading tools and thereby the chance of catching and unravelling the helix is minimized.

There are alternative structures for the helix and its associated jackets which will result in different thicknesses or sizes of steel pipe. For example, it has been found that it is advantageous to use a layer of clear glass roving coated with epoxy next to the helix because it forms a better bond between the helix and lossy jacket than the lossy jacket does when placed against the helix. The reason for this is that the lossy material surrounding the glass fibers tends to inhibit the epoxy-glass bond which, in the vicinity of the helical conductor, results in reduced adhesion. Another reason for the use of this jacket of dielectric material between the lossy jacket and the helix is for an impedance match between the helix and the lossy jacket as disclosed in the copending application of H. G. Unger, Serial No. 679,929, filed August 23, 1957.

Another alternative is in the construction of the lossy jacket. This lossy jacket may be composed of strands of dielectric material that are coated with a thin metallic semiconductive or resistive film of low resistance and then laminated with a suitable dielectric plastic as disclosed in the copending application of G. T. Kohman et al., Serial No. 679,835, filed August 23, 1957, now U.S. Patent 2,966,643, issued December 27, 1960.

In all cases, it is understood that the above-described arrangement is illustrative of one of the many possible specific embodiments that represent applications of the principles of the invention. Numerous and varied other arrangements can readily be devised in accordance with these principles by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A method for constructing a hollow, helical wave guide of round transverse cross section having an outer protective metallic jacket comprising the steps of: cleaning a mandrel having an outside diameter greater than one wavelength of the wave energy supportable by said helical wave guide; coating said mandrel with a material having the characteristics of a mold release; winding a conductive material around said mandrel in a substantially helical form; winding about said conductive material to cover entirely said conductive material a nonconductive layer of roving comprised of glass fibers impregnated with an electrically dissipative material and coated with a thermosetting synthetic resin, said resin acting as a lubricant, voidless filler, and adhesive; sliding a hollow metallic cylindrical jacket longitudinally over said layer; curing said synthetic resin over a period of several hours; and continually rotating the entire assembly comprising said mandrel, conductive material, layer, and metallic jacket, as a unit, during said curing period.

2. A method for constructing a hollow wave guide of round transverse cross section comprising the steps of: conforming a conductive element substantially to the shape of the outside surface of a coated cylindrical mandrel; applying about said conductive element a nonconductive layer of material coated with an uncured, thermosetting synthetic resin to cover entirely said element, sliding a hollow metallic cylindrical jacket longitudinally over said layer; curing said synthetic resin over a period of several hours; and continually rotating the entire assembly during said curing period.

3. A method for constructing a hollow wave guide of round transverse cross section comprising the steps of: conforming a conductive element substantially to the shape of the outside surface of a coated cylindrical mandrel; applying about said conductive element a nonconductive layer of material coated with a fluid plastic to cover entirely said element; and sliding a rigid hollow cylindrical jacket longitudinally over said layer.

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