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[54] HELICAL WAVEGUIDE

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[52] **U.S. Cl.** .... **333/95 R**, 333/95 A, 174/131 A

[51] **Int. Cl.** **H01p 3/12**, H01p 3/14

[58] **Field of Search** .... 333/95 A, 95 R, 84 R, 333/31 A; 174/113 C, 131 A; 117/227

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[57] **ABSTRACT**

A waveguide having an internal wall formed by a helix of one or more insulated straps, each strap having a core of a material having a specific weight less than 2 covered by a layer of metal of high conductivity, the thickness of the layer being 3–4 times the reference depth at the frequency of the waves transmitted, a layer of tape over the helix and a sheath of thermoplastic surrounding the tape layer.

10 Claims, 2 Drawing Figures

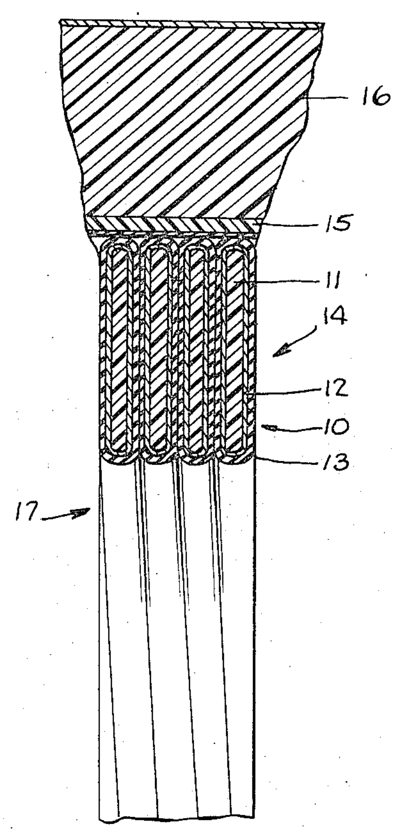


Fig. 1.

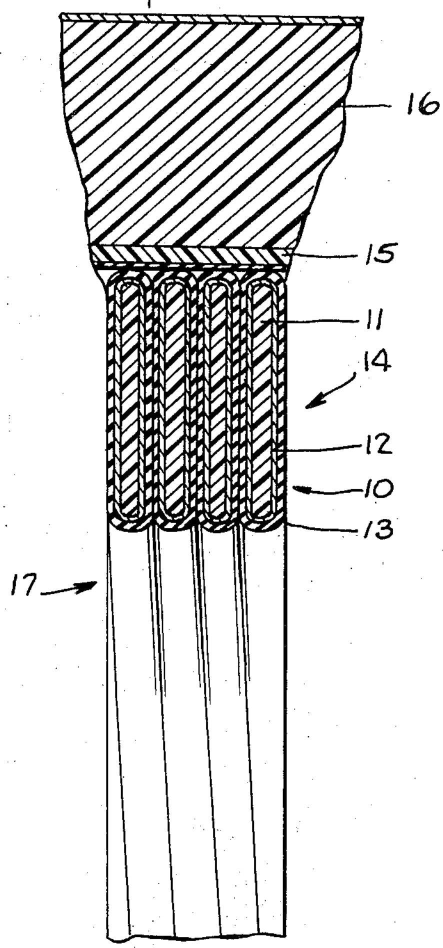
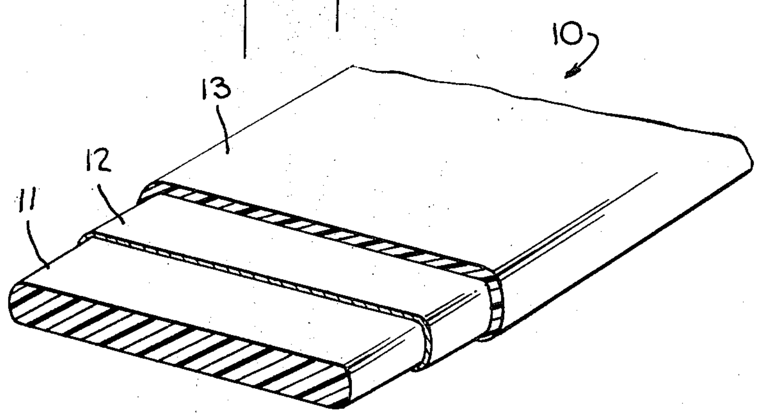


Fig. 2.



HELICAL WAVEGUIDE

This invention relates to waveguides of the type disclosed in our abandoned application Ser. No. 139,436 filed May 3, 1971, and in the co-pending application of Antonio Ferrentino, Ser. No. 176,499 filed Aug. 31, 1971, now U.S. Pat. No. 3,701,060, both applications being entitled "Improved Helical Waveguide" and to an improved conductor for forming such waveguides.

The waveguide of the invention comprises a cylindrical helix formed by an insulated metal strap wound on edge and covered by at least an insulating sheath.

The waveguides disclosed in said applications are of the type in which at least one sheath of thermoplastic material covers a cylindrical helix having well aligned and closely adjacent coils and are particularly suitable, because of their flexibility, to extend between optically misaligned points. They are also suitable, because of their particular construction, to be manufactured in the desired length, limited practically only by the capacity of the storing and transporting drums.

The cylindrical helix described in both of said applications is formed by helically winding an insulation covered metal strap on edge or upright, that is, with the major surfaces thereof extending transversely to the axis of the helix and with the major surfaces of one turn facing the major surfaces of the next adjacent turn. The turns are close wound and successive turns are in contact along at least one helical line. The strap may have major surfaces which are rectilinear or curvilinear in cross-section, and the width of the major surfaces is greater than the thickness of the strap. For example, it may have a thickness of one to four tenths of a millimeter and a width of 1 millimeter or greater. The metal of the strap preferably is copper or aluminum, or copper or silver plated aluminum. The strap is covered by an insulating layer, preferably a layer of enamel having a thickness of the order of hundredths of a millimeter.

The waveguide described in said application Ser. No. 176,499 differs from the one described in said application Ser. No. 139,436 in that the cylindrical helix is formed by winding at least a pair of straps on edge, each strap being of a different cross-section or being differently disposed so as to leave a space between the major surfaces of adjacent turns. Adjacent turns are in contact with each other along at least one helical line and preferably the cross-sectional shapes of the straps are such that adjacent turns contact along two helical lines.

Such waveguides in which the cylindrical helix is formed by a strap or straps wound on edge have, as compared to waveguides in which the cylindrical helix is formed by a conductive wire, the advantage of possessing a greater resistance to deformation due to possible loads which, incidentally or necessarily, are applied to it during laying or use. The present invention is applicable to the waveguides disclosed in said co-pending applications.

It will be understood that the cylindrical helices forming part of the waveguides of said applications can be compared to compact cylinders, which have therefore a considerable weight and a related cost, due to the valuable materials employed.

It is known moreover, that in a conductor the current tends to distribute on the surface thereof, involving only a small portion of the thickness (penetration thickness) of the conductor itself.

A waveguide transmits waves of very high frequency, of the order of gigahertz, for which the penetration thickness is very small. In other words, taking into account the section of the strap, the current concentrates only on a peripheral thickness, of the order of some thousandths of a millimeter.

The object of the present invention is an improved helical waveguide formed from an improved strap made from cheap materials having a low specific weight, i.e., low weight per unit volume in absolute units, which permits the manufacture of a waveguide which is easily handled, both during transport and laying thereof, and which is considerably more economical than the conventional helical waveguides.

More precisely, the object of the present invention is an improved helical waveguide and an improved conductive strap therefor, characterized in that the strap comprises an inner support made of a material of low specific weight, the inner support corresponding to the portion of the strap not involved in current flow and being covered with a thin layer of a conductive metal which is surrounded by a thin insulating layer.

The objects and advantages of the invention will be apparent to those skilled in the art from the following description of a presently preferred embodiment thereof, which description should be considered in conjunction with the accompanying drawing in which:

FIG. 1 is a fragmentary, longitudinal section of the waveguide of the invention incorporating the improved strap of the invention; and

FIG. 2 is a fragmentary, perspective view of the strap incorporated in the waveguide shown in FIG. 1.

Referring first to FIG. 2, the strap **10** has a thickness ranging preferably between 1/10 and 4/10 millimeters and a width greater than 1 mm and comprises a tape-like inner support **11** made from a material of a low relative specific weight, preferably smaller than 2. The support **11** of the illustrated embodiment is made of a synthetic resin which can be either thermoplastic, e.g., polyvinylchloride or polystyrene or thermosetting, e.g., a polyester resin or a polycarbonate resin. The particular resin employed may be readily selected or formulated by those skilled in the art bearing in mind that its physical characteristics must be such as to permit it to bend into the helical shape and yet be sufficiently rigid, after bending, to withstand the pressures to which it will be subjected during handling and after installation.

The support **11** occupies, in volume, the portion of strap **10** which does not carry electric currents of any significance.

The surface of the support **11** is completely covered with a thin layer **12** of a high conductivity metal. Preferred metals are copper and silver, but aluminum or gold may be used, gold being used only for special purposes since its cost is high and does not offer advantages over the other metals.

Preferably, the layer **12** is applied by known metallization processes, such as those using a vacuum, which ensure a uniform metallization. In this way, it is possible to obtain a thickness of the metal of the order of thousandths of a millimeter, which, by means of a possible further plating treatment, can be brought, if necessary, to a higher value. The thickness of the layer **12** should be at least three to four times the "reference depth" which is defined by the following formula:

$$\text{reference depth in inches} = 3160 \sqrt{p/u\,f}$$

where p = resistivity of the metal in ohm inches
u = relative permeability of the metal
f = frequency in hertz

Such thickness of three to four times the reference is referred to herein as the "penetration" thickness. As an example, if the layer **12** is a layer of copper and the minimum operating frequency is 30GHz, the reference depth is:

$$\text{reference depth} = 3160 \quad \sqrt{0.68 \times 10^{-6}/1 \times 50 \times 10^{9}} = 1.5\times10^{-5} \text{ ins.}$$

Accordingly, the penetration thickness, or thickness of the layer **12**, preferably would be of the order of 6×10^{-5} inches or approximately 0.06 mils.

The metal layer **12** represents the conductive portion of the strap, which is insulated by means of a thin insulating layer **13**. Said layer **13**, as conventionally used, can be enamel. However, instead of employing enamel, which polymerizes at a very high temperature, it is preferred to use a varnish, such as an epoxy resin, which polymerizes at room temperature and which, as is known, can be spread in very thin films having high adhesion and elasticity characteristics, and consequently does not give rise to cracking phenomena when the strap is deformed due to the stresses to which it is subjected during the manufacture, laying and operation of the waveguide. Another preferred varnish which can be used is one selected from the known polyester resins which polymerize at room temperature.

The illustrated strap **10** is of the rectilinear type but, of course, it could be otherwise shaped, curved, bent at an obtuse angle, etc., as illustrated in said co-pending applications.

The shape of the strap could be obtained after forming the rectilinear strap illustrated, by acting thereon with appropriate forming means.

As illustrated in FIG. **1**, the strap **10** may be wound in helical form to form a helical waveguide **17** comprising a plurality of helical turns **14** surrounded by an insulating sheath **16**, e.g., a sheath of thermoplastic resin, with or without intermediate layers **15** of tape. If desired, the sheath **16** may be surrounded by a layer of armor which may be made of metal.

It will be understood by those skilled in the art that various modifications of the invention may be made without departing from the principles of the invention and, for example, the waveguide may be constructed as shown in the various embodiments illustrated in said co-pending applications.

We claim:

1. A waveguide comprising an inner wall formed by a helix of at least one strap wound on edge and disposed with its major surfaces extending transversely to the axis of said helix, said strap having a solid core surrounded by a layer of a metal of high conductivity in contact with said core and a layer of insulation surrounding said layer of metal, said layer of metal being thin relative to the thickness of said core and the material of said core having a relative specific weight which is lower than the relative specific weight of the metal of said layer, and a sheath of insulating material surrounding said helix.

2. A waveguide as set forth in claim **1**, wherein the material of said core has a relative specific weight less than two.

3. A waveguide as set forth in claim **2**, wherein the material of said core is a synthetic resin.

4. A waveguide as set forth in claim **1**, wherein the material of said core is selected from the group consisting of thermoplastic and thermosetting resins.

5. A waveguide as set forth in claim **4**, wherein the metal of said layer of metal is selected from the group consisting of copper, silver, aluminum and gold and is a coating on said core.

6. A waveguide as set forth in claim **1**, wherein the metal of said layer of metal is selected from the group consisting of copper, silver, aluminum and gold.

7. A waveguide as set forth in claim **1**, wherein the material of said core is a synthetic resin selected from the group consisting of polyvinylchloride, polystyrene, polyester and polycarbonate resins.

8. A waveguide as set forth in claim **1**, wherein said layer of insulation surrounding said layer of metal is a layer of varnish which is polymerizable at room temperature.

9. A waveguide as set forth in claim **8**, wherein said varnish is a resin selected from the group consisting of epoxy and polyester resins.

10. A waveguide as set forth in claim **1**, wherein the metal of said layer is selected from the group consisting of copper, silver, aluminum and gold and the thickness of said layer is at least three times the reference depth at the lowest operating frequency of said waveguide.

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