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[54] **COILABLE WAVEGUIDE**

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[52] **U.S. Cl.** ..... **29/600,** 72/206, 29/477.7, 29/480, 333/95 A

[51] **Int. Cl.** **H01p 11/00,** H01q 13/00

[58] **Field of Search** ..... 333/95, 95 A; 29/600, 601, 477.7, 480; 174/102, 107

[56] **References Cited**

UNITED STATES PATENTS

3,299,374	1/1967	Schickle et al.	333/95 A
3,200,356	8/1965	Schuttloffel et al.	333/95 A
3,372,352	3/1968	Krank et al.	333/95 A

OTHER PUBLICATIONS

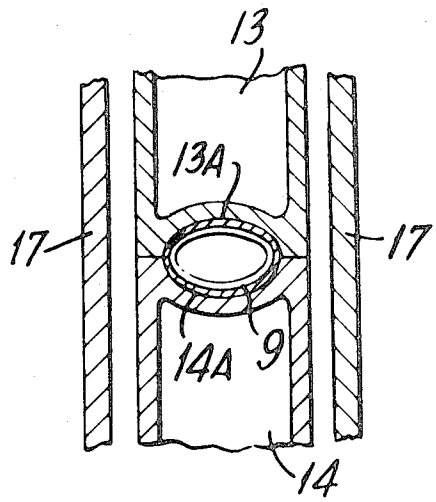
"New Flexible Heliax Waveguide" for Microwave Systems, Bulletin 8529A; February 1964 – Andrew.

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[57] **ABSTRACT**

A coilable, corrugated waveguide having an elliptical cross section and a dielectric covering on the outer surface thereof; and a method of making the same.

2 Claims, 4 Drawing Figures



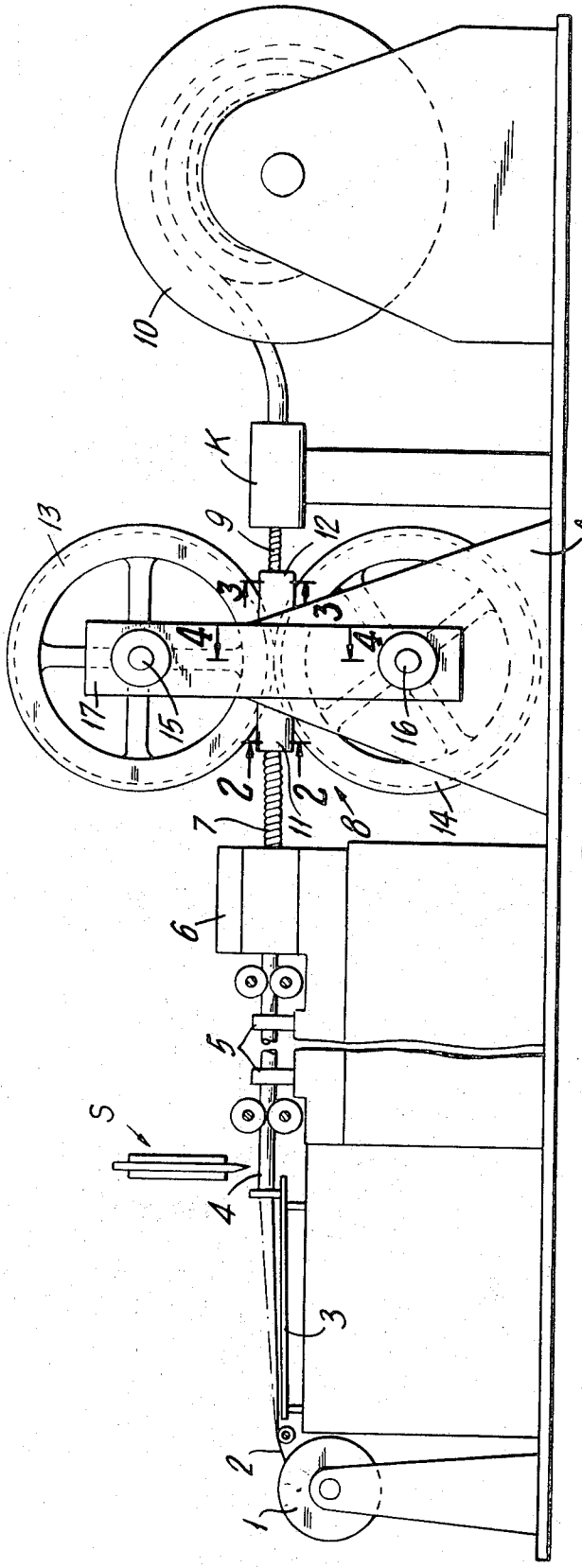


FIG. 1

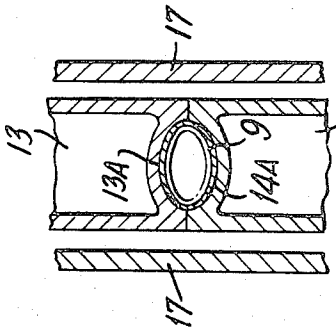


FIG. 4

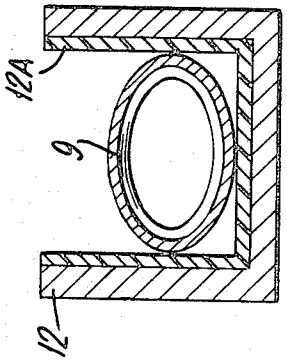


FIG. 3

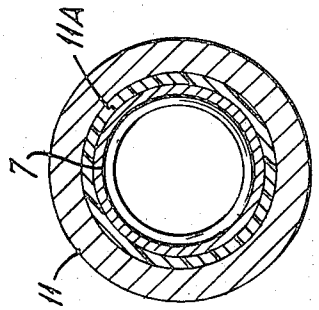


FIG. 2

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COILABLE WAVEGUIDE

This application is a division of application Ser. No. 478,905, filed Aug. 11, 1965, now U.S. Pat. No. 3,383,895.

In the generation and transmission of microwaves it may be necessary to guide the wave energy over the non-rectilinear paths. Up to the present, coaxial cables were generally used as flexible coilable conductors for transmission of polarized electromagnetic waves of high frequency, i.e., the lower frequency microwaves. However, at very high frequencies, i.e., higher frequency microwaves, coaxial cables have too great an attenuation factor to permit economic transmission of wave energy. Therefore, attempts have been made to employ corrugated waveguides of circular cross-section as flexible conductors for very high frequency waves. In order to obtain sufficient mechanical flexibility of such a wave guide, the corrugations must be made correspondingly deep. However, these deep corrugations either generate undesired modes of oscillations or else cause an applied polarized wave to split into two components. The corrugations, in addition, produce rotation of the directions of polarization of an applied polarized wave. The amount of rotation depends upon the length and curvature of the guide and the frequency of the waves. Furthermore, in transmission of a wave with a wide frequency band, very bad depolarization occurs, making withdrawal of the applied wave energy impossible without incurring heavy losses in the available energy.

It has been proposed to reduce depolarization and corresponding loss of energy in such circular corrugated wave guides by sectionally deforming the guide cross-section into ellipses or to rotate two sections of identical waveguides with respect to each other in the direction of polarization. It is apparent that such measures are time consuming and unreliable and make the mounting of such round waveguides very difficult.

Attempts have been made to make the well known rectangular waveguide flexible by providing notches in its walls or by inserting flexible sections. In such cases undesired discontinuities result, and a waveguide of rectangular cross-section is hardly coilable without serious deformation of the cross-section.

It is accordingly an object of the invention to provide a coilable waveguide for the transmission of very high frequency electromagnetic waves.

It is another object of the invention to provide a corrugated waveguide which minimally depolarizes polarized electromagnetic waves transmitted down the waveguide.

It is a further object of the invention to provide a coilable corrugated waveguide which is the one hand relatively inexpensive to fabricate and on the other hand is a highly efficient and reliable in the transfer of very high frequency polarized electromagnetic waves.

Broadly, the invention is based on the possibility of using certain wave transmission modes in elliptic wave guides for transmission of electromagnetic wave energy.

In accordance with an aspect of the invention, there is contemplated the provision of a longitudinally seam welded, helically corrugated hollow tube of elliptic cross-section as a coilable corrugated waveguide for transmission of polarized electromagnetic waves of very high frequency, and particularly for transmission of a linearly polarized H_{11} type of wave.

It should be noted that such an elliptic waveguide can be optimally matched to the cross-section of apparatus coupled to the guide (particularly of rectangular cross section) by proper choice of the ratio of large to small ellipse diameters, pitch and depth of the corrugations.

It should also be noted that measurements have shown that for such a waveguide the boundary values and depolarization of the electromagnetic wave to be transmitted are substantially equivalent to conditions prevailing in a rectangular waveguide with a corresponding ratio of sides.

It should be further noted that because of the transverse rigidity of the elliptic waveguide the mechanical and electrical properties remain unchanged after repeated coiling, provided that the radius of curvature of the coil turns is not too small.

Another aspect of the invention is the method of making the wave guide simply and continuously by a procedure wherein a flat metal strip is formed into a circular tube, the abutting edges welded together and the tube then helically corrugated. Subsequently, the tube passes through suitable means in which its cross-section is deformed to an elliptic section. The tube is then, optionally, provided with a wear resistant, synthetic resin outer sheath and coiled on a reel.

In order to insure a uniform tube cross-section so as to prevent transmission discontinuities and associated electromagnetic wave reflections, uniform forming without bends and creases is essential. Therefore, according to a feature of this aspect of the invention, there is provided a roller system comprising two balanced wheels with diameters much larger than the diameter of the tube to be formed. The wheels are provided with peripheral grooves corresponding to the elliptic cross-section of the tube being deformed. The wheels rotate freely and are mounted in a plummer block vertically above one another so that they touch each other in the horizontal plane through the tube axis.

Other objects, features and advantages of the invention will be apparent from the following detailed description when read with the accompanying drawings which show by way of example and not limitation in:

In the drawing,

FIG. 1 is a schematic showing of an apparatus for making waveguides in accordance with the invention;

FIG. 2 is an enlarged cross-section on the line 2—2 of FIG. 1;

FIG. 3 is an enlarged cross-section on the line 3—3 of FIG. 1; and

FIG. 4 is a sectional view taken on the line 4—4 of FIG. 1.

Referring now to FIG. 1, a flat metal strip 2 is moved by suitable transport means generally indicated at 5 from the supply roll 1 and is progressively formed into a tube of circular cross-section on forming table, including curved shaping elements, not shown, all in a well known manner. The longtiudinal abutting edges of the tube are welded at welding station S, preferably by an electric arc. The tube so obtained is corrugated helically in conventional corrugator 6. The helically corrugated tube 7 of circular cross-section enters the elliptical cross-section forming apparatus 8 through a circular inlet bushing 11 and is elliptically deformed therein. The elliptical cross-sectioned waveguide 9, upon leaving outlet channel 12 is sheathed with a wear resistant synthetic resin coating applied at a spraying station K

and is then coiled on a take-up reel **10.** The coating may be polyethylene, polyvinylchloride or similar plastic synthetics with or without fillers. The sprayed on coating preferably fills the troughs of the corrugations to provide a perfectly smooth surfaced conduit.

The elliptical cross-section forming apparatus **8** comprises a pair of parallel plummer blocks **17** mounted on standards A in a vertical position and supporting two balanced forming wheels **13** and **14,** having diameters much greater than the diameter of the corrugated tube **7.** For the purpose of deforming the corrugated circular cross-sectioned tube into an elliptical cross-section, the periphery of forming wheels **13** and **14** are provided with grooves **13A** and **14A** of corresponding cross-section (FIG. **4**). Wheels **13** and **14** are mounted vertically above each other in such a manner that they almost or actually contact each other at a peripheral point in the horizontal plane through the longitudinal axis of the corrugated tube **7.** Grooves **13A** and **14A** each have the shape of half an ellipse, so that the minor axis of the ellipse is preferably perpendicular, i.e., in a plane including a line joining the axes of rotation of forming wheels **13** and **14** as shown in FIG. **4.** Alternatively, the major axis of the ellipse could be so disposed, but then there is greater danger of creasing the corrugated tube or forming a non-uniform elliptic section.

As mentioned above, the corrugated tube **7** must be elliptically formed as uniformly as possible. Ideal forming of the tube would be accomplished if the diameters of wheels **13** and **14** were infinite. This obviously is impossible, but the ratio of diameters of forming wheels **13** and **14** and corrugated tube **7** should be as large as possible. Experiments have shown that a ratio of greater than 40:1 is adequate to provide uniform deformation of the circular to elliptic sections.

Wheel bearings **15** and **16** in the plummer blocks **17** are vertically adjustable by means (not shown) in a well known manner, in order to adjust the position of the wheels **13** and **14** to that of the tube **7** and to adjust the spacing of the wheels within limits for forming different elliptical cross-sections. In order to prevent chafing or scratching of the corrugated tube **7** in the entrance or inlet bushing **11** or exit or outlet channel **12,** both are made of or lined with wear resistant, smooth synthetic material, such as high molecular polyethylene.

The so formed elliptical cross-sectioned corrugated waveguides are coilable without change of mechanical and electrical characteristics when coiled. Accordingly, such a waveguide is particularly applicable for use in radar. When used in rigid mountings, such as an antenna feed line in a transmitter tower, and similar applications, the cable according to the invention can be paid off from the supply reel at the construction site and then cut off when the proper length has been found. It is then only necessary to provide the necessary input and output matching couplers. Flexing and curving of the waveguide have no influence on the electric characteristics of the cable. The waveguide of the invention can even be used to advantage as compared with conventional waveguides, when two directions of polarization are to be supplied to an antenna. The laying of two wave guides as provided by this invention is always simpler and less expensive than the laying of two rectangular wave guides or a single circular waveguide, which must be perfectly compensated and matched after laying and thereby require time consuming additional work.

There has thus been shown a helically corrugated waveguide of elliptical cross-section, as well as a method for making such a waveguide, which is easily coilable and which has outstanding electrical properties and which minimally depolarizes polarized very high frequency electromagnetic waves. In addition, as a feature of the invention, particular elliptical cross-section forming apparatus has been shown which produces uniformly formed waveguides with a minimum possibility of introducing undesired creasing or chafing to the guide.

There will now be obvious to those skilled in the art many modifications and variations which satisfy many or all of the objects but which do not depart from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. The method of making a waveguide for electromagnetic waves comprising the successive immediate steps of forming an elongated strip of metal material into a continuously extending tubing of circular cross section with longitudinally abutting edges, continuously moving said tubing in a longitudinal path, continuously welding the longitudinally abutting edges of the moving tubing at a given point in said path, continuously helically corrugating said welded seam tubing in said path in a direction along and about the longitudinal axis of said tubing, continuously engaging said moving corrugated tubing in said path with opposed ellipital cross sectional rotatable deforming means to convert the circular cross section of said moving corrugated tubing to an elliptical cross section.

2. The method of claim **1** and further including the step of spraying a solidifying liquid plastic on the outer surface of the corrugated tubing of elliptical cross section to fill the corrugation troughs for providing a continuously smooth sheath.

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