United States Patent [19]

Bankert, Jr. et al.

[11] **3,750,058**

[45] **July 31, 1973**

[54] **WAVEGUIDE STRUCTURE UTILIZING COMPLIANT HELICAL SUPPORT**

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[22] Filed: **Dec. 8, 1971**

[21] Appl. No.: **205,796**

[52] **U.S. Cl.** .... **333/95 R,** 333/98 R, 333/98 M

[51] **Int. Cl.** **H01p 1/16,** H01p 3/12

[58] **Field of Search** .... 174/99 R, 98 R, 107, 174/42; 333/98 R, 95 R, 95, 98; 138/106, 112

[56] **References Cited**

UNITED STATES PATENTS

3,605,046	9/1971	Miller	333/98 R
1,880,060	9/1932	Wanamaker	174/107
2,381,003	8/1945	Ryan	174/29
366,174	7/1887	Kruesi	174/29 X
2,197,616	4/1940	Lehne et al.	174/29
2,556,244	6/1951	Weston	174/29
327,483	9/1885	Spalding	174/98
1,959,368	5/1934	Kennedye	138/112 X
2,585,484	2/1952	Menes	174/107 X
2,587,521	2/1952	Peterson	174/42 X
2,848,696	8/1958	Miller	333/95
3,246,073	4/1966	Bouche et al.	174/42
3,357,664	12/1967	Geyer	248/54 R
3,479,621	11/1969	Martin	333/95
3,603,715	9/1971	Eilhardt	174/29

FOREIGN PATENTS OR APPLICATIONS

462,496	3/1937	Great Britain	174/29

OTHER PUBLICATIONS

Unger, H. G., "Circular Electric Wave Transmission Through Serpentine Bends," Bell System Tech. Jr. 36, 9–1957, pp. 1,279–1,291

Mallory et al., "Cable Core Wrap Having Air Chambers Western Electric Tech. Digest No. 23, 7–1971, pp. 41–42

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[57] **ABSTRACT**

A waveguide structure having a compliant effectively continuous support is obtained by wrapping an elongated compliant member such as a rubber tube, a stranded compliant member or a coiled wire around a waveguide in a helical or braided pattern and then inserting the waveguide into a conduit. The pitch of the helix, the elastic modulus of the material, and wall thickness of the compliant member can be varied to change the stiffness of the support and to minimize electrical losses due to both weight loading induced deflections and deflections caused by earth forces on the conduit.

6 Claims, 6 Drawing Figures

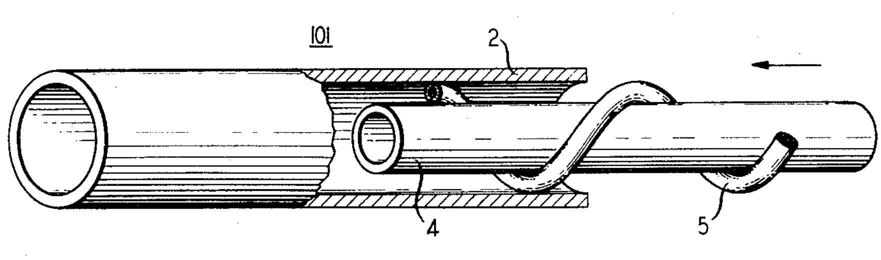


FIG. 1

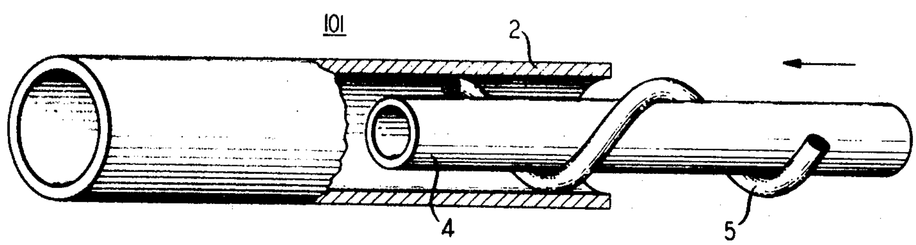


FIG. 2

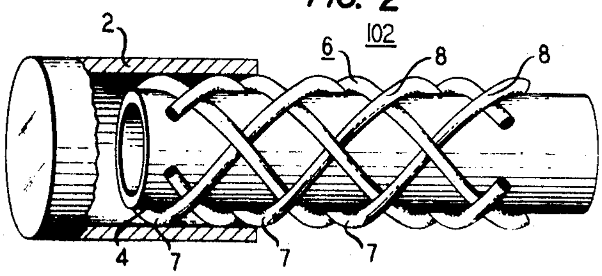


FIG. 4

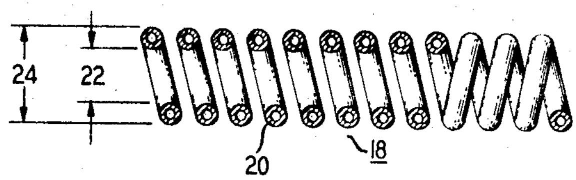


FIG. 6

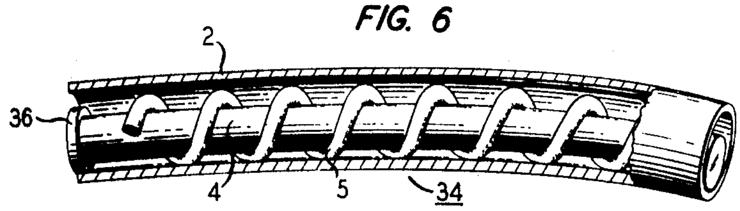


FIG. 3

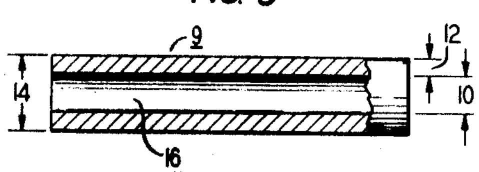
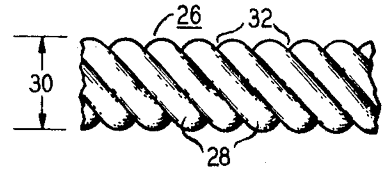


FIG. 5



WAVEGUIDE STRUCTURE UTILIZING COMPLIANT HELICAL SUPPORT

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to waveguide transmission systems and in particular to a waveguide structure having a compliant effectively continuous member for supporting the waveguide within a conduit and isolating it from disturbances in the surrounding environment and for reducing weight loading induced deflections.

2. Description of the Prior Art

The ever-increasing demand for communications facilities is producing an increasing interest in the use of waveguide transmission lines as extremely broad frequency band, long distance transmission media. One requirement for such a waveguide transmission system is that the waveguide tube must be isolated from disturbances in the surrounding environment because the performance of the waveguide is critically dependent upon the maintenance of proper alignment and position. Thus, buried waveguide in particular must be isolated from disturbances in the surrounding environment such as irregularities in the trench bottom as well as earth tremors, vibrations, and faultings.

A limited degree of isolation may be achieved by simply enclosing the waveguide in a relatively large diameter conduit. When disturbances in the surrounding environment distort the conduit, the waveguide can move away from the conduit walls and thereby maintain its alignment.

A waveguide structure having an improved waveguide support system is disclosed in U.S. Pat. No. 3,007,122 issued to F. T. Geyling on Oct. 31, 1961. This patent teaches mounting the waveguide on fluid filled flexible members or bellows which are interconnected by a feeder tube and supported within a protective conduit.

Another waveguide structure having a support system utilizing a pulley and interconnecting cord arrangement is disclosed in the copending application of M. Lutchansky, Ser. No. 40,767 filed May 27, 1970, issued Sept. 28, 1971 as U.S. Pat. No. 3,605,603, and assigned to the assignee of this application.

Still another waveguide structure having a support system which places the waveguide under tension within the conduit thereby to maintain the straightness is shown in the copending application of S. E. Miller, Ser. No. 806,663 filed Mar. 12, 1969 issued Sept. 14, 1971 as U.S. Pat. No. 3,605,046, and assigned to the assignee of this application.

Despite the substantial improvements disclosed in the foregoing waveguide structures, the support systems of these waveguide structures remain more complex than desired for a system which must be quickly and economically installed underground.

Another problem with most of the presently known waveguide structures is the amount of distortion or mode conversion produced therein by deflections of the waveguide because of its own weight loading. Such deflections are especially pronounced when discrete support points are utilized.

Accordingly, it is an object of this invention to simplify the apparatus for supporting a waveguide within a conduit.

Another object is to improve waveguide structures to eliminate distortions from the weight loading of the waveguide.

SUMMARY OF THE INVENTION

The foregoing objects and others are achieved in accordance with the principles of this invention by a waveguide structure having a waveguide supported within a conduit by an elongated compliant member such as a rubber tube, a stranded rope or a coiled wire which is wrapped in a helical or braided pattern around the waveguide. The elongated member has an outer diameter approximately equal to one-half the difference between the inner diameter of the conduit and the outer diameter of the enclosed waveguide for the helical pattern, and approximately one-quarter the difference for the braided pattern. After the member is wrapped about the waveguide, the waveguide is inserted into the conduit and is supported therein by the compliant member. The compliant member essentially serves as a continuous support which eliminates weight deflections in the waveguide. The stiffness of the support provided by the member can be varied by varying the pitch of the helix, the elastic modulus of the material, and wall thickness of the compliant member. The member can be designed to bottom and thereafter provide a very stiff support to protect the waveguide from deleterious contact with the conduit when subjected to large deflecting forces.

BRIEF DESCRIPTION OF THE DRAWING

The invention will be more fully comprehended from the following detailed description and accompanying drawing in which the same numbers refer to corresponding elements throughout and in which:

FIG. 1 is a partially sectional view of a waveguide structure formed in accordance with this invention utilizing a simple helical pattern for the compliant support;

FIG. 2 is a partially sectional view of a waveguide structure utilizing a plurality of helically wrapped compliant members to form a braided compliant support;

FIG. 3 is a partly sectional view of a compliant rubber tube which can be used to form the helical support of FIGS. 1 and 2;

FIG. 4 is a partly sectional view of a coiled wire or rod which can be used for the helical support of FIGS. 1 and 2;

FIG. 5 is a view of a stranded rope configuration for the compliant member utilized in FIGS. 1 and 2; and

FIG. 6 is a partly sectional view of a waveguide structure similar to that shown in FIG. 1 being utilized in a waveguide bend.

DETAILED DESCRIPTION

Referring now to FIG. 1 there is shown a waveguide structure **101** comprising a conduit **2** and a waveguide **4** supported and protected therein. Conduit **2** comprises a tube of material such as steel, polyvinylchloride (PVC) or the like. Waveguide **4** can comprise any of the known types of waveguide such as helix waveguide, dielectric-lined waveguide, etc., each of which normally includes a metal tube as its outer jacket.

Waveguide structure **101** is joined with like structures to form a continuous waveguide transmission system by connecting the ends of conduit **2** and waveguide **4** to the respective ends of the conduit and waveguide in adjacent waveguide structures. In forming such a waveguide transmission system it is necessary to eliminate or minimize distortions of the waveguide resulting from thermally induced stresses and disturbances in the surrounding environment. Additionally, it is desirable to eliminate deflections or deformations of the waveguide due to its own weight loading. Possible distortions due to thermal stresses or loadings are presently controlled through the use of expansion joints. Distortions caused by disturbances in the environment can be controlled by the use of presently known waveguide support systems. However, none of the presently known support systems adequately controls deformations due to weight loading.

Waveguide distortions from the previously mentioned factors are eliminated or controlled within acceptable limits by supporting waveguide 4 within conduit 2 by a compliant effectively continuous support. One embodiment of such a support is obtained by utilizing a single elongated member 5 of low modulus or compliant material which is wrapped about waveguide 4 in a helical pattern as shown in FIG. 1. Another embodiment of such a support is obtained by utilizing a plurality of elongated members 7 each of which is wrapped in a helical path around waveguide 4 to form a braided or intertwined support 6 as shown in FIG. 2 in structure 102.

Elongated member 5 can comprise a rubber tube 9 as shown in FIG. 3, a coiled member 18 as shown in FIG. 4, or a stranded member 26 as shown in FIG. 5. Member 5 has an outer diameter substantially equal to one-half the difference between the inner diameter of conduit 2 and the outer diameter of waveguide 4 whereas members 7 have outer diameters substantially equal to one-fourth the difference because of the double thickness at the crosspoints 8 in the braided pattern 6. Accordingly, the outer diameters 14, 24, and 30 of members 9, 18, and 26, respectively, will depend upon the specified embodiment of the support used. Members 5 and 7 center waveguide 4 within conduit 2.

As shown in FIG. 3, member 9 can comprise a tube having an inner diameter 10 approximately equal to one-half of its outer diameter 14 and a resulting wall thickness 12 of approximately one-fourth the outer diameter 14. These relative dimensions are given by way of example only. The low modulus compliant material in member 9 readily flattens or deforms to accommodate distortions in conduit 2 without transmitting significant stresses to waveguide 4.

As shown in FIG. 4, member 18 comprises a coiled member 20 such as a coiled cord or wire. Member 18 has an outer diameter 24 and an inner diameter 22 substantially equal to the outer diameter 14 and inner diameter 10, respectively, of member 9. Thus, the diameter of the wire or cord 20 forming member 18 is substantially equal to the wall thickness 12 of member 9.

As shown in FIG. 5, members 5 and 7 of FIGS. 1 and 2, respectively, also can comprise a stranded member 26 including a plurality of smaller members 28 such as small tubes or cords which are stranded together by well-known techniques. If hollow tubes are used for members 28, member 26 will offer substantial compliance through the deformation and flattening of these tubes. If solid cords are utilized for members 28, member 26 will still possess some compliance through the relative shifting of members 28 when a force is applied thereto. Member 26 offers some advantage over member 9 in that the interstices 32 between members 28 more effectively permit any liquid contaminant such as water to drain from low spots in conduit 2.

Members 9, 18, and 26 can be formed from a variety of materials. When the configuration of FIGS. 3 and 5 are utilized a compliant material advantageously can be used. In the coiled configuration of FIG. 4, compliance is provided by the coiled configuration of member 18 and accordingly, either a compliant material or a non-compliant material can be utilized. Rubber advantageously can be utilized in all of the configurations to obtain such properties as long life with good creep behavior and resistance to environmental factors such as corrosion.

The configurations of members 9, 18, and 26 provide a very advantageous deflection limiting action when used in support structures in a waveguide bend as illustrated in FIG. 6 with respect to the helical support similar to FIG. 1. When the waveguide 4 is utilized in a route bend, it is under stress and moves toward the inside of the conduit, i.e., toward the center of curvature of the bend, thereby compressing support member 5. However, it is desirable that waveguide 4 not be in substantial contact with conduit 2 itself. On the other hand, it is also desirable that member 5 permit as much relative motion as possible between waveguide 4 and conduit 2 and provide a low modulus support during such motion. Accordingly, the dimensions of member 5 are chosen so that member 5 is completely flattened just before or at the time when any part of waveguide 4 first contacts conduit 2. Thereafter member 5 provides a very stiff support which prevents further movement of waveguide 4 toward conduit 2. In the illustrative embodiment, coupling flange 36 has the largest diameter of any part of waveguide 4 and will thus be the first part of waveguide 4 to contact conduit 2. The dimensions of member 5 are chosen so that member 5 is completely flattened along the inner wall of conduit 2 when flange 36 first contacts conduit 2. Specifically, when tubular member 9 of FIG. 3 is utilized, it provides a low modulus support until the inner diameter 10 thereof is completely compressed and will thereafter provide a much stiffer support. Thus, the inner diameter 10 and wall thickness 12 of tubular member 9 are selected so that inner diameter 10 is completely compressed when flange 36 first contacts conduit 2. Likewise, when coiled member 18 as shown in FIG. 4 is used, the inner diameter 22 and the diameter of member 20 are selected so that coiled member 18 is completely compressed or flattened when flange 36 first contacts conduit 2. The dimensions of stranded member 26 also can be tailored so that this member is completely compressed when flange 36 first contacts conduit 2 so that a very stiff support is provided thereafter.

When the braided or intertwined support structure 6 of FIG. 2 is used in a waveguide bend, the dimensions of the members 7 can be tailored in accordance with the foregoing description so that these members are completely compressed at crosspoints 8 when the flange first contacts conduit 2.

Referring again to FIG. 1, member 5 provides an essentially continuous support for waveguide 4 with respect to the length thereof but the support is periodic in the sense of angular orientation with respect to the longitudinal axis of waveguide 4. Thus, deflections or distortions due to weight loading of the waveguide itself are also periodic. These distortions become most troublesome when the wavelength thereof coincides with the beat wavelength of the desired mode of transmission, i.e., the TE_{01} circular wave mode, and spurious modes such as the TM_{11} and TE_{12} modes. Troublesome distortions can be substantially eliminated by selecting the pitch of the helix pattern to be smaller than the smallest beat wavelength of concern in the frequency band being utilized. It should be readily apparent that the pitch of the helix pattern of member 5 can be easily varied to meet this requirement and to vary the modulus or stiffness of the support provided by member 5. Although the support provided by the braided structure 6 of FIG. 2 is more continuous than that of FIG. 1 with respect to angular orientation, the pitch of the helix path of members 7 can still be selected to prevent any troublesome distortions.

Thermal stresses or loadings become troublesome in waveguides having discrete support points. In such situations the thermal stresses produce sharp distortions about the discrete support points unless expansion joints are provided. However, in the instant waveguide structures 101 and 102 expansion joints can be eliminated. Members 5 and 7 provide continuous support along the length of waveguide 4 and thus there are no discrete support points at which troublesome distortions are produced. The thermal stresses remain in the waveguide 4 but do not produce troublesome distortions as the wavelengths of the distortions produced are below the smallest beat wavelength of concern as discussed above.

Waveguide structures 101 and 102 can be mass fabricated in a factory and shipped to the field for installation. Members 5 or 7 can initially be wrapped about waveguide 4 in the desired patterns and secured in place by tape or adhesive. Waveguide 4 and members 5 or 7 are then inserted into conduit 2 and the entire unit is shipped. Members 5 and 7 allow axial slippage or movement of conduit 2 with respect to waveguide 4. Thus, at the installation site conduit 2 can be slipped axially along waveguide 4 to permit coupling of waveguide 4 with the adjacent waveguide section. Conduit 2 is then slipped back into alignment and coupled to the corresponding adjacent conduit.

One specific example of a waveguide structure according to this invention comprises a dielectric-lined waveguide having an inner diameter of approximately 2 inches, and an outer diameter of approximately 2.3 inches. A natural rubber tube having an outer diameter of one inch, a wall thickness of one-fourth inch, and a durometer reading of 50 is wound about the waveguide in a helix pattern with the pitch of the pattern being approximately 18 inches. The combination of the waveguide and helically wound tube is then inserted into a steel tube conduit having an internal diameter of approximately 4.3 inches. The helically wound tube provides a low modulus support for the waveguide having a foundation modulus of approximately 15 pounds per square inch. The foundation modulus is the equivalent spring constant per unit length of the continuous elastic support.

Although the invention has been described with respect to specific embodiments thereof, it is to be understood that various modifications can be made thereto without departing from its spirit and the scope.

What is claimed is:

1. A waveguide structure comprising a section of waveguide which can transmit a plurality of electromagnetic wave modes, said wave modes including the TE_{01} circular wave mode and spurious wave modes having beat wavelengths with said TE_{01} wave mode at specified frequencies so that TE_{01} mode interchanges energy with said spurious modes when said section of waveguide has mechanical deformations therein corresponding to said beat wavelengths;

a section of rigid protective jacket surrounding said section of waveguide and spaced therefrom; and

an elongated compliant member wrapped in the form of a helix about said section of waveguide and supporting said section of waveguide within said jacket, said helix having a pitch smaller than the smallest one of said beat wavelengths so that said mechanical deformation of said waveguide resulting from weight and thermal loadings corresponding to said beat wavelengths are eliminated.

2. Apparatus in accordance with claim 1 wherein said elongated compliant member comprises a compliant rubber tube.

3. Apparatus in accordance with claim 1 wherein said elongated compliant member comprises a structure formed into a plurality of relatively closely spaced coils along the length thereof, said coils having outer diameters substantially equal to one-half the difference between the outer diameter of said waveguide and the inner diameter of said jacket so that said waveguide is supported by said coils.

4. Apparatus in accordance with claim 1 wherein said elongated compliant member comprises a stranded structure including a plurality of compliant tubular members.

5. Apparatus in accordance with claim 1 including a plurality of said elongated compliant members each of which is wrapped in the form of a helix about said section of waveguide, a first portion of said members wrapped in a first direction about said section and a second portion of said members wrapped in a second direction about said section so as to form a structure of intertwined compliant members for supporting said waveguide.

6. Apparatus in accordance with claim 1 wherein said elongated compliant member includes an axial opening therethrough which is compressed when said section of waveguide deflects toward said jacket, said member providing a relatively low modulus support before said opening is completely compressed and a relatively high modulus support after said opening is completely compressed, said member having dimensions so that said opening is completely compressed when said waveguide contacts said jacket whereby further deflection of said section of waveguide toward said jacket is prevented.

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