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METHOD OF MAKING WAVEGUIDE

3,092,896

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FIG. 1

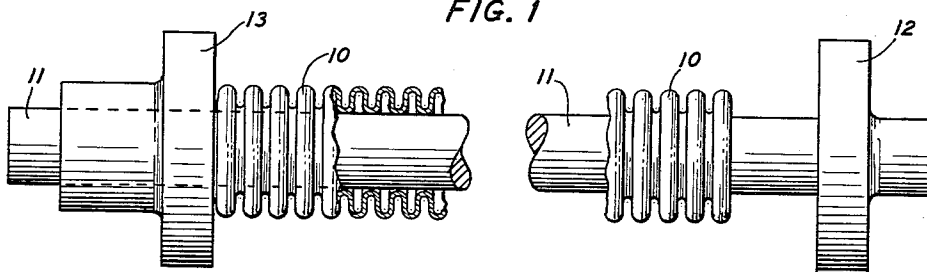


FIG. 2

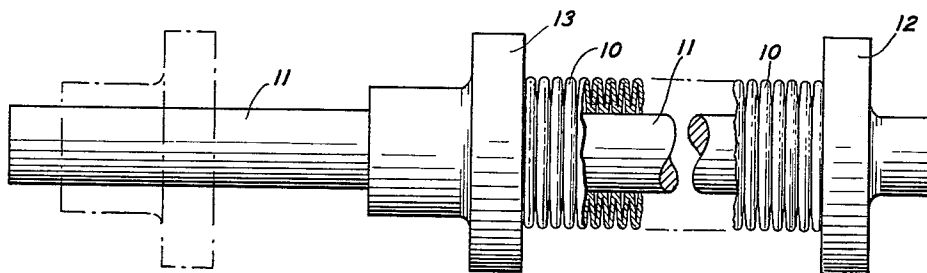


FIG. 3

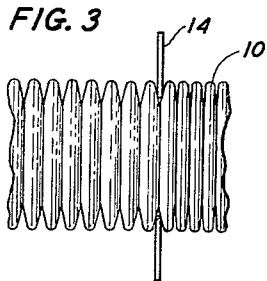


FIG. 4

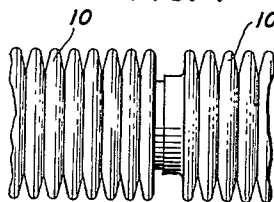
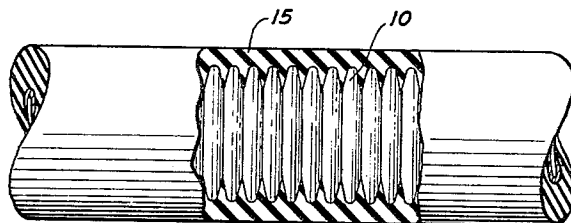


FIG. 5



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METHOD OF MAKING WAVEGUIDE

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2 Claims. (Cl. 29—155.5)

The present invention relates to a process for manufacturing waveguides and, in particular, to a process for manufacturing corrugated waveguides where the corrugations are substantially rectangular in cross section.

When a waveguide is capable of transmitting energy in two or more modes having approximately the same phase constants, it is known that slight discontinuities in the waveguide may produce a one-way transfer of a substantial amount of energy from a preferred one of these modes to one of the others. The TE_{01} mode in circular waveguides, for example, is ideally suited for the long distance transmission of high frequency signals as the attenuation characteristic of this mode, unlike those of all other modes, decreases with increasing frequency. However, as the TE_{01} mode is not the dominant mode supported in a circular waveguide, discontinuities may produce a one-way energy transfer from this mode to other modes with most of the energy being transferred to the TM_{11} mode. Furthermore, although the TE_{01} mode is the dominant mode for transmitting energy in rectangular waveguides, a transfer of energy between this mode and other modes may occur because of slight discontinuities in the guides.

In the prior art the above-described one-way transfer of energy has been reduced by providing a greater difference between the phase constants of the preferred mode of transmission and the mode to which most of the energy would otherwise be transferred. Several examples of circular waveguides which produce this greater difference are shown in U.S. Patents 2,649,578 and 2,779,006 issued to W. J. Albersheim on August 18, 1953 and January 22, 1957, respectively, and U.S. Patent 2,751,561 issued to A. P. King on June 19, 1956. The inner walls of waveguides shown in these patents are corrugated so that the corrugations are perpendicular to the axis of the waveguides and rectangular in cross section. Although more fully explained in the patents, it may be broadly stated that the corrugations introduce reactive effects in a manner to provide a greater difference between the phase constants of certain TE and TM modes at the same operating frequencies while providing efficient transmission in the preferred TE mode. Furthermore, when the innermost portions of the rectangular corrugations have substantially the same inner diameters and are in axial alignment, a highly efficient and distortion free transmission of the TE_{01} mode may be effected.

The above-cited patents suggest several methods of constructing waveguides having rectangular corrugations. In general, the illustrated waveguides are fabricated by assembling a plurality of accurately machined rings in axial alignment so that the rings are spaced apart from one another and then surrounding the rings with a sheath of metal or some other material. Although waveguides may be manufactured in this manner, manufacturing becomes more difficult as the frequencies at which the guides are to be used are increased. That is, at higher frequencies, the dimensions of the guides become smaller with the rings necessarily becoming smaller and more difficult to handle. The King patent suggests circumventing this difficulty by partially compressing a piece of commercially available corrugated waveguide having a sinusoidal waveform type of cross section so that the internal gaps between the corrugations are reduced. How-

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ever, modifying a piece of guide in this manner does not produce flat inner faces on the corrugations nor does it control the inner diameters of the corrugations and the axial alignment of the corrugations.

It is an object of the present invention to manufacture waveguides having internal corrugations which are substantially rectangular in cross section, have accurate internal dimensions and are in axial alignment without having to handle a multiplicity of relatively small accurately machined parts.

In accordance with the present invention, waveguides having internal corrugations of substantially rectangular cross section are produced from commercially available corrugated tubing having a sinusoidal waveform type of cross section. The commercially available tubing, which may be either circular or rectangular, is placed on a mandrel and compressed axially. The compression of the tubing while on the mandrel causes flat surfaces to be formed on the innermost surfaces of the corrugations and the gaps between these innermost surfaces to be reduced. The compressed tubing is then removed from the mandrel. If desired, the extent to which the tubing is compressed may be controlled either by placing thin pieces of material in the outer gaps of the corrugations before compressing or by inserting thin pieces of material in the outer gaps after the compressing step is completed. These pieces of material may be left in place or removed before using the tubing. The compressed tubing may be strengthened and protected by covering it with either a rigid material or a flexible material such as rubber.

As discussed and illustrated in the patents referred to above, providing rectangular corrugations in a flexible or curved waveguide reduces the one-way transfer of energy that occurs as a result of discontinuities introduced by the curvature of the guide, while providing a highly efficient and distortion free transmission path. Waveguides produced in accordance with the present invention may be used as flexible or curved rectangularly corrugated waveguides. The waveguides when covered with a flexible material or in its uncovered form may be used for this purpose, or a fixed curved guide may be produced by curving the guide before covering it with a rigid material.

In addition to the above-described advantages secured by waveguides manufactured in accordance with the present invention, it has been found that several additional advantages are secured which are not present in the waveguide before modification. In the first place, buckling, which sometimes occurs when flexing or curving a waveguide, is reduced because of stresses established in the metal as a result of the compressing action. Secondly, the present invention may be used to provide many rectangular corrugations per wavelength at frequencies as high as the millimeter range. This makes flexible waveguides practical at millimeter wavelengths. Thirdly, it has been found that the ratio of the dimensions of the inner wall base to the inner wall gap is greater than one, thus reducing the attenuation of the desired mode.

These and other objects and features of the invention will become apparent from the following description. In the drawings:

FIG. 1 shows a piece of commercially available corrugated tubing placed on a mandrel;

FIG. 2 shows a piece of commercially available corrugated tubing in a partially compressed condition on a mandrel;

FIG. 3 illustrates a piece of corrugated tubing compressed in accordance with the present invention;

FIG. 4 illustrates several pieces of compressed cor-

rugated tubing joined together to form a longer piece of tubing; and

FIG. 5 shows a piece of compressed corrugated tubing covered with a protective material.

In FIG. 1, a piece of commercially available corrugated tubing 10 having a sinusoidal waveform type of cross section is shown on a mandrel 11. The cross sectional shape of mandrel 11 is determined by the type of waveguide to be formed while its dimensions are substantially equal to the desired internal dimensions of the finished waveguide. Furthermore, the surface of mandrel 11 may have a polished finish to facilitate the removal of the finished waveguide and to provide a better finish on the interior walls of the waveguide. One end of mandrel 11 is terminated in a fixed stop 12 while a movable stop 13 shown on the mandrel may be moved along its length.

Corrugated tubing 10 is first placed on mandrel 11 and then movable stop 13 is placed on the mandrel as shown in FIG. 1. Movable stop 13 is then moved either by hand or by machine towards fixed stop 12, thereby compressing tubing 10 as shown in FIG. 2. As movable stop 13 is moved along mandrel 11, the innermost surfaces of the corrugations are forced against mandrel 11 so that they become flattened as shown in the cutaway portion of FIG. 2. When movable stop 13 is removed from mandrel 11, tubing 10, which remains in its compressed and flattened condition, may be removed.

It is frequently found that tubing 10, in its compressed and flattened condition, does not easily slide off mandrel 11 but instead must be forcibly pulled off. This has been found to be desirable as the innermost walls of the corrugations are burnished by mandrel 11, thereby providing highly accurate internal dimensions and smooth internal surfaces that are in excellent axial alignment.

FIG. 3 shows tubing 10 after it has been compressed and removed from mandrel 11. The extent to which tubing 10 is compressed may be controlled by inserting and removing thin pieces of material 14 between the outer gaps of the corrugations. Pieces of material 14 may be either held between the outer gaps of the corrugations during the compressing operation or inserted after tubing 10 is compressed. If desired, material 14 may be left in the gaps.

Because of the force sometimes required when removing the compressed tubing 10 from mandrel 11, it may be desirable to compress relatively short lengths of tubing 10 and then to form a longer tubing by joining

several of the shorter ones. FIG. 4 shows several relatively short lengths of tubing 10 soldered together to form a longer one. This is performed in a conventional manner by tinning the ends of tubing 10, placing them together and then heating them to cause the solder on the tinned ends to flow together.

Waveguides produced in accordance with the present invention may have either a rigid or flexible covering for protection purposes. FIG. 5 shows a piece of tubing 10 covered by a material 15. When this material is of a flexible nature, the waveguide may be flexed to provide either a curved or flexible waveguide.

In the previous description the particular means used for compressing the tubing was illustrative only. Any other means for compressing the tubing once it has been placed on a mandrel may be used without departing from the spirit and scope of the invention.

What is claimed is:

1. The method of making a corrugated waveguide having internal corrugations of rectangular cross section that comprises applying to a smooth surfaced mandrel a length of corrugated metal tubing having convexly curved internal corrugations, axially compressing the tubing until the surfaces of the internal corrugations are forced against the mandrel and become flattened in the axial direction to snugly fit the mandrel and then removing the mandrel.

2. The method of claim 1 that includes fitting external spacers between the corrugations to limit the reduction in axial spacing of the corrugations.

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