

[54] **CORRUGATED WAVEGUIDE
CONSTRUCTION**

[75] Inventor: **Michel Merle**, Palos Heights, Ill.
[73] Assignee: **Andrew Corporation**, Orland Park,
Ill.
[22] Filed: **May 6, 1971**
[21] Appl. No.: **140,820**

[52] U.S. Cl. **333/95 A, 333/95 R**
[51] Int. Cl. **H01p 3/14**
[58] Field of Search **333/95 R, 95 A**

[56] **References Cited**
UNITED STATES PATENTS

2,528,248 10/1950 Schlaflly, Jr. 333/95 A
2,751,561 6/1956 King 333/95 A

2,986,713 5/1961 Kent 333/95 A

Primary Examiner—James W. Lawrence
Assistant Examiner—Wm. H. Punter
Attorney, Agent, or Firm—Wolfe, Hubbard, Leydig,
Voit & Osann, Ltd.

[57] **ABSTRACT**

Corrugated waveguide has a corrugation depth which is non-uniform around the tube from which it is formed to produce an inner shape formed by the corrugation troughs which is different from the outer shape formed by the corrugation crests. Embodiments are described for producing mechanical or electrical improvements of the performance of various prior art waveguide shapes.

8 Claims, 6 Drawing Figures

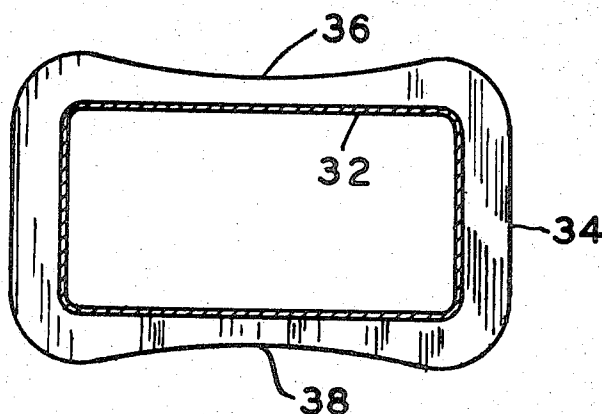


Fig. 1

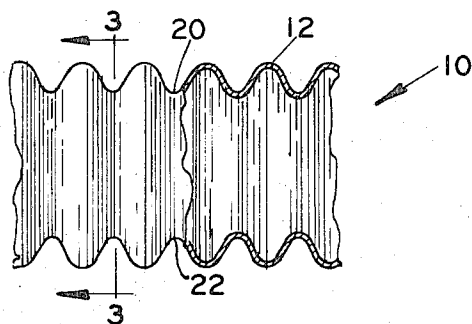


Fig. 3

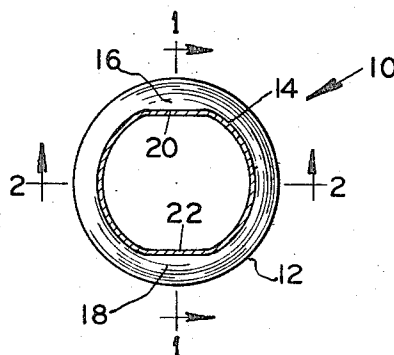


Fig. 2

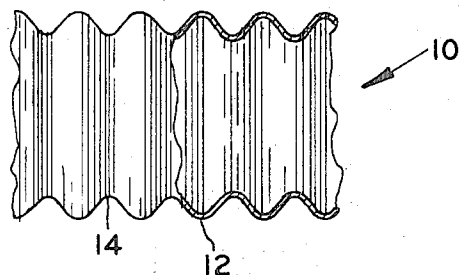


Fig. 4

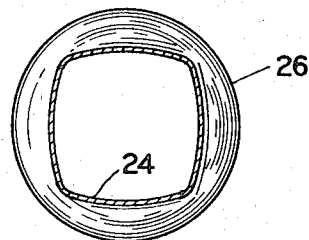


Fig. 6

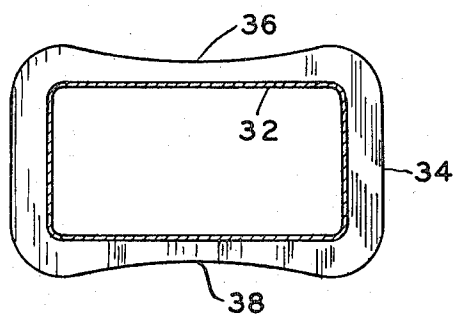
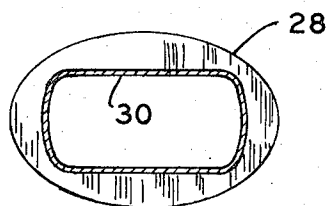


Fig. 5



INVENTOR:
MICHEL MERLE
BY
Leonard Merle
ATTY.

CORRUGATED WAVEGUIDE CONSTRUCTION

This invention relates to waveguide, and more specifically to corrugated waveguide.

Waveguide formed of corrugated metallic tubing has for some time been commercially marketed in elliptical form. (It will be understood that references to "elliptical" herein do not import conformity to the mathematical definition of a true ellipse, but merely to generally oval or ellipse-like shape, as is common in the art.) The elliptical shape represents a compromise between the more desirable electrical properties of a rectangular guide and the more desirable mechanical properties, and relative simplicity of fabrication, of a round guide, the latter being impractical from an electrical standpoint in most uses because of difficulty of maintaining the polarization direction of the propagated fundamental-mode wave.

In addition to elliptical waveguide, other shapes of corrugated metallic waveguide has been proposed for various purposes, particularly to approach rectangularity, but none have achieved the acceptance of elliptical guide as optimizing the degree of sacrifice of electrical performance, on the one hand, or mechanical characteristics, on the other.

The present invention stems from observation that the compromises between desirable electrical properties and desirable mechanical properties, in selecting waveguide shape, go beyond what is basically necessary, and that such compromises can be minimized by departing from the uniform corrugation depth which is conventionally employed. In the present invention, by varying the corrugation depth in successive regions around the periphery of the guide, so that the corrugation roots define an inner cross-sectional shape substantially differing from the outer cross-sectional shape defined by the corrugation crests, the compromises between achievement of desired electrical characteristics and achievement of desired mechanical characteristics are substantially reduced. The invention may be advantageously applied to improve mechanical or electrical performance of a number of shapes of corrugated waveguides.

The variation of corrugation depth around the periphery of the guide may be employed for a variety of specific purposes. As already suggested in the above discussion of elliptical waveguide, a convex corrugated wall is well known to have greater resistance to crushing than a planar or rectilinear section wall. On the other hand, it is normally desirable from an electrical standpoint that a waveguide have a cross-sectional shape with at least one portion of its wall substantially closer to rectilinearity than that of a circular tube, preferably approximating wholly rectilinear straightness of two or more opposed walls. By varying the corrugation depth around the tubular guide, a convex outer shape in any given wall region may be accompanied by a substantially less convex, or wholly rectilinear, inner shape in the same region. Thus a circular corrugation crest configuration may be accompanied by a corrugation root configuration substantially departing from circularity. Likewise for internal shapes which would require impractically great variation in corrugation depth to permit a wholly circular outer shape, the outer shape may itself be substantially deformed from circularity, for example where the desired internal configuration is that of a rectangle having one pair of sides considerably longer than the other pair.

In other exemplary manner of utilization of the invention, corrugation depth is maximized in the side portions of a rectangular guide, where corrugation depth has very little or no effect on a propagated dominant mode wave, and minimized in the central region of the top and bottom walls, where electrical performance may be substantially impaired if corrugation depth is too large in this region. In such an example the resulting outer shape is concave, rather than convex, but here again the inner shape defined by the corrugation roots has regions substantially closer to rectilinearity than the corresponding portion of the outer shape defined by the corrugation crests.

Although in principle it is within the contemplation of the invention to employ any desired magnitude of variation of corrugation depth, it is found, as a further aspect of the invention, desirable to employ a ratio of maximum to minimum corrugation depth of from 1.05 to 2.0, and preferably of from 1.2 to 1.5. If the ratio of corrugation depths is too small, the benefit obtained by employment of the varying corrugation depth is relatively trivial. On the other hand, if the variation is excessive, it is found that with simple fabrication processes the flexibility and bending-strength characteristics which are an important purpose of employing corrugated structure are essentially or entirely lost. Corrugating is normally performed by inward deformation of tubes which are smooth and of uniform wall thickness prior to corrugation. Where variation of corrugation depth beyond the ratios just mentioned is sought to be used, the structure either becomes excessively subject to cracking, etc., at the regions of maximum corrugation depth or inadequately flexible at the regions of minimum corrugation depth, or both.

The invention will be more completely understood, particularly in its narrower aspects, by reference to the exemplary embodiments illustrated in the attached drawing, in which:

FIG. 1 is a fragmentary view in side elevation, partially broken away in section, of a corrugated waveguide embodying the invention, having a circular outer shape and an inner shape flattened at opposite ends of a diameter;

FIG. 2 is a top plan view of the waveguide of FIG. 1;

FIG. 3 is a sectional view taken along the line 3—3 of FIG. 1;

FIG. 4 is a sectional view similar to FIG. 3, but illustrating a guide having an approximately square internal shape;

FIG. 5 is a similar view illustrating a guide embodying the invention having an elliptical outer shape and a more rectangular (less convex) inner shape; and

FIG. 6 is a similar view illustrating a rectangular guide embodying the invention.

The embodiment of FIGS. 1 through 3 consists of a corrugated circular tube 10 with corrugation crests 12 and corrugation roots 14. The crests 12 of the corrugations follow the circular configuration of the original tube prior to corrugation. However, the roots 14 of the corrugations depart substantially from the circular configuration of the crests to form an inner or root shape substantially different from the circular outer or crest shape. The corrugations are made substantially deeper in oppositely disposed regions 16 and 18 although other portions of the corrugation roots conform to the circular configuration. Such a construction is most

readily fabricated by performing any conventional corrugation method on round tubing and deepening the corrugations at regions 16 and 18 by suitable linear motion of a corrugation tool to produce substantially straight or rectilinear opposed parallel root portions 20 and 22.

The deepening of the corrugations at 20 and 22 produces a root configuration which maintains the polarization direction of the fundamental or lowest-frequency mode of waveguide transmission, as in a uniformly deformed tube. Electrical performance of the guide is of course basically similar to that of elliptical waveguide. However, the mechanical characteristics, particularly as regards resistance to crushing, are basically similar to those of a circular tube with ordinary uniform-depth corrugations.

For simplicity of illustration, the corrugations shown in the drawing are of the type known as annular, i.e., with corrugation direction wholly perpendicular to the axis of the tube. However the invention is equally useful with helical corrugations. In this case, the deepening of corrugations corresponding to those at 20 and 22 may be effected with slightly canted linear motion of a corrugating tool if the tube is stationary when the deepening is performed; in helical-corrugation manufacturing processes wherein the tube is continuously advanced, as is preferred, a corrugating tool used for the deepening may be moved wholly transversely in proper synchronism with the advancing motion of the tube.

FIG. 4 illustrates a waveguide employing the invention to produce an inner or root shape 24 which is more or less square while the outer or crest shape 26 remains substantially round. The internal shape is generally similar to those which have heretofore been proposed to be formed from round tubing of uniform-depth corrugated construction by the employment of deforming dies, etc. Such a generally square shape is of course desirable for cross-polarized transmissions. In principle, a more exactly square shape may be fabricated by deepening the corrugations at 16 and 18 of FIG. 3, earlier described, to the point where the linear roots at 20 and 22 subtend 90° arcs of the outer circular configuration and duplicating this deepening in the orthogonal direction. From a practical standpoint, however, this is found very difficult, at least with any fully practical quantity production process, the required ratio of corrugation depths being excessive for the reasons earlier mentioned. A guide for cross-polarized waves satisfactory for most purposes may of course be constructed by forming an additional pair of short flattened regions orthogonal to the pair shown at 20 and 22 in FIG. 3. However where required electrical performance, particularly operating bandwidth, dictates a closer approach to squareness, the above-mentioned maximum variation of corrugation depth may be retained by outward bowing of the sides of the square as in FIG. 4, but at the expense of substantial complication of the corrugating equipment.

In FIG. 5 is shown a further embodiment wherein the outer or crest shape at 28 is elliptical, while the inner or root shape 30 has all regions substantially more rectilinear to closely approximate the 2-to-1 rectangular shape which is more or less conventional for rectangular waveguide. The relative mechanical weakness of an ordinarily formed rectangular guide is eliminated, and complexity of manufacture minimized, without great

sacrifice of the electrical advantages which rectangular guide possesses over elliptical guide.

In FIG. 6 there is illustrated an embodiment in which the broader aspects of the invention are utilized in a somewhat different manner. As in the earlier embodiments illustrated, the inner shape defined by the corrugation roots 32 has regions substantially closer to rectilinearity (wholly rectilinear in the illustrated case) than corresponding regions of the outer shape defined by the corrugation crests 34. However in the present instance, the shape of such corresponding regions is concave, rather than convex as in the previous embodiments. The crest shape is that of a rectangle with the central regions of the long sides slightly concave. With the rectangular inner or root shape, there are thus produced opposed regions 36 and 38 wherein the corrugation depth is substantially less than in other parts of the structure. With this construction, the corrugation depth is relatively small in the region of maximum intensity of the electric field in fundamental-mode transmission in the rectangular guide. By grading the corrugation depth according to the variation of electric field strength in the electromagnetic waveguide pattern, the mechanical benefit of deep corrugation in reinforcing the corners is obtained without the increase in attenuation which occurs where similarly deep corrugations are employed uniformly about the guide.

Persons skilled in the art will readily utilize the invention in embodiments substantially different from those illustrated in the drawing and described above. Accordingly, the scope of the protection to be afforded the invention should not be limited to the particular embodiments shown and described, but should extend to all utilizations of the invention as defined in the appended claims.

What is claimed is:

1. A corrugated waveguide for high-frequency transmission, said waveguide comprising a continuous unitary tube having a substantially uniform thickness around its circumference, said tube being corrugated to provide the tube with improved mechanical strength and to make the tube flexible, said corrugations varying in depth in successive regions around the periphery, to form corrugation roots which define an inner cross-sectional shape having at least one pair of opposite sides which are substantially closer to rectilinearity than the corresponding sides of the outer cross-sectional shape defined by the corrugation crests.

2. The waveguide of claim 1 wherein the outer shape is convex.

3. The waveguide of claim 1 having a substantially circular outer shape defined by the corrugation crests.

4. The waveguide of claim 1 having an elliptical outer shape and a substantially rectangular inner shape.

5. A corrugated waveguide for cross-polarized transmissions comprising the waveguide of claim 1 having an approximately circular outer shape defined by the corrugation crests and an approximately square inner shape defined by the corrugation roots.

6. The waveguide of claim 1 wherein the ratio of maximum to minimum corrugation depth is from 1.05 to 2.0.

7. A corrugated waveguide for high-frequency transmission, said waveguide having corrugations that vary substantially in corrugation depth in successive regions around the periphery so that the corrugation roots de-

5

fine an approximately rectangular inner shape and having substantially less corrugation depth in the central region of at least one pair of opposite sides of the rectangle than at the corners.

8. A corrugated waveguide for high-frequency transmission, said waveguide having substantially varying corrugation depth in successive regions around the pe-

6

riphery, so that the corrugation roots define an inner cross-sectional shape differing from the outer cross-sectional shape defined by the corrugation crests, and wherein the ratio of maximum to minimum corrugation depth is from 1.2 to 1.5.

* * * * *

10

15

20

25

30

35

40

45

50

55

60

65