June 12, 1951 D. INGALLS 2,556,187

FLEXIBLE WAVEGUIDE WITH SPACED CONDUCTING SECTIONS AND METHOD OF MAKING THE SAME

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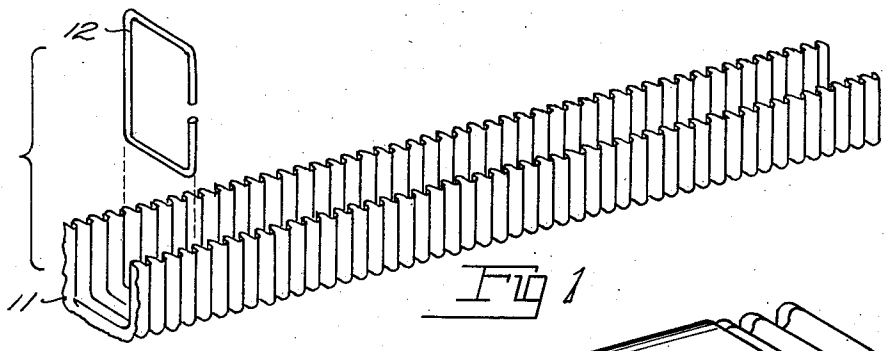


Fig 1

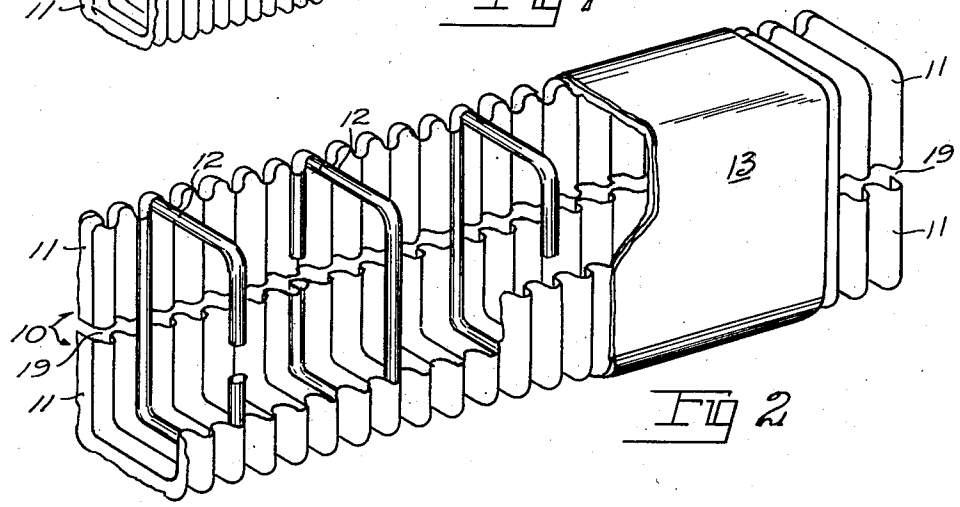


Fig 2

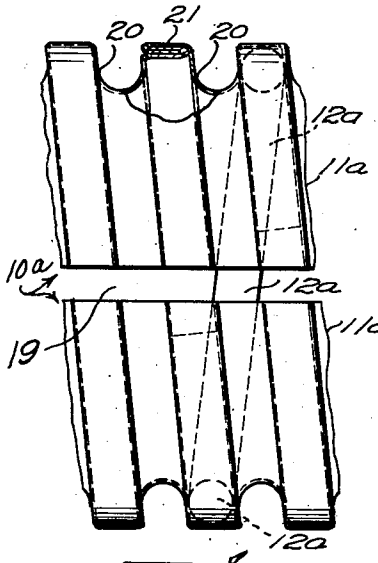


Fig 4

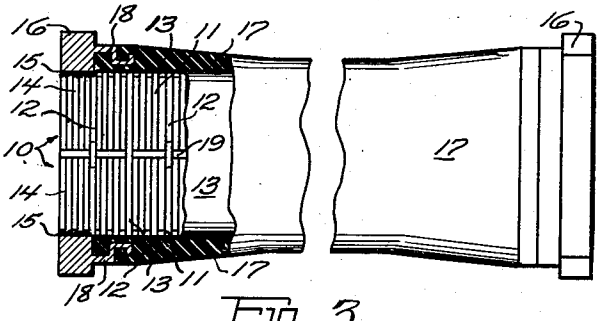


Fig 3

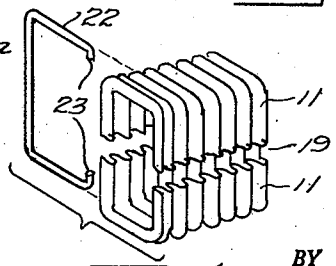


Fig 5

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FLEXIBLE WAVEGUIDE WITH SPACED CONDUCTING SECTIONS AND METHOD OF MAKING THE SAME

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22 Claims. (Cl. 178—44)

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This invention relates to improvements in flexible waveguides and to an improved method of making such devices.

Waveguides, as referred to herein, are conduits preferably having a tubular conductive element or core, generally of rectangular cross-section, and used for transmitting micro-waves in radar and television equipment and in other equipment in which electrical impulses, usually of high frequency, require conduction between various components of the apparatus.

Waveguides are made in various lengths and some are made flexible to facilitate their installation between the several parts of an apparatus. Flexible waveguides, heretofore used, have been of several types. In one type the core has been of transversely corrugated sheet metal, folded and seamed longitudinally to form a tube of rectangular cross-section. Such a core has good conducting qualities and can be flexed about either of two transverse axes which are perpendicular to each other, but it cannot be twisted. In another type, the core is formed of longitudinally convoluted thin metal strip, spirally wound on a rectangular arbor to form a tube of rectangular cross-section, the spiral juncture of adjacent turns of the strip being interlocked and soldered. This core also has good conducting qualities and may be flexed about two perpendicular transverse axes, but it cannot be twisted. In another type, the rectangular core is formed of spirally wound interlocked strip which is not soldered at its spiral seam. Slippage at the seam permits twisting of the core as well as flexing about two perpendicular transverse axes, but its conducting qualities are inferior to the two first mentioned types, probably because of the non-soldered seam.

An important object of the present invention is the provision of a flexible waveguide which has the good conducting qualities obtainable from pressed, corrugated sheet metal or spirally wound, soldered seam cores, and which also is twistable, as well as being flexible about two perpendicular transverse axes. The capacity to twist as well as to flex renders it more readily adaptable for connection between non-aligning parts of an apparatus.

Another important object is the provision of an improved method for making a flexible waveguide.

Another important object is the provision of an improved method for making a twistable waveguide.

The foregoing and other objects are accomplished according to the present invention by

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forming a pair of elongate channels of relatively thin conductive material which is transversely convoluted or corrugated to render each channel flexible and twistable, and by yieldably holding said channels adjacent to but spaced from each other with the channels facing each other to form a tube of rectangular cross-section. These channels are so held by any suitable means such as clips and/or a molded or other suitable outer jacket, and the corresponding ends of the channels may be united by being soldered to flanges by which the waveguide may be connected between several parts of an apparatus.

For illustrative purposes, and without limiting this invention thereto, several embodiments of the invention have been described in the following specification and illustrated in the accompanying drawing, in which:

Figure 1 is a perspective view of one of the mentioned channels formed of thin, conductive, sheet metal with corrugations pressed therein, with an interconnecting clip in position to be inserted into one of the corrugations.

Fig. 2 is a somewhat enlarged perspective view showing a core in the form of a rectangular tube consisting of two similar, pressed, sheet metal channels connected and held in spaced relationship by interior clips and also held together by a thin flexible sheath surrounding the two channels.

Fig. 3 is a side elevation of a complete flexible waveguide having a core such as is illustrated in Fig. 2, the waveguide being broken away at one end to show the component parts thereof.

Fig. 4 is a greatly enlarged side elevation of a fragmentary portion of a modified form of core which may be employed in waveguides according to this invention.

Fig. 5 is a fragmentary view of adjacent portions of two convoluted or corrugated channels showing an exterior connecting clip in position to be applied in outwardly opening corresponding corrugations in said channels to hold the two against separation.

Referring first to Figures 1 to 3, inclusive, a flexible waveguide according to this invention may comprise a conducting core 10 consisting of two, similar, elongate, transversely corrugated channels 11, formed of any suitable, relatively thin, electrically conductive metal which has been pressed between suitably shaped dies to form the mentioned corrugations. These channels may be held in their facing positions, as shown in Figure 2, and held spaced apart somewhat by any suitable means.

As illustrated, the two channels 11 are held in a desired spaced relationship by a plurality of interior wire clips 12 which preferably are generally C-shaped and are disposed each with its upper portion within an inner corrugation of one of the channels and its lower portion within a corresponding or mating inner corrugation of the other channel.

The clips 12 are more or less evenly distributed along the core 10, the spacing between the clips being sufficient to avoid any material inhibition of the twisting quality of the core. The clips 12, preferably are formed of wire which is resilient but nevertheless, stiff enough to maintain the spacing between the two channels 11. To assure that proper spacing is maintained between the two channels, at both sides thereof, alternate clips, preferably, are disposed with their open sides facing toward opposite sides of the core 10.

The clips 12 may fit closely but freely within the corrugations of the channels if desired, but by proportioning these parts so that the clips fit within the corrugations with a moderately tight friction fit, the clips may serve to hold the two channels together, at least until certain outer portions, hereinafter described have been placed or formed over the core.

It has become customary to provide flexible rubber or rubber-like jackets surrounding the core of a waveguide for the reasons, among others, of avoiding short-circuiting with other other parts of an apparatus in which the waveguide is installed, and to enable the waveguide to contain air or other fluid under pressure to derive enhanced conducting characteristics which have been found to result from pressurizing the waveguide.

A sheath 13, preferably of thin flexible, tubular material or thin flexible sheet material wound or folded into a tube, is placed over the core comprising the channels 11 and the interior clips 12. This sheath, appearing as a thin rubber or rubber-like tube in the drawing, may be slid endwisely or rolled onto the said core to embrace the latter closely. It preferably covers all except the end portions 14 of the core, at which portions the core is soldered or welded as at 15 to connecting flanges 16 at opposite ends of the waveguide, these flanges having suitable bolt holes or other means (not shown) for connecting the waveguide between component parts of an apparatus.

After the sheath 13 and flanges 16 have been applied to the core in the manner described, a jacket 17 of flexible rubber, synthetic rubber or other flexible fluid-impervious material is molded over the sheathed core, this jacket flowing, during molding, to extend completely around the core and into interlocking fluid-tight relationship with interlocking portions 18 of the flanges 16. Under this arrangement the waveguide may contain fluid pressure to the extent of the capacity of the jacket 17 to hold such pressure without excessive bulging or bursting. Obviously, the jacket may be formed with reinforcing fabric or other reinforcing means therein to enable it to contain higher pressures.

The sheath 13 serves to hold the two channels together while the flanges 16 and jacket 17 are being applied. Also, the said sheath serves to prevent the jacket material from flowing into the convolutions of the core or into the interior of the latter while the jacket 17 is being molded into place. The sheath also preserves access of the contained pressure, within the core, to the

outer surface of the latter, thereby maintaining substantial equality of pressure applied to the inner and outer surfaces of the core and avoiding any objectionable transverse deformation of the latter.

In the drawings, spaces 19 between adjacent edges of the channels 11 are shown as being quite substantial or in exaggerated form; but, in actual practice, the spaces 19 need only be quite small transversely as it is necessary to space the channels apart only sufficiently to avoid interference of the edges of the channels with each other when the waveguide is twisted.

It may be observed that the spaces 19 extend centrally along the opposite broader sides of the core. This arrangement is based upon the known condition that the path followed by micro-waves along the core is more or less localized in the vicinities of the core at opposite sides of a longitudinal plane which (if the waveguide is considered as being perfectly straight and not twisted) includes the central longitudinal line of each of the two broader sides of the core. The side portions of the core, bordering such a plane are relatively neutral or non-conducting; hence, the provision of the spaces 19 along such a plane localize the breach in the conductive core material at the neutral part thereof and thus avoids impairment of the conductive qualities of the core.

The core of a waveguide according to this invention may be of other types than hereinbefore particularly described. It may be as shown, for example, in Figure 4, wherein a core 10*a* is formed by spirally winding a thin conductive metal, longitudinally-preformed strip 20 upon a rectangular arbor and spirally seaming and soldering it as at 21 to form a complete spirally corrugated or convoluted tube of rectangular cross-section. After the seamed and soldered tube of the desired length has been formed, it is cut lengthwisely along parallel, central, longitudinally extending lines along the opposite broader sides of the tube, thus providing a pair of channels 11*a* which, in general, are substantially like the previously described channels 11.

The channels 11*a* may be held in desired spaced relationship by the wire clip arrangement hereinbefore described, the only difference being that each clip 12*a* will follow the spiral of the turn of the convolution with which it is associated, instead of extending in a transverse plane as is the case with the clips 12. Also, a core 10*a* may be fitted with a rubber sheath 13, and flanges 16, and a flexible rubber jacket 17, in the manner already described with reference to Figure 3, to form a complete waveguide.

Although flexible waveguides are generally provided with the jacket 17, nevertheless if no insulation is desired and if a waveguide is not to be pressurized, the sheath 13 and jacket 17 may be omitted and simple connecting flanges provided at opposite ends of the waveguide. In this circumstance, it is desirable to provide means additional to the interior clips 12 for holding the two channels, at intermediate points, against material separation beyond the desirable maintenance of the spaces 19 between the edges of the channel. For this purpose, exterior wire clips 22 are provided. These clips are of suitable wire which is somewhat resilient but nevertheless stiff enough to function as here described. They are, preferably substantially U-shaped, with the ends of the U turned in slightly as at 23 so that when the clip 22 is slid trans-

versely onto the core, within an outwardly opening corrugation thereof, the inturned ends 23 will extend slightly beyond and snap into the far side of that corrugation, thereby assuring against its unintentional dislodgement. The clips 22 may be provided at suitable intervals along the waveguide.

Although it has been indicated that the clips 22 are primarily for use where the sheath and rubber jacket are to be omitted, nevertheless, said clips may be employed also in structures wherein the sheath and rubber jacket are to be applied, in which case said clips would be applied just before the application of the end flanges 16 and the rubber sheath 13.

Although it has been suggested that the sheath 13 be of rubber or rubber-like material, nevertheless, it may be of other thin, pliant material as, for example, tin or aluminum foil, which may be wrapped, spirally wound or otherwise disposed about the core before the jacket 17 is applied.

It should be obvious that the hereinbefore stated objects are achieved by the improved waveguide structures and methods of making those structures as disclosed and described herein. Also, it is to be understood that the present inventive concept may be embodied in other structures than those herein disclosed and described, without departing from the invention as set forth in the accompanying claims.

What I claim is:

1. A flexible waveguide comprising a conducting core having opposed, elongate, transversely-grooved flexible channel portions of electrically conductive material, and means for holding said portions with their respective longitudinal edges adjacent to but spaced from each other throughout a substantial intermediate portion of the length of said channel portions, whereby to constitute the said channel portions as a conducting conduit.

2. A flexible waveguide according to claim 1, the said holding means being in holding engagement with the interior of said channel portions at plural places, including at least one intermediate place, along said channel portions.

3. A flexible waveguide according to claim 1, the said conducting conduit, formed by said channel portions, being twistable.

4. A flexible waveguide comprising opposed elongate, transversely corrugated channel portions of flexible, electrically-conductive material, and means engaging said channel portions, within interior corrugations therein, for holding said portions with their respective edges adjacent to but spaced from each other, whereby to constitute the said channel portions a conducting conduit.

5. A flexible waveguide comprising opposed, elongate, flexible, electrically conductive channel portions arranged in substantial parallelism with their longitudinal edges adjacent to but spaced from each other, and spacing means in engagement with interior portions of both said channel portions for maintaining the mentioned spaced relationship of the two channel portions.

6. A flexible waveguide according to claim 5, further including connection elements at opposite ends of said channel portions for connecting the waveguide to other apparatus, the said channel portions being fixedly united, toward their ends, with said connection elements, and the said spacing means being associated with the said channel portions at one or more places intermediate said connection elements.

7. A flexible waveguide according to claim 5, the said channel portions having both interiorly opening and exteriorly opening peripherally extending corrugations, the said spacing means comprising clips within corresponding interiorly opening of said corrugations in said channel portions, and the waveguide including also one or more wire clips disposed in corresponding exteriorly opening corrugations in said channel portions and substantially embracing both channel portions to hold the two against relative displacement.

8. A flexible waveguide according to claim 5, further including a flexible covering substantially surrounding both said channel portions and restraining them against relative displacement.

9. A flexible waveguide according to claim 5, the said channel portions having transverse corrugations opening interiorly thereof, and the said spacing means comprising one or more clips engaging both said channel portions within corresponding corrugations thereof to maintain the mentioned spaced relationship of said channel portions.

10. A flexible waveguide according to claim 9, the said clips being of wire and being substantially completely within said corresponding corrugations and disposed exteriorly of planes which include the innermost surfaces of the said channel portions.

11. A flexible waveguide according to claim 9, the said spacing clip or clips being in such relatively tight frictional fit within related corrugations of the channel portions as to restrain the latter against separation from each other.

12. A flexible waveguide according to claim 9, further including a flexible covering, substantially surrounding both said channel portions and restraining them against relative displacement, the said covering being a fluid impervious, pressure-containing jacket fluid-tightly united with the said connection elements at opposite ends of the channel portions.

13. A twistable waveguide comprising opposed, elongate, U-shaped channel portions formed of electrically conductive material which is relatively thin and flexible and formed with transverse corrugations to render the channel portions both flexible and twistable, the said portions being arranged in substantial parallelism with their longitudinal edges adjacent to but spaced from each other, thereby constituting a conducting conduit of approximately oblong rectangular cross-section, with longitudinally-extending breaks centrally along opposite greater dimensional sides of said conduit, means coacting with the corrugations of said channel portions for maintaining the latter in their mentioned parallel, spaced relationship, and a flexible insulating jacket substantially surrounding and intimately embracing said conduit to aid in opposing departure of the channel portions from their said adjacent spaced relationship.

14. A flexible waveguide comprising opposed, elongate, electrically-conductive, channel portions having exteriorly opening transverse corrugations therein imparting flexibility to said channel portions; means coacting between said channel portions for holding them with their respective longitudinal edges adjacent to each other to constitute said channel portions as a conducting conduit; a relatively thin, pliant sheath, surrounding said conduit, in contact therewith but not extending materially into said corrugations; and a jacket of pliant material

surrounding said sheath, the latter constituting a barrier to prevent the jacket material from entering said corrugations and from passing between the longitudinal edges of the channel portions, into the said conduit.

15. The method of making a flexible waveguide which comprises the steps of forming two substantially similar, elongate channel elements substantially to the shape of a U in cross-section with transverse corrugations therein extending without material interruption between the longitudinal edges of said channel elements; associating spacing means with said channel elements and holding the latter and said spacing means in an association in which the channel elements have their open sides facing each other and their said edges substantially parallel and adjacent to each other but slightly spaced apart by said spacing means; and affixing connection elements to opposite ends of said associated channel elements for holding the latter in their mentioned association and for affording means for connecting said associated channel elements to other parts of an apparatus in which the waveguide is employed.

16. The method according to claim 15, wherein each channel element is formed of a flat sheet of relatively thin, flexible, conducting material, which sheet is impressed with transverse corrugations and bent upwardly from the general plane of the sheet, along opposite longitudinal marginal portions to give the sheet the shape of a U in cross-section.

17. The method according to claim 15, wherein the channel elements are formed by spirally winding longitudinally convoluted, flexible, conductive metal strip upon an arbor of generally rectangular cross-section, interlocking and soldering a continuous spiral seam between successive turns of the strip, then cutting the rectangular tube, thus formed, from its one end to its other end along a central longitudinal plane which includes the center longitudinal lines of the opposite large sides of said tube.

18. The method according to claim 15, further including the steps, taken subsequent to the mentioned association of the channel elements and spacing means, of applying relatively thin, pliant material about said associated channel

elements and spacing means to form a thin sheath therearound; and forming a pliant jacket about said sheath.

19. The method according to claim 15, further including the step, taken subsequent to the mentioned association of the channel elements and spacing means, of forming a pliant jacket about said associated elements.

20. The method according to claim 18, wherein the said jacket is molded upon the said associated channel elements, the said sheath thereon serving to prevent the jacket material from entering the corrugations of the channel elements to any material extent during the molding of the jacket.

21. The method according to claim 19, wherein the said jacket is made fluid-impervious and is fluid-tightly joined to said connection elements.

22. The method of making a flexible waveguide which consists of forming two substantially similar, elongate, channel elements substantially to the shape of a U in cross-section with transverse corrugations therein extending without material interruption between the longitudinal edges of said channel elements, placing said channel elements with their open sides facing each other and their said edges substantially parallel and adjacent to each other but slightly spaced apart with spacing means between said elements to maintain the mentioned spacing, disposing a relatively thin pliant, tubular sheath about said channel elements to hold them together in the form of a conduit, affixing connection elements to opposite ends of said conduit, and forming a flexible jacket about said sheathed conduit and extending from one to the other of said connection elements.

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