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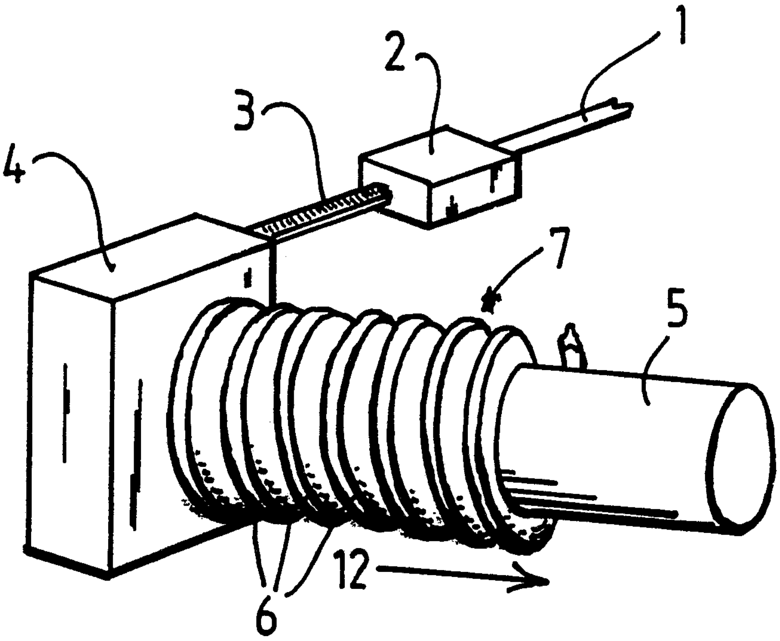
(54) Title: ELLIPTICAL WAVEGUIDE



(57) Abstract

Elliptical waveguide is formed by feeding an electrically conductive strip (1) through a forming tool (2) and pressing the formed strip onto a mandrel (5) in a helical configuration. The adjacent edges of the strip are mechanically interlocked by folding over each other to impart flexible and twistable properties to the waveguide. A seaming wire may be interposed in the folds to reduce escape of electromagnetic energy. The edges may also be soldered to form flexible waveguide.

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ELLIPTICAL WAVEGUIDE

TECHNICAL FIELD OF THE INVENTION

This invention relates to the manufacture of flexible or flexible and twistable elliptical waveguide.

BACKGROUND

Waveguides are widely used for the transmission of electromagnetic energy in the RF, microwave and millimetric wavelength range. Such transmission can take place within the confines of the conductive wall of the waveguide, with a minimum of loss, reflection and distortion of the signal.

Standard waveguides are formed of extruded rigid metal tubing which is available in approximately 4.5 metre straight lengths which can then be bent or twisted to shape using specialist manufacturing equipment. Longer lengths are attained by joining shorter lengths together using standard or custom made flanges. In microwave systems it is common for the waveguide runs to require several bends and twists to enable the waveguide to avoid various obstacles in its path. The use of standard rigid waveguides therefore requires the production of a series of detailed manufacturing drawings to accurately define the shape of the required waveguide. This adds to the cost of the system, as does the operation of forming the waveguide into shape and the subsequent inspection and fitting of the waveguide. Retro-fitting and replacement of rigid waveguides is also a potentially expensive operation, especially in more complex systems.

An important type of waveguide is elliptical cross section waveguide. This has a lower microwave loss when operating in the e TE 11 mode than the equivalent comparable standard rectangular waveguide. Elliptical waveguide is also capable of transmitting higher microwave power than the equivalent rectangular waveguide operating in the H 10 mode. Since the wall of elliptical waveguide is convexly curved in all areas, the external compressive strength of such waveguide is greater than that of rectangular or double ridged waveguide designed to operate within the same frequency range. This increased resistance to deformation is of importance in adverse mechanical or environmental conditions.

Flexible elliptical waveguide is currently manufactured in two halves, each of which is pressed to form a series of transversely extending shallow corrugations. The two halves are then axially soldered, brazed or welded to form the complete waveguide. In general however, this form of waveguide is very stiff to bend by hand and is not, to any significant extent, twistable. In addition, such elliptical waveguide is expensive to manufacture, and can only be manufactured in certain fixed sizes for which tools are available, and in fixed lengths.

An object of the present invention may be viewed as being to provide a form of elliptical waveguide which is more flexible than has hitherto been available and is inexpensive to manufacture in long lengths and in a wide variety of sizes.

SUMMARY OF THE INVENTION

The present invention proposes waveguide of substantially elliptical cross-section, having a wall which comprises an electrically conductive strip formed in a general helical configuration about the axis of the waveguide.

It should be understood that the term "elliptical" as used herein is intended to cover other non-circular and substantially ellipse-like shapes such as ovals.

The strip is preferably formed such that when the waveguide is viewed in longitudinal section its wall is formed in a series of ribs and intervening grooves. The adjacent edges of adjacent turns of the strip are preferably mechanically interlocked, e.g. by being folded over each other.

An electrically conductive element is preferably interposed between the folded edges to reduce electromagnetic leakage. In flexible and twistable waveguide there will usually be just a non-rigid mechanical interlock between adjacent turns, but flexible and non-twistable waveguides may be manufactured by rigidly securing the adjacent turns to each other, e.g. by soldering, brazing or welding.

The invention includes a method of forming waveguide of substantially elliptical cross-section, which comprises winding an electrically conductive strip about a mandrel in a generally helical configuration.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is exemplified in the accompanying drawings, in which:

<u>Figure 1</u> is a perspective view of waveguide of the invention in the process of manufacture,

<u>Figure 1a</u> is an end view of the waveguide of Fig. 1 whilst wound on the mandrel,

<u>Figure 2</u> is a longitudinal section through a wall portion of the waveguide,

<u>Figure 3</u> is a further longitudinal section through a wall portion of a different waveguide of the invention

<u>Figure 4</u> is a side view of a joint between two lengths of waveguide of the invention,

<u>Figures 5 and 6</u> show an adaptor connected to an end of the waveguide in perspective view and longitudinal section respectively, and

<u>Figures 7 to 9</u> are longitudinal sections through different forms of the adaptor.

DETAILED DESCRIPTION OF THE DRAWINGS

By way of example, the waveguide of the present invention may be manufactured from a thin (e.g. 0.106 mm) strip of brass, metal-plated brass (e.g. plated with a 3 to 4 um layer of silver, tin, gold, nickel or palladium nickel), or other metallic or conductive material (e.g. solid silver). The strip may typically be 5.715 mm wide.

Referring to Fig. 1, the strip 1 is passed through formers 2 (e.g. rollers) which form the strip into the required cross-sectional profile at 3. The profiled strip 3 is then fed through a forming tool 4 which feeds the strip around an elliptical arbour (mandrel) 5 of the required major and minor dimensions (e.g. 14.71 mm by 8.29 mm) such that adjacent turns 6 of the resulting helix 7 form a mechanical interlock with each other. By pressing the profiled strip against the arbout the forming tool 4 performs a final forming operation on the strip 3 so that the final waveguide includes a series of angular helical ribs 6 of substantially square or rectangular cross section separated by intervening grooves. As the waveguide is formed it is pushed along the arbour 5 in direction 12 so that a continuous length of waveguide passes off the end of the arbour 5. The cross sectional size of the waveguide can easily be changed simply by changing the size of the arbour.

Figure 2 shows a mechanical interlock 8 which can be used to form flexible and twistable waveguide. In this example the profiled strip 3 is wound onto the arbour 5 together with a support element 9 which supports the ribs 6 to prevent their collapse and also supports the interlock 8 during final engagement. The adjacent edges of the turns are folded back upon each other by the forming tool 4 to complete the mechanical interlock 8, which is supported by the element 9 during manufacture of the waveguide. The element 9 may be an aluminium wire or a nylon filament, having a diameter of 0.91 mm for example.

It will be appreciated that the interlock 8 could also be formed at the bottom of the grooves, supported by the mandrel 5.

The mechanical interlock 8 of Fig. 2 also incorporates an electrically conductive seaming wire 10 which is wound onto the elliptical arbour 5 together with the profiled strip 3 and is interposed between the folded-back edges of adjacent turns 6. This seaming wire 10 may for example be of 0.21 mm thick copper wire plated with tin or silver. The seaming wire 10 enhances the mechanical performance of the waveguide and reduces microwave leakage from the waveguide.

The mechanical interlock 8 which is shown in Fig. 3 is similar to that of Fig. 2 but is suitable for flexible and non-twistable waveguide. A support element 9 is again included, but the seaming wire 10 is replaced by a length of solder wire 11 of e.g. 0.23 mm diameter. After formation of the helical waveguide as described, the waveguide is heated to melt the solder 11 which is then allowed to cool so that the adjacent turns 6 become rigidly bonded together in the region of the interlock 8.

Long lengths of the waveguide can be manufactured by joining shorter lengths using a jointing flange 15 (Fig. 4) which is soldered, brazed or welded to the adjacent ends of the two lengths of waveguide. Another method is to join a new strip 3 onto the end of a previous strip 3 prior to application to the mandrel, by soldering brazing or welding or by other suitable means, so that the resulting waveguide is of a substantially continuous form with less-obvious joints.

The helix 7 may be covered by a protective layer of elastomer, heat-shrunk polymer, organic or metallic braid, or the like, to provide added environmental and mechanical protection. Flexible and twistable versions can have a further covering of an electrically conductive elastomer for example, in order to provide improved electromagnetic screening and isolation properties.

Another version of the waveguide may be manufactured so that the screening effectiveness is deliberately very low, thus forming a "leaky feeder" waveguide. This can be achieved by forming the waveguide with a loose, non-rigid interlock between adjacent turns, and/or by omitting the seaming wire 10.

In order to electrically connect and match the elliptical waveguide to a different microwave transmission link, e.g. a standard rectangular waveguide, a special elliptical-to-rectangular waveguide flanged adaptor is required. This can be soldered, clamped or attached by other suitable means onto the end of the elliptical waveguide. A suitable adaptor 20 is shown in Fig.s 5 and 6, and comprises a rectangular-section waveguide part 21 which terminates in a flange interface 22. The opposite end of the rectangular part 21 is joined to an elliptical section 23, the internal dimensions of which are similar to those of the elliptical waveguide 7. The free end of the elliptical section 23 is provided with an internal annular recess 24 to receive the elliptical waveguide, which is soldered, mechanically fixed, adhesively bonded or otherwise secured therein. An internal step 25 is formed between the rectangular and elliptical sections 21 and 23. A set of tuning screws 26 are inserted through the wall of the rectangular and elliptical sections, and these screws are placed one eighth of a wavelength apart so that by screwing them in and out of the adaptor they can be tuned to match the rectangular and elliptical sections.

Instead of the step 25 the elliptical section of the adaptor 20 can be tapered, as shown in Fig. 7. In each case the tuning screws can be located in both of the wider walls of the waveguide or omitted altogether.

The adaptors of Fig.s 5 to 7 may be of brass, copper, aluminium, stainless steel, titanium, alloy or polymer. The inner surface of the recess 24 may be plated with silver, tin or gold for example, to aid soldering to the elliptical waveguide.

The waveguide of the invention could also be interfaced to other forms of transmission line via a similar matching adaptor of suitable design, for example cirular, double ridge, single ridge, and quad ridged dielectric waveguides, or elliptical waveguide of a different size or orientation. Fig. 8 shows an adaptor for matching into coaxial transmission lines, the adaptor including a launching probe 28 and tuning screws 29.

The waveguide can also be coupled to surface propagating microwave lines, such as strip line, microstrip line and finline. Fig. 9 shows an adaptor for matching into microstrip line 30, incorporating a matching waveguide ridge 31 and tuning screws 32.

The waveguide is used to conduct electromagnetic wave energy from an electromagnetic generator. The performance of the waveguide of the invention is superior to that of flexible rectangular waveguide designed to operate at the same frequency. For example, the microwave attenuation of rectangular flexible waveguide type WG19 from 16 to 20 GHz is 0.9 dB/metre whereas the microwave attenuation of the equivalent waveguide of the invention is less than 0.4 dB/metre.

The maximum microwave power handling of the waveguide of the invention is also superior to standard waveguides. For example, from 16 to 20 GHz the maximum power handling capability of rectangular flexible waveguide type WG19 is 0.21 KW whereas the figure for the equivalent waveguide of the invention is 0.5 KW, with the waveguides filled with air at ambient temperature and pressure, and dry.

The return loss of the waveguide of the invention to elliptical transitions at each end depends upon its length and size. By way of example, a one metre length of the waveguide described above has a return loss of better than 27dB within its operating band.

The minimum bend radius in the E plane for the waveguide of the invention is better than for other forms of elliptical waveguide. For a typical waveguide of the kind described, the minimum bend radius whilst maintaining the microwave specification is 25 mm in the E plane and 62 mm in the H plane. The minimum bend radius for other kinds of flexible elliptical waveguide is typically 150 mm in the E plane and 380 mm in the H plane.

A further advantage of the flexible and twistable form of waveguide of the present invention is the high degree of twisting which can be achieved without degrading the performance of the waveguide beyond the permitted specification. The maximum amount of twist is typically 360° per metre. The maximum twist for other forms of flexible elliptical waveguide is typically only 6° per metre.

A given waveguide of the present invention operates effectively within a relatively small frequency band, for example 15 to 20 GHz. However, a range of different sizes can be manufactured to cover a typical range of, but not limited to, 0.50 GHz to 50GHz.

* * * * * * * *

CLAIMS

1. Waveguide of substantially elliptical cross-section, characterised in that the waveguide has a wall which which comprises an electrically conductive strip (1) formed in a general helical configuration about the axis of the waveguide.

2. Waveguide according to Claim 1, in which the strip is formed such that when the waveguide is viewed in longitudinal section its wall is formed in a series of ribs (6) separated by intervening grooves.

3. Waveguide according to Claim 1, in which adjacent edges of adjacent turns of the strip are mechanically interlocked (8).

4. Waveguide according to Claim 3, in which the adjacent edges are mechanically interlocked by being folded over each other.

5. Waveguide according to Claim 4, in which an electrically conductive seam wire (10) is interposed between the folded-over edge portions of adjacent turns.

6. Waveguide according to Claim 1, in which the adjacent edges of adjacent turns of the strip are soldered together (11).

7. A method of forming waveguide of substantially elliptical cross-section, characterised

by winding an electrically conductive strip (1) about a mandrel (5) in a generally helical configuration.

8. A method according to Claim 7, in which, prior to being wound on the mandrel (5), the strip (1) passes through formers (2, 4) which modify its cross sectional profile.

9. A method according to Claim 7, in which the formers modify the cross-sectional profile of the strip (1) to form a series of ribs (6) separated by intervening grooves, and the strip is wound onto the mandrel (5) together with a support element (9) for supporting the ribs.

10. A method according to Claim 10, in which the strip is wound onto the mandrel (5) together with a solder wire which is interposed between the adjacent edges of adjacent turns of the strip, and the solder wire is melted (11) to solder together the adjacent edges of the strip.

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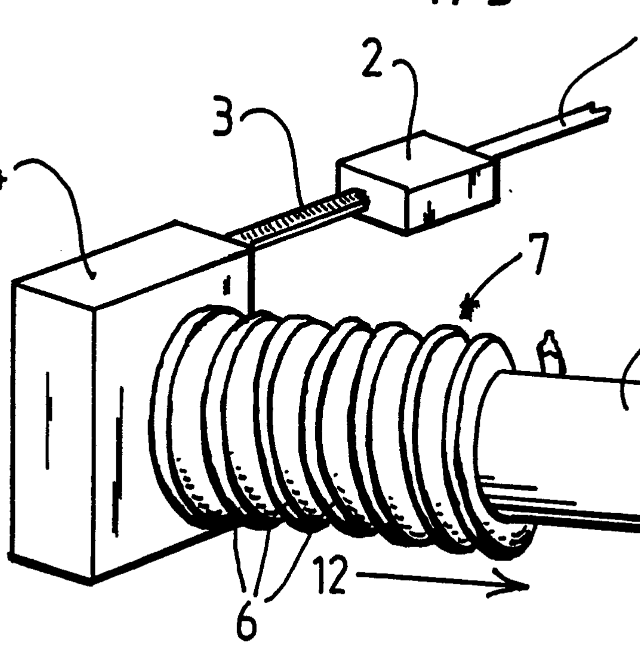

FIG 1

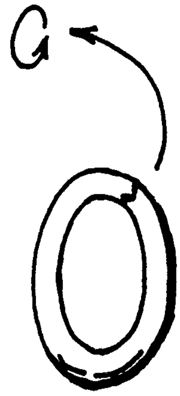

FIG 1a

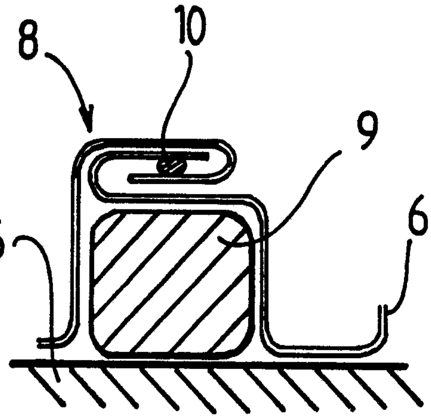

FIG 2

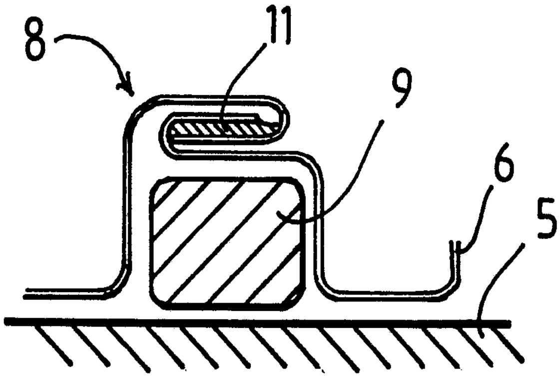

FIG 3

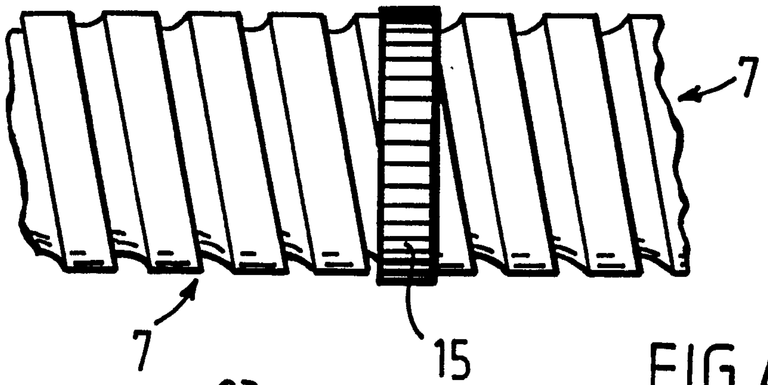

FIG 4

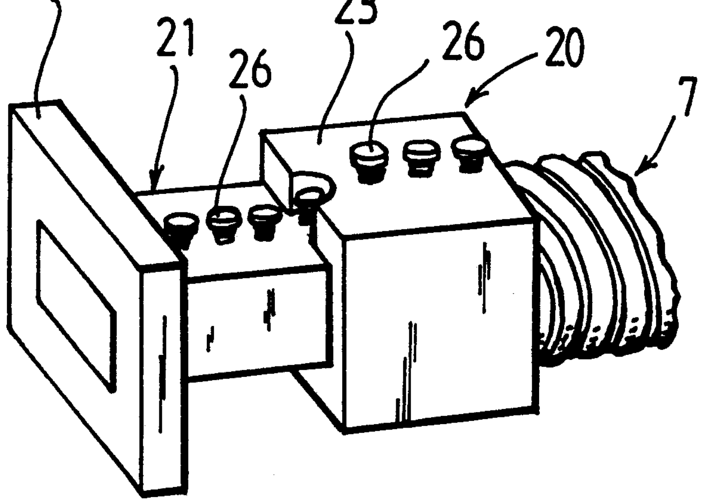

FIG 5

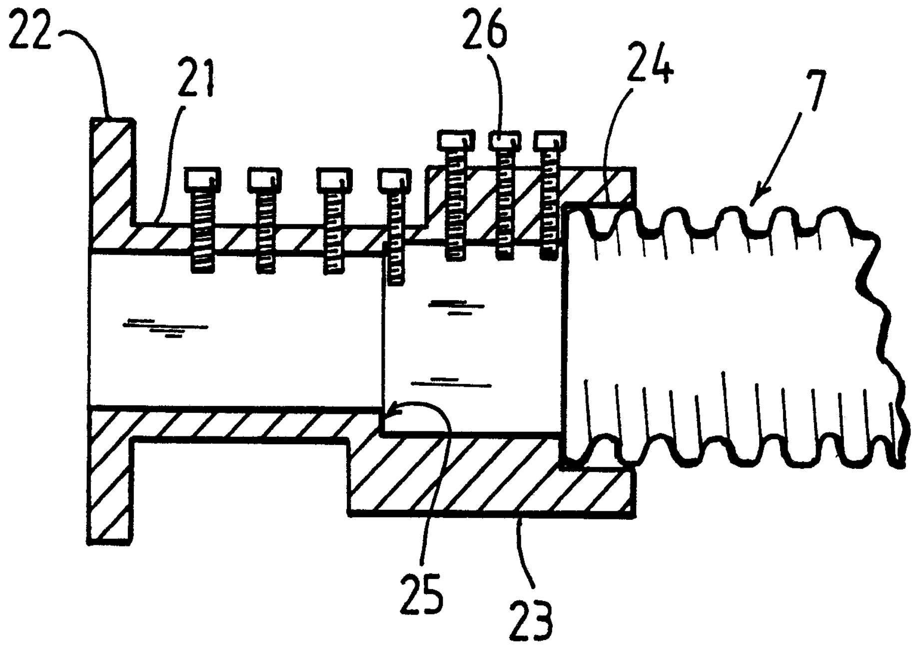

FIG 6

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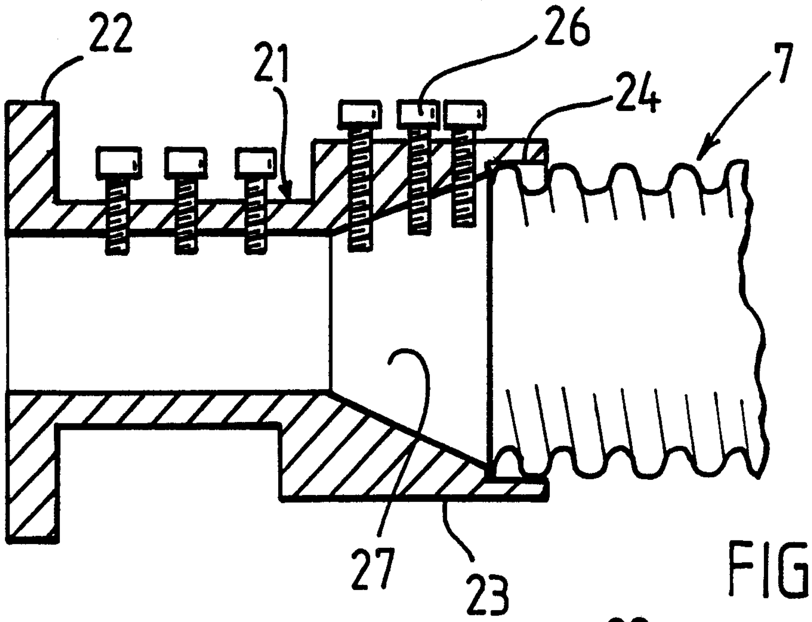

FIG 7

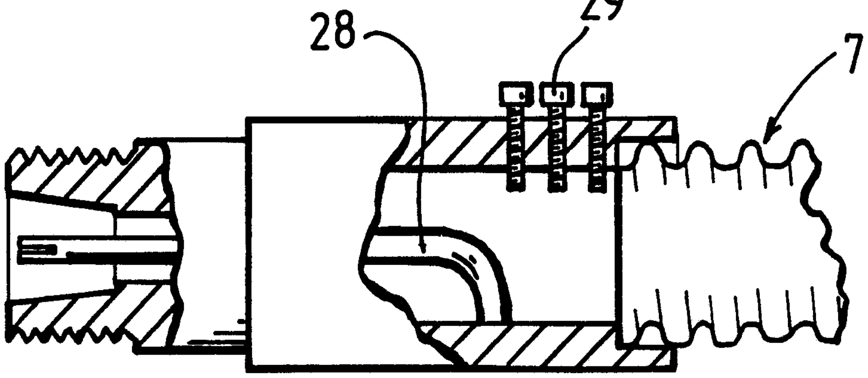

FIG 8

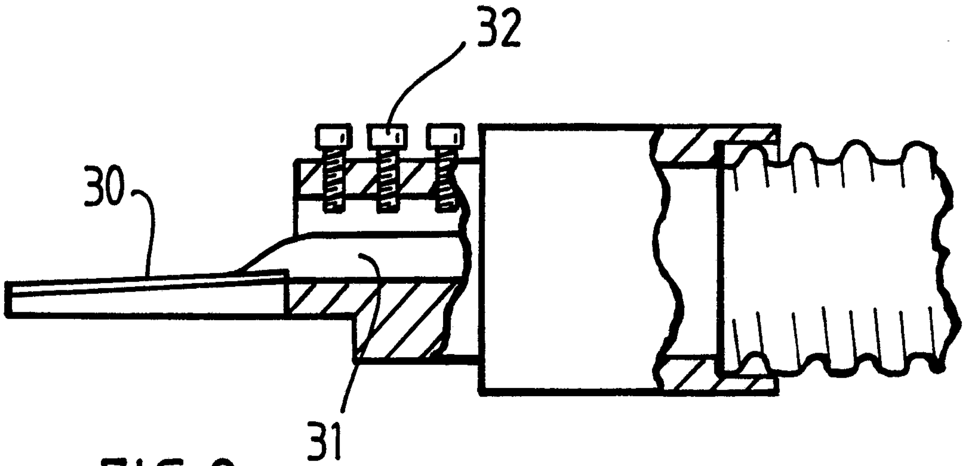

FIG 9

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 92/00260

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H01P3/127; H01P3/14; H01P11/00

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	H01P

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category°	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	DE,B,1 297 722 (KABEL- UND METALLWERKE GUTEHOFFNUNGSHUTTE AG) 19 June 1969 see column 1, line 1 - line 29; figure 1	1,6-8
Y		2-5
Y	US,A,2 636 083 (PHILLIPS ET AL.) 21 April 1953 see column 1, line 1 - line 10 see column 1, line 52 - column 2, line 4 see column 3, line 22 - column 4, line 14; figures 1,2	2-5
A		10
X	US,A,3 383 895 (LEHNERT) 21 May 1968 see column 1, line 72 - column 2, line 29 see column 2, line 56 - column 3, line 43; figures 1-3	1,2

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
10 APRIL 1992	16.04.92
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	DEN OTTER A.M.

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	FR,A,1 329 358 (RADIALL) 29 April 1963 see page 1, left column, line 18 - line 32 see page 2, left column, line 26 - line 36; figure 1 ---	1,6-8
X	FR,A,2 528 240 (THOMSON-CSF) 9 December 1983 see page 1, line 17 - line 28 see page 3, line 6 - page 4, line 8; figures 1-3 ---	1-4,7
A	DE,A,1 690 310 (TELEFUNKEN PATENTVERWERTUNGS GMBH) 13 May 1971 see page 2, line 14 - page 3, line 1; figure ---	1,2
A	DE,C,892 003 (SIEMENS & HALSKE AG) 5 October 1953 see page 2, line 11 - line 13 see page 2, line 45 - line 58; figures 3,6 ---	1,3,7

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 9200260
SA 56334

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-B-1297722		None	
US-A-2636083		FR-A- 1037608 GB-A- 677967	
US-A-3383895		US-A- 3772772	20-11-73
FR-A-1329358		None	
FR-A-2528240	09-12-83	None	
DE-A-1690310	13-05-71	None	
DE-C-892003		None	

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