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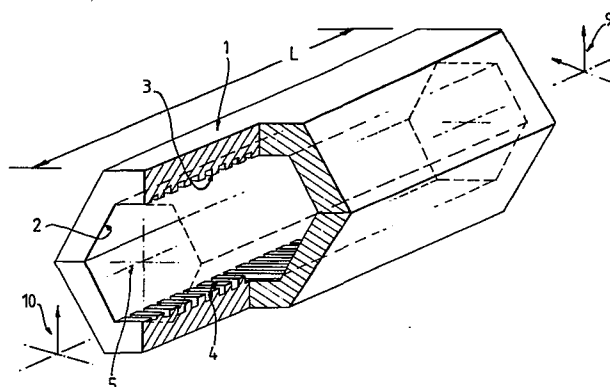
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54 **Circular polariser.**

57 A circular polariser comprises a waveguide (1), which has different cut off frequencies for orthogonal linear polarisations passed by the waveguide, and which has, spaced opposite each other on the inside (2) of the waveguide (1), two parallel sets of periodically arranged parallel slots (3) and (4) which are transverse to the direction of wave propagation through the waveguide, each set of slots (3), (4) extending along substantially the whole length of the waveguide. Depending on the cross sectional shape and dimensions of the waveguide, and the dimensions of the slots (3) and (4), the polariser can be arranged to operate over two separate frequency bands or a single broader frequency band.



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"Circular Polariser"

5. This invention relates to circular polarisers, i.e. circularly polarising waveguides which are capable of producing, from a linearly polarised input wave, a circularly polarised output in which the 90° phase differential between the orthogonal hands of polarisation is accurate to about $\pm 1^\circ$, or less, over a particular frequency range.

10. The conventional type of circular polariser is known as a pin or iris polariser, and comprises a circular waveguide in which a number of obstacles are arranged on its inside surface to form a series of discrete discontinuities along its length (acting electrically as inductive/capacitive elements) for introducing the required phase differential. However, 15. there are a number of drawbacks with this type of polariser. For example, it is not a broadband device (i.e. it is not accurate over a relatively wide frequency range), and it is extremely difficult to modify in order to obtain an accurate phase 20. shift while maintaining good matching characteristics to joining waveguides.

According to our invention, a much improved form of circular polariser comprises a waveguide which

- has different cut-off frequencies for orthogonal linear polarisations and which has, spaced opposite each other on the inside of the waveguide, two parallel sets of periodically arranged parallel
5. slots which are transverse to the direction of wave propagation through the waveguide, each set extending along substantially the whole length of the waveguide. By suitable selection of the cut-off frequencies (determined by the cross-sectional
10. shape and dimensions of the waveguide), the length of the waveguide, and the slot dimensions, i.e. slot width, distance between slots, slot depth, and slot length, the waveguide can be arranged to provide a circularly polarised output from a linearly polarised
15. input over two separate frequency bands or a single broader frequency band.

- This principle of construction may be applied to waveguides of many different configurations, but primarily it is intended to be applied to circular
20. waveguides and to waveguides having a polygonal cross-sectional shape in which there is an even number of sides, preferably four, six or eight, and an axis of symmetry can be drawn to bisect a pair of parallel opposite sides. In this case the two sets of slots
25. are located on this pair of parallel opposite sides, whereas in a circular waveguide the two sets would be located in a pair of opposite segments formed by two parallel chords of the circular cross-section.

- In general however, polygonal waveguide polarisers
30. will be preferred because they are easier to manufacture accurately than the circular waveguide polarisers. Also, they can be used with circular waveguides, with suitable end transitions, without any particular problems or loss of performance. In addition, the

polygonal cross-sectional shape of the polariser makes it particularly suitable for use with correspondingly shaped primary feed horns in multiple feed reflector antennae.

5. If desired, the width of the frequency band or bands over which a polariser in accordance with the invention is effective may be increased if the inside of the waveguide is provided with a further two parallel sets of periodically arranged parallel
10. slots which are transverse to the direction of wave propagation through the waveguide, the two further sets of slots extending along the length of the waveguide and being spaced opposite each other and perpendicular to the other two sets. Generally this
- 15 arrangement will be restricted to waveguides having a polygonal cross-section in which there are a multiple of four sides, and usually only to rectangular or octagonal waveguides. The periodicity of the slots in the four sets will be the same in each case,
20. but the depth of the slots in the additional two sets may be different from that in the first two sets.

- We have found that a circular polariser formed in accordance with the invention possesses very
25. good electrical performance characteristics. In addition to the fact that the polariser may be designed to exhibit the required 90° phase differential to produce a circularly polarised output wave either over a continuous broad frequency band or over two
30. widely separated frequency bands, it exhibits low and equal values of transmission loss for each hand of the circular polarisation over the operating frequency band or bands. The polariser provides low values of VSWR (return loss) characteristics

- for the two orthogonal hands of polarisation with negligible differential return loss performance between the two hands, and what is more the differential phase characteristic may be modified relatively easily (by variation of the slot depth) without affecting the good VSWR performance. Also, the polariser possesses a high mode purity, producing low mode conversion when the waveguide cross section is dimensioned to allow the propagation of higher order modes. Furthermore, these properties are obtained in a polariser which may have a relatively rugged construction which is insensitive to vibration, is relatively short in overall length and in most cases is relatively simple to construct, and is less sensitive to its required phase characteristics being affected by RF and environmental temperature variations than conventional polarisers.

- Particular examples of circular polarisers in accordance with the present invention will now be described with reference to the accompanying drawings, in which:-

- Figure 1 is a perspective view of a first example, part of the polariser being cut away to illustrate more clearly the arrangement of its two opposite sets of periodic slots;

- Figure 2 is a diagram illustrating the cross sectional shape of the waveguide from which the polariser of Figure 1 is constructed, and indicating the location of the two sets of periodic slots in relation to the waveguide;

- Figure 3 is a diagram plotting phase coefficient β (radians per metre) as a function of frequency f (GHz) for the orthogonal hands of polarisation passed by the polariser of Figures 1 and 2;

Figure 4 is a diagram plotting the phase difference $\Delta\phi$ (degrees) between the orthogonal hands of polarisation as a function of frequency f (GHz) for the polariser of Figures 1 and 2;

5. Figure 5 and 6 are diagrams similar to that of Figure 2 but illustrating the cross sectional shapes of two further examples of polarisers which exhibit phase characteristics similar to those of the polariser shown in Figures 1 and 2;

10. Figure 7 is a perspective view of an example of a polariser in accordance with the invention and comprising a rectangular waveguide having sets of periodic slots on both pairs of opposite inside walls;

15. Figure 8 is a scrap section illustrating the form of the slots on one pair of opposite inside walls of the polariser shown in Figure 7;

Figure 9 is a scrap section illustrating the form of the slots on the other pair of opposite inside walls of the polariser shown in Figure 7; and,

20.

Figures 10 and 11 are diagrams plotting phase coefficient β (radians per metre) as a function of frequency f (GHz) for the orthogonal hands of polarisation produced by two different arrangements of the polariser shown in Figures 7 to 9.

25.

The polariser shown in Figure 1 comprises a waveguide 1 having a hexagonal internal cross-section 2 and two identical periodic sets of slots 3 and 4 on two opposite parallel sides of the internal cross section 2. The two sets of slots 3, 4 are arranged over the whole length L of the waveguide 1, the slots of each set

30.

extending parallel to each other and transversely to the direction of wave propagation through the waveguide, i.e. the waveguide axis 5. The dimensions of the slots in each set 3, 4 are chosen to suit the required characteristics of the polariser, and are regular except adjacent the input and output ends of the waveguide 1 where, for matching purposes, the depth of the slots 3, 4 progressively increases to the required value at about the third or fourth slot in from the end.

The internal cross sectional shape 2 of the polariser waveguide 1 is shown more accurately in Figure 2, which shows that the hexagonal cross section 2 is dimensioned such that it can be inscribed within a square 6, the two sides of the cross section 2 on which the sets of slots 3, 4 are located lying centrally on two opposite sides of the square, and, the two sets of slots 3, and 4 being located outside the square 6. In this example the dimensions of the waveguide cross section 2 are such that the ratio $\frac{a}{b}$ (see Figure 2) is approximately 0.5. This results in widely different cut off frequencies for orthogonal polarisations (indicated by the vertical and horizontal arrows 7 and 8) in the waveguide, it being one of the primary design characteristics affecting the differential phase performance of a polariser in accordance with the invention that the waveguide cut off frequencies must be different for orthogonal polarisations.

In the case of hexagonal waveguides generally, the waveguide cut off frequencies for orthogonal hands of polarisation are different, varying according to the ratio $\frac{a}{b}$ indicated in Figure 2. Table 1 below illustrates how these cut off frequencies vary as

the ratio $\frac{a}{b}$ is changed from 0 to 1 in the case of a hexagonal waveguide of the kind shown in Figure 2 in which the side of the square 6 measures approximately 30 mms.

5.

TABLE I

10.	Ratio $\frac{a}{b}$	Cut-off frequency for TE ₁₀ vertical component 7. GHz	Cut-off frequency for TE ₁₀ horizontal component 8. GHz
	0.0	5.0	5.0
	0.2	5.532	5.206
15.	0.4	6.096	5.437
	0.6	6.588	5.734
20.	0.8	6.902	6.192
	1.0	7.071	7.071

25. For each of the extreme cases, $\frac{a}{b} = 0$ (corresponding to a waveguide of square cross section) and $\frac{a}{b} = 1$ (corresponding to a waveguide of diamond shaped cross section), the waveguide cut-off frequencies for the orthogonal hands of polarisation 7 and 8 are equal, which means that such regular and symmetrical waveguides cannot be used for the purposes of the present invention.

The effect of the different cut-off frequencies and the periodic slot arrangements in the opposite

- sides of a hexagonal cross section polariser such as is shown in Figures 1 and 2 is illustrated in the phase/frequency diagram shown in Figure 3. At a higher frequency away from the waveguide cut on
5. frequency the two opposing sets of periodic slots in the waveguide become the dominant feature in respect of the vertical component of the polarisation, the vertical component wave (represented by the line 7' in Figure 3) changing from a fast to a
10. slow wave when the V_p (phase velocity) = C line is crossed. On the other hand, the opposing sets of periodic slots have little or no effect on the horizontal component of the polarisation, and at higher frequencies the horizontal component
15. wave (represented by the dashed line 8') asymptotically approaches the $V_p = C$ line. It will be understood that by selecting the length L of the waveguide the required substantially 90 degree phase difference between the orthogonal vectors of a circularly
20. polarised output will occur within two widely separated frequency bands f_1 to f_2 and f_3 to f_4 . This is shown more clearly in Figure 4 which plots the phase difference between the orthogonal vectors of polarisation as a function of frequency for the
25. particular polariser. It can be seen from this that the polariser of Figures 1 and 2 will produce efficiently (i.e. within acceptable tolerances) a circularly polarised output 9 (Figure 1) from a linearly polarised input 10 within the two frequency
30. bands f_1 to f_2 and f_3 to f_4 .

Once the polariser is constructed, its differential phase characteristic may be adjusted, if necessary, simply by varying the depth of the slots 3 and 4. In addition, the slots are tailored

to a predetermined shallow depth (which is approximately equal to $\frac{\lambda}{10}$) so that the VSWR (return loss) exhibited to both orthogonal hands of the energy input is near equal and at a very low value. As

5. mentioned earlier, a particular advantage of the polariser is that the differential phase characteristic is easily modified without affecting its good VSWR performance.

10. Figures 5 and 6 illustrate the cross-sectional shapes of different hexagonal waveguides which can be used to provide polarisers having similar phase characteristics to the polariser of Figures 1 and 2. In the case of Figure 5, the hexagonal cross section 11 of the waveguide is regular, as indicated by the
15. exscribed circle 12, and the two sets of periodic slots indicated at 13 and 14 are located inside the hexagonal cross section 11. In the case of Figure 6, the arrangement is similar to that of Figure 2, except that the hexagonal cross section 15 of the
20. waveguide is inscribed within a rectangle 16 having sides of different lengths as shown, the two sets of periodic slots 17 and 18 being located outside the hexagonal cross section 15.

25. The polariser shown in Figure 7 comprises a waveguide 19 having a rectangular cross section and a set of periodically arranged slots on each of the four inside walls 20, 21, 22 and 23. The sets on the top and bottom walls 20, 22, are identical to each other, covering the whole length
30. of the waveguide 19, and the individual slots 24 extending parallel to each other transversely of the waveguide axis. As shown by Figure 8, the slots 24 in the top and bottom walls 20 and 22 have a width g , a depth h_2 , (except at the ends of

the waveguide where the depth is decreased for matching purposes), and are repeated with a period P . The sets of slots on the two opposite side walls 21 and 23 are also identical to each other, and are similar to the sets on the top and bottom walls 20, 22 except that, as shown in Figure 9, the effective depth h_1 of the individual slots 25 is different. Since the periodicity P and the width g of the slots on the four walls 20 to 23 is the same, the slots 24 and 25 register with each other at the junctions of the waveguide walls, as shown at 26.

With this arrangement the two orthogonal modes of polarisation passed by the waveguide 19 both exhibit a pass band characteristic as shown in Figures 10 and 11, changing from fast to slow waves when the $V_p = C$ line is crossed at higher frequencies away from the waveguide cut on frequencies. Judicious choice of the polariser dimensions a , d , h_1 , h_2 , P and g can yield, as in the earlier examples, a substantially 90 degree phase difference either over two separate frequency bands f_1 to f_2 and f_3 to f_4 as shown in Figure 10, or over a single wide frequency band f_1 to f_2 as shown in Figure 11.

As indicated in Figure 7 the waveguide 19 is constructed from four plates or blocks 27, 28, 29 and 30 which are bolted together, being located accurately relative to each other by means of tongues and grooves as indicated at 31, and each of which has the required set of parallel slots machined (prior to assembly) on its inner face.

C L A I M S

1. A circular polarizer comprising a waveguide which has different cut-off frequencies for orthogonal linear polarizations and which has, spaced opposite each other on the inside of the
5. waveguide, two parallel sets of periodically arranged parallel slots which are transverse to the direction of wave propagation through the waveguide, each set extending along substantially the whole length of the waveguide.
10. 2. A circular polarizer according to claim 1, in which the waveguide has a circular cross-section and the two sets of slots are located in a pair of opposite segments formed by two parallel chords of the circular cross-section.
15. 3. A circular polarizer according to claim 1, in which the waveguide has a polygonal cross-sectional shape in which there is an even number of sides and an axis of symmetry can be drawn to bisect a pair of parallel opposite sides, the
20. two sets of slots being located on said pair of parallel opposite sides.
4. A circular polarizer according to claim 3, in which the cross-sectional shape of the waveguide is hexagonal.
25. 5. A circular polarizer according to claim 4, in which the hexagonal cross-section of the waveguide can be inscribed within a square, the two opposite sides on which the sets of slots are located lying along two opposite sides of the square
30. and having a length which is substantially half that of the sides of the square, and the slots being external to the square.

6. A circular polarizer according to claim 3, in which the polygonal cross-sectional shape of the waveguide has a multiple of four sides, and the inside of the waveguide is provided with a
5. further two parallel sets of periodically arranged parallel slots which are transverse to the direction of wave propagation through the waveguide, the two further sets of slots extending along the length of the waveguide and being spaced opposite each
10. other perpendicular to the first two sets, and the periodicity of the slots in the two further sets being the same as in the first two sets.
7. A circular polarizer according to claim 6, in which the cross-sectional shape of the
15. waveguide is rectangular or octagonal.
8. A circular polarizer according to claim 6 or claim 7, in which the depth of the slots in the further two sets is different from the depth of the slots in the first two sets.
20. 9. A circular polarizer according to any one of the preceding claims, which is operative to produce a circularly polarized output from a linearly polarized input over two discrete frequency bands.
25. 10. A circular polarizer according to any one of claims 1 to 8, which is operative to produce a circularly polarized output from a linearly polarized input over a continuous broad frequency band.

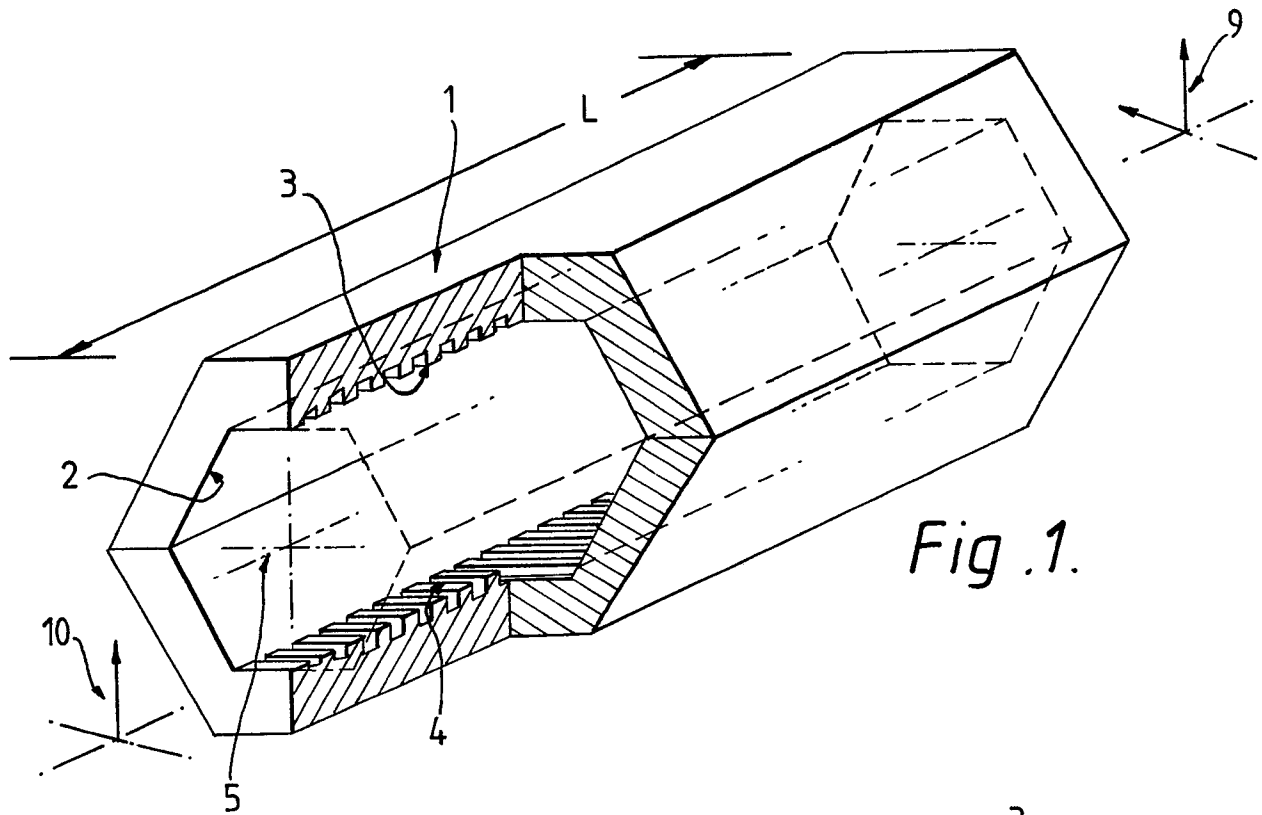


Fig. 1.

Fig. 2.

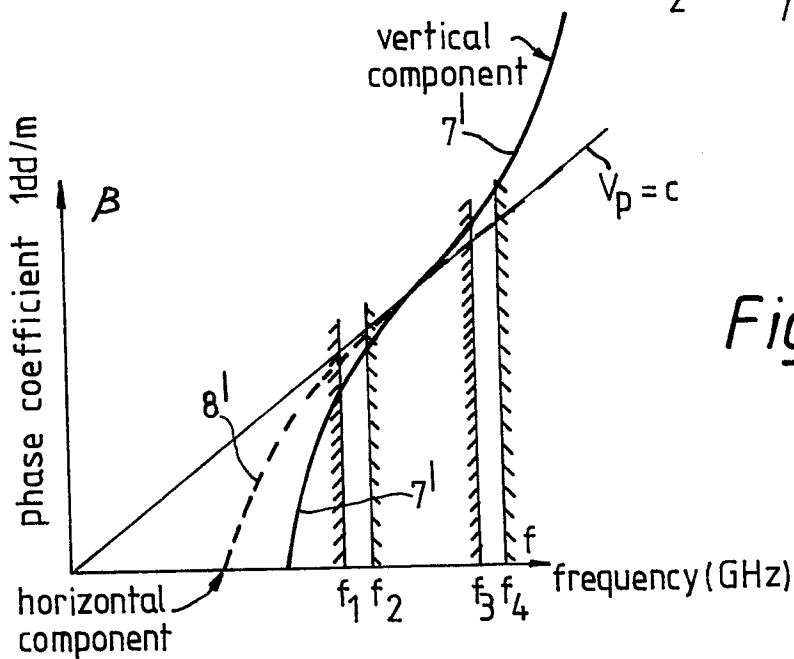
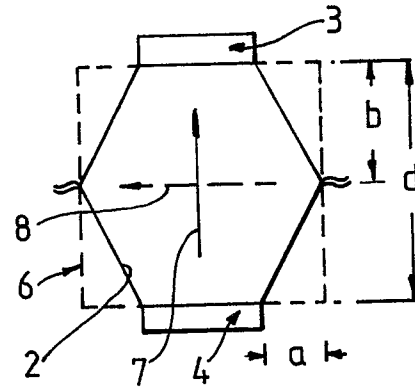
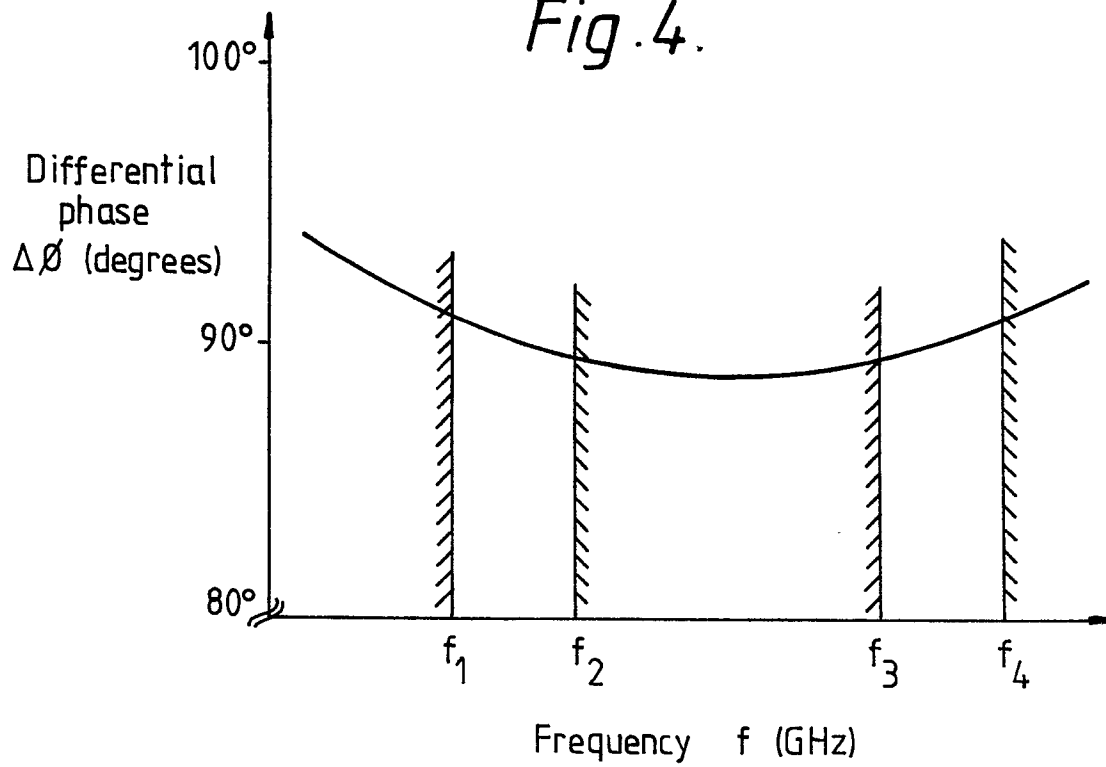
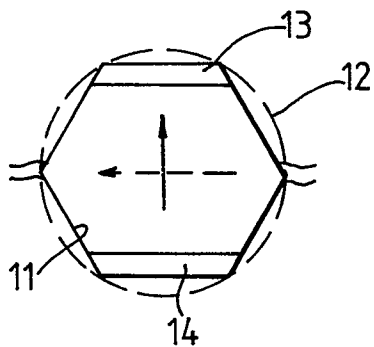
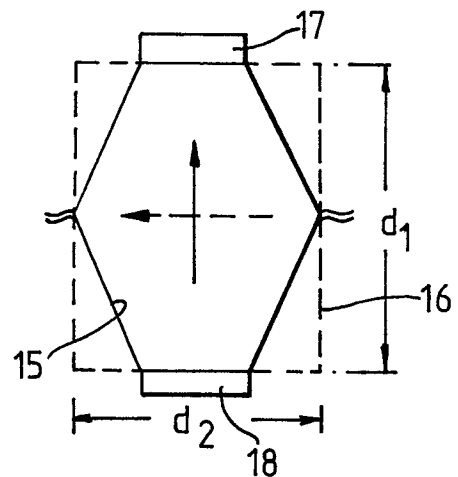
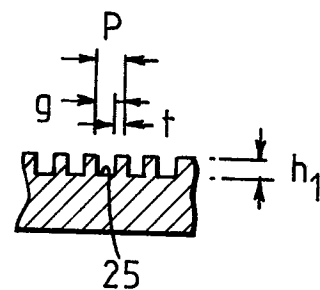
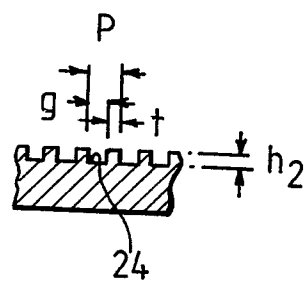
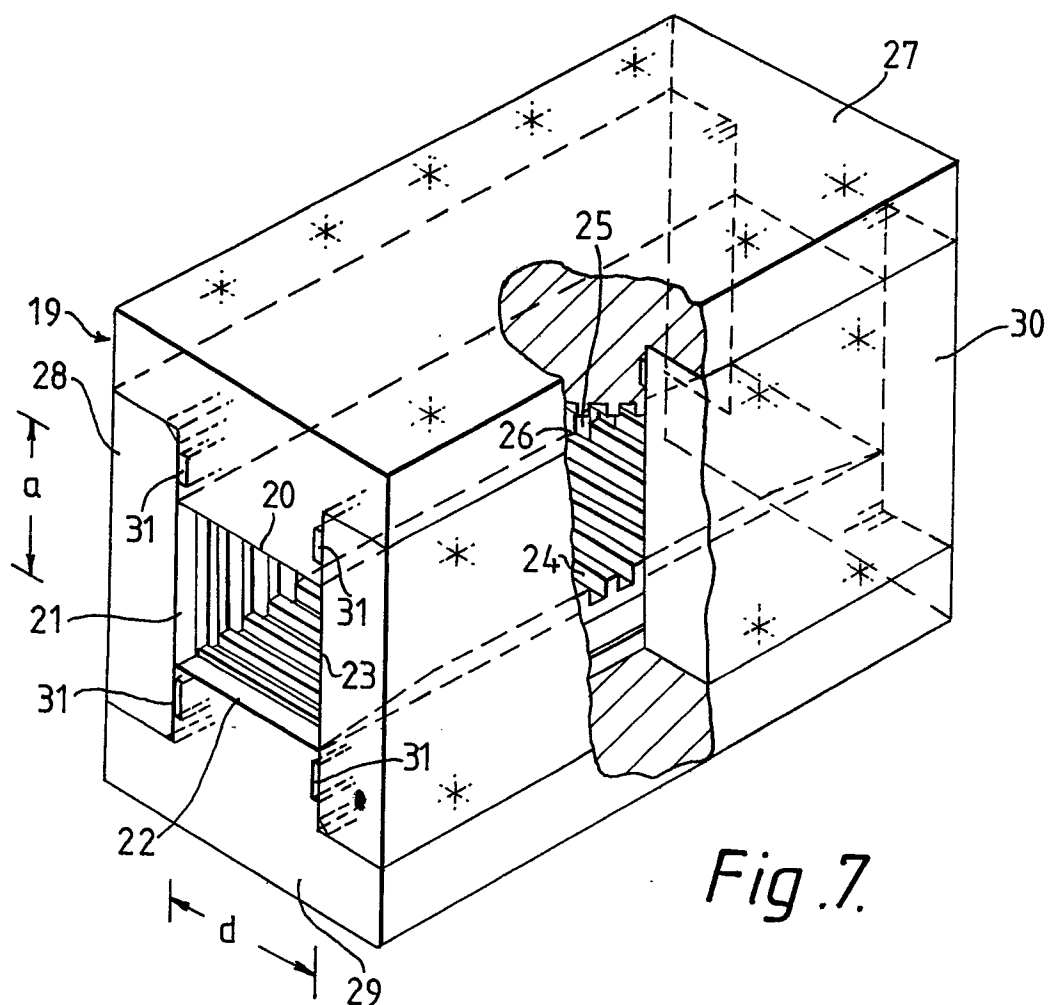


Fig. 3.

Fig. 4.*Fig. 5.**Fig. 6.*

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4/4

Fig .10.

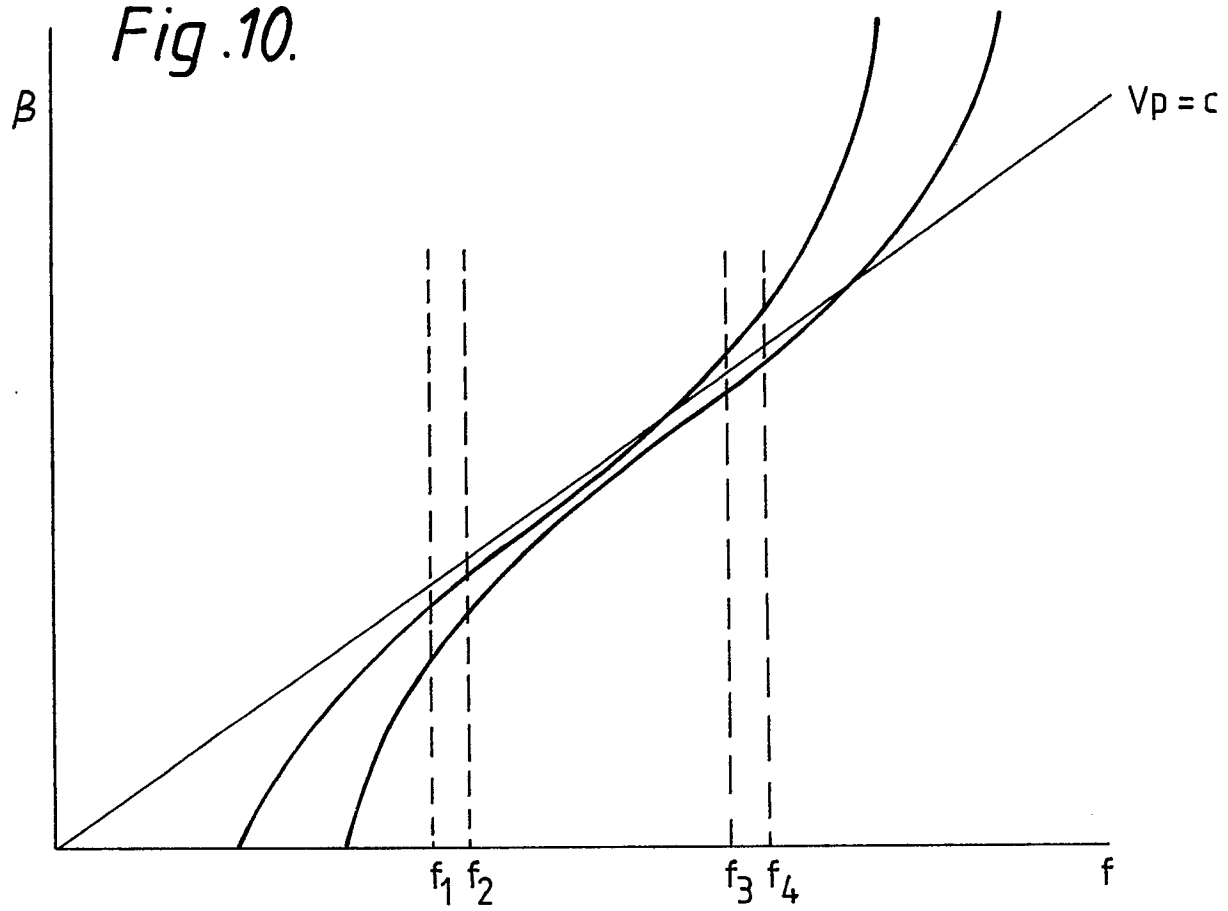
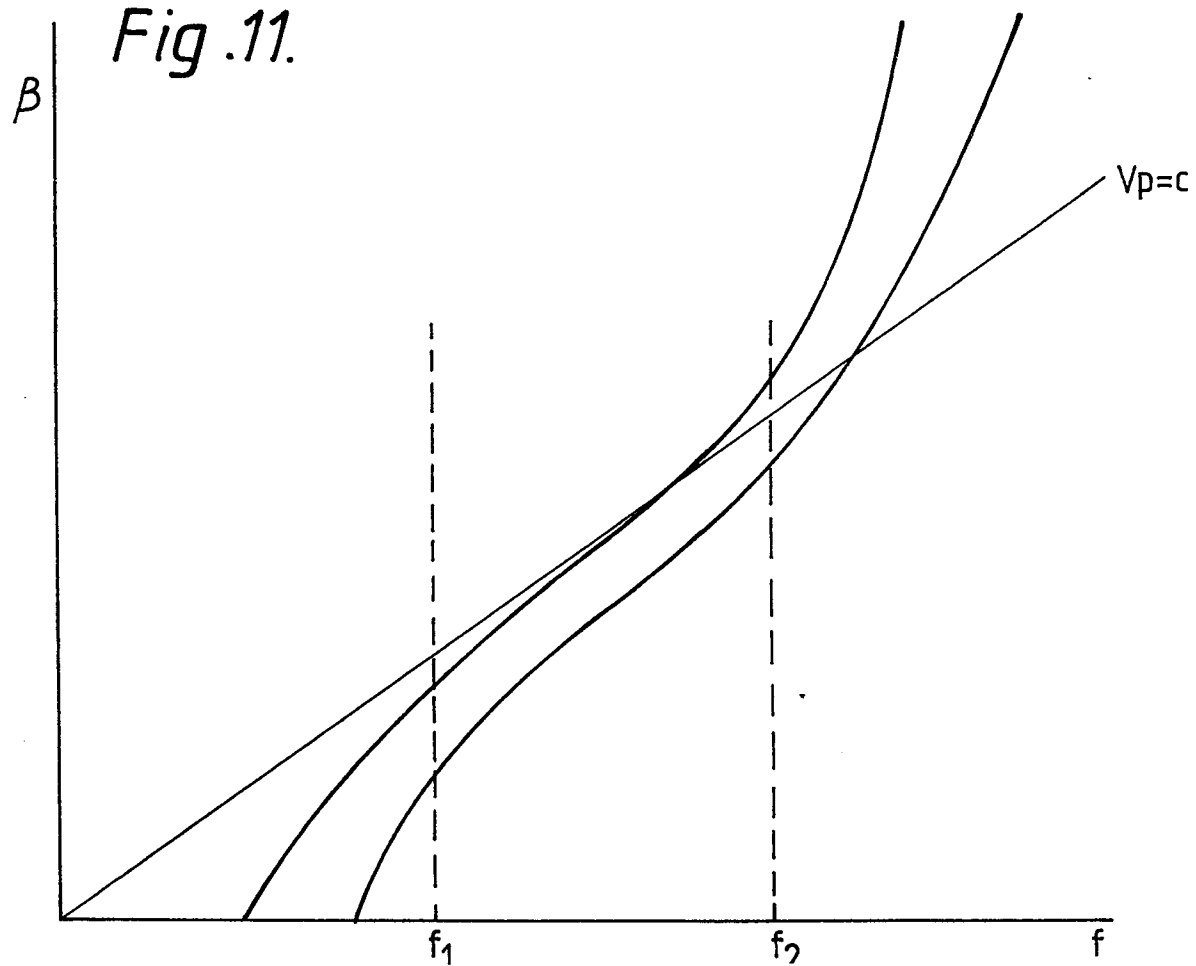


Fig .11.





European Patent
Office

EUROPEAN SEARCH REPORT

0014099
Application number
EP 80 30 0233

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
X	<u>GB - A - 1 365 484</u> (THE PLESSEY COMPANY) * Whole document * --	1,3,6,7,10	H 01 P 1/17
X	<u>US - A - 2 772 400</u> (A.J. SIMMONS) * Whole document * --	1,3,6,7,10	
X	<u>US - A - 4 100 514</u> (J.G. DI TULLIO et al.) * Whole document * --	1-3,6,7,10	TECHNICAL FIELDS SEARCHED (Int.Cl. ³)
	<u>US - A - 3 758 882</u> (G. MORZ) * Whole document * --	1-3,6,7,9	H 01 P 1/17 1/165 3/123
A	PROCEEDINGS OF THE INSTITUTION OF ELECTRICAL ENGINEERS, vol. 120, no. 4, April 1973, pages 431-432 London, G.B. P.A. LAURA: "Review of Methods for Numerical Solution of the Hollow-Waveguide Problem" * Whole document * ----	3,4	CATEGORY OF CITED DOCUMENTS
			X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application D: document cited in the application L: citation for other reasons
☒	The present search report has been drawn up for all claims		&: member of the same patent family, corresponding document
Place of search		Date of completion of the search	Examiner
The Hague		29-04-1980	LAUGEL