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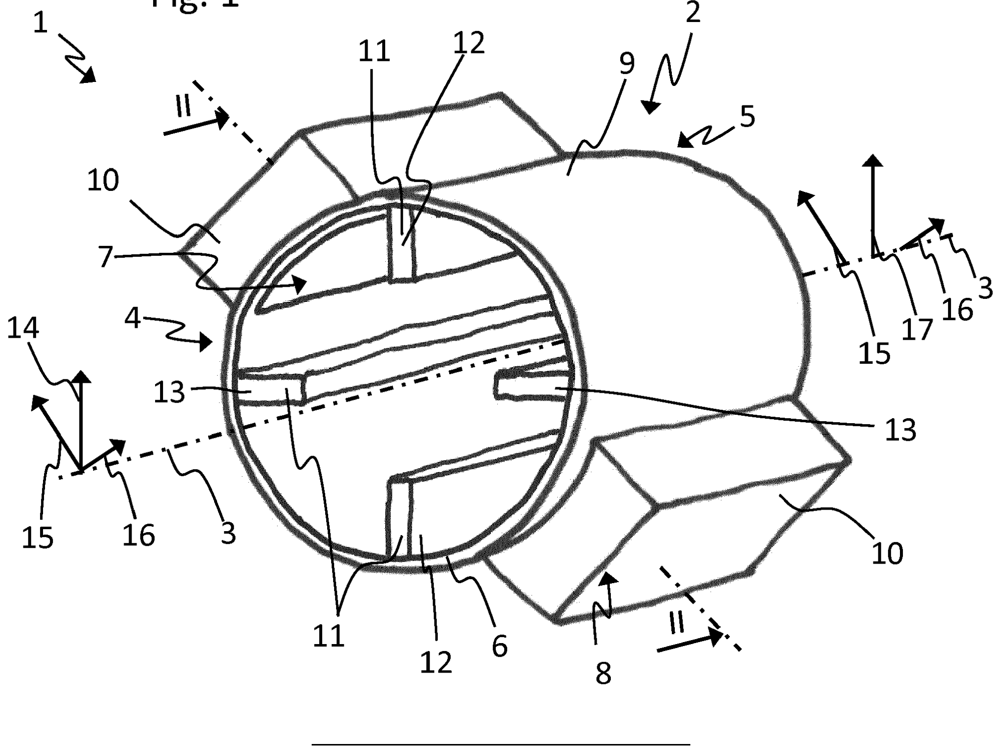
(54) **WAVEGUIDE POLARIZER**

(57) A waveguide polarizer (1) for polarizing a radio frequency signal with a hollow waveguide body (2). The waveguide body (2) extends along a central axis (3) between a first open end (4) and a second open end (5). The waveguide body (2) comprises a body wall (6) of an electrically conductive material. The body wall (6) encloses a waveguide cavity. In a section of the waveguide body (2) the body (6) wall is recessed outwardly as to form a groove (7) in the waveguide body (2) extending at least sectionwise along the central axis (3). The waveguide polarizer (1) comprises at least one ridge element (11) of the conductive material. The at least one ridge element (11) is arranged at a non-recessed section of the body wall (6) of the waveguide body (2). The at least one ridge element (11) projects inwardly from the body wall (6) and extends at least sectionwise along the central axis (3) .

Fig. 1



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Description

Technical Field

[0001] The invention relates to a waveguide polarizer for polarizing a radio frequency signal with a hollow waveguide body extending along a central axis between a first open end and a second open end, whereby the waveguide body comprises a body wall of an electrically conductive material, whereby the body wall encloses a waveguide cavity and whereby in a section of the waveguide body the body wall is recessed outwardly as to form a groove in the waveguide body extending at least sectionwise along the central axis.

Background of the invention

[0002] A waveguide for polarizing a radio frequency signal converts a linearly polarized radio frequency signal to a circularly polarized radio frequency signal or vice versa when transmitting a radio frequency signal from a first open end to a second open end. Within this application radio frequency comprises a range of frequencies from 30 MHz to 300 GHz. The waveguide for polarizing a radio frequency signal operates by separating an incoming radio frequency signal into two orthogonal radio frequency signal components and delaying one of the orthogonal radio frequency signal components by a 90 degree phase shift with respect to the other orthogonal radio frequency signal component. US 6,664,866 B2 teaches that said 90 degree phase shift between the orthogonal radio frequency signal components can be obtained by arranging for at least one groove formed along a central axis inside a circular hollow waveguide.

[0003] In hollow waveguide polarizers the radio frequency signal propagates as electromagnetic waves along the hollow waveguide body. For frequencies below a cut-off frequency, being dependent on the dimensions perpendicular to a central axis of the waveguide polarizer, electromagnetic waves cannot propagate along the hollow waveguide polarizer. As the cut-off frequency is inversely related to the largest dimension of a waveguide cavity orthogonal to the central axis of the waveguide polarizer, there is a minimal size requirement for the waveguide polarizer for a given frequency. This minimal size requirement can impede in particular a space saving integration into polarizing waveguide feeds and polarizing open waveguide radiating elements of antenna arrays.

[0004] In planar phased array antennas with a multitude of polarizing open waveguide radiating elements arranged next to each other on an antenna plane a lateral spacing between a central axis of the polarizing open waveguide radiating elements is typically around half a wavelength of the radio frequency signal that is the operating frequency for the phased array antenna. Notably, the cut-off frequency of a quadratic hollow waveguide polarizer coincides with a minimal lateral extension of a side of the waveguide cavity of half a wavelength of the radio frequency signal and in case of a circular hollow waveguide polarizer with a diameter of approximately 0.59 of the wavelength. Thus, even for the quadratic hollow waveguide polarizer a lateral spacing of half a wavelength of the radio frequency signal is not feasible taking twice a thickness of a body wall surrounding the waveguide cavity into account.

[0005] Accordingly, there is a need for a waveguide polarizer as described above allowing for further miniaturization.

Summary of the invention

[0006] The present invention relates to a waveguide polarizer as described above, characterized in that the waveguide polarizer comprises at least one ridge element of the conductive material, with the at least one ridge element arranged at a non-recessed section of the body wall of the waveguide body projecting inwardly from the body wall and extending at least sectionwise along the central axis. The cut-off frequency of the waveguide polarizer is reduced by arranging the at least one ridge element within the waveguide body. In such a way the waveguide polarizer can be manufactured with smaller dimensions orthogonal to the central axis for a given cut-off frequency, allowing for miniaturization of the waveguide polarizer. Moreover, the at least one ridge element can have a different effect on the two orthogonal radio frequency components propagating along the waveguide body. By a suitable arrangement of the at least one ridge element with respect to the groove of the waveguide body an axial length of the waveguide body, necessary for effecting the 90 degree phase shift between the orthogonal radio frequency components, can be shortened.

[0007] The ridge element can extend from the first open end to the second open end of the waveguide body. Alternatively, according to the invention, the at least one ridge element can extend only sectionwise along the waveguide body. Advantageously, a cross section of the at least one ridge element orthogonal to the central axis is square or rectangular. In such a way the at least one ridge element comprises a ridge tail surface oriented towards the central axis and two sidewall surfaces, with the latter two connecting the ridge tail surface of the at least one ridge element with the adjacent part of the body wall. Alternatively, the cross section of the at least one ridge element can also be semi-circular or semi-oval. A length and a width of the at least one ridge element can be constant along the central axis. It is also possible that the length or the width of the at least one ridge element or both vary along the central axis.

[0008] The hollow waveguide body can be fabricated from a suitable metallic conductor as e.g. copper or aluminium. An inwardly oriented side of the waveguide body is advantageously coated with silver or gold. The groove can be formed as a non-continuous recess in the body wall of the waveguide body. It is also possible that the waveguide body is multi-piece with a central piece with a continuous recess and a lid element covering the continuous recess of the central piece, thus forming the groove.

[0009] Preferably, the waveguide polarizer comprises a first pair of opposing ridge elements. More preferably the waveguide polarizer comprises a second pair of opposing ridge elements. Most preferably the first and the second pair of opposing ridge elements are arranged orthogonal to each other.

[0010] To simplify the manufacturing of the waveguide polarizer according to a preferred aspect of the invention, a cross section orthogonal to the central axis of the non-recessed section of the waveguide body is circular.

[0011] Preferably, the waveguide body comprises a supporting groove extending along the central axis. Most preferably the supporting groove is arranged opposite to the groove. In such a way the axial length of the waveguide necessary for effecting the 90 degree phase shift between the orthogonal radio frequency components can be further shortened.

[0012] According to an advantageous aspect of the invention, an adapting element comprising a dielectric material with a relative permittivity larger than air is arranged inside the waveguide body. By arranging a dielectric material inside the waveguide body, the cut-off frequency of the waveguide polarizer can be further reduced. Hence, for a given cut-off frequency the waveguide polarizer comprising the adapting element can be manufactured using smaller lateral dimensions as a waveguide polarizer without the adapting element. The dielectric material can be fabricated from suitable materials as polytetrafluoroethylene (PTFE), acrylonitrile butadiene styrene (ABS), silicone dioxide, silicone dioxide, epoxy resin, aluminium dioxide or a combination thereof. Particularly, the dielectric material can be a composite material like, for instance, glass-reinforced epoxy laminate.

[0013] Preferably the adapting element is in contact with the ridge tail surface of one of the at least one ridge elements. Most preferably the adapting element is in contact with the ridge tail surface of all of the ridge elements of the waveguide polarizer. In case of a waveguide polarizer with at least one pair of opposing ridge elements featuring opposing ridge tail surfaces the electrical field formed between the opposing ridge tail surfaces when the radio frequency signal propagates along the waveguide can efficiently be concentrated in the adapting element.

[0014] According to an advantageous aspect of the invention, the adapting element is spaced apart from the body wall. Thus, the dielectric material arranged inside the waveguide cavity is geometrically confined to the adapting element with the adapting element being spaced apart from the body wall. For a waveguide polarizer with the at least one pair of opposing ridge elements featuring the opposing ridge tail surfaces with the opposing ridge tail surfaces in contact with the adapting element the adapting element can have a different influence on an electric field formed between the opposing ridge tail surfaces and an electric field formed between adjacent sections of the body wall. Preferably, a cross section of the adapting element is cross-shaped. With the cross shaped adapting element arranged in between and contacting the ridge tail surfaces of the two orthogonal pairs of ridge elements the different influence of the adapting element on the electric field formed between the opposing ridge tail surfaces and the electric field formed between adjacent sections of the body wall between two neighbouring ridge elements can be further increased. The adapting element can also feature a square, rectangular, circular or oval cross section.

[0015] According to an advantageous aspect of the invention, the waveguide polarizer is a radiating element. A radiating element can be used to emit or receive a radio frequency signal. Thus, the waveguide polarizer is designed to transmit a radio frequency signal along the waveguide polarizer and to emit the radio frequency signal at one end of the waveguide. The waveguide polarizer can be e.g. an open-ended waveguide antenna. An end region of the open-ended waveguide polarizer can be adapted to support the emission or reception of a radio frequency signal with a frequency that is also suitable for signal transmission along the waveguide.

Brief description of the drawings

[0016] The present invention will be more fully understood, and further features will become apparent, when reference is made to the following detailed description and the accompanying drawings. The drawings are merely representative and are not intended to limit the scope of the claims. In fact, those of ordinary skill in the art may appreciate upon reading the following specification and viewing the present drawings that various modifications and variations can be made thereto without deviating from the innovative concepts of the invention. Like parts depicted in the drawings are referred to by the same reference numerals.

Figure 1 illustrates a perspective view of a waveguide polarizer,

Figure 2 illustrates a downsized sectional view of the waveguide polarizer as shown in figure 1 taken along the line II-II,

Figure 3 illustrates a perspective view of an alternative embodiment of the waveguide polarizer,

Figure 4 illustrates a downsized sectional view of the waveguide polarizer as shown in figure 3 taken along the line IV-IV,

Figure 5 illustrates a perspective view of another alternative embodiment of the waveguide polarizer,

Figure 6 illustrates a sectional view of the waveguide polarizer as shown in figure 5 taken along the line VI-VI, and

Figure 7 illustrates a downsized sectional view of the waveguide polarizer as shown in figure 5 taken along the line VII-VII.

[0017] Figure 1 illustrates a perspective view of an embodiment of the waveguide polarizer 1. The waveguide polarizer 1 comprises a circular waveguide body 2 extending along a central axis 3 from a first open end 4 to a second open end 5. The body wall 6 of the waveguide is recessed outwardly forming a groove 7 and a supporting groove 8 with the supporting groove 8 being arranged opposite to the groove 7. In the embodiment shown in figure 1 the waveguide body 2 comprises a central piece 9 and two lid pieces 10. The two grooves 7, 8 are formed by continuous recesses inside the central piece 9 with each of the recesses being covered on the outside of the central piece 9 by the respective lid element 10. The waveguide polarizer 1 comprises four ridge elements 11 projecting inwardly from a non-recessed section of the body wall 6. The four ridge elements 11 are arranged as a first pair 12 and a second pair 13 of opposing ridge elements, with the two pairs 12, 13 of opposing ridge elements being orthogonal to each other. The two pairs of opposing ridge elements 12, 13 lower a cut-off frequency of the waveguide polarizer.

[0018] A linearly polarized radio frequency signal 14 suitable to be transmitted by the waveguide polarizer 1 is depicted at the first open end 4. The linearly polarized radio frequency signal 14 comprises two orthogonal radio frequency signal components 15, 16 being in phase. After transmission of the linearly polarized radio frequency signal 14 along the waveguide polarizer 1 from the first open end 4 to the second open end 5 the orthogonal radio frequency signal component 15 is delayed with respect to the orthogonal radio frequency signal component 16 by a 90 degree phase shift, thereby creating a circularly polarized radio frequency signal 17 at the second open end 5.

[0019] Figure 2 illustrates a sectional view of the waveguide polarizer 1 as shown in figure 1 taken along the line II-II. The ridge elements 11 comprise opposing ridge tail surfaces 18. The opposing ride tail surfaces 18 of the ridge elements are connected via side wall surfaces 19 with adjacent sections of the body wall 6.

[0020] Figure 3 illustrates another embodiment of the waveguide polarizer 1 and figure 4 illustrates a sectional view of the waveguide polarizer 1 as shown in figure 3 taken along the line IV-IV. The waveguide polarizer 1 depicted in figures 3 and 4 corresponds to the waveguide polarizer 1 illustrated in figures 1 and 2 except for a cross-shaped adapting element 20 arranged inside the waveguide body 2 between the ridge elements 11. The adapting element 20 comprises a dielectric material 21. With arranging the adapting element 20 within the waveguide body 2 the cut-off frequency of the waveguide polarizer 1 is further reduced as compared to a waveguide polarizer 1 without the adapting element 20. In such a way the waveguide polarizer 1 can be manufactured with smaller lateral dimensions for a given frequency.

[0021] Figure 5 illustrates a perspective view of an alternative embodiment of the waveguide polarizer 1. Figures 6 and 7 illustrate sectional views along the line VI-VI and VII-VII of the embodiment of the waveguide polarizer 1 illustrated in figure 5. The sectional view in figure 7 is downsized as compared to figures 5 and 6. The embodiment of the waveguide polarizer 1 depicted in figures 5, 6 and 7 comprises a waveguide body 2 formed in one piece with a square outline and a substantially circular inner side. The groove 7 and the supporting groove are formed by non-continuous recesses in the body wall 6 of the waveguide body 2.

Claims

1. A waveguide polarizer (1) for polarizing a radio frequency signal with a hollow waveguide body (2) extending along a central axis (3) between a first open end (4) and a second open end (5), whereby the waveguide body (2) comprises a body wall (6) of an electrically conductive material, whereby the body wall (6) encloses a waveguide cavity and whereby in a section of the waveguide body (2) the body (6) wall is recessed outwardly as to form a groove (7) in the waveguide body (2) extending at least sectionwise along the central axis (3), **characterised in that** the waveguide polarizer (1) comprises at least one ridge element (11) of the conductive material, with the at least one ridge element (11) arranged at a non-recessed section of the body wall (6) of the waveguide body (2) projecting inwardly from the body wall (6) and extending at least sectionwise along the central axis (3) .

2. Waveguide polarizer (1) according to claim 1, **characterized in that** the waveguide polarizer (1) comprises a first pair (12) of opposing ridge elements (11).

3. Waveguide polarizer (1) according to claim 2, **characterised in that** the waveguide polarizer (1) comprises a second pair (13) of opposing ridge elements (11).

4. Waveguide polarizer (1) according to claim 3, **characterised in that** the first (12) and the second pair (13) of opposing ridge elements (11) are arranged orthogonal to each other.

5. Waveguide polarizer (1) according to any of the preceding claims, **characterised in that** a cross section

orthogonal to the central axis (3) of the non-recessed section of the waveguide body (2) is circular.

6. Waveguide polarizer (1) according to any of the preceding claims, **characterised in that** the waveguide body (2) comprises a supporting groove (8) extending along the central axis (3).

7. Waveguide polarizer (1) according to any of the preceding claims, **characterised in that** an adapting element (20) comprising a dielectric material (21) with a relative permittivity larger than air is arranged inside the waveguide body (2).

8. Waveguide polarizer (1) according to claim 7, **characterised in that** the adapting element (20) is in contact with a ridge tail surface (18) of one of the at least one ridge elements (11).

9. Waveguide polarizer (1) according to claim 8, **characterised in that** the adapting element is spaced apart from the body wall.

10. Waveguide (1) polarizer according to any of the preceding claims, **characterized in that** the waveguide polarizer (1) is a radiating element.

Fig. 1

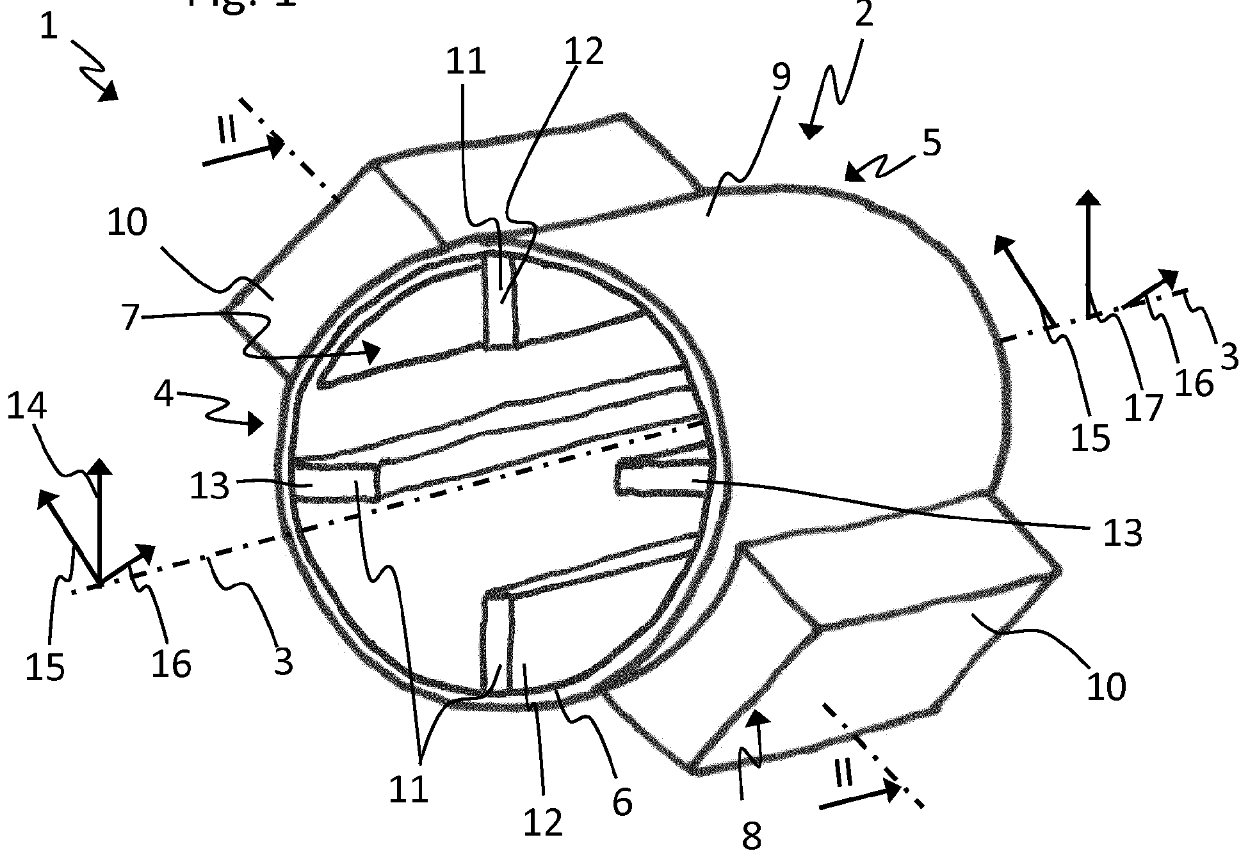
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Fig. 2

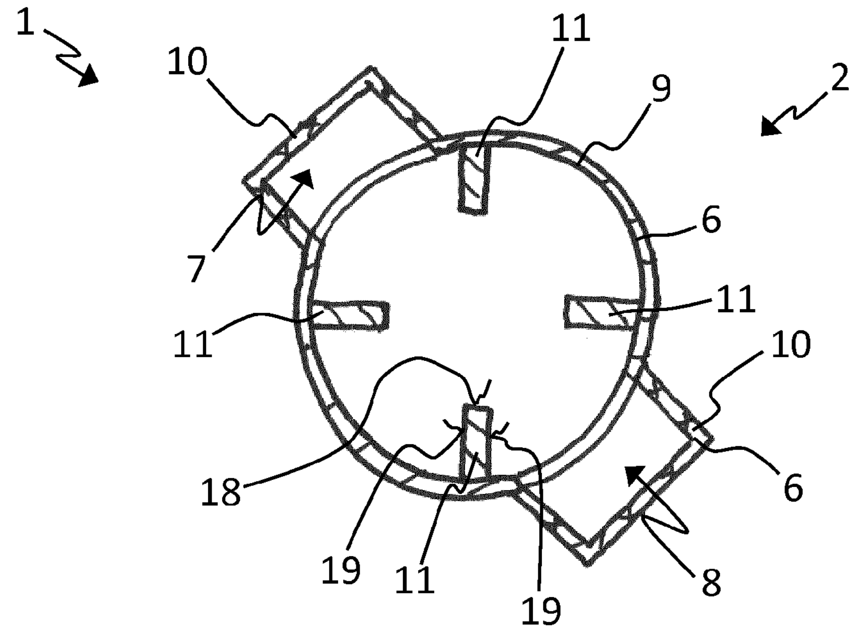
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Fig. 3

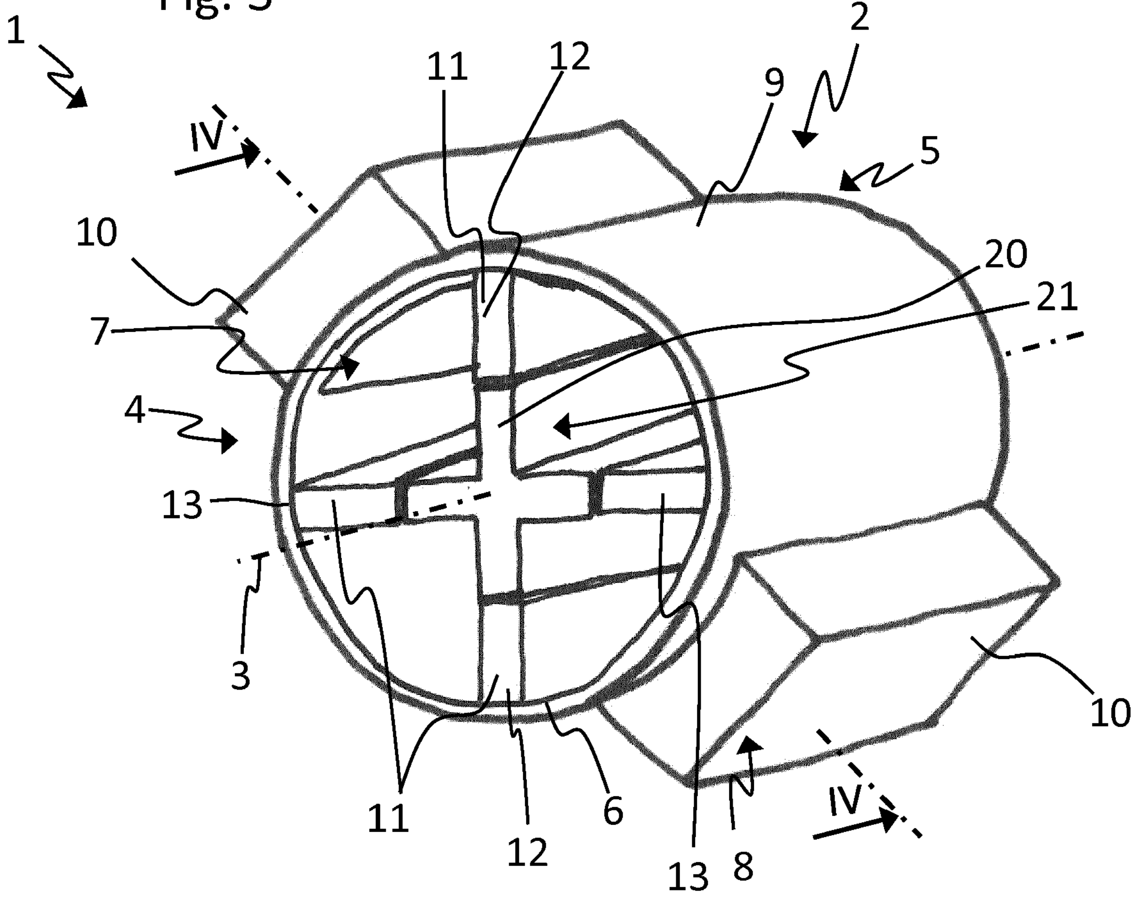
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Fig. 4

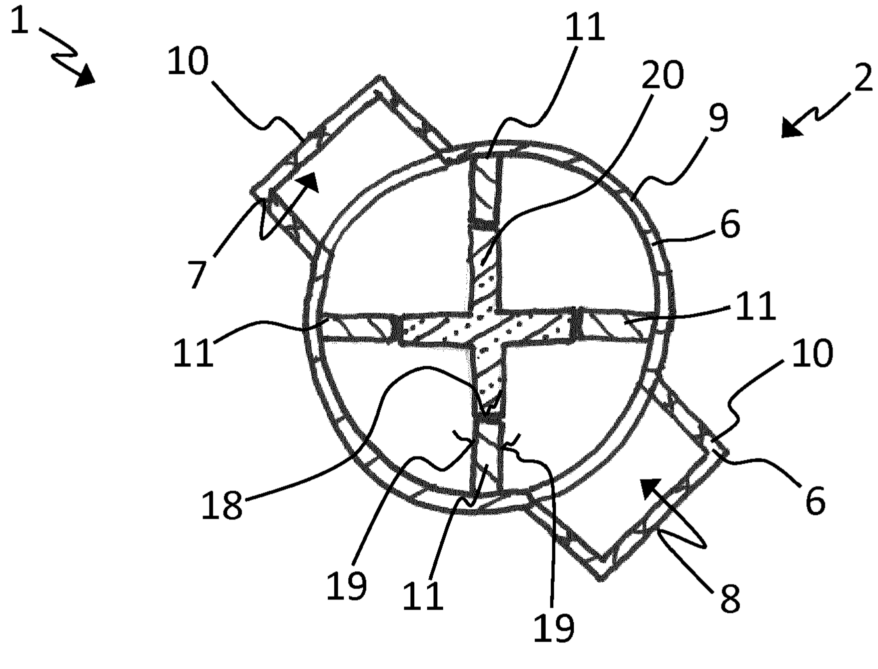
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Fig. 5

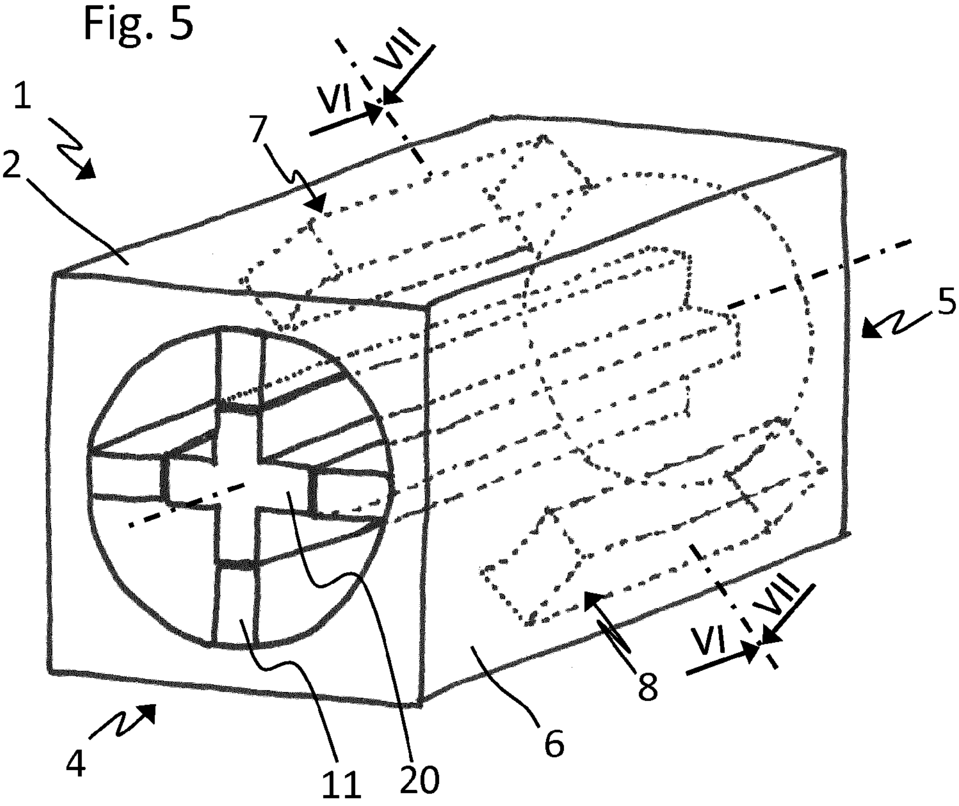


Fig. 6

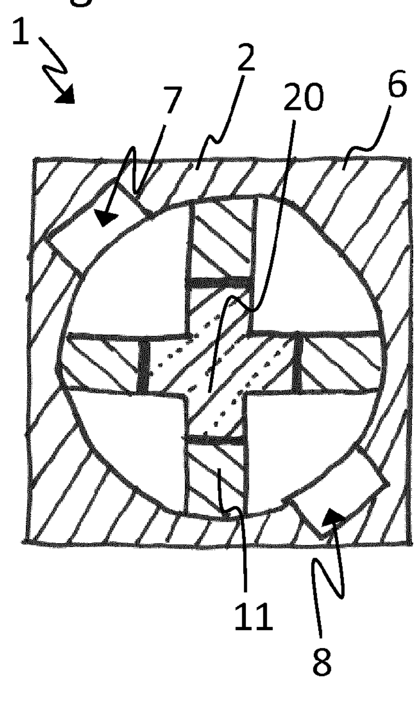
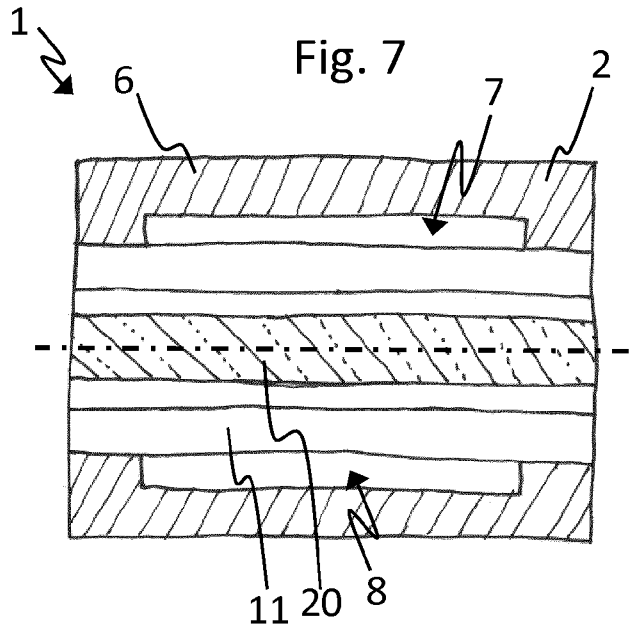


Fig. 7



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EUROPEAN SEARCH REPORT

Application Number
EP 19 19 8160

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	CN 107 275 724 A (CHENGDU SAINAWEITE TECH CO LTD) 20 October 2017 (2017-10-20) * paragraphs [0021] - [0032]; figures 1, 4, 5 *	1-6 7-10	INV. H01P1/17 H01P3/123 H01P3/127 H01P7/06 H01Q13/06 H01Q21/06
Y	US 2002/044097 A1 (YUANZHU DOU [JP]) 18 April 2002 (2002-04-18) * paragraphs [0008], [0014] - [0015], [0036] - [0041]; figures 7,8,9a,9b,9c *	7-9	
Y	US 9 972 897 B1 (RAO SUDHAKAR K [US] ET AL) 15 May 2018 (2018-05-15) * column 2, line 61 - column 3, line 64; figures 2,3 *	10	
A	YONEDA N ET AL: "A DESIGN OF NOVEL GROOVED CIRCULAR WAVEGUIDE POLARIZERS", 2000 IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM DIGEST. IMS 2000. BOSTON, MA, JUNE 11-16, 2000; [IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM], NEW YORK, NY : IEEE, US, 11 June 2000 (2000-06-11), pages 1449-1452, XP000967499, ISBN: 978-0-7803-5688-7 * lines 1-9 of section II. Configuration.; page 2446, right-hand column; figure 1 *	1-10	TECHNICAL FIELDS SEARCHED (IPC) H01P H01Q

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	31 January 2020	Georgiadis, A

CATEGORY OF CITED DOCUMENTS

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Patent document cited in search report		Publication date	Patent family member(s)	Publication date
CN 107275724	A	20-10-2017	NONE	
US 2002044097	A1	18-04-2002	NONE	
US 9972897	B1	15-05-2018	NONE	

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Patent documents cited in the description

- US 6664866 B2 **[0002]**