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(54) WAVEGUIDE ASSEMBLY

(57) The invention relates to a waveguide for electromagnetic waves in a specific bandwidth around a guide wavelength λ_g, comprising metallic walls which define:
• a first straight waveguide length (1) having a rectangular cross section (*re*) along a first axis (*A*),
• a second straight waveguide length (3) having a square cross section (*sq*) along a second axis (*B*), said second axis crossing the first axis (*A*) at a bending point (*C*), the second axis (*B*) being parallel to the shorter sides of the rectangular cross-section (*re*) of the first straight waveguide length (1),
wherein the first straight waveguide length (1) extends beyond the bending point (*C*) to define a parallelepipedic chamber (5) closed by a transverse wall (7), and the waveguide comprises three transverse ridges (r_1, r_2, r_3) which extend inside the inner space with an axial length, and are orthogonal to both first and second axes (*A, B*).

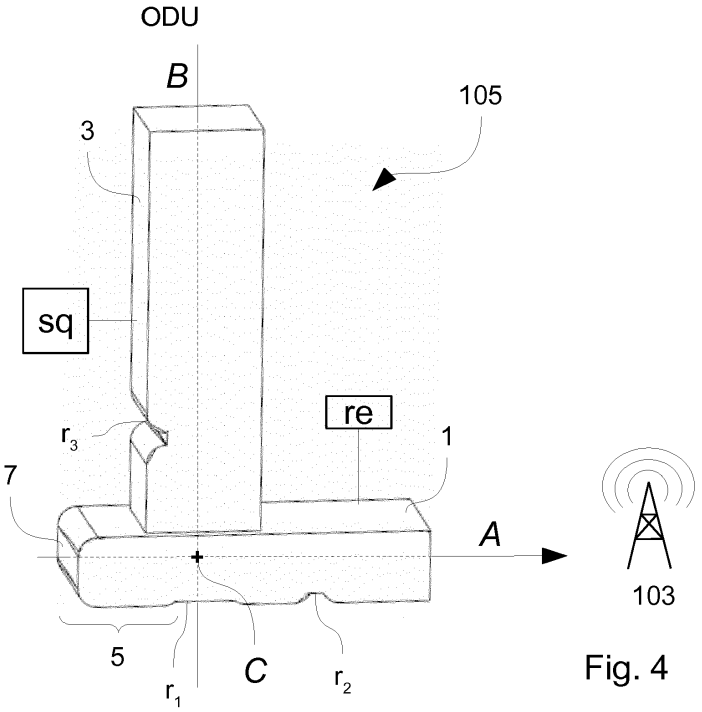

Fig. 4

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Description

[0001] The present invention concerns a waveguide assembly, in particular for microwave frequency, for example for use in orthogonal mode transmitters.

[0002] Waveguides, in particular microwave guides are made using tubular segments of constant or near-constant transverse section. The tubular segments are for example pipes made of metallic material at least on the inner surface of the walls (e.g. metal sheet on plastic walls). The skin effect and geometric properties of the waveguide then ensure that waves propagate along a longitudinal axis of the tubular segment, divided into stable electrical and magnetic propagation modes which are individual solutions to the linear propagation equation.

[0003] The tubular segments are connected to each-other using flanges, bends and articulated connectors, resulting in waveguide assemblies combining different waveguide segments, each with particular functions (combiners, bends, change in transverse section, waveband filtering, orthogonal mode selector, etc.)

[0004] The orthogonal mode transmitters use generally two microwave generating outdoor units, each producing a microwave signal using modes orthogonal to each other (e.g. TE01 and TE10). Said signals are then combined in an orthogonal mode transmission, which is forwarded to the antenna where it is emitted for wireless transmission (radar, cellular network in 2G, 3G, LTE or 4G, television etc.).

[0005] In reverse or downlink function, the orthogonally polarized signal from a receiving antenna can be separated in two single mode signals in separate guides.

[0006] The usual waveguide assemblies for orthogonal mode transmitters comprise a T shaped combiner, with two orthogonally oriented rectangular sections, and one or more rectangular to square section adapters to transform the combined rectangular single mode wavefronts in a single combined square wavefront.

[0007] In particular, said assemblies often require to combine a bend, in most cases at a straight angle, and a rectangular to square section waveguide adapter.

[0008] The waveguide segments with a bend are usually curved, chamfered or stepped angle bends with a rectangular section. The waveguide segment with a section transition may then be a stepped, straight segment in the prolongation of the rectangular bend.

[0009] The combination of said elements represents an important length, which is space consuming, costly and implies an important radiation loss due to Eddy currents during the propagation through a longer waveguide.

[0010] In order to overcome the aforementioned drawbacks, the present invention has for object a waveguide for electromagnetic waves in a specific bandwidth around a guide wavelength λ_g, comprising metallic walls which define:

- a first straight waveguide length having a rectangular cross section along a first axis,
- a second straight waveguide length having a square cross section along a second axis, said second axis crossing the first axis at a bending point, the second axis being parallel to the shorter sides of the rectangular cross-section of the first straight waveguide length,

wherein the first straight waveguide length extends beyond the bending point to define a parallelepipedic chamber closed by a transverse wall, and the waveguide comprises three transverse ridges which extend inside the inner space with an axial length and are orthogonal to both first and second axes.

[0011] The waveguide thus obtained combines a bend and a square to rectangular section transition in a compact and easily obtainable fashion. The waveguide may present one or more of the following characteristics, taken separately or in combination.

[0012] It may further comprise:

- a first transverse ridge placed on a side of the first straight waveguide length, at the point where second axis crosses the side of the first straight waveguide length opposite the second straight waveguide length,
- a second transverse ridge on the same side of the first straight waveguide length than the first transverse ridge, set apart from the first transverse ridge in the direction opposite the parallelepipedic chamber,
- a third transverse ridge on the side of the second straight waveguide length facing the parallelepipedic chamber.

[0013] The second transverse ridge may be set apart from the first transverse ridge at a length between $\lambda_g/4$ and $3\lambda_g/4$ in the direction opposite the parallelepipedic chamber, and the third transverse ridge is at a distance between $\lambda_g/4$ and $3\lambda_g/4$ of the side featuring the first and second transverse ridges.

[0014] The transverse ridges may have a transverse height inside the waveguide comprised between $\lambda_g/20$ and $\lambda_g/10$, and an axial length comprised between $\lambda_g/20$ and $3\lambda_g/8$

[0015] The first straight waveguide length may extend beyond bending point C by a length between $\lambda_g/4$ and $3\lambda_g/4$ to define the parallelepipedic chamber.

[0016] It may be formed in a non-metallic material, its inner walls being covered by a metallic sheet.

[0017] It may be formed in a metallic material.

[0018] The axial length of the first transverse ridge may be double the axial length of the second and third transverse ridges.

[0019] The axial length of the first transverse ridge may be comprised between $\lambda_g/8$ and $3\lambda_g/8$, and the axial length of the second and third transverse ridges is comprised between $\lambda_g/20$ and $\lambda_g/10$.

[0020] The invention also relates to the associated orthogonal mode transmitter, comprising :

- a first outdoor unit, generating an electromagnetic wave polarized according to a first polarization direction,
- a second outdoor unit, generating an electromagnetic wave polarized according to a second polarization direction,
- an orthogonal mode transducer, configured to combine the electromagnetic waves of the first and second outdoor units,

wherein one of the outdoor units is connected to the square section straight waveguide portion, and the other to the rectangular cross-section straight waveguide portion of a waveguide as mentioned, said waveguide being in turn connected to an orthogonal mode transducer.

[0021] The invention finally concerns the method of manufacturing a waveguide for electromagnetic waves with a wavelength around a guide wavelength λ_g, and a cut-off wavelength λ_c, comprising the following steps :

- forming in a solid material plate of a first and second straight recesses with a depth comprised between $\lambda_c/8$ and $3\lambda_c/8$ along a first and a second perpendicular axes which cross at a bending point, the first straight recess along the first axis having a width comprised between $\lambda_c/8$ and $3\lambda_c/8$, the second straight recess along the second axis having a width comprised between $\lambda_c/4$ and $3\lambda_c/4$, wherein the straight recess along the first axis extends beyond the bending point by a length comprised between $\lambda_g/4$ and $3\lambda_g/4$ to form a parallelepipedic chamber, said straight recesses presenting steps forming transverse ridges in the milled out volume, comprising :
    - a first transverse ridge placed on a side of the first straight recess, at the point where second axis crosses the side of the first straight recess opposite the second straight recess,
    - a second transverse ridge on the same side of the first straight recess than the first transverse ridge, set at a length between $\lambda_g/4$ and $3\ \lambda_g/4$ apart from the first transverse ridge in the direction opposite the parallelepipedic chamber,
    - a third transverse ridge on the side of the second straight waveguide length facing the parallelepipedic chamber, at a distance between $\lambda_g/4$ and $3\lambda_g/4$ of the straight recess featuring the first and second transverse ridges;
- forming of symmetrical straight recesses in another plate of solid material,
- assembling the milled plates to obtain a waveguide.

[0022] The solid material plate may then be a metal plate, the straight recesses milled in said plate and the step of assembling the milled plates may comprise a step of brazing the milled metal plates together.

[0023] The solid material plate may alternatively be made of plastic, and the process may further comprise a step of covering the inner walls of the straight recesses with a metallic layer.

[0024] The milled material plates may also be assembled using at least one of the following : screws, rivets, glue, flanges or cooperating complementary forms.

[0025] Other characteristics and advantages of the invention will appear at the reading of the following description, given in an illustrative and not limiting fashion, of the following figures, among which :

- figure 1 is a schematic representation of an orthogonal mode combiner for mobile network antenna,
- figure 2 is a schematic view of the waveguide used in the orthogonal mode combiner of figure 1,
- figures 3a and 3b illustrate the dimensioning of the square and rectangular cross sections of different segments of the waveguide,
- figure 4 is a schematic view of the inner space of a waveguide bend according to an aspect of the invention,
- figure 5 is a cut away of the inner space of the waveguide of figure 4,
- figure 6 is a flowchart of a process to obtain a waveguide according to figures 4 and 5,
- figures 7 and 8 illustrate some of the steps of the process of figure 6.

[0026] In all figures, the same references apply to the same element.

[0027] Though the figures refer to precise embodiments of the invention, other embodiments may be obtained by combining or altering slightly the represented embodiments, said new embodiments are also within the scope of the invention.

[0028] Figure 1 shows a schematic representation of an orthogonal mode transmitter (OMT) 100. Such orthogonal mode transmitters 100 are used in 3G and 4G wireless networks to transmit data from one antenna to a next one in the network, and thus forward data from cell to cell at network level.

[0029] The orthogonal mode transmitter 100 comprises a first outdoor unit ODU1 and a second outdoor unit ODU2.

[0030] Each outdoor unit ODU1, ODU2 generate a polarized electromagnetic wave, for example using oscillating dipoles. The electromagnetic waves of the first and second outdoor units ODU1, ODU2 are polarized in orthogonal fashion to each-other.

[0031] To generate the electromagnetic waves, the outdoor units ODU1, ODU2 may use spatially oriented dipoles. Said dipoles are oriented in orthogonal directions. In the case of circular or other non static polarization, the orthogonality may be ensured by a phase shift between the generated signals equal to $\pi/2$.

[0032] The electromagnetic waves of the outdoor units ODU1, ODU2 are combined in an orthogonal mode wave in a combiner 101. A waveguide then carries the orthogonal mode wave to an antenna 103 where the signal is emitted in electromagnetic wave form.

[0033] The orthogonal mode combiner 101 and in particular the waveguides used to combine and transmit the orthogonal mode signals are represented in greater detail in figure 2, by means of a representation of the contour of the inner free space of the waveguides. The waveguide portions with a rectangular cross section are labelled *re* in a rectangle, the portions with a square cross section are labelled *sq* in a square.

[0034] The waves in the rectangular cross sections *re* are of two different sorts : horizontally polarized (output of ODU1, *see E* field arrow) and vertically polarized (output of ODU2, *see E* field arrow). The horizontally polarized waves propagate in a rectangular cross section *re* where the longer sides of the rectangle are vertical, the vertically polarized waves propagate in a rectangular cross section *re* where the longer sides of the rectangle are horizontal.

[0035] Therefore, the output of ODU1 is here channelled in a waveguide with a vertically oblong rectangular cross-section, as shows the rectangle around the *re* caption for the corresponding waveguide segment, and the output of ODU2 is channelled in a waveguide with a horizontally oblong rectangular cross-section, as shows the orientation of the rectangle around the *re* caption for the corresponding waveguide segment.

[0036] The signal emitted by the first outdoor unit ODU1 is polarized in a transverse horizontal fashion (e.g. TE01 polarization, see *E* field arrow). Said signal is received in a square section *sq* waveguide portion, and enters a waveguide 105 according to the invention, which combines a bend and a square to rectangular cross section converter, with a transverse vertical longer side. The inner cavity of said waveguide 105 is shown in more detail in figures 4 and 5.

[0037] The signal emitted by the second outdoor unit ODU2 is polarized in a transverse vertical fashion (e.g. TE10 polarization, *see E* field arrow). Said signal is received in a square section *sq* waveguide and goes into a square to rectangular converter 107. The output of said square to rectangular converter 107 is a rectangular cross section *re* signal, with a longer transverse horizontal side. The square to rectangular converter 107 may in particular be a stepped converter as already known.

[0038] The rectangular section *re* waves are then sent to an orthogonal mode transducer 109, where the two orthogonally polarized signals with rectangular *re* cross section are combined in a single orthogonally polarized signal with a square cross section *sq.* Such orthogonal mode transducers 109 are known from the state of the art and comprise for example a T-shaped combiner and one or more stepped or inclined waveguide bends. The output of the orthogonal mode transducer 109 is then fed to the antenna 103.

[0039] The dimensioning of the square *sq* and rectangular *re* cross-sections are shown in further detail in figures 3a and 3b.

[0040] The electromagnetic waves conveyed in the waveguide are comprised in a frequency band comprised between two extremal frequency values with a factor of 2 between a lower and an upper cut-off frequency, f_1 and f_2 respectively.

[0041] The square *sq* cross section has for side length the parameter *a* (figure 3a). Said side length *a* is also the length of the longer side of the rectangular *re* cross section, the short side of which has for length *a*/2 (half the length parameter *a*).

[0042] The length parameter *a* is bound to the lower cut off frequency by $a \geq 163/f_1$ where *a* is given in millimetres (mm) and f_1 is given in gigahertz (GHz). In particular, the chosen length *a* defines a guide cut-off wavelength λ_c given by $2a = \lambda_c$. The chosen frequency band also defines a nominal waveguide length λ_g. In the discussions hereafter, the lengths are given in terms of said nominal guide and cut-off wavelength valuec λ_g, λ_c.

[0043] In particular, the frequency domain than can be used with a waveguide according to the invention is reaching from 5,9GHz to 86GHz with different side length parameters *a* for different frequency bands.

[0044] The inner space of the waveguide bend 105 as defined by its walls is represented in more detail in figures 4 and 5.

[0045] In figure 4, the form of said inner space is represented in perspective. Figure 5 is a cross section of the waveguide around the bend.

[0046] The waveguide bend 105 comprises two straight portions : a first straight waveguide length 1 having a rectangular *re* section along a first axis *A*, and a second straight waveguide length 3 having a square section *sq* along a second axis *B.* The square section *sq* is oriented with two of its sides parallel to the second axis *B.*

[0047] The first and second axes *A* and *B* cross at a bending point *C* and define a sagittal symmetry plane for the represented volume.

[0048] The first straight waveguide portion 1 extends beyond bending point *C* by a length comprised between $\lambda_g/4$ and $3\lambda_g/4$, in particular around $\lambda_g/2$, and defines a parallelepipedic chamber 5 closed by a transverse wall 7 on its far end from bending point *C* on the side opposite the opening leading to the antenna 103.

[0049] The waveguide bend 105 also comprises three transverse ridges: a first transverse ridge r_1, a second transverse ridge r_2, and a third transverse ridge r_3, which extend inside the inner space at a transverse height comprised for example between $\lambda_g/20$ and $\lambda_g/10$, and an axial length comprised for example between $\lambda_g/20$ and $3\lambda_g/8$. The first, second and third transverse ridges, respectively r_1, r_2, r_3 cover the whole transverse breadth (orthogonal to axes *A* and *B*) of their respective straight waveguide lengths 1, 3.

[0050] The first transverse ridge r_1 is placed on a side of the first straight waveguide length 1, at the point where second axis *B* crosses the side of the first straight waveguide length 1 opposite the second straight waveguide length 3, and has a length parallel to first axis *A* comprised between $\lambda_g/8$ and $3\lambda_g/8$, in particular around $\lambda_g/4$.

[0051] The second transverse ridge r_2 is set on the same side of the first straight waveguide length 1 than the first one, at a length between $\lambda_g/4$ and $3\lambda_g/4$, in particular around $\lambda_g/2$, apart from the first one in the direction opposite to the parallelepipedic chamber 5, with a length along the first axis *A* comprised between $\lambda_g/20$ and $\lambda_g/8$, in particular around $\lambda_g/10$.

[0052] The third transverse ridge r_3 is located on the side of the second straight waveguide length 3 facing the parallelepipedic chamber 5, at a distance between $\lambda_g/4$ and $3\lambda_g/4$, in particular around $\lambda_g/2$ of the first axis *A*, with a length along the first axis *A* comprised between $\lambda_g/20$ and $\lambda_g/8$, in particular around $\lambda_g/10$.

[0053] The second and third transverse ridges r_2, r_3 modify the wavefront of the incoming electromagnetic waves in direction of bending point *C,* so that a stationary wave is generated in the space corresponding to the parallelepipedic chamber 5, prolonged inside the rectangular cross section *re* waveguide length 1 until reaching the first transverse ridge r_1. The stationary wave and the inclined wavefronts ensure a loss remaining under 25dB over the whole considered frequency domain (e.g. the E band in EHF domain, from 71 to 86GHz).

[0054] The parallelepipedic chamber 5, with a length around $\lambda_g/2$, forms a "stub"; it acts as a resonance cavity, in which a standing wave resides in continuous operating. The three transverse ridges r_1, r_2, r_3, create small perturbations inside the waveguide, and improve matching and transmission over the waveguide bend 105, while increasing the transmittable frequency through the waveguide bend 105.

[0055] In the figures 4 and 5, the edges extending along the transverse axis orthogonal to both axes *A* and *B* are represented rounded, since the waveguide bend 105 can be obtained by milling in a plate parallel to the sagittal plane along said transverse axis, so that the edges are rounded to the diameter of the cutting-tool.

[0056] An example of a process to elaborate such a waveguide bend 105 is represented in figures 6 to 8. Figure 6 is a flowchart of the process 200 depicting its main steps in linear fashion.

[0057] The first step 201, as illustrated in figure 7 is the milling in a solid material plate 9 of a volume corresponding to one half of the previously described volume as divided by the sagittal plane. In particular, the first step 201 is made by milling a first and a second straight recesses 1a, 3a with a depth comprised between $\lambda_c/8$ and $3\lambda_c/8$, in particular around $\lambda_c/4$.

[0058] The first straight recess 1a is milled along first axis *A* with a width comprised between $\lambda_c/8$ and $3\lambda_c/8$, in particular equal to its depth, and extends beyond bending point *C* by a length comprised between $\lambda_g/4$ and $3\lambda_g/4$, in particular around $\lambda_g/2$, to define the parallelepipedic chamber 5. Said first straight recess 1a corresponds to one half of the first straight waveguide length 1.

[0059] The second straight recess 3a is milled along second axis *B* with a width comprised between $\lambda_c/4$ and $3\lambda_c/4$, in particular around $\lambda_c/2$, and equal to double its depth. Said second straight recess 3a corresponds to one half of the second straight waveguide length 3.

[0060] The first, second and third transverse ridges r_1, r_2, r_3 are also delimited by preserving three steps on the sides of the milled straight recesses 1a and 3a, a first step corresponding to the first transverse ridge r_1 placed on a side of the first milled straight recess 1a, at the point where second axis *B* crosses the side of the first straight recess opposite the second straight recess 3a, a second step corresponding to the second transverse ridge r_2 on the same side of the first straight recess 1a than the first step (corresponding to the first transverse ridge r_1), set at a length between $\lambda_g/4$ and $3\lambda_g/4$ apart from the first step corresponding to the first transverse ridge r_1 in the direction opposite the parallelepipedic chamber 5, and a third step corresponding to the third transverse ridge r_3 on the side of the second straight recess 3a facing the parallelepipedic chamber, at a distance between $\lambda_g/4$ and $3\lambda_g/4$ of the side featuring the first and second transverse ridges r_1, r_2.

[0061] In a second step 203, a symmetrical form is milled in a second plate 11 (figure 8) using the plane containing the axes *A* and *B* as symmetry plane.

[0062] In the case of a plastic material plate 9, an additional step 205 must be integrated, in which the interior walls of the straight recesses 1a, 3a are covered with a layer of metal, for example by applying a metallic sheet on said walls, by sputtering or by chemical vapour deposition (CVD); layer thick enough to generate a skin effect (at least 4 or 5 times the skin depth of the metal at the highest considered wavelength).

[0063] In case the milling is performed in metallic plates 9, 11, the additional step 205 can be a step of reducing the roughness of the interior surfaces, using for example a second milling pass with a different cutting tool, a higher rotation speed and lower chipping depth.

[0064] The next step 207 is the assembling of the two plates 9, 11, as depicted in figure 8.

[0065] The assembling can be done using brazing in the case where the plates 9, 11 are metallic. As an alternative the assembling can be done using screws, rivets, glue, flanges or cooperating complementary forms.

[0066] The straight recesses 1a along axis *A* then form the first straight waveguide portion 1, and the straight recesses 3a along axis *B* then form the second waveguide straight portion 3.

[0067] The waveguide bend 105 combining a bend and a square to rectangular converter can then be implemented in an orthogonal mode transmitter 100 as depicted in figures 1 and 2. Other possible uses include radar imaging, and network communication other than 3G or 4G cell-to-cell.

Claims

1. Waveguide for electromagnetic waves in a specific bandwidth around a guide wavelength λ_g, comprising metallic walls which define:

- a first straight waveguide length (1) having a rectangular cross section (*re*) along a first axis (*A*),
- a second straight waveguide length (3) having a square cross section (*sq*) along a second axis (*B*), said second axis crossing the first axis (*A*) at a bending point (*C*), the second axis (*B*) being parallel to the shorter sides of the rectangular cross-section (*re*) of the first straight waveguide length (1),

wherein the first straight waveguide length (1) extends beyond the bending point (*C*) to define a parallelepipedic chamber (5) closed by a transverse wall (7), and the waveguide comprises three transverse ridges (r_1, r_2, r_3) which extend inside the inner space with an axial length, and are orthogonal to both first and second axes (*A, B*).

2. Waveguide according to claim 1, comprising:

- a first transverse ridge (r_1) placed on a side of the first straight waveguide length (1), at the point where second axis (*B*) crosses the side of the first straight waveguide length (1) opposite the second straight waveguide length (3),
- a second transverse ridge (r_2) on the same side of the first straight waveguide length (1) than the first transverse ride (r_1), set apart from the first transverse ridge (r_1) in the direction opposite the parallelepipedic chamber (5),
- a third transverse ridge (r_3) on the side of the second straight waveguide length (3) facing the parallelepipedic chamber (5).

3. Waveguide according to claim 1 or 2, wherein the second transverse ridge (r_2) is set apart from the first transverse ridge (r_1) at a length between $\lambda_g/4$ and $3\lambda_g/4$ in the direction opposite the parallelepipedic chamber (5), and the third transverse ridge (r_3) is at a distance between $\lambda_g/4$ and $3\lambda_g/4$ of the side featuring the first and second transverse ridges (r_1, r_2).

4. Waveguide according to any of the preceding claims, wherein the transverse ridges have a transverse height inside the waveguide comprised between $\lambda_g/20$ and $\lambda_g/10$, and an axial length comprised between $\lambda_g/20$ and $3\lambda_g/8$

5. Waveguide according to any of the preceding claims, wherein the first straight waveguide length (1) extends beyond the bending point (*C*) by a length between $\lambda_g/4$ and $3\lambda_g/4$ to define the parallelepipedic chamber (5).

6. Waveguide according to any of claims 1 to 5, wherein it is formed in a non-metallic material, its inner walls being covered by a metallic layer.

7. Waveguide according to any of claims 1 to 5, wherein it is formed in a metallic material.

8. Waveguide according to any of the preceding claims, wherein the axial length of the first transverse ridge (r_1) is double the axial length of the second and third transverse ridges (r_2, r_3).

9. Waveguide according to claim 8, wherein the axial length of the first transverse ridge (r_1) is comprised between $\lambda_g/8$ and $3\lambda_g/8$, and the axial length of the second and third transverse ridges (r_2, r_3) is comprised between $\lambda_g/20$ and $\lambda_g/8$.

10. Orthogonal mode transmitter, comprising:

- a first outdoor unit (ODU1), generating an electromagnetic wave polarized according to a first polarization direction,
- a second outdoor unit (ODU2), generating an electromagnetic wave polarized according to a second polarization direction,
- an orthogonal mode transducer (109), configured to combine the electromagnetic waves of the first and second outdoor units (ODU1, ODU2),

wherein one of the outdoor units (ODU1) is connected to the square cross-section (*sq*) straight waveguide portion (3) and the other outdoor unit (ODU2) to the rectangular cross-section (*re*) straight waveguide portion (3) of a waveguide according to any of claims 1 to 9, said waveguide being in turn connected to the orthogonal mode transducer (109).

11. Method of manufacturing a waveguide for electromagnetic waves with a wavelength around a guide wavelength λ_g, and with a cut-off wavelength λ_c comprising the following steps :

- forming in a solid material plate (9) of a first and second straight recesses (1a, 3a) with a depth comprised between $\lambda_c/8$ and $3\lambda_c/8$ along a first and a second perpendicular axes (*A, B*) which cross at a bending point (*C*), the first straight recess (1a) along the first axis (*A*) having a width comprised between $\lambda_c/8$ and $3\lambda_c/8$, the second straight recess (3a) along the second axis (*B*) having a width comprised between $\lambda_c/4$ and $3\lambda_c/4$, wherein the first straight recess (1a) along the first axis (*A*) extends beyond the bending point (*C*) by a length comprised between $\lambda_g/4$ and $3\lambda_g/4$ to form a parallelepipedic chamber (5), the first and second straight recesses (1a, 3a) presenting steps forming transverse ridges (r_1, r_2, r_3) in the milled volume, comprising:
  - a first transverse ridge (r_1) placed on a side of the first straight recess, at the point where the second axis (*B*) crosses the side of the first straight recess (1a) opposite the second straight recess (3a),
  - a second transverse ridge (r_2) on the same side of the first straight recess (1a) than the first transverse ridge (r_1), set at a length between $\lambda_g/4$ and 3 $\lambda_g/4$ apart from the first transverse ridge (r_1) in the direction opposite the parallelepipedic chamber (5),
  - a third transverse ridge (r_3) on the side of the second straight recess (3z) facing the parallelepipedic chamber (5), at a distance between $\lambda_g/4$ and $3\lambda_g/4$ of the first straight recess (1a) featuring the first and second transverse ridges (r_1, r_2);
- forming of symmetrical recesses in another plate of solid material (11),
- assembling the milled plates (9, 11) to obtain a waveguide.

12. Method according to claim 11, wherein the solid material plate (9, 11) is a metal plate, the straight recesses (1a, 3a) are milled in said plate (9, 11) and the step of assembling the milled plates (9, 11) comprises a step of brazing the milled metal plates (9, 11) together.

13. Method according to claim 11, wherein the solid material plate (9, 11) is made of plastic, and it further comprises a step of covering the inner walls of the straight recesses (1a, 3a) with a metallic layer.

14. Method according to claim 11, 12 or 13, wherein the milled material plates (9, 11) are assembled using at least one of the following : screws, rivets, glue, flanges or cooperating complementary forms.

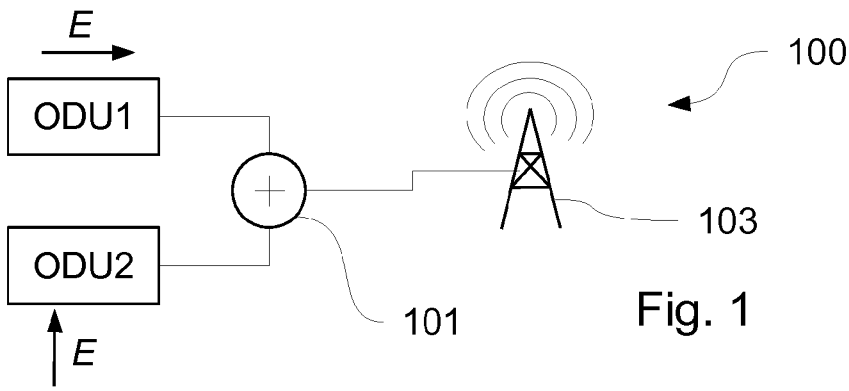


Fig. 1

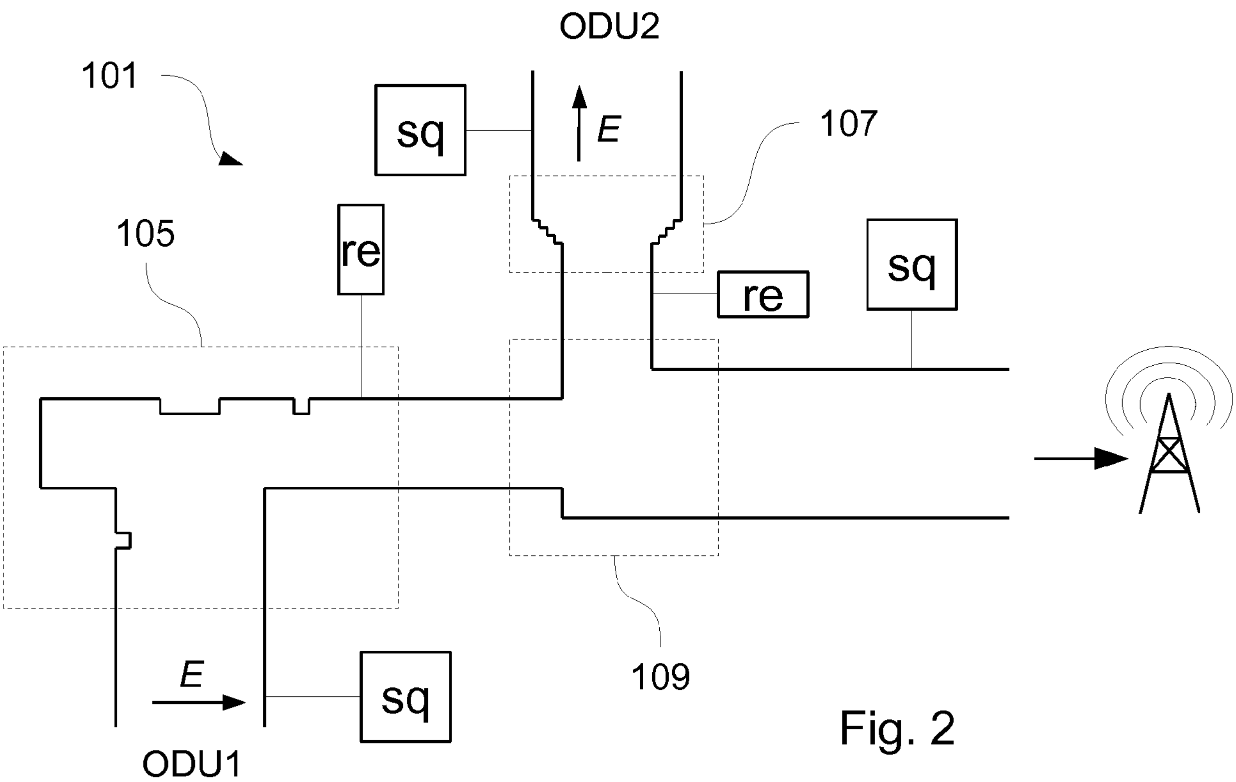


Fig. 2

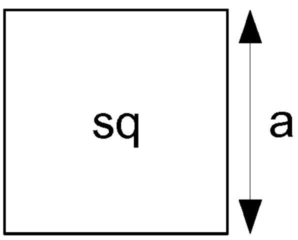


Fig. 3a

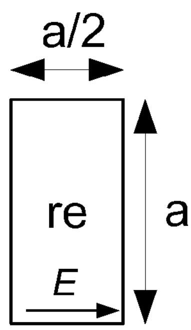
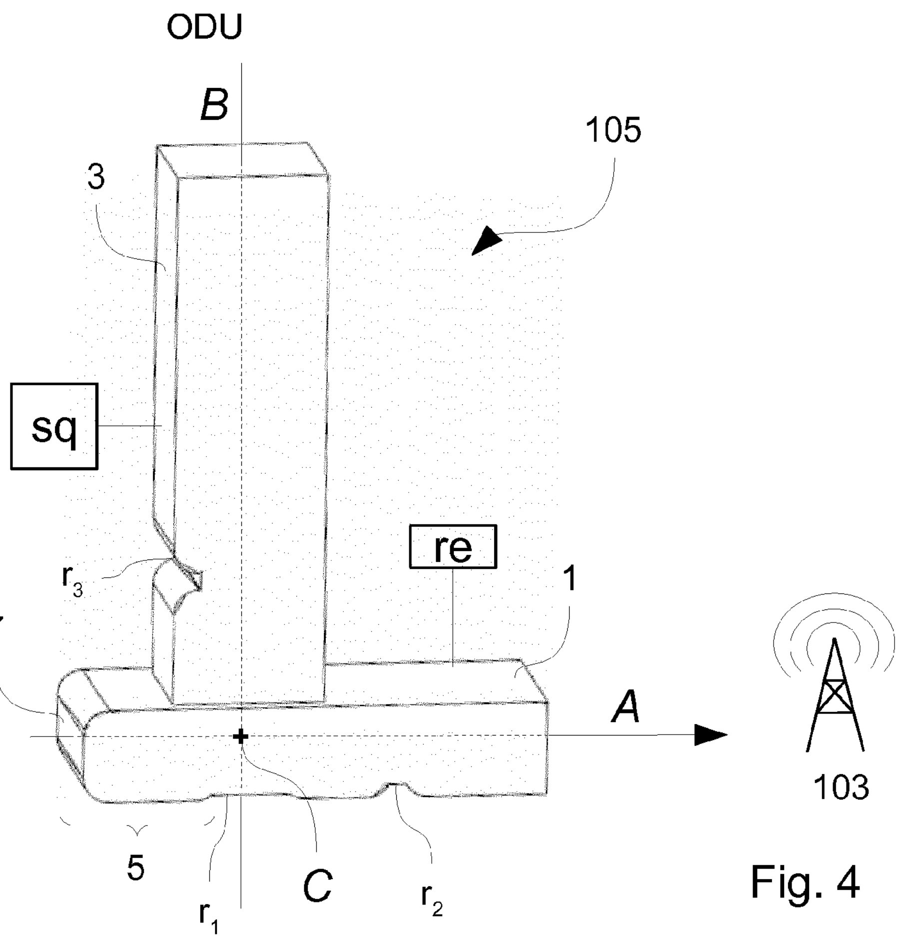


Fig. 3b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105
3
sq
re
r3
1
7
A
103
5
C
r1
r2

Fig. 4

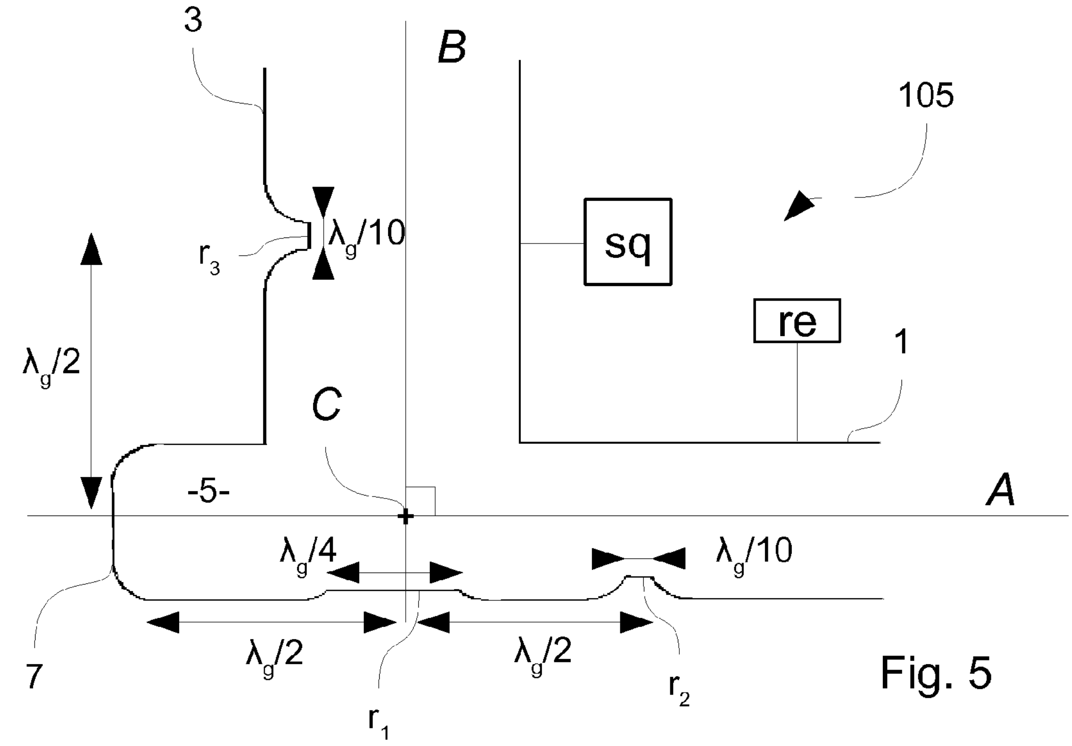
3
B
105
λg/10
r3
sq
λg/2
re
1
C
-5-
A
λg/4
λg/10
λg/2
λg/2
7
r2
r1

Fig. 5

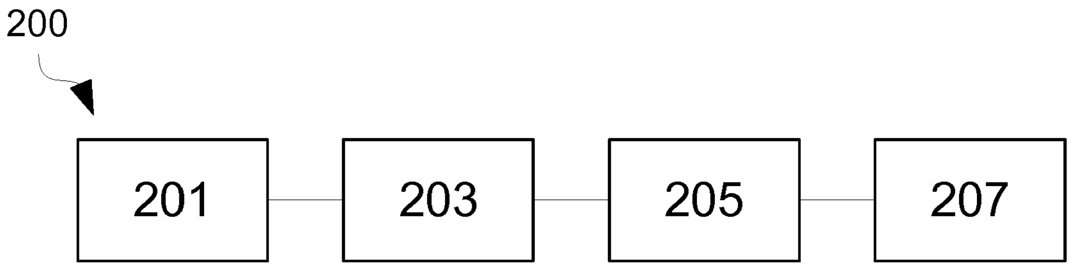

Fig. 6

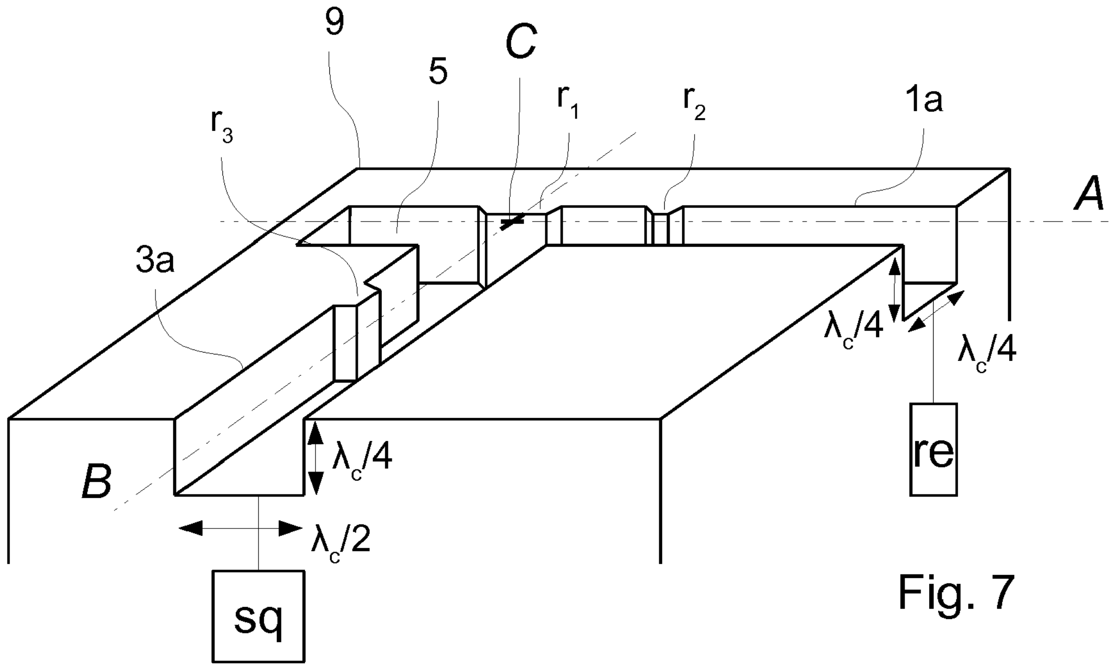

Fig. 7

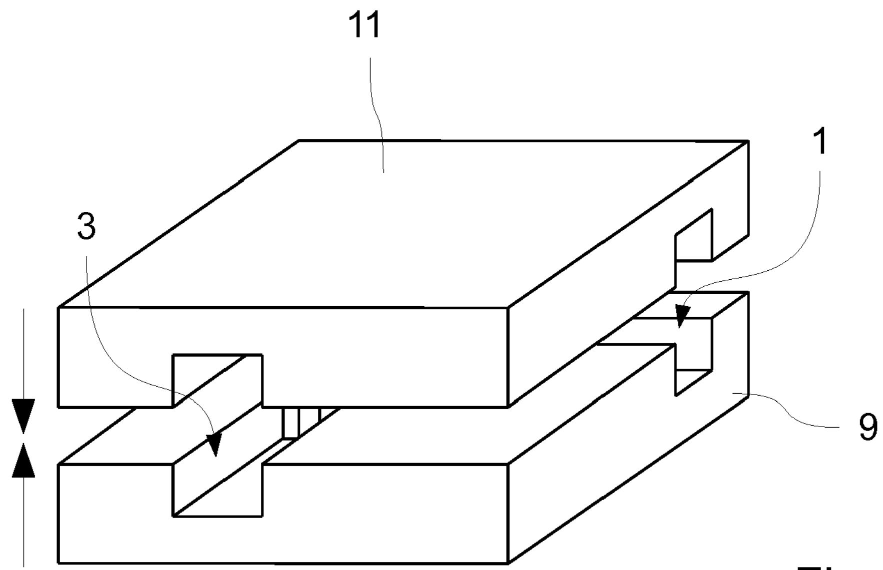

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
The Hague	5 March 2018	Pastor Jiménez, J

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	5 March 2018	Pastor Jiménez, J

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