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(54) WAVEGUIDE-TO-STRIPLINE TRANSITION

(57) The invention provides a waveguide-to-stripline transition, in particular for application in microwave systems, transmitters and receivers operating, in particular, on the E-band.

Waveguide-to-stripline transition comprising: a first ground layer (1), a second ground layer (2), a third ground layer (3) comprising a waveguide aperture (12), a first dielectric layer (4), a second dielectric layer (5), a stripline (6), a galvanic connector (7), a waveguide (8) with a closed profile, a patch (9) comprising a patch hole (11), wherein the first ground layer (1), the second ground layer (2) and the third ground layer (3) are galvanically connected to each other via a galvanic connector (7) and between the first ground layer (1) and the second ground layer (2) the first dielectric layer is positioned (4), and between the second ground layer (2) and the third ground layer (3) the second dielectric layer is arranged (5), wherein the waveguide (8), with its head face, abuts the third ground layer (3) so that the waveguide aperture (12) is positioned at the centre of the opening of the waveguide (8), and furthermore, at the level of the third ground layer (3) the patch is arranged (9) within the waveguide aperture (12), wherein at the level of the second ground layer (2) the stripline is arranged (6) which is arranged perpendicularly to the edge of the waveguide aperture (12) and it is positioned over the waveguide aperture (12) and the patch (9), wherein the galvanic connector (7) is arranged around the waveguide aperture (12), wherein the third ground layer (3) is positioned over the waveguide aperture (12) and the galvanic connector (7), and the second ground layer (2) is positioned at least in the region of the galvanic connector (7).

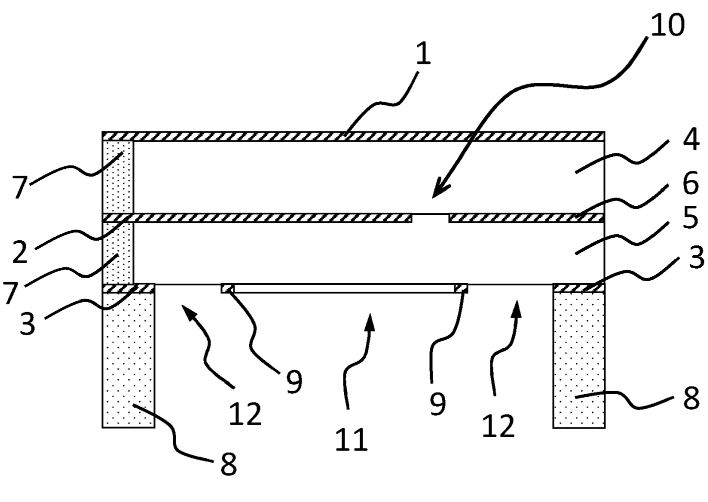

Fig. 2

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Description

[0001] The invention provides a waveguide-to-stripline transition applicable, in particular, in microwave systems, transmitters and receivers, in particular when operating on E-band.

[0002] A waveguide-to-stripline transition is necessary in building microwave systems / transmitters / receivers operating on E-band. Commercially available microwave systems such as e.g. Morpheus transceiver available from Filtronic or ADMV7310 frequency band up-converter available from Analog Devices, have inputs in a form of a WR-12 waveguide. In order to enable further relaying the output signal from the aforementioned devices and integrating it with a broader system it is necessary to provide an orthogonal transition between the waveguide and the microwave system via transmission lines, e.g., a stripline.

[0003] Document CN102074772B discloses a stripline-waveguide switch, which comprises a laminated combined body consisting of an upper strip line floor, strip line, a matching unit and a lower strip line floor, wherein the upper strip line floor is fixedly connected onto a waveguide interface of a standard waveguide; the strip line is provided with metallized via holes; the upper strip line floor and the lower upper strip line floor form navigation-limiting electromagnetic wave energy through the metallized via holes on the strip line and the navigation-limiting electromagnetic wave energy only enters a carinal cavity transmitted by a main die of the standard waveguide, so that the energy is concentrated at the periphery of a clearance formed between two ends of the matching unit and the wide side of the standard waveguide, and the strip line is transmitted to the standard waveguide. The invention has the advantages of low insert loss, high conversion efficiency, simple and compact structure and low requirements for the positioning precision of the connection, can be connected by screws and is especially suitable for a Ka waveband transmission line mode.

[0004] Publication "Design and Experimental Investigation of the Waveguide-to-Stripline Transition for V-Band Applications" discloses a simple and easy for implementation in a conventional PCBs manufacturing process a waveguide-to-stripline transition for V-band applications. A construction of the back-to-back type simulated by means of EM is characterized by the width of the operational bandwidth of 4.15 GHz (5,9%) and 1,18 dB insertion loss at the centre frequency of 70 GHz. Experimental results show a shift in frequency response by 5 GHz (~7%) which is identified as a result of absence of coaxiality of the waveguide. This finding has been additionally confirmed by EM simulations which illustrate a similar bandwidth and insertion loss as measured.

[0005] The object of the invention is a waveguide-to-stripline transition comprising a first ground layer, a second ground layer, a third ground layer comprising a waveguide aperture, a first dielectric layer, a second dielectric layer, a stripline, a galvanic connector, a waveguide with a closed profile, a patch comprising a patch hole, and is characterized in that the first ground layer, the second ground layer and the third ground layer are galvanically connected to each other via a galvanic connector, wherein between the first ground layer and the second ground layer the first dielectric layer is arranged, and between the second ground layer and the third ground layer the second dielectric layer is arranged. The waveguide with its head face abuts the third ground layer so that the waveguide aperture is positioned at the centre of the opening of the waveguide. Furthermore, at the level of the third ground layer the patch is arranged within the waveguide aperture, wherein the galvanic connector is arranged around the waveguide aperture. The third ground layer is in turn arranged over the waveguide aperture and the galvanic connector, and the second ground layer is arranged symmetrically at the centre of the waveguide aperture, wherein at the level of the second ground layer a line of the stripline type is arranged perpendicularly to the edge of the waveguide aperture and positioned over the waveguide aperture and the patch. Further on, the galvanic connector is arranged around the waveguide aperture.

[0006] Preferably, the second ground layer is positioned over the waveguide aperture, patch and the patch hole, and moreover between the second ground layer and the stripline there is a spacing.

[0007] Preferably, the patch hole is positioned symmetrically at the centre of the patch.

[0008] Preferably, stripline is positioned in the symmetry axis of the waveguide aperture.

[0009] Preferably, before the stripline an impedance transformer is positioned additionally in a form of at least one discrete change in the stripline width.

[0010] Preferably, the galvanic connector is implemented in a form of bushes distributed around the waveguide aperture, additionally the bushes are round.

[0011] Preferably, the patch, the patch hole and the waveguide aperture are rectangular.

[0012] Preferably, the waveguide is rectangular, and additionally is of a WR-12 type or a WR-15 type.

[0013] Preferably, the first dielectric layer and/or second dielectric layer have a thickness of 0.0635-0.1905 mm +/-10%, preferably the thickness is 0.127 mm +/-10%.

[0014] Preferably, the first dielectric layer and the second dielectric layer have the same thickness.

[0015] Preferably, the end of the stripline is positioned 0.075mm from the edge of the patch, specifically the end of the stripline is positioned over the patch hole.

[0016] It is the aim of the invention to obtain a microwave transition with the use of a line of the type of a stripline and a waveguide to enable building a multilayered integrated systems and by which in the link structure no adapter is necessary.

[0017] The subject-matter of the invention is shown in an embodiment in the drawings where:

fig. 1 is a top view of a layer of the waveguide-to-stripline transition comprising the third ground layer,

fig. 2 shows a cross-section A-A of fig. 1 of all the layers of the waveguide-to-stripline transition,

fig. 3 is a top view of a layer of the waveguide-to-stripline transition comprising a second ground layer,

fig. 4 is a top view of the stacker-up layers of the waveguide-to-stripline transition comprising a second ground layer and a third ground layer,

fig. 5 shows a plot of reflection parameters for a specific embodiment,

fig. 6 shows a plot of transmission parameter for a specific embodiment.

[0018] The invention is a developed transition between a waveguide, in particular a WR-12 waveguide, and a line of a stripline type operating on the bandwidth of 73-76GHz (parameters Sxx<-15dB). Nevertheless it should be emphasized that suitable changes in the dimensions may change the operational bandwidth and a person skilled in the art will be aware, based on the disclosure of the subject solution, of the impact of the individual elements on the parameters of the waveguide-to-stripline transition.

[0019] The waveguide-to-stripline transition according to an embodiment comprises a first ground layer 1, a second ground layer 2, a third ground layer 3 comprising a waveguide aperture 12, a first dielectric layer 4, a second dielectric layer 5, a stripline 6, a galvanic connector 7, a waveguide 8 with a closed profile, and a patch 9 comprising a patch hole 11. The first ground layer 1, the second ground layer 2 and the third ground layer 3 are galvanically connected to each other via a galvanic connector 7. Between the first ground layer 1 and the second ground layer 2 the first dielectric layer 4 is positioned, and between the second ground layer 2 and the third ground layer 3 the second dielectric layer 5 is arranged. The waveguide 8 abuts the third ground layer 3 so that the waveguide aperture 12 is positioned at the centre of the opening of the waveguide 8, and the waveguide 8 abuts with its head face which during signal transmission is orthogonal the direction of wave propagation. At the level of the third ground layer 3 the patch is arranged 9 within the waveguide aperture 12. At the level of the second ground layer 2 the stripline 6 is arranged which is positioned perpendicularly to the edge of the waveguide aperture 12 and it is positioned over the waveguide aperture 12 and the patch 9. The galvanic connector 7 is arranged around the waveguide aperture 12 and it provides a possibly equal and the same potential in the whole region of the first ground layer 1, second ground layer 2 and the third ground layer 3. The third ground layer 3 is positioned over the waveguide aperture 12 and the galvanic connector 7, and the second ground layer 2 is positioned at least in the region of the galvanic connector 7. The waveguide 8 is made of metal.

[0020] In an embodiment, the first dielectric layer 4 and the second dielectric layer 5 are made from the material Isola Astra MT 77, and a person skilled in the art will appreciate that another material with a similar permittivity may be used instead. For example, the first dielectric layer 4 and/or the second dielectric layer 5 have a thickness of 0.0635-0.1905 mm +/-10%, preferably the thickness is 0.127 mm +/-10%. It should be noted that a transition may be produced in which the first dielectric layer 4 and the second dielectric layer 5 have the same thickness, and this facilitates calculation work as well as simplifies the technological process. A person skilled in the art will appreciate that a change in the thickness of the first dielectric layer 4 and/or the second dielectric layer 5 will surely involve a necessity for a change in the dimensions of the patch 9 as well as the width of the stripline 6 and the way it overlaps the patch 9. Additionally, a change in the height of the first dielectric layer 4 and/or second dielectric layer 5 most probably will affect the operational frequency bandwidth of the transition.

[0021] The galvanic connector 7 may be implemented in any way, and the technologically simplest solution is the use of bushes distributed around the waveguide aperture 12. Preferably, the bushes are round.

[0022] The transition into a stripline 6 and not to a microstrip enables building multi-layered systems. Additionally, the developed transition does not require any special adapter or structures made of metal for proper operation, an example of such structures and adapters is shown in the publication "WR12 to planar transmission line transition on organic substrate". The whole structure may be made by means of a standard, relatively inexpensive technological process for preparing printed circuit boards. Nevertheless, there is no contradiction to making it in the LTCC technology.

[0023] In another embodiment, the second ground layer 2 is positioned over the waveguide aperture 12, the patch 9 and the patch hole 11, and between the second ground layer 2 and the stripline 6 there is a spacing 10.

[0024] The waveguide 8 is open at the site of contact with the structure. It should not remain open since the power would also emanate through the unclosed end of the waveguide 8. "Closure of the waveguide" - short circuiting may occur thanks to the first ground layer 1, as in the case of the mentioned article "Design and Experimental Investigation of the Waveguide-to-Stripline Transition for V-Band Applications", or the second ground layer 2. For the transition to operate correctly, the power in the closed waveguide 8 should be introduced into the stripline 6. Power should be directed and conditions should be created for the wave to propagate in the stripline 6.

[0025] When closing is effected with the use of the second ground layer 2, the distance of the second ground layer 2 to the first ground layer 1 is of less importance for directing energy from the waveguide 8 to the stripline 6. This distance determined the stripline's 6 impedance. When changing the thickness of the dielectric, i.e., the first dielectric layer 4 and/or second dielectric layer 5, it is a good practice to change these thicknesses equally and then adjust the width of the line 50Ω and the impedance transformer 13 so that to restore their correct impedance. Additionally, due to the fact that the distance between the patch 9 and the short circuiting is changed, the resonance conditions of the patch 9 also change. Therefore, a shorter dimension of the patch 9 should be modified and the size of the cut-out in the patch 8 should be modified proportionally, and a person skilled in the art basing on the average knowledge concerning microwave systems will be able to do it without any difficulty. In the case in which the first dielectric layer 4 and/or the second dielectric layer 5 are thickened, the shorter dimension of the patch 9 should be reduced, and if a thinned first dielectric layer 4 and/or second dielectric layer 5 are selected, the shorter dimension of the patch 9 should be slightly increased.

[0026] The second dielectric layer 5 at the stripline 6 performs the following functions:

- shorts a waveguide 8 at the end,
- directs the wave in suitable direction, and more specifically, it constitutes a transformer of modes of manners for propagating electromagnetic wave which is different for the waveguide 8 and for the stripline 6.

[0027] In another embodiment, the patch 9 is arranged symmetrically at the centre of the waveguide aperture 12. In still another embodiment, the patch hole 11 is positioned symmetrically in the centre of the patch 9. In another preferable embodiment, the stripline 6 is positioned in the symmetry axis of the waveguide aperture 12. All of the above options will be clear for a person skilled in the art - symmetry in the transitions of a waveguide-stripline is desired because it enhances the parameters of the system operation. Nevertheless, it should be noted that slight asymmetry will cause that the waveguide-to-stripline transition will be operable and the parameters of such transition will not be optimal.

[0028] In still another embodiment, the end of the stripline 6 is spaced by 0.075mm do the edge of the patch 9, preferably the end of the stripline 9 is positioned over the patch hole 11. This dimension depends on which dimensions are for the remaining elements of the transmission. The depth at which the stripline 6 is inserted and its width determine impedance of the waveguide-to-stripline transition, therefore, its dimension is adjusted so that impedance is suitably adjusted, and this leads to maximization of energy transfer. It should be understood thereby that deviations from this dimension are admissible and the parameters of such a transition will not be optimal.

[0029] In another embodiment, the waveguide 8 has a rectangular profile. In a preferable option, the waveguide 8 is of a WR-12 type or of a WR-15 type, in particular WR-12.

[0030] Due to the assumed operational bandwidth of between 71-76GHz, solely a waveguide 8 of the type WR12 and possibly WR15 may be used. If a waveguide 8 Wr-15 is used, that is bigger, and the waveguide aperture 12 is enlarged correspondingly, and the galvanic connector 7 is suitably shifted, then a change in the resonance frequency of the system of about 1,5GHz is obtained - the size of the resonant cavity is changed.

[0031] If, on the other hand, a waveguide 8 of a WR15 type is used, but all the remaining dimensions remain unchanged, then the transition will show resonance at the frequencies of 75-77GHz, and these frequencies are not recommended to be used in the case of WR15 due to a possibility to activate higher modes. It should be noted here that the use of a waveguide 8 of a WR12 type is recommended, and use of a waveguide 8 of a WR15 type is possible but may result non-optimal.

[0032] In a further embodiment, before the stripline 9 an impedance transformer 12 is positioned, preferably in a form of at least one discrete change in the width of the stripline 9. As illustrated in fig. 3, the impedance transformer 12 may be implemented as two discrete changes in the width of the stripline 6. It should be also noted that the impedance transformer 12 is not necessary for the operation of the waveguide-to-stripline transition, provided that in the entire system a 8 with the same impedance is used. With regard to the fact that impedance in microwave systems is a standard value, usually 50Ω, for the practice-related reasons such impedance transformer 12 will be necessary for proper connection of the waveguide-to-stripline transition to the rest of the system.

[0033] In another embodiment, the patch 9 is rectangular. In still another option, the patch hole 11 is rectangular. In a further embodiment, the waveguide aperture 12 is rectangular. The purpose of these features is to support one-mode propagation.

Detailed embodiment

[0034] A detailed embodiment is presented below. Nevertheless, it should be noted that a person skilled in the art will know that the provided parameters are optimal, but some deviations from the indicated dimensions are admissible. It should be noted here that in the light of other options the example presented below provides the best operational parameters.

[0035] A detailed embodiment will be described layer after layer. Between the layers there is a first dielectric layer 4 and a second dielectric layer 5, respectively - each made of the material Isola Astra MT 77 with a thickness of 0.127 mm.

[0036] Layer 1: waveguide aperture 12 with a waveguide aperture size WR12 (3.1x1.55mm) and a centrally positioned patch 9 (1.88x0.99mm) with a rectangular patch hole 11 (0.3×0.89mm).

[0037] Layer 2: stripline 6 with a primary impedance of 50Ω (initially width 0.14mm), impedance transformer 13 (width 0.24 mm and length 0.54mm), and the stripline 6 further on provides suitable decoupling of the electromagnetic field (width 0.42mm), which stripline 6 is slid over the patch 9 to a distance of 0.075mm to the outer edge of the patch 9. The second ground layer 2 covers almost the entire waveguide aperture 12 (apart from the cut-out on the stripline 6). The first ground layer 1, the second ground layer 2 and the third ground layer 3 ale mutually galvanically connected with the use of a row of bushes (diameter 0.2mm, distance between the centers of the subsequent bushes 0.3mm) which almost entirely fill the circumference of the waveguide aperture 12.

[0038] Layer 3: entirely covered by the first ground layer 1 that constitutes short-circuiting for the transition and reference ground for the stripline 6.

[0039] Electromagnetic wave propagated in the waveguide falls onto the patch 9 for which the reference layer/-ground is the second ground layer 2. Electromagnetic field initiates propagation between the patch 9 and the second ground layer 2. Stripline 6 is activated - TEM mode is generated and the electromagnetic wave is further propagated by the stripline 6.

[0040] For the above parameters, signal matching and power loss at the output have been performed. As shown in fig. 5, where the vertical axis expresses reflections in dB, and the horizontal axis shows the frequencies in GHz, within the entire assumed operational bandwidth, i.e., 73-76 GHz, the reflection parameters are at least -15dB. As seen for 511, dark line, the best reflection conditions are about -33dB and they are present for a frequency of about 73,8GHz, and for S22, light line, the best reflection conditions are at least -43dB and they are present for a frequency of about 75GHz. As shown in fig. 6, where the vertical axis expresses reflections in dB, and the horizontal axis shows frequencies in GHz, loss at the transition S21 amount to from 0,78 to 1.01dB within the entire bandwidth.

1	first ground layer
2	second ground layer
3	third ground layer
4	first dielectric layer
5	second dielectric layer
6	stripline
7	galvanic connector
8	waveguide
9	patch
10	spacing
11	patch hole
12	waveguide aperture
13	impedance transformer

Claims

1. A waveguide-to-stripline transition comprising:

a first ground layer (1),
a second ground layer (2),
a third ground layer (3) comprising a waveguide aperture (12),
a first dielectric layer (4),
a second dielectric layer (5),
a stripline (6),
a galvanic connector (7),
a waveguide (8) with a closed profile,
a patch (9) comprising a patch hole (11),
wherein the first ground layer (1), the second ground layer (2) and the third ground layer (3) are galvanically connected to each other via a galvanic connector (7) and between the first ground layer (1) and the second ground layer (2) the first dielectric layer is positioned (4), and between the second ground layer (2) and the third ground layer (3) the second dielectric layer is arranged (5),
wherein the waveguide (8), with its head face, abuts the third ground layer (3) so that the waveguide aperture (12) is positioned at the centre of the opening of the waveguide (8), and furthermore, at the level of the third ground layer (3) the patch is arranged (9) within the waveguide aperture (12),
wherein at the level of the second ground layer (2) the stripline is arranged (6) which is arranged perpendicularly to the edge of the waveguide aperture (12) and it is positioned over the waveguide aperture (12) and the patch (9),
wherein the galvanic connector (7) is arranged around the waveguide aperture (12),
wherein the third ground layer (3) is positioned over the waveguide aperture (12) and the galvanic connector (7), and the second ground layer (2) is positioned at least in the region of the galvanic connector (7).

2. The waveguide-to-stripline transition according to claim 1, wherein the second ground layer (2) is positioned over the waveguide aperture (12), the patch (9) and the patch hole (11), and between the second ground layer (2) and the stripline (6) there is a spacing (10).

3. The waveguide-to-stripline transition according to claim 1 or 2, wherein the patch (9) is arranged symmetrically at the centre of the waveguide aperture (12).

4. The waveguide-to-stripline transition according to any of the preceding claims, wherein the patch hole (11) is positioned symmetrically at the centre of the patch (9).

5. The waveguide-to-stripline transition according to any of the preceding claims, wherein stripline (6) in positioned in the symmetry axis of the waveguide aperture (12).

6. The waveguide-to-stripline transition according to any of the preceding claims, wherein the waveguide (8) has a rectangular profile.

7. The waveguide-to-stripline transition according to claim 6, wherein the waveguide (8) is of a WR-12 type or a WR-15 type.

8. The waveguide-to-stripline transition according to any of the preceding claims, wherein before the stripline (9) an impedance transformer (12) is positioned, preferably in a form of at least one discrete change in the width of the stripline (9).

9. The waveguide-to-stripline transition according to any of the preceding claims, wherein the galvanic connector (7) is implemented in a form of bushes distributed around the waveguide aperture (12), preferably the bushes being round.

10. The waveguide-to-stripline transition according to any of the preceding claims, wherein the patch (9) is rectangular.

11. The waveguide-to-stripline transition according to any of the preceding claims, wherein the patch hole (11) is rectangular.

12. The waveguide-to-stripline transition according to any of the preceding claims, wherein the waveguide aperture (12) is rectangular.

13. The waveguide-to-stripline transition according to any of the preceding claims, wherein the first dielectric layer and/or the second dielectric layer have a thickness of 0.0635-0.1905 mm +/-10%, preferably the thickness is 0.127 mm +/-10%.

14. The waveguide-to-stripline transition according to any of the preceding claims, wherein the first dielectric layer and the second dielectric layer have the same thickness.

15. The waveguide-to-stripline transition according to any of the preceding claims, wherein the end of the stripline (6) is positioned at a distance 0.075mm to the edge of the patch (9), preferably the end of the stripline (9) being positioned over the patch hole (11).

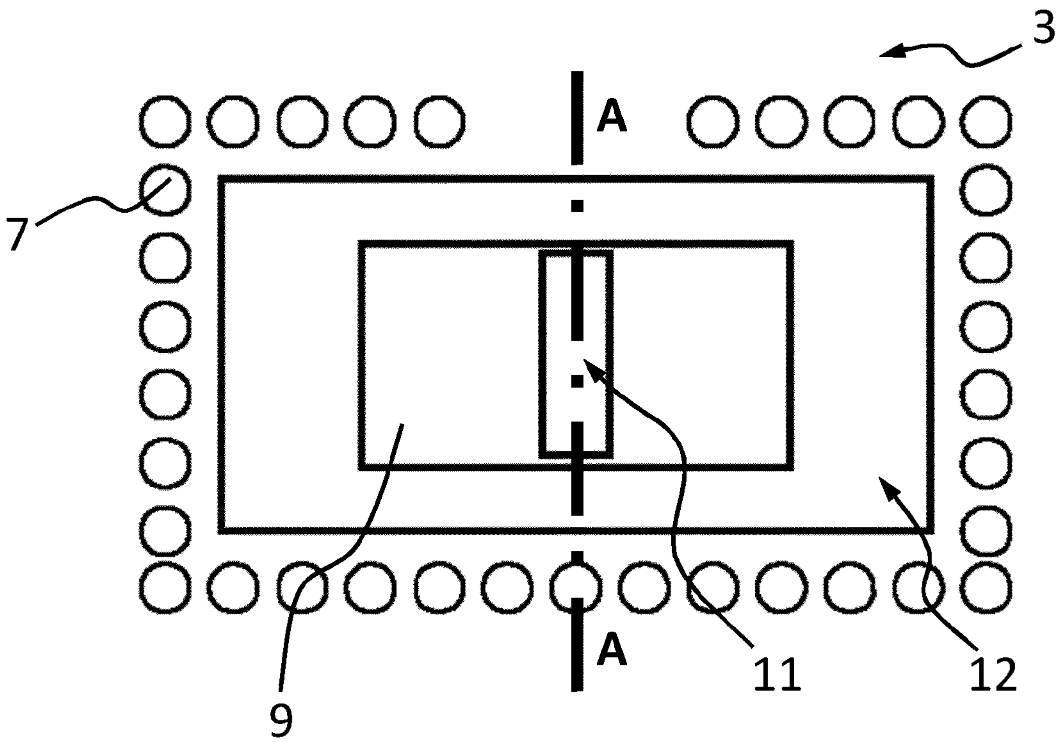

Fig. 1

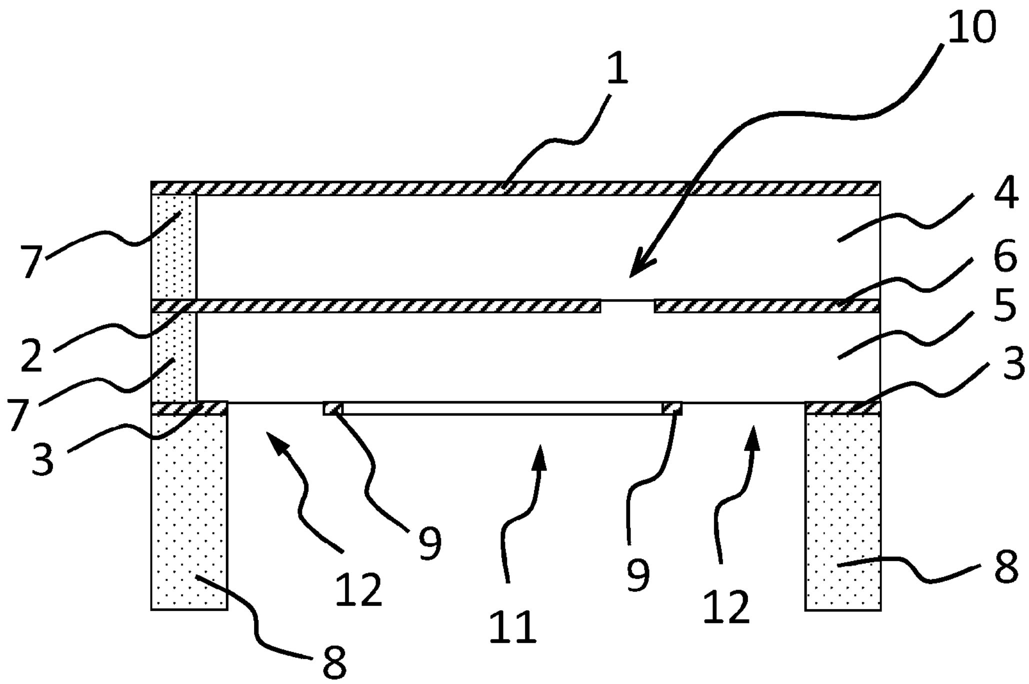

Fig. 2

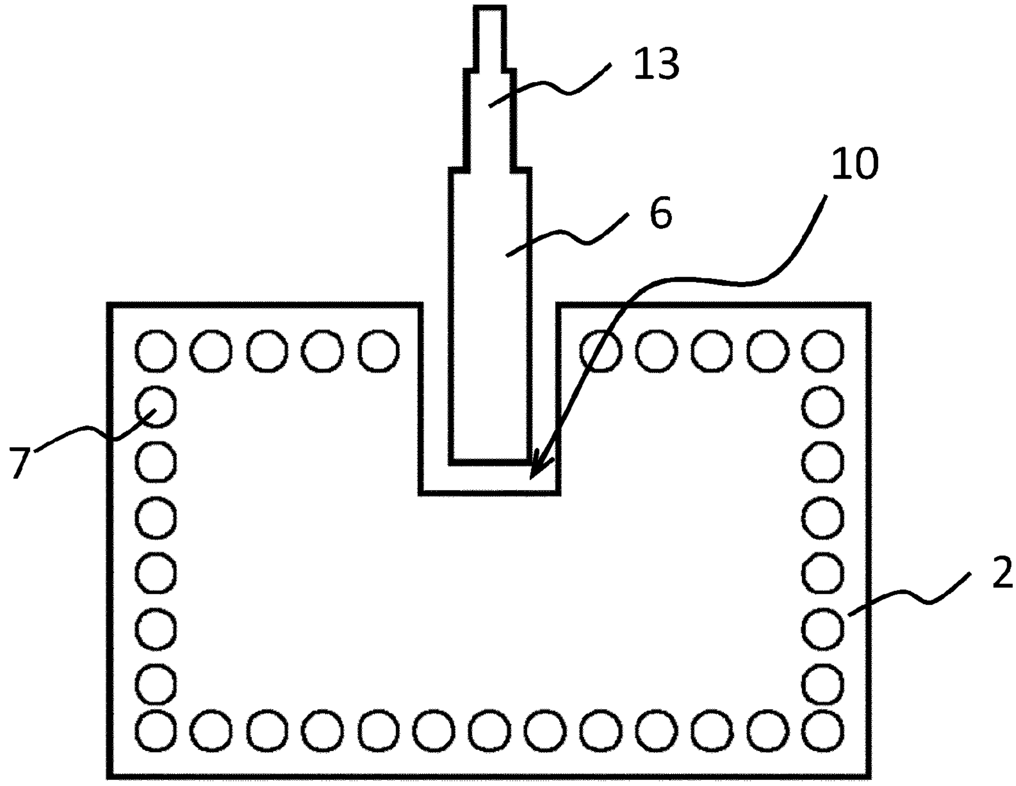

Fig. 3

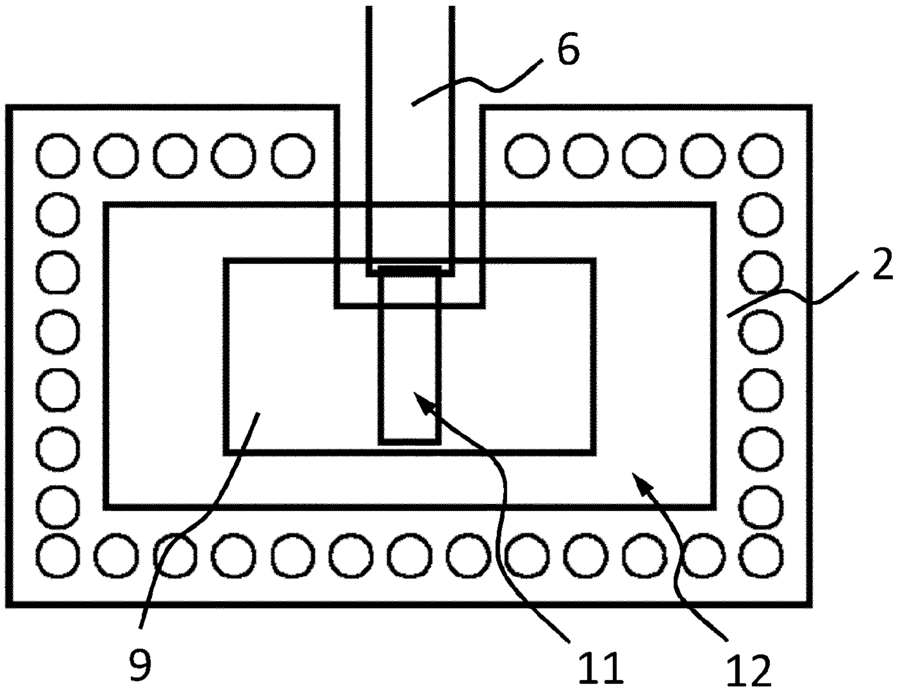

Fig. 4

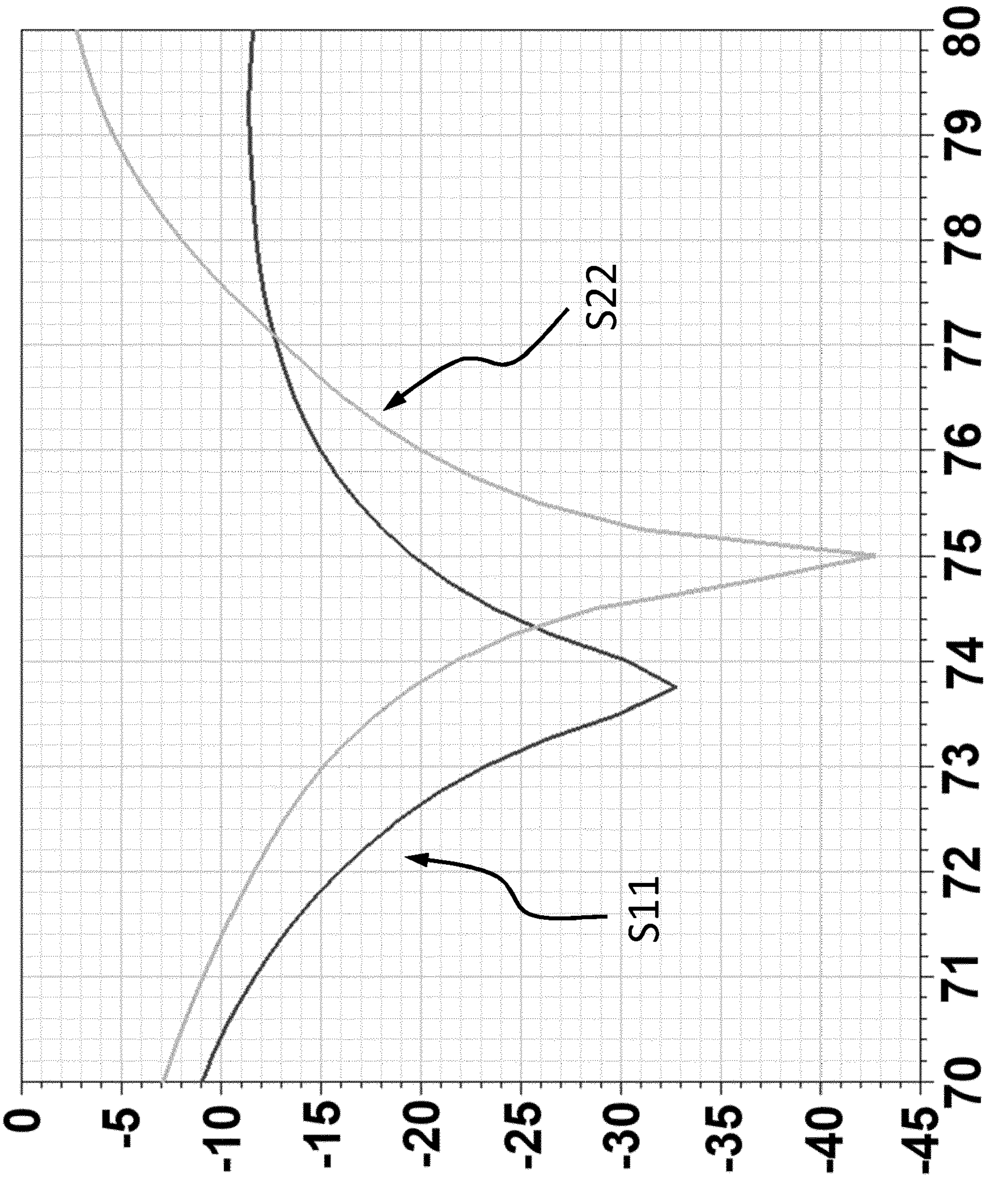

Fig. 5

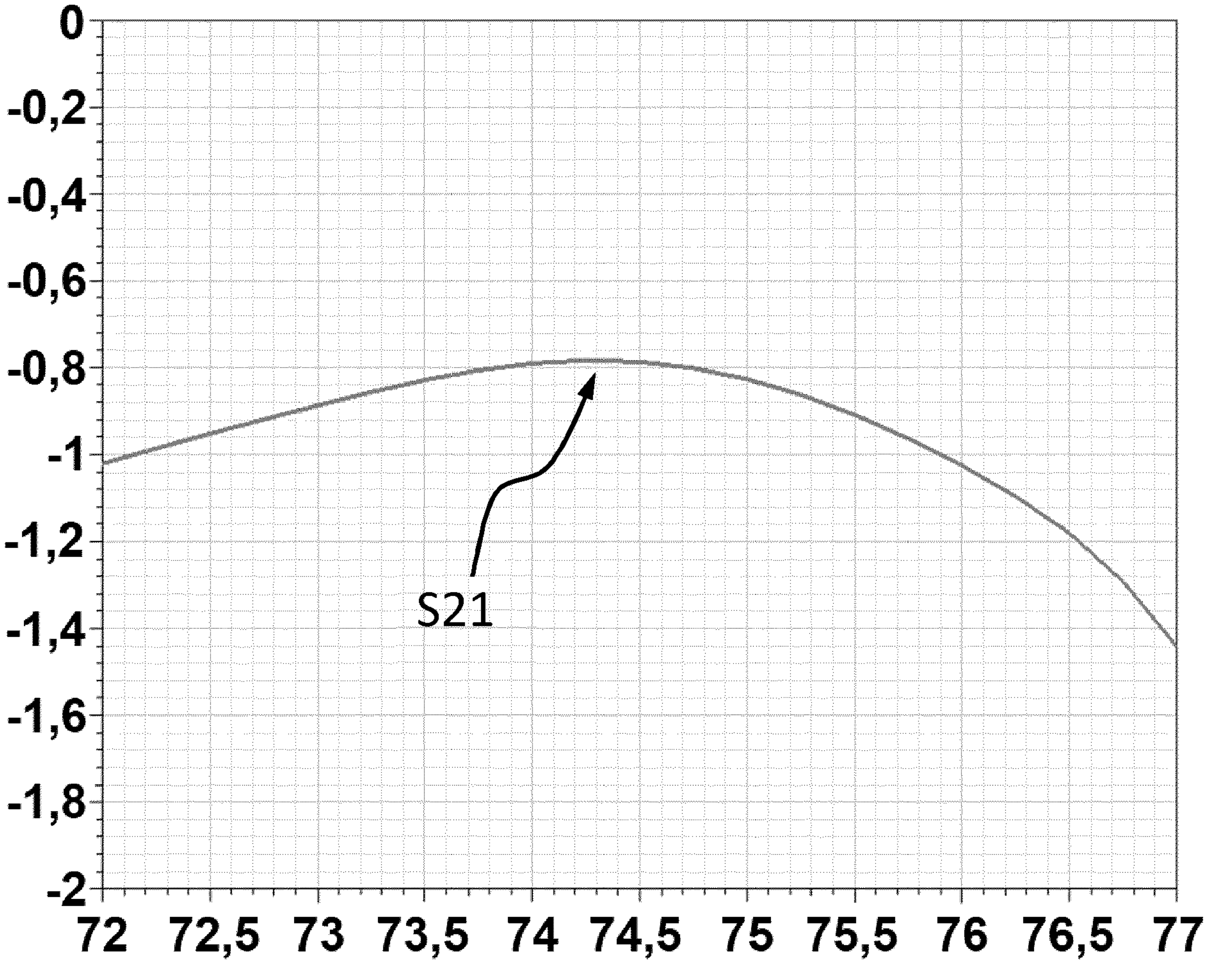

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 23 46 1650

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	JP 2017 022686 A (JAPAN RADIO CO LTD) 26 January 2017 (2017-01-26) * paragraph [0014] - paragraph [0016] * * paragraph [0037] - paragraph [0062]; figure 4 * -----	1-15	INV. H01P5/107
A	US 10 938 082 B2 (BOEING CO [US]) 2 March 2021 (2021-03-02) * column 6 - column 10; figures 1-4 * -----	1	
A,D	BARTECZKA-WILK BEATA ET AL: "Design and Experimental Investigation of the Waveguide-to-Stripline Transition for V-Band Applications", 2022 24TH INTERNATIONAL MICROWAVE AND RADAR CONFERENCE (MIKON), WARSAW UNIVERSITY OF TECHNOLOGY, 12 September 2022 (2022-09-12), pages 1-3, XP034214843, [retrieved on 2022-10-25] * chapter II; figure 1 * -----	1,8	

TECHNICAL FIELDS SEARCHED (IPC)

H01P

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	15 February 2024	Hueso González, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 46 1650

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15-02-2024

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US 10938082 B2	02-03-2021	NONE	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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