Folded waveguide resonator

Zhurbenko, Vitaliy

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(71) Applicant: **DANMARKS TEKNISKE UNIVERSITET** [DK/DK]; Anker Engelundsvej 1, Bygning 101A, 2. sal, DK-2800 Kgs. Lyngby (DK).

(72) Inventor: **ZHURBENKO, Vitaliy**; Grønnevej 56, 1th, DK-2830 Virum (DK).

(74) Agent: **SCHWARZE, Holm**; Guardian IP Consulting I/S, Diplomvej, Building 381, DK-2800 Kgs. Lyngby (DK).

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(54) Title: FOLDED WAVEGUIDE RESONATOR

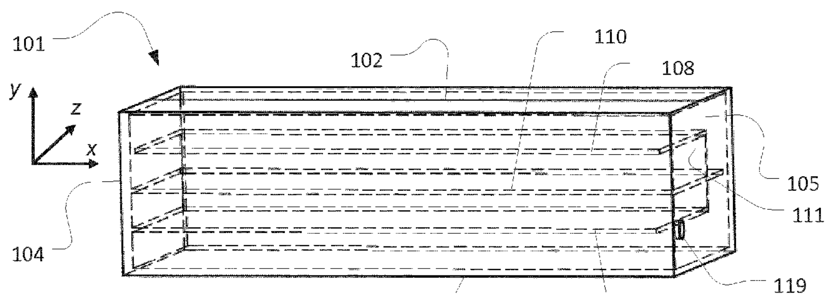

Fig. 1 a)

(57) Abstract: A waveguide resonator comprising a number of side walls defining a cavity enclosed by said sidewalls defining the cavity; and two or more conductive plates extending into the cavity, each conductive plate having a first side and a second side opposite the first side, and wherein the conductive plates are adapted to cause a standing electromagnetic wave to fold around the conductive plates along at least a first and a second direction and to extend on both sides of each of the conductive plates; wherein the conductive plates are adapted to cause the standing electromagnetic wave to fold multiple times along at least the second direction.

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Folded waveguide resonator

Field of the invention

This invention generally relates to waveguide resonators for radiofrequency (RF) or microwave filters.

Background of the invention

Waveguide resonators are important components in a wide range of devices for wireless communication, radar and other RF or microwave systems. They are frequently used as filters for selecting, rejecting, separating, and/or combining electromagnetic signals in RF/microwave systems.

There has been an increasing demand for miniaturisation and a small footprint of such components while maintaining a high quality. It is further generally desirable to maintain low or even reduced construction costs and flexibility in using such components in different applications.

A resonant cavity generally refers to a cavity that is completely enclosed by conducting walls defining the cavity. One form of a cavity resonator is thus a hollow tubular conductor blocked at both ends and along which an electromagnetic wave can be supported. Other forms of cavity resonators may be filled by a dielectric rather than being hollow. A resonant cavity allows electromagnetic fields to oscillate therein and has resonant properties. It can be viewed as a waveguide short-circuited at both ends and will also be referred to as a waveguide resonator. A waveguide resonator may have a number of resonant modes, each mode having associated with it a resonant frequency. The mode having the lowest resonant frequency is also referred to as the dominant mode of the waveguide resonator. When an electromagnetic signal is impressed on the waveguide resonator, a standing electromagnetic wave is generated within the cavity. If the frequency of the impressed signal is equal to a resonant frequency of the waveguide resonator, the amplitude of the standing wave has a maximum.

Waveguide resonators have a number of advantages, including a high quality factor, high reliability and ruggedness, low losses, response stability, accurate tunability, usability in wide frequency ranges. However, it is generally desirable to reduce the size of a resonator cavity. In particular, it would be desirable to reduce the size of the resonator cavity without – or at least only to a limited degree - negatively affecting the above parameters and/or without unduly increasing the production costs.

Height reductions of waveguide resonators have e.g. been obtained by realising them using dielectric substrates. This kind of waveguide component is also known as a laminated waveguide or substrate integrated waveguide (SIW). For example, a rectangular guide may be provided within a substrate metalized on both sides and caging the structure with rows of metal plated vias on either side. To an electromagnetic wave the rows of vias function as sidewalls, and the structure thus functions as a dielectrically-filled rectangular waveguide cavity with reduced height.

Hence, while the height of a cavity filter may be kept low, the dimensions of the footprint are related to the resonant frequency of the waveguide resonator and thus the filter characteristics.

Recently, so-called folded waveguide resonators have been proposed where the field is forced to fold inside the cavity by means of a metallic plate inserted inside the resonator, e.g. as disclosed in “Compact Partial H-Plane Filters” by Dong-Won Kim, Dong-Jin Kim, and Jeong-Hae Lee, IEEE Transactions on Microwave Theory and Techniques, Vol. 54, No. 11, November 2006. In the prior art it has been demonstrated that a 4-fold reduction can be achieved by this method when the field is caused to fold in two dimensions, e.g. as disclosed in “Miniature Folded Waveguide Resonators”, Sultan K. Alotaibi, and Jia-Sheng Hong, Sultan K. Alotaibi, and Jia-Sheng Hong, Proceedings of the 37th European Microwave Conference or in “Miniaturized Bandpass Filters With Double-Folded Substrate Integrated Waveguide Resonators in LTCC” by Hung-Yi Chien et al.; IEEE Transactions on Microwave Theory and Techniques, Vol. 57, No. 7, July 2009.

However, it remains a problem to further reduce the size of waveguide resonators.

Summary

Disclosed herein is a waveguide resonator comprising a number of side walls defining a cavity enclosed by said sidewalls defining the cavity; and two or more conductive plates extending into the cavity, each conductive plate having a first side and a second side opposite the first side, and wherein the conductive plates are adapted to cause a standing electromagnetic wave to fold around the conductive plates along at least a first and a second direction and to extend on both sides of each of the conductive plates; wherein the conductive plates are adapted to cause the standing electromagnetic wave to fold multiple times along at least the second direction.

The inventor has realised that resonant modes can be obtained where the electromagnetic field folds in two dimensions and multiple times in at least one of the dimensions by inserting two or more conductive plates into the cavity. Hence, as the electromagnetic field is folded along two directions and at least in one direction folded multiple times, e.g. more than two times, the footprint of the waveguide resonator is substantially reduced. In some embodiments, the electromagnetic field may distribute perpendicular to the plane defined by the directions along which the electromagnetic field is folded, thus further reducing the footprint of the waveguide resonator.

Embodiments of the resonator disclosed herein have a high quality factor and may be designed to have high power handling capability. For example, the quality and/or power handling may be controlled by suitable selecting the distances between the conductive plates and between the conductive plates and the side walls. Generally, increasing these distances increases the quality and power handling capability.

Some or all of the side walls may be formed by conductive plates such as metal plates or other conductive layers. Alternatively or additionally, at least some of the sidewalls may be formed by a grid of vias, i.e. conductive connections between conductive layers. The cavity may be filled by a dielectric material such as air or another suitable gas, a dielectric substrate of a SIW, and/or the like, thus causing a further reduction of the size for a given resonance frequency. The size of the resonator may be further decreased by reducing its height. For example, embodiments of the resonator described herein are compatible with planar technologies. In particular, embodiments of the waveguide resonator disclosed herein may be embodied as a cavity resonator, as a substrate integrated waveguide, as a multilayer resonator, and/or using another suitable manufacturing technology.

The cavity may be a rectangular cavity defined by pairwise parallel side walls including a pair of base walls, a pair of end walls and a pair of lateral side walls where the distance between the pair of base walls defines a height of the cavity, while the distance between the pair of end walls defines a length of the cavity and the distance between the pair of lateral side walls defines a width of the cavity. The footprint of such a cavity may be defined by the surface area of the base walls.

Each conductive plate may have at least one edge or rim that is attached to one of the side walls of the cavity. In one embodiment, some of the conductive plates each have at least two edges that are attached to respective ones of the side walls of the cavity. Each conductive plate has at least one edge that is not attached to any of the side walls, thus leaving a slot between the unattached edge and a side wall facing the unattached edge of the conductive plate. The cavity walls and the conductive plates define a waveguide geometry which meanders around the unattached edges of the conductive plates and thus extends on both sides of each of the conductive plates. At least one of the conductive plates defines a first gap or slot between a first edge of said conductive plate and a side wall where the gap extends normal to the first direction, thus causing the standing electromagnetic wave to fold around said first edge in the first direction. One or more of the conductive plates define second and third gaps or slots between second and third edges of respective ones of said one or more conductive plates and respective side walls where the second and third gaps extend normal to the second direction, thus causing the standing electromagnetic wave to fold around said second and third edges in the second direction, thus causing the standing electromagnetic wave to fold multiple times in at least the second direction. The second and third edges may face opposite side walls.

The conductive plates may be parallel to each other, and they may be parallel to one of the side walls, e.g. the base walls.

The conductive plates may be manufactured as separate plates and subsequently attached to one or more or the side walls e.g. using a suitable bonding technique such as welding, soldering, gluing, or the like. In another embodiment, the plates and one or more of the side walls of the cavity may be formed as an integral component, e.g. by a suitable extrusion process, a moulding process, a milling process, or any other suitable manufacturing process. In any event each conductive plate is attached to at least one of the side walls of the cavity and extends from the side wall into the cavity.

In some embodiments, the waveguide resonator comprises three conductive plates extending into the cavity. The three conductive plates may be parallel to the base walls, a central one of the three conductive plates being sandwiched between two outer ones of the three conductive plates.

The waveguide resonator may comprise a connecting plate arranged perpendicular to the three conducting plates and extending between respective first edges of the two outer conductive plates, parallel to one of the end walls of the cavity. Hence, the connecting plate may be attached to the respective first edges of the two outer conductive plates. In some embodiments, the connecting plate is not directly attached to the central conductive plate, i.e. the central conductive plate may have a free edge parallel to the connecting plate but not attached to the central plate thus defining a gap between the central conductive plate and the connecting plate.

In some embodiments, one or more gaps are formed between respective edges of the conductive plates and respective ones of the side walls of the cavity. For example, a conductive plate may form one gap between one of its edges and a side wall of the cavity, alternatively a conductive plate may form two gaps: one between a first one of its edges and a first side wall of the cavity and another gap between a second one of its edges and a second side wall of the cavity; similarly a conductive plate may form three gaps between three respective ones of its edges and three respective side walls of the cavity.

In particular, a first one of the outer conductive plates may have a second edge parallel to the first edge and connected to an end wall of the cavity. A second one of the outer conductive plates has a second edge parallel to the first edge and not connected to any side wall of the cavity. The outer conductive plates each have a third and a fourth edge; where the third edge is connected to a lateral side wall of the cavity and where the fourth edge is parallel to the third edge and not connected to any side wall of the cavity.

Such an arrangement of the plates allows efficient folding of the electromagnetic field twice in the direction between the lateral side walls of the cavity, and at least four times in the direction between the end walls of the cavity. This directly leads to 2×4 reduction in size of the cavity resonator.

Furthermore, the effective path of the electromagnetic field distribution also extends in the direction between the base walls thus further extending the path length and resulting in a resonator that is shorter in the direction between the end walls. Resonators may be provided that are two times narrower and 5 times shorter than conventional cavity resonators which leads to a 10-fold more compact structure.

In some embodiments, the length of the resonator cavity is equal or smaller than $\lambda_g/8$ where λ_g is the guided wavelength in the medium of the material filling the resonant cavity of a dominant mode of the waveguide resonator, i.e. the wavelength of a resonant mode having the lowest frequency. The width of the resonator cavity may be a quarter of the guided wavelength λ_g. Generally an N-fold folding causes the dimension of the cavity in the direction of folding to be about $\lambda_g/(2N)$.

The height of the resonator has little effect on the resonant frequency and may e.g. be chosen in the range between 0 and the length of the cavity.

The gaps or slots formed between edges of the conductive plates and the side walls of the cavity may be different in size and may be chosen in the range between 0 and half the length of the resonator cavity.

The present invention relates to different aspects including the waveguide resonator described above and in the following, and corresponding methods, devices, and/or product means, each yielding one or more of the benefits and advantages described in connection with the first mentioned aspect, and each having one or more embodiments corresponding to the embodiments described in connection with the first mentioned aspect and/or disclosed in the appended claims.

Brief description of the drawings

The above and/or additional objects, features and advantages of the present invention, will be further elucidated by the following illustrative and non-limiting detailed description of embodiments of the present invention, with reference to the appended drawings, wherein:

Fig. 1 illustrates an example of a cavity resonator, where fig. 1a shows a perspective view of the resonator, fig. 1b shows a top view of the resonator while figs. 1c-d show sectional views of the resonator.

Fig. 2 illustrates a comparison of relative sizes of different types of resonators where fig. 2a shows a conventional cavity resonator, fig. 2b shows a coaxial resonator, and fig. 2c shows an embodiment of a resonator described herein.

Fig. 3 shows a measured response of an embodiment of a waveguide resonator described herein.

Detailed description

In the following description, reference is made to the accompanying figures, which show by way of illustration how the invention may be practiced. Throughout the drawings, like reference numerals refer to like or corresponding components, elements, and features.

Fig. 1 illustrates an example of a cavity resonator, where fig. 1a shows a perspective view of the resonator, fig. 1b shows a top view of the resonator while figs. 1c-d show sectional views of the resonator along lines F-F and D-D, respectively.

The cavity resonator, generally designated 101, comprises a metallic housing having six pairwise parallel sidewalls 102, 103, 104, 105, 106, 107 defining a hollow resonant cavity having a rectangular cross section and a height *b*, a length *c*, and a width *a*. The height *b* is defined by the distance between a first pair of the sidewalls 102 and 103 which are also referred to as base walls. The length *c* is defined by the distance between a second pair of side walls 106 and 107, also referred to as end walls, while the width *a* is defined by the distance between a third pair of side walls 104 and 105, also referred to as lateral side walls. A Cartesian coordinate system may be defined such that the x-direction is normal to the lateral side walls 104 and 105, the y-direction is normal to the base walls 102 and 103, and the z-direction is normal to the end walls 106 and 107.

The cavity resonator further comprises three rectangular interleaved metallic plates 108, 109, and 110, disposed within the cavity and all attached to a first lateral side wall 104 of the housing. The metallic plates 108-110 are parallel to each other and to the base walls 102 and 103, thus defining a central plate 110 sandwiched between two outer plates 108 and 109. A further rectangular metallic plate 111 disposed inside the cavity is perpendicular to the plates 108-110 and extends between respective edges 116 and 117 of the interleaved plates 108 and 109 so as to conductively interconnect the two outer interleaved plates 108 and 109. The outer plates 108 and 109 are not connected to the lateral side wall 105 of the housing opposite lateral side wall 104, thus forming a gap or slot of width *d1* between respective edges 112 and 113 of the plates 108 and 109 and the lateral side wall 105 of the housing. The central plate 110 is connected to both lateral side walls 104 and

105 and to end wall 107 of the housing, but not to the opposite end wall 106, thus leaving a slot or gap of width *d2* between an edge 120 of the central plate 110 and the end wall 106. While the outer plate 108 is connected to the end wall 107 and extends from the perpendicular plate 111 to the end wall 107, the other outer plate 109 is not connected to the end wall 107 and leaves a slot or gap of width *d3* between an edge 118 of the plate 109 and the end wall 107.

The side walls and interleaved plates may be made of metal or any other conductive material, or any other suitable material coated with a conductive layer such that the interior surfaces of the side walls and the surfaces of the interleaved plates are conductive.

Such an arrangement of the plates causes the electromagnetic field in a resonant mode to fold two times in the x-direction and at least four times in the z-direction. This directly leads to a 2×4 reduction in size of the footprint of the cavity resonator, i.e. a reduction in size in the x-z plane, compared to a conventional cavity resonator. Furthermore, due to the gaps, the effective path of the electromagnetic field distribution is becoming longer, as the field is also distributed in the y direction, which leads to even shorter (in z direction) resonators. The resonator shown in fig. 1 is two times narrower and five times shorter than a conventional cavity resonator which leads to a 10-fold more compact structure. For a given desired resonance frequency, a further reduction in size is possible by filling the resonator with a dielectric.

It will be appreciated that the size of the resonator can be further decreased by reducing its height (along the y direction in fig. 1). For example, alternative embodiments of the resonator may be manufactured using planar technology, e.g. as an SIW where the base walls 102 and 103 and the interleaved plates 108-110 are formed by layers of a layered structure separated from each other by a dielectric substrate, and where the end walls

106 and 107, the lateral side walls 104 and 105, and the plate 111 are formed by conductive vias connecting the conductive layers.

The resonator 101 comprises a feeding point 119 for coupling and/or exciting an electromagnetic wave in the resonator using any suitable technique known as such, e.g. by a coupling probe or antenna oriented in the direction of the electric field, by a current carrying loop in a plane perpendicular to the magnetic field, by a small slit or aperture in the resonator connecting it to a waveguide, and or the like. Hence, generally, embodiments of the resonator disclosed herein are compatible with standard excitation schemes, and may thus comprise any suitable means for coupling and/or exciting an electromagnetic wave in the resonator.

The dimensions of the resonator may be selected so as to match the desired resonant frequency, i.e. the desired wavelength λ_g of the resonant mode, where the wavelength λ_g is the wavelength in the medium filling the cavity and of the dominant resonant mode. This wavelength will also be referred to as the guided wavelength λ_g.

The width a of the resonator may be selected to be a quarter of a guided wavelength λ_g. The length c of the resonator may be selected to be equal or below $\lambda_g/8$. The height b of the resonator has a little effect on the resonant frequency and can be chosen in the range between 0 and a. The widths $d1$, $d2$, and $d3$ of the gaps between edges of the respective interleaved plates 108, 109, 110 may be the same or different from each other; they may be chosen in the range between 0 and $c/2$. The distance between the three interleaved metallic plates (along the y direction) can be chosen arbitrarily.

It will be appreciated that the dimensions of the resonator and the position and size of the interleaved plates may be determined based on suitable numerical simulations of the resulting resonant modes, using conventional techniques, such as exhaustive computer-aided full wave analysis. Such optimisation normally starts by setting the primary values of parameters and parameter ranges over which optimization is to take place. The suggested parameter ranges are given above and the primary values will be set within those ranges. Then, the goal functions of the optimization are defined based on the resonator specifications, i.e. the desired resonant frequency, quality factor, overall size, power handling capabilities, etc. Commonly used optimisation algorithms can be employed, such as random, gradient, minmax, genetic, and others.

Fig. 2 illustrates a comparison of relative sizes of different types of resonators where fig. 2a shows a conventional cavity resonator, fig. 2b shows a coaxial resonator, and fig. 2c shows an example of a resonator described herein.

A conventional rectangular cavity resonator as illustrated in fig. 2a has a length and a width equal to half the guided wavelength λ_g, as determined by the resonance conditions for a resonant mode of the electromagnetic field. A coaxial resonator illustrated in fig. 2b has a length of a quarter of the guided wavelength. An embodiment of the resonator disclosed herein and as illustrated in fig. 2c has a width of a quarter of the guided wavelength and a length of 10% of the guided wavelength.

Fig. 3 shows a measured response of an example of a waveguide resonator disclosed herein as a function of the relative deviation of the frequency f from the resonant frequency f_0. In the present example, the resonant frequency was 900 MHz. It will be appreciated from fig. 3 that examples of the waveguide resonator disclosed herein have a high Q factor.

Embodiments of the invention disclosed herein may be used in a variety of applications and in a wide range of frequencies. Examples of applications include applications within telecommunication systems, such as cellular base stations, aviation and maritime radars, and instrumentation applications such as radio astronomy systems.

An example of a resonator as disclosed herein may be milled in brass or aluminium for simplicity but the basic proposed structure is expected to be compatible with industry standard low-cost planar technology such as stacking of printed circuit boards and the use of standard excitation schemes.

Embodiments of the folded cavity resonator disclosed herein combine the superior performance of a cavity resonator with the attractive compact size of the coaxial resonator. The use of such resonators optimized for low insertion loss and high shape factor may allow for reduced electromagnetic pollution (interference), lower power consumption of radio transmitters, and smaller size.

In device claims enumerating several means, several of these means can be embodied by one and the same structural component. The mere fact that certain measures are recited in mutually different dependent claims or described in different embodiments does not indicate that a combination of these measures cannot be used to advantage.

It should be emphasized that the term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

Claims:

1. A waveguide resonator comprising a number of side walls defining a cavity enclosed by said sidewalls defining the cavity; and two or more conductive plates extending into the cavity, each conductive plate having a first side and a second side opposite the first side, and wherein the conductive plates are adapted to cause a standing electromagnetic wave to fold around the conductive plates along at least a first and a second direction and to extend on both sides of each of the conductive plates; wherein the conductive plates are adapted to cause the standing electromagnetic wave to fold multiple times along at least the second direction.

2. A waveguide resonator according to claim 1, wherein at least some of the side walls are formed by conductive plates.

3. A waveguide resonator according to any one of the preceding claims, wherein at least two of the side walls are formed by conductive layers and at least some of the side walls are formed by a grid of conductive connections between the conductive layers.

4. A waveguide resonator according to any one of the preceding claims, comprising three conductive plates extending into the cavity.

5. A waveguide resonator according to any one of the preceding claims, wherein each of the conductive plates extending into the cavity has at least one edge attached to one of the side walls of the cavity.

6. A waveguide resonator according to claim 5, wherein each conductive plate extending into the cavity has at least one edge that is not attached to any of the side walls so as to define a slot between the unattached edge and a side wall facing the unattached of the conductive plate.

7. A waveguide resonator according to claim 6, wherein the slot formed between an unattached edge of the conductive plates and the side wall of the cavity has a width smaller than half the longest dimension of the resonator cavity.

8. A waveguide resonator according to any one of the preceding claims, wherein the conductive plates extending into the cavity are parallel to each other.

9. A waveguide resonator according to any one of the preceding claims, wherein the cavity is a rectangular cavity defined by pairwise parallel side walls including a pair of base walls, a pair of end walls and a pair of lateral side walls, where the distance between the pair of base walls defines a height of the cavity, the distance between the pair of end walls defines a length of the cavity and the distance between the pair of lateral side walls defines a width of the cavity.

10. A waveguide resonator according to claim 9, comprising three conductive plates extending into the cavity, wherein the three conductive plates are parallel to the base walls, a central one of the three conductive plates being located between two outer ones of the three conductive plates, and wherein the waveguide resonator comprises a connecting plate arranged perpendicular to the three conducting plates extending into the cavity, where the connecting plate extends between respective first edges of the two outer conductive plates, parallel to one of the end walls of the cavity.

11. A waveguide resonator according to claim 10, wherein a first one of the outer conductive plates has a second edge parallel to the first edge and connected to an end wall of the cavity, wherein a second one of the outer conductive plates has a second edge parallel to the first edge and not connected to any side wall of the cavity; wherein the outer conductive plates

each have a third and a fourth edge; where the third edge is connected to a lateral side wall of the cavity and where the fourth edge is parallel to the third edge and not connected to any side wall of the cavity.

12. A waveguide resonator according to any one of claims 9 through 11, wherein one or more gaps are formed between respective edges of the conductive plates and respective ones of the side walls of the cavity.

13. A waveguide resonator according to any one of claims 9 through 12, wherein the length of the resonator cavity is equal to or smaller than an eighth of a wavelength in a medium filling the resonant cavity of a dominant mode of the waveguide resonator.

14. A waveguide resonator according to any one of claims 9 through 13, wherein the height of the resonator is smaller than the length of the resonator cavity.

15. A waveguide resonator according to any one of claims 9 through 14, wherein the width of the resonator cavity is equal to a quarter of a wavelength in a medium filling the resonant cavity of a dominant mode of the waveguide resonator.

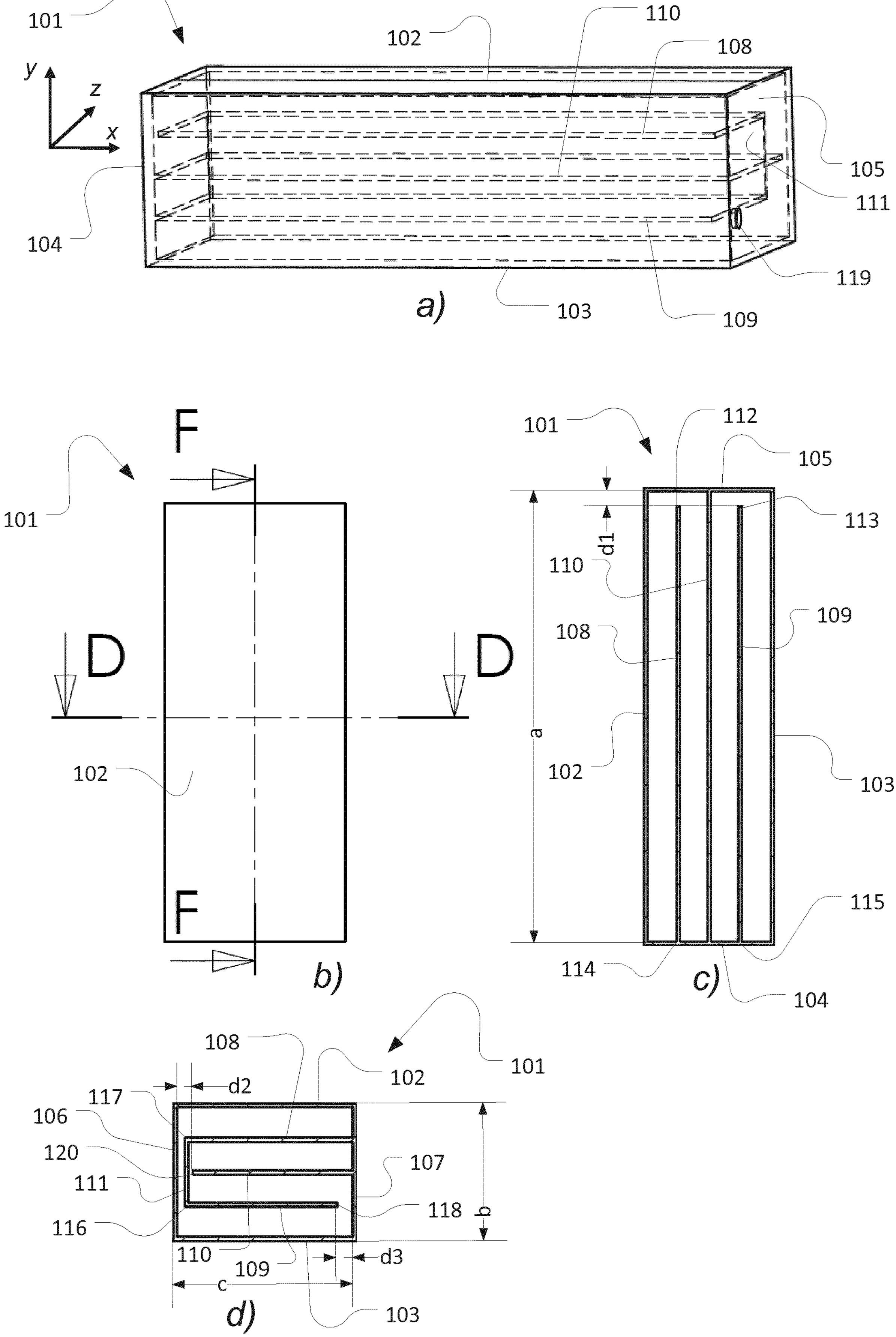
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Fig. 1

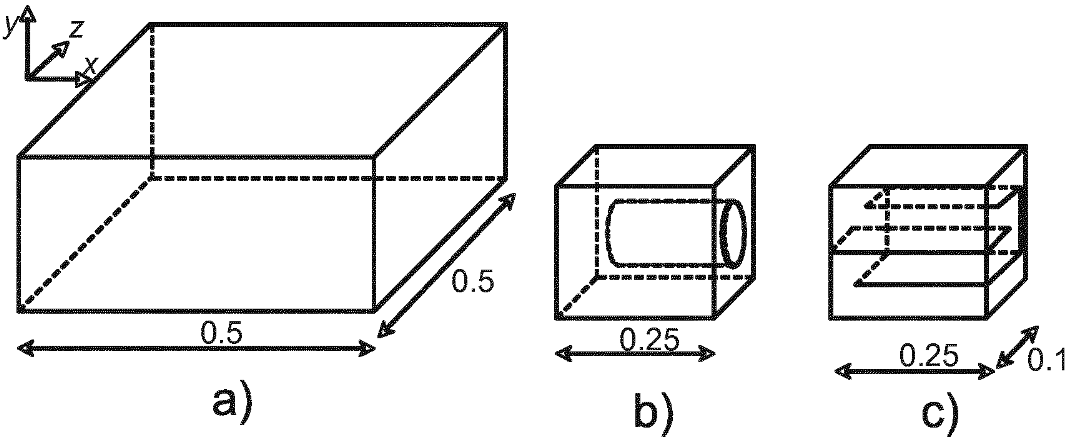
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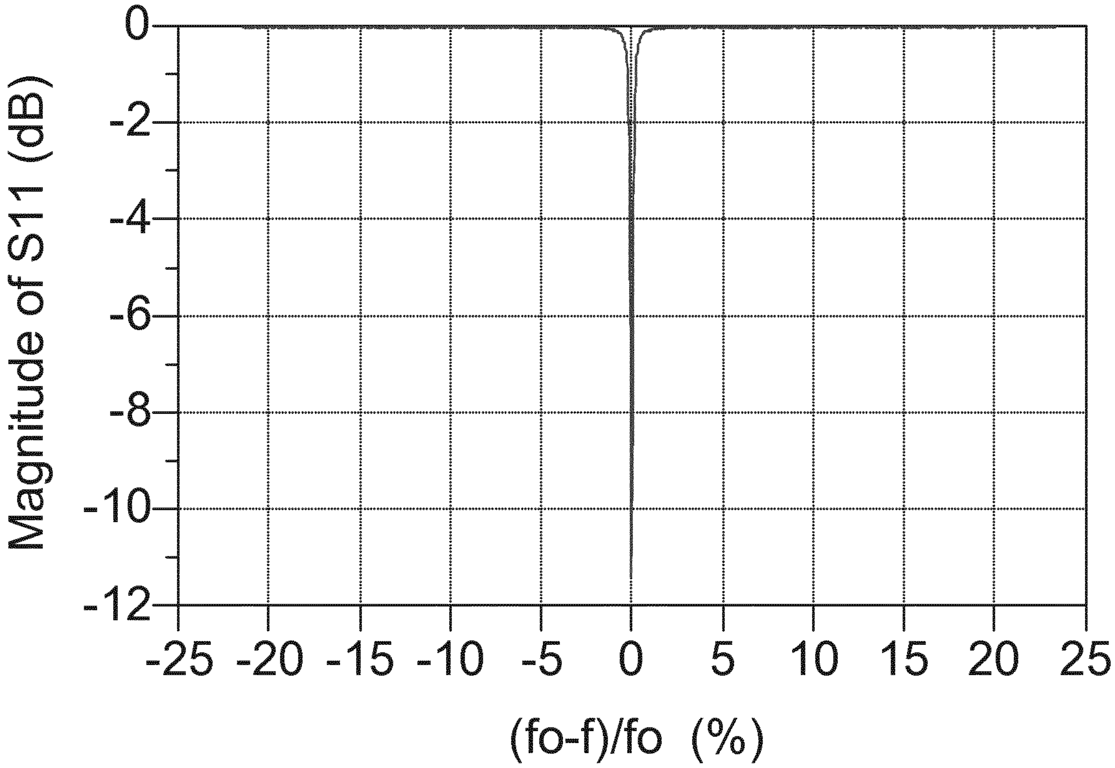
Fig. 2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20
25
(fo-f)/fo (%)

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2013/055111

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01P7/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GUO-SHU HUANG ET AL: "Nonuniformly Folded Waveguide Resonators and Their Filter Applications", IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS, IEEE SERVICE CENTER, NEW YORK, NY, US, vol. 20, no. 3, 1 March 2010 (2010-03-01), pages 136-138, XP011347746, ISSN: 1531-1309, DOI: 10.1109/LMWC.2010.2040209 page 136, left-hand column, line 1 - right-hand column, line 26 -----	1-9, 12-15
X	US 2 281 552 A (LANIER BARROW WILMER) 5 May 1942 (1942-05-05) page 1, line 9 - line 20 page 2, line 60 - line 17; figures 3,4 ----- -/--	1-9

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Name and mailing address of the ISA/
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer
Pastor Jiménez, J

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 728 910 A (OWENS THOMAS L [US]) 1 March 1988 (1988-03-01) column 3, line 13 - line 66; figure 1 column 8, line 56 - column 9, line 33; figures 4,5 -----	1-9
X	YAN DING ET AL: "Miniaturization Techniques of Substrate Integrated Waveguide Circuits", ART OF MINIATURIZING RF AND MICROWAVE PASSIVE COMPONENTS, 2008. IMWS 2008. IEEE MTT-S INTERNATIONAL MICROWAVE WORKSHOP SERIES ON, IEEE, PISCATAWAY, NJ, USA, 14 December 2008 (2008-12-14), pages 63-66, XP031424216, ISBN: 978-1-4244-2876-2 page 64, right-hand column, line 1 - page 65, left-hand column, line 1; figure 2 -----	1-9
A	WO 2008/075039 A1 (OMNI ID LTD [GB]; BROWN JAMES ROBERT [GB]; LAWRENCE CHRISTOPHER ROBERT) 26 June 2008 (2008-06-26) page 10, line 1 - line 21; figures 1a-2 page 12, line 29 - page 13, line 22; figure 9 -----	1-9

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2013/055111

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2281552 A	05-05-1942	NONE	
US 4728910 A	01-03-1988	NONE	
WO 2008075039 A1	26-06-2008	CN 101595596 A	02-12-2009
		EP 2102937 A1	23-09-2009
		JP 2010514243 A	30-04-2010
		US 2010230497 A1	16-09-2010
		WO 2008075039 A1	26-06-2008