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(54) **DIELECTRIC RESONATOR ANTENNA**

(57) A dielectric resonator antenna is disclosed, comprised of: a dielectric material having first and second electrically-conductive and elements on first and second substantially opposed surfaces of the dielectric material. The antenna may further comprise a feed structure comprising a substrate positioned adjacent the dielectric material, the substrate comprising one or more feed conductors, and a ground plane adjacent the substrate, the ground plane having one or more apertures therein in substantial respective alignment with the one or more feed conductors.

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Description

Field

[0001] Example embodiments relate to a dielectric resonator antenna (DRA).

Background

[0002] A dynamic resonator antenna is an antenna formed from a dielectric material which acts as a resonator, usually mounted on a metal surface acting as a ground plane. The resonant frequency of the antenna is determined by the dielectric constant of the dielectric material and also its dimensions. Dynamic resonator antennas provide relatively wide bandwidth and are commonly used at microwave and higher frequencies. They tend to have relatively small dimensions, controllable properties and are relatively resilient in terms of structure.

Summary

[0003] According an one aspect, there is provided an apparatus comprising: a dielectric resonator antenna comprised of: a dielectric material having first and second electrically-conductive and elements on first and second substantially opposed surfaces of the dielectric material; and a feed structure comprising a substrate positioned adjacent the dielectric material, the substrate comprising one or more feed conductors, and a ground plane adjacent the substrate, the ground plane having one or more apertures therein in substantial respective alignment with the one or more feed conductors.

[0004] The feed structure substrate may be substantially planar and positioned substantially parallel to the first and second surfaces of the dielectric material. The dielectric material and feed structure may be spaced apart. The ground plane may be formed of substantially planar, electrically conductive material.

[0005] The apparatus may further comprise an electrically conductive material defining a cavity beneath the feed structure, on the opposite side of the substrate to that of the dielectric material.

[0006] The electrically conductive material of the cavity may be in electrical contact with the ground plane.

[0007] The ground plane may have a plurality of slot-like apertures therein for different polarizations.

[0008] The ground plane may comprise first and second slot-like, intersecting apertures.

[0009] The substrate may carry first and second feed conductors in substantial respective alignment with the first and second apertures of the ground plane, the feed conductors being on opposite sides of the substrate.

[0010] The substrate may be a printed wire board (PWB) or the like, formed of electrically insulative material.

[0011] The first and second elements on the dielectric material may have different surface areas. The first and second elements may be substantially planar with first and second differently-sized major surfaces. The first and second elements may be disk-like. The first element may have a smaller surface area than the second element, the second element being closer to the feed structure than the first element.

[0012] Another aspect provides an electronic communications device comprising the apparatus of any preceding definition.

[0013] Another aspect provides an apparatus comprising: a dielectric resonator antenna comprised of: a dielectric material having first and second electrically-conductive and elements on first and second substantially opposed surfaces of the dielectric material; and a feed structure comprising a substrate positioned adjacent the dielectric material, the substrate comprising one or more feed conductors, and a ground plane adjacent the substrate, the ground plane having one or more apertures therein in substantial respective alignment with the one or more feed conductors.

[0014] The feed structure substrate may be substantially planar and positioned substantially parallel to the first and second surfaces of the dielectric material. The dielectric material and feed structure may be spaced apart. The dielectric material and feed structure may be spaced apart by a plurality of non-conductive legs. The ground plane may be formed of substantially planar, electrically conductive material. The apparatus may further comprise an electrically conductive material defining a cavity beneath the feed structure, on the opposite side of the substrate to that of the dielectric material.

[0015] The electrically conductive material of the cavity may be in electrical contact with the ground plane. The ground plane may have a plurality of slot-like apertures therein for different polarizations. The ground plane may comprise first and second slot-like, intersecting apertures. The first and second intersecting apertures may be oriented for orthogonal polarisation. The substrate may carry first and second feed conductors in substantial respective alignment with the first and second apertures of the ground plane, the feed conductors being on opposite sides of the substrate. On one side of the substrate may be provided plural first feed conductors arranged generally in an X-shape and on the other side of the substrate may be provided plural second feed conductors arranged generally in an X-shape and generally aligned with the plural first feed conductors. The substrate may be a printed wire board (PWB) or the like, formed of electrically insulative material. The first and second elements on the dielectric material may have different surface areas. The first and second elements may be substantially planar with first and second differently-sized major surfaces. The first and second elements may disk-like. The first element may have a smaller surface area than the second element, the second element being closer to the feed structure than the first element. The dielectric material may comprise an internal air-gap between the first and second elements.

[0016] Another aspect provides an apparatus, comprising a dielectric resonator antenna comprised of: a dielectric material having first and second electrically-conductive and elements on first and second substantially opposed surfaces of the dielectric material; a feed structure comprising a substrate positioned adjacent, and spaced from, the dielectric material, the substrate comprising first and second substantially opposed surface, wherein, on the first surface, the feed structure comprises two pairs of antenna element arms arranged generally in an X-shape and, on the second surface, two pairs of antenna arms arranged generally in an X-shape and aligned with the antenna element arms on the first surface, the aligned antenna arms being electrically interconnected through the substrate; and a ground plane adjacent the substrate, the ground plane having one or more apertures therein in substantial respective alignment with the one or more feed conductors.

[0017] The ground plane may be part of a back cavity.

Drawings

[0018] Embodiments will now be described by way of non-limiting examples, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a dielectric block with plural conductive elements, forming part of an antenna according to an embodiment;
Figure 2 is a perspective view of a dielectric block with plural conductive elements, forming part of an antenna according to another embodiment;
Figure 3A is a perspective view of an antenna which uses the Figure 2 dielectric block, according to some embodiments;
Figure 3B is a side view of the Figure 3A antenna;
Figure 3C is a sectional view of the Figure 3A antenna;
Figure 4 is a plan view of a ground plane having a slot for use in the Figure 3A antenna according to some embodiments;
Figure 5 is a plan view of a substrate carrying conductive feeds for use in the Figure 3A antenna according to some embodiments;
Figure 6 is a partial perspective view of the Figure 5 substrate for use in the Figure 3A antenna according to some embodiments;
Figure 7A is a frequency response plot of the Figure 3A antenna;
Figure 7B is a frequency response plot of another antenna for comparison purposes;
Figure 8A is a two-dimensional far-field radiation pattern of the Figure 3A antenna;
Figure 8B is a two-dimensional far-field radiation pattern of another antenna for comparison purposes;
Figure 9A is a Smith chart relating to the Figure 3A antenna; and
Figure 9B is a Smith chart relating another antenna for comparison purposes.

Detailed Description

[0019] Example embodiments relate to dielectric resonator antennas (DRAs).

[0020] A dielectric resonator antenna is a radio antenna that typically consists of a block of non-metallic material having a higher dielectric constant than air. Ceramics are commonly used. The block of material may comprise various shapes, and may be mounted on a metallic ground plane. A signal is introduced into the block of material from a feed structure, where the antenna is to be used to transmit signals, and the signals tend to form standing waves within the walls of the block, some of which leave and radiate into space. Such antennas are commonly used at microwave frequencies and higher, making them ideal for wireless and satellite applications. Where the antenna is to be used to receive signals, signals are provided to the feed structure by the block of material. In some embodiments, the antenna may operate in both transmit and receive modes. Such dielectric resonator antennas as described herein find application in many wireless electronic communication systems, modules and devices for wireless voice and/or data transmission and/or reception, such as, and not limited to, antenna arrays, base stations, broadcasting antennas, fixed network equipment, satellite antennas and equipment, mobile network equipment, wireless electronic communications equipment carried by or installed in vehicles (for example, and not limited to: cars, trucks, boats, ships, aircraft, drones, bicycles, motorcycles, toys), mobile or portable communications equipment and stationary communications equipment.

[0021] Embodiments herein relate to dielectric resonator antennas in which first and second electrically-conductive elements (hereafter "first and second elements") are provided on respective parts of the dielectric block. The first and second elements may not contact one another and/or they may be electrically floating, i.e. they are not galvanically connected or coupled to anything else, instead depending upon electromagnetic coupling between themselves and the feed structure. The first and second elements may be formed of metal material. The first and second elements may be on substantially opposite sides of the dielectric block, e.g. such that they are generally parallel. The first and second elements may be substantially plate-like. The first and second elements may have different surface areas, for example one having a major surface which is of a greater area than that of the other (with comparable depths or thicknesses). It is found that the provision of a plurality of elements in this general manner improves at least the bandwidth properties of such an antenna.

[0022] Referring to Figure 1, a dielectric block 20 according to an embodiment is shown having first and second substantially opposed major faces 30, 40. The dielectric block 20 is generally cylindrical or puck-shaped. First and second electrically conductive elements 50, 60 (which may be formed of metal or carbon-based material such as graphite, graphene etc.) may be provided on the respective major faces 30, 40. The first and second conductive elements 50, 60 are therefore substantially opposed and parallel to one another. The first and second conductive elements 50, 60 may be disk shaped, although other shapes may be used.

[0023] A feed structure for energising the dielectric block 20 to create the standing waves is in practise provided adjacent the dielectric block 20, although is not shown in Figure 1. As mentioned above, for a receiving antenna, the signals are received via the conductive elements 50, 60.

[0024] Figure 2 is a dielectric block 70 according to another embodiment. Similar to the Figure 1 embodiment, the dielectric block is generally cylindrical or puck-shaped but in this case has a ring-shaped recess 80 defining an outer wall 90 and an inner wall 100. A first metallic element 110 is mounted on the inner wall 100. A second electrically conductive element (not shown), similar to the second conductive element 60 illustrated in the first embodiment and Figure 1, may be positioned on the base of the dielectric block 70. The second conductive element may have the same central axis X-X as that of the first conductive element 110, which is a central axis of the dielectric block 70.

[0025] In some embodiments, a bore may extend through the centre of the dielectric block 70, substantially aligned with the central axis X-X so that there is an air gap between the first conductive element 110 and second conductive element (not shown).

[0026] The material used for the dielectric block 20 may be any suitable dielectric, which may for example be a ceramic. Example types may comprise beryllium oxide (k = 6), alumina (k = 9-10), sapphire (k = 9.3 - 11), high dielectric ceramic-filled Teflon glass (k = 6 - 10) and possibly quartz (k = 3.78).

[0027] A feed structure for energising (in the case of a transmitting antenna) the dielectric block 20 to create the standing waves is in practise provided adjacent the dielectric block 20, although is not shown in Figure 2. The feed structure is for receiving signals in the case of a receiving antenna.

[0028] In other embodiments, non-puck-shaped dielectric bodies may be provided. For example, rectangular, square, triangular and other shaped bodies may be provided.

[0029] Figure 3A shows the Figure 2 dielectric block 70 when mounted on an example feed structure 200, to provide a dielectric resonator antenna 210 according to example embodiments. The feed structure 200 comprises in this example a slot fed structure with a back cavity, which may also be called a cavity-backed slot antenna. Slot fed structures in general comprise an aperture on a ground plane upon which the dielectric block resonator is placed. The aperture can be fed by a transmission line, such as a microstrip line, a slotline, coplanar strips or a waveguide, such as a coplanar waveguide.

[0030] Figure 3B is a side view of the Figure 3A antenna 210. The dielectric block 70 is shown suspended or similarly mounted above the feed structure 200, for example by one or more supporting legs. Either way, there is a gap between the dielectric block 70 and the feed structure 200. The feed structure 200 comprises a box or tray-like base 210 defining a cavity 222; note that the cavity is shown in dotted line for reference and is not ordinarily seen from the side. The base 210 may comprise a base wall and four upstanding walls, or other mechanical structures may be used. The base 210 may be formed of metal material. The cavity 222 acts as a waveguide in use. The first and second metallic elements 120, 112 are shown on opposite sides of the dielectric block 70.

[0031] Provided above the cavity 222, e.g. located on upper walls or in recesses of the base side walls, is a feed substrate 220. The feed substrate 220 covers the cavity 222 and in this example provides the lower surface of the feed structure 200. It is generally formed of areas of an electrically conductive, e.g. metal, material and also areas which are formed of non-conductive material (FR4 for example), for example the feed substrate 220 is a printed wire board (PWB), and the feed substrate 220 is in contact with the base 210, which is also electrically part of the ground plane.

[0032] Located above the feed substrate 220 is a spacer 230 which may be a frame formed of conductive, e.g. metal, and/or insulative material. The frame or spacer 230 spaces the feed substrate 220 from the next layer above which is a ground plane member 240, e.g. on a printed wire board (PWB) or a piece of metal. The ground plane member 240 may form all or only a part of the overall ground plane for the antenna.

[0033] A PWB can be any form of printed wiring board, including printed circuit boards, flexi circuits, semi-flexible circuits and other forms of printable substrates and laminates.

[0034] The feeder substrate 220 may comprise upper and lower, opposed, surfaces. The feeder substrate 220 carries one or more feed elements from a feed point.

[0035] Figure 3C shows an angular cut-through of the Figure 3A antenna 210, shown for completeness.

[0036] Referring to Figure 4, a plan view of one side of the ground plane member 240 is shown, on which is provided first and second slots 222, 224 formed in a conductive sheet which may provide one side of the cavity 222, the slots being arranged in a general cruciform shape to provide a single "X" aperture. The dimensions (mainly due to the lengths of each slot 222, 224) may be a fraction (e.g. $\lambda/2$, $\lambda/4$) of the centre frequency of operation within an operational frequency band.

[0037] Referring to Figure 5, a plan view of one side of the feeder substrate 220 is shown. The feeder substrate 220 has first and second feed elements 242, 244 formed therein, arranged with a general cruciform shape. The first and second feed elements 242, 244 are effectively divided into four branches or arms 242A, 242B, 244A, 244B which can be adjusted in terms of dimensions and/or orientation to adjust properties of the electromagnetic energy when transferred to the dielectric block 70.

[0038] The first and second feed elements 242, 244 are respectively connected to respective radios by means of conductors 246, 247. Connection may be by means of a respective feed point 248, as shown in Figure 6, which may be coaxial.

[0039] As is more clearly shown in Figure 6, the first and second feed elements 242, 244 formed on the feed substrate 220 are arranged such that their respective branches or arms 242A, 242B and 244A, 244B are provided on both sides or surfaces of the feeder substrate 240. The two-layers of each set of overlaid branches 242A, 242B, 244A, 244B interconnect by means of via connectors 250 as shown. The branches 242A, 242B of the first feed element 242 connect at a first region 249 on one of the sides, in this case the upper side, and the branches 244A, 244B of the second feed element 244 connect at a second region 245 on the other, lower side, without making contact with the first region 249.

[0040] It will be seen that the orientations of the first and second feed elements 242, 244 are in substantial alignment with those of the first and second slots 222, 224 on the ground plane member 240. That is, the first and second feed elements 242, 244 may overlie most of the first and second slots 222, 224 when mounted as shown in Figures 3A - 3C.

[0041] In some embodiments, the intersection point 'x' shown in Figure 5 is aligned with the central axis X-X.

[0042] By way of example, the Figures 3A - 3C antenna 210 may have the following dimensions:

Diameter of dielectric body 70:	26.5 mm;
Depth of dielectric body 70:	6.75 mm;
Diameter of first metallic element 110:	8.6 mm;
Diameter of second metallic element 112:	14.5 mm;
Gap between feed structure 200 & dielectric body:	2.25 mm;
Depth of spacer 230:	0.61 mm;
Depth of substrate 220:	0.61 mm; &
Permittivity of dielectric body:	70

[0043] It will be appreciated that these are provided merely for reference and other dimensions and arrangements may be used.

[0044] It is found that the bandwidth of an antenna, such as that shown in Figures 3A - 3C, exhibits a wider bandwidth by virtue of the plural conductive elements 110, 112 in combination with a slot feed structure 200. This is indicated in the plots of Figures 7A and 7B which respectively show frequency responses for the Figures 3A - 3C antenna 210 and an antenna using only a single conductive element.

[0045] Referring to Figure 7A for example, in terms of S-parameters, a first curve 301 represents the S11 response, and a second curve 302 represents the S22 response, both versus frequency and measured in dB. As will be appreciated, these are usually referred to as return loss (dB). It can be seen that markers 1 and 2 indicate a broad bandwidth between 4.4 and 4.9 GHz. It will also be noted that the 10dB bandwidth, i.e. the bandwidth measure at 10dB return loss on either side of the dip in the response is much greater than the desired operational frequency band of 4.4 to 4.9 GHz; it is approximately 4.2 to 5.2 GHz, i.e.1 GHz bandwidth.

[0046] A third curve 303 represents the S12 response, and a fourth curve 204 represents the S21 response, both versus frequency and measured in dB. The markers 3 and 4 again cover the desired operation frequency band lower and upper limits respectively.

[0047] Figures 8A and 8B indicate respective two-dimensional far-field radiation patterns for the Figure 3A - 3C antenna 210 and an antenna using only a single conductive element. The frequency in both cases was 4.9 GHz. The directivity and angles for each is shown.

[0048] Figures 9A and 9B are Smith charts respectively relating the Figures 3A - 3C antenna 210 and an antenna using only a single conductive element. It will be seen from reference numeral 310 in Figure 9A that there is an additional resonance, related to wider bandwidth.

[0049] The antenna 210 may be configured to operate in at least one of a plurality of operational resonant bandwidths. For example, the operational frequency bandwidths may include (but are not limited to): amplitude modulation (AM) radio (0.535-1.705 MHz), digital radio mondiale (DRM) (0.15-30 MHz), frequency modulation (FM) radio (76-108 MHz), digital audio broadcasting (DAB) (174.928-239.2 MHz, 1452.96-1490.62 MHz), digital video broadcasting - handheld (DVB-H) (470-702 MHz), Long Term Evolution (LTE) (US) (734 to 746 MHz and 869 to 894 MHz), Long Term Evolution (LTE) (rest of the world) (791 to 821 MHz and 925 to 960 MHz), US - Global system for mobile communications (US-GSM) 850 (824-894 MHz) and 1900 (1850 - 1990 MHz), European global system for mobile communications (EGSM) 900 (880-960 MHz) and 1800 (1710 - 1880 MHz), European wideband code division multiple access (EU-WCDMA) 900 (880-960 MHz), personal communications network (PCN/DCS) 1800 (1710-1880 MHz), DVB-H US (1670-1675 MHz), personal communications service (PCS) 1900 (1850-1990 MHz), time division synchronous code division multiple access (TD-SCDMA) (1900 MHz to 1920 MHz, 2010 MHz to 2025 MHz), US wideband code division multiple access (US-WCDMA) 1700 (transmit: 1710 to 1755 MHz , receive: 2110 to 2155 MHz) and 1900 (1850-1990 MHz), wideband code division multiple access (WCDMA) 2100 (transmit: 1920-1980 MHz, receive: 2110-2180 MHz), worldwide interoperability for microwave access (WiMax) (2300-2400 MHz, 2305-2360 MHz, 2496-2690 MHz, 3300-3400 MHz, 3400-3800 MHz, 5250-5875 MHz), global positioning system (GPS) (1570.42-1580.42 MHz), Bluetooth (2400-2483.5 MHz), wireless local area network (WLAN) (2400-2483.5 MHz), ultra wideband (UWB) Lower (3100-4900 MHz), hiper local area network (HiperLAN) (5150-5850 MHz), UWB Upper (6000-10600 MHz), radio frequency identification ultra high frequency (RFID UHF) (433 MHz, 865-956 MHz, 2450 MHz), and 5G frequency bands covering (from 2GHz up to 90GHz, the actual bands are not fully agreed at present). Naturally, the antenna 210 may be configured to operate in any frequency band in the radio frequency and microwave spectrum from 3MHz to 300GHz and possibly beyond these bounds.

[0050] While the forgoing examples are illustrative of the principles of the present invention in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation can be made without the exercise of inventive faculty, and without departing from the principles and concepts of the invention. Accordingly, it is not intended that the invention be limited, except as by the claims set forth below.

Claims

1. Apparatus comprising:
a dielectric resonator antenna comprised of:

a dielectric material having first and second electrically-conductive and elements on first and second substantially opposed surfaces of the dielectric material;
a feed structure comprising a substrate positioned adjacent the dielectric material, the substrate comprising one or more feed conductors, and a ground plane adjacent the substrate, the ground plane having one or more apertures therein in substantial respective alignment with the one or more feed conductors.

2. The apparatus of claim 1, wherein the feed structure substrate is substantially planar and positioned substantially parallel to the first and second surfaces of the dielectric material.

3. The apparatus of claim 1 or claim 2, wherein the dielectric material and feed structure are spaced apart.

4. The apparatus of any preceding claim, wherein the ground plane is formed of substantially planar, electrically conductive material.

5. The apparatus of claim 4, further comprising an electrically conductive material defining a cavity beneath the feed structure, on the opposite side of the substrate to that of the dielectric material.

6. The apparatus of claim 5, wherein the electrically conductive material of the cavity is in electrical contact with the ground plane.

7. The apparatus of any preceding claim, wherein the ground plane has a plurality of slot-like apertures therein for different polarizations.

8. The apparatus of claim 7, wherein the ground plane comprises first and second slot-like, intersecting apertures.

9. The apparatus of claim 7 or claim 8, wherein the substrate carries first and second feed conductors in substantial respective alignment with the first and second apertures of the ground plane, the feed conductors being on opposite sides of the substrate.

10. The apparatus of any preceding claim, wherein the substrate is a printed wire board (PWB) or the like, formed of electrically insulative material.

11. The apparatus of any preceding claim, wherein the first and second elements on the dielectric material have different surface areas.

12. The apparatus of claim 11, wherein the first and second elements are substantially planar with first and second differently-sized major surfaces.

13. The apparatus of claim 12, wherein the first and second elements are disk-like.

14. The apparatus of any of claims 11 to 13, wherein the first element has a smaller surface area than the second element, the second element being closer to the feed structure than the first element.

15. An electronic communications device comprising the apparatus of any preceding claim.

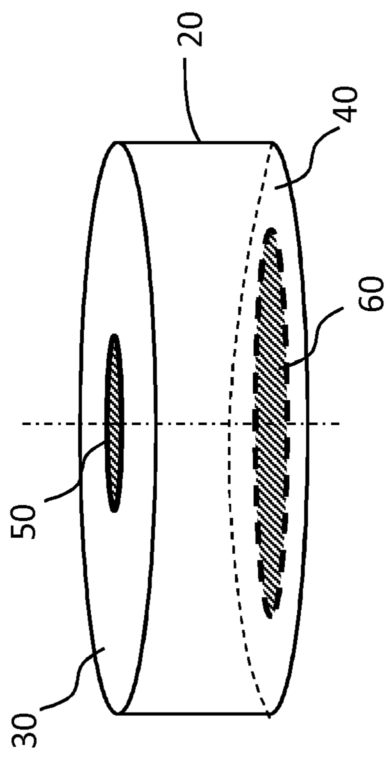

Fig. 1

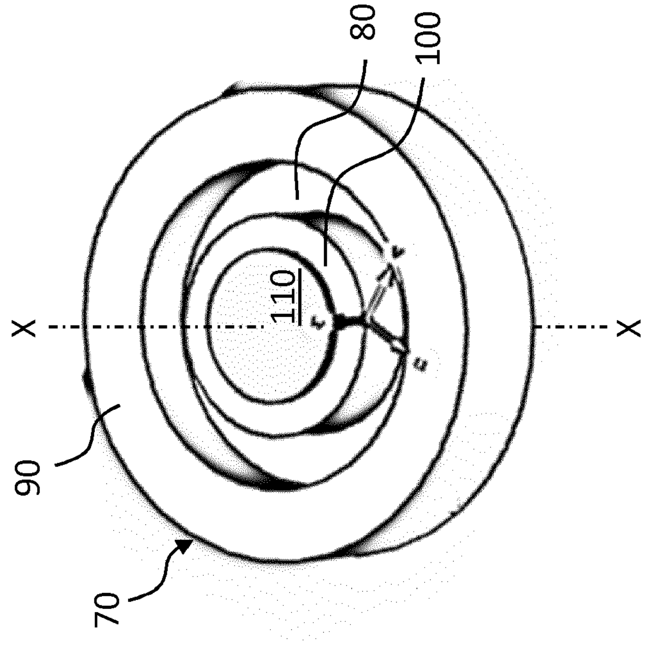

Fig. 2

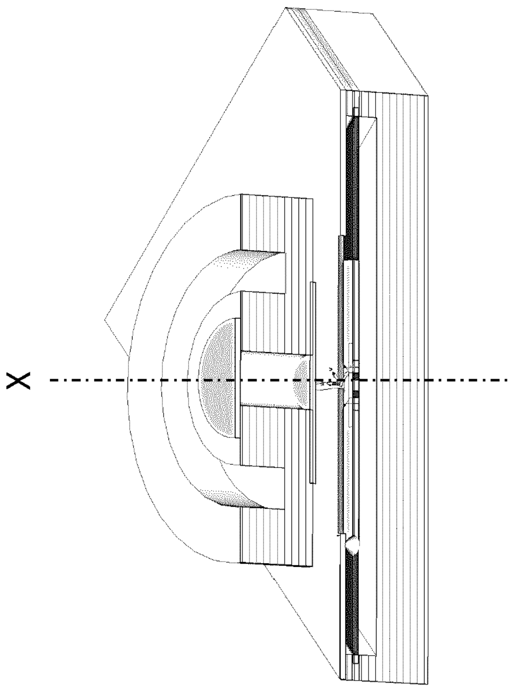

Fig. 3C

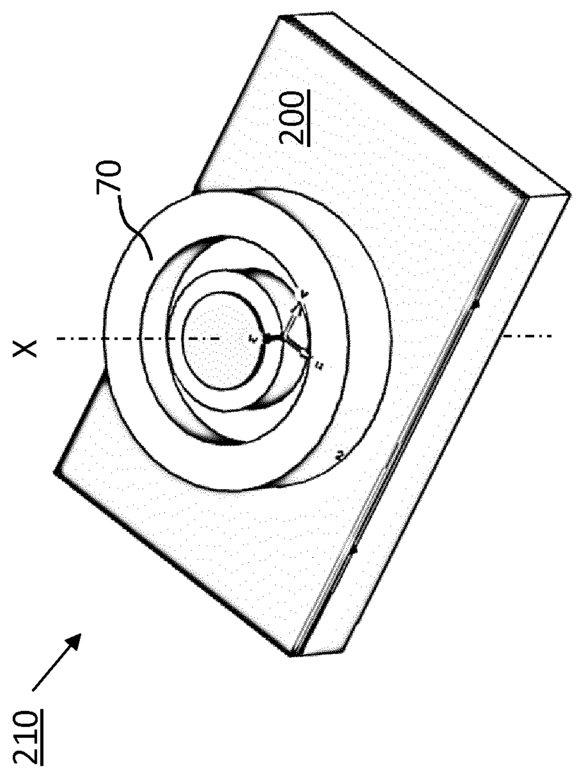

Fig. 3A

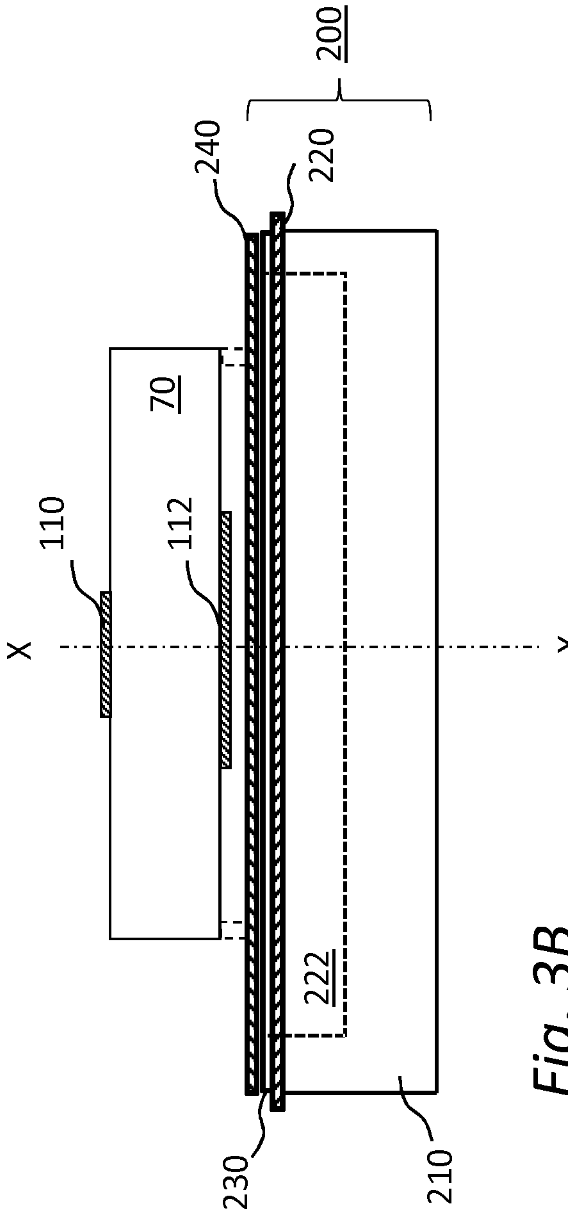

Fig. 3B

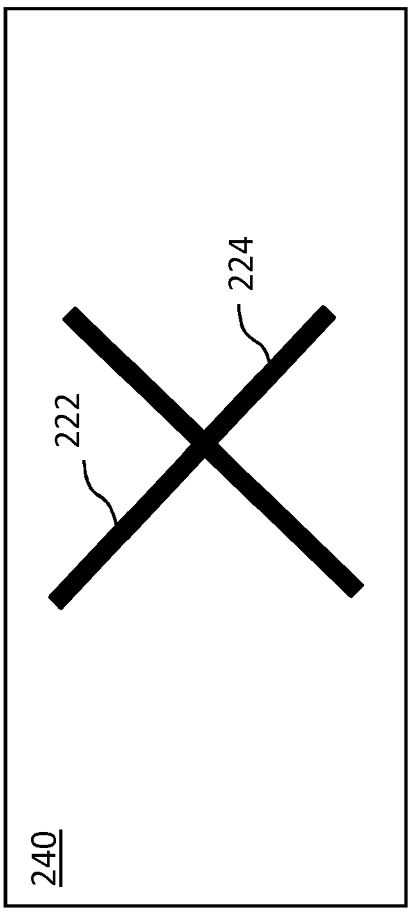

Fig. 4

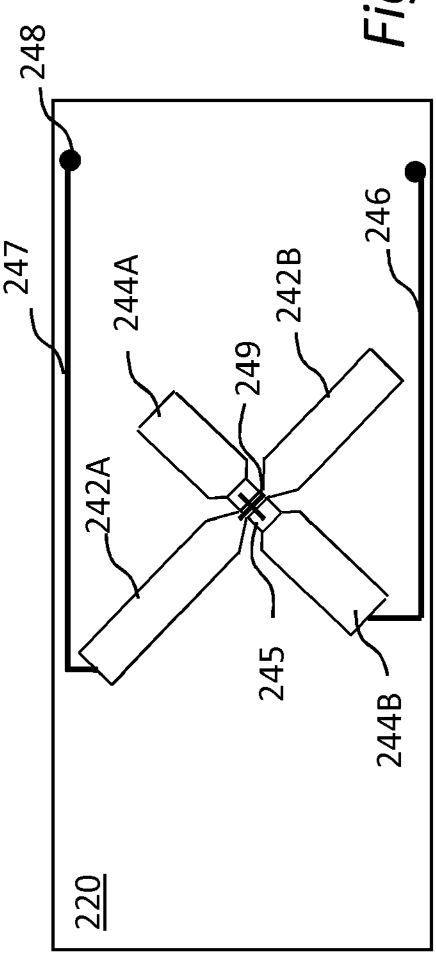

Fig. 5

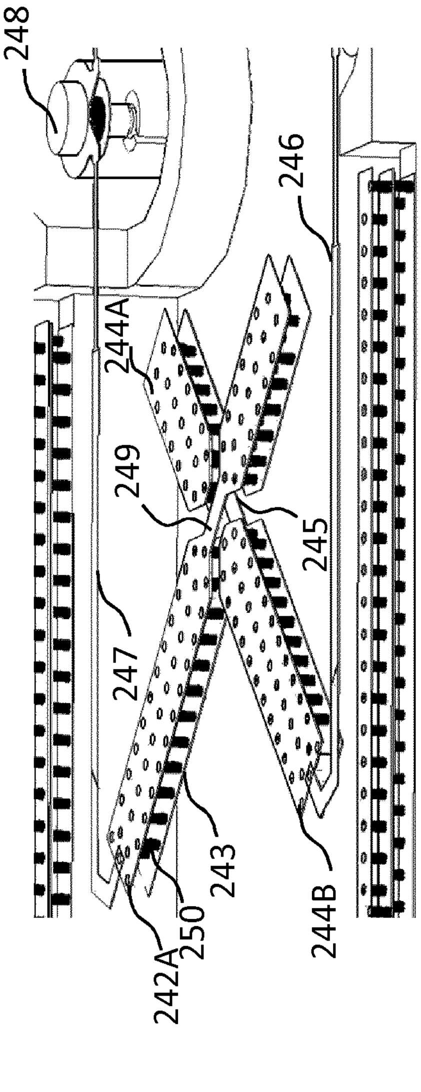

Fig. 6

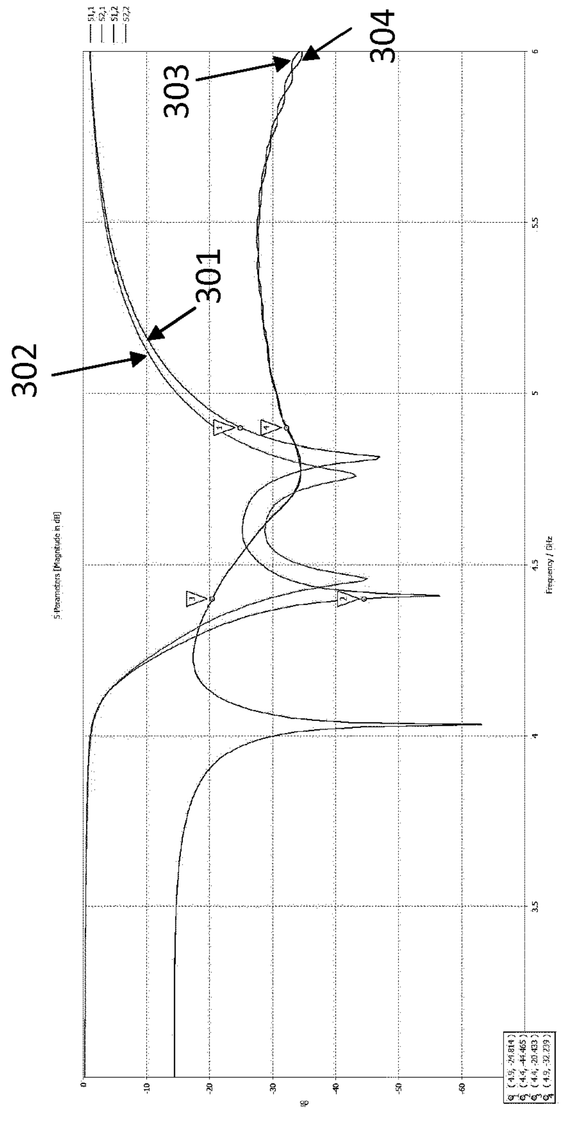

Fig. 7A

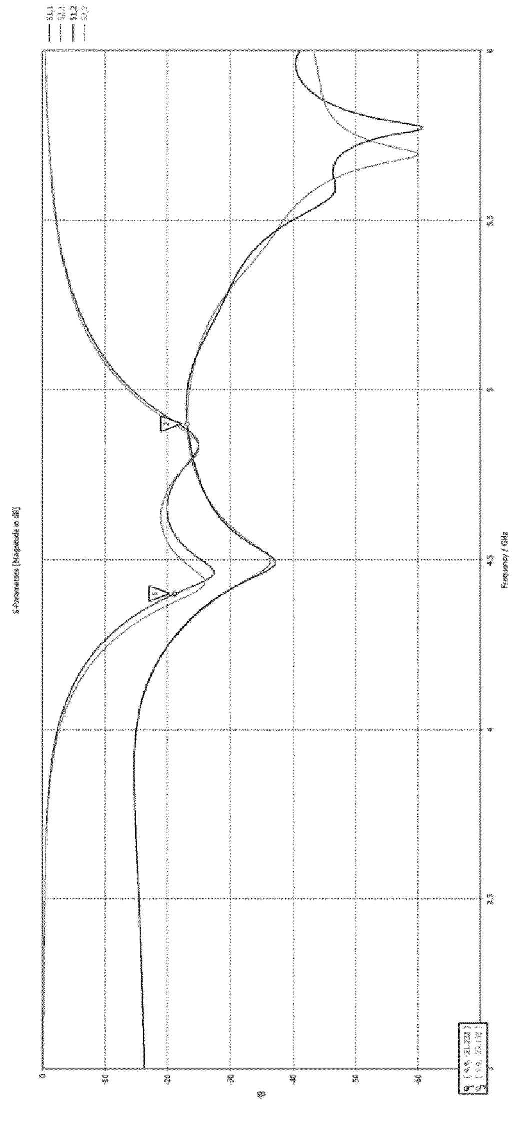

Fig. 7B

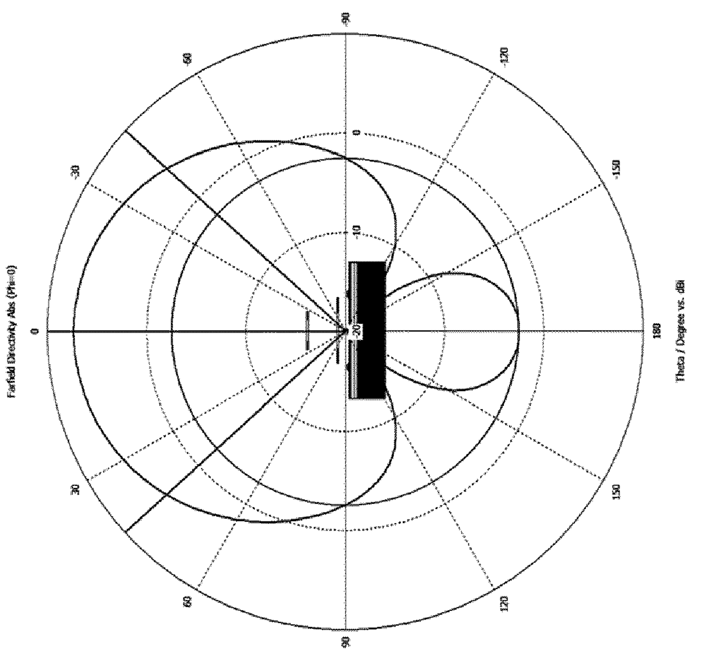
Farfield Directivity Abs (Phi=0)
Theta / Degree vs. dBi

Fig. 8A

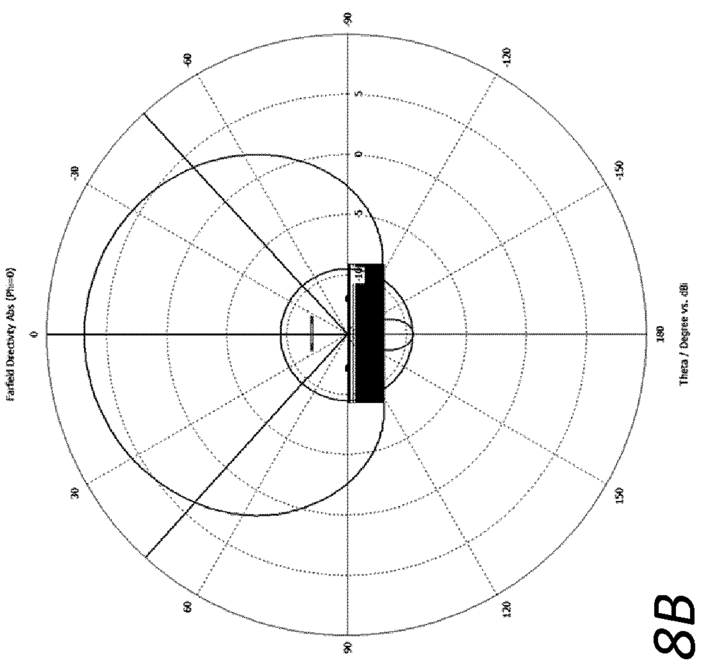
Farfield Directivity Abs (Phi=0)
Theta / Degree vs. dBi

Fig. 8B

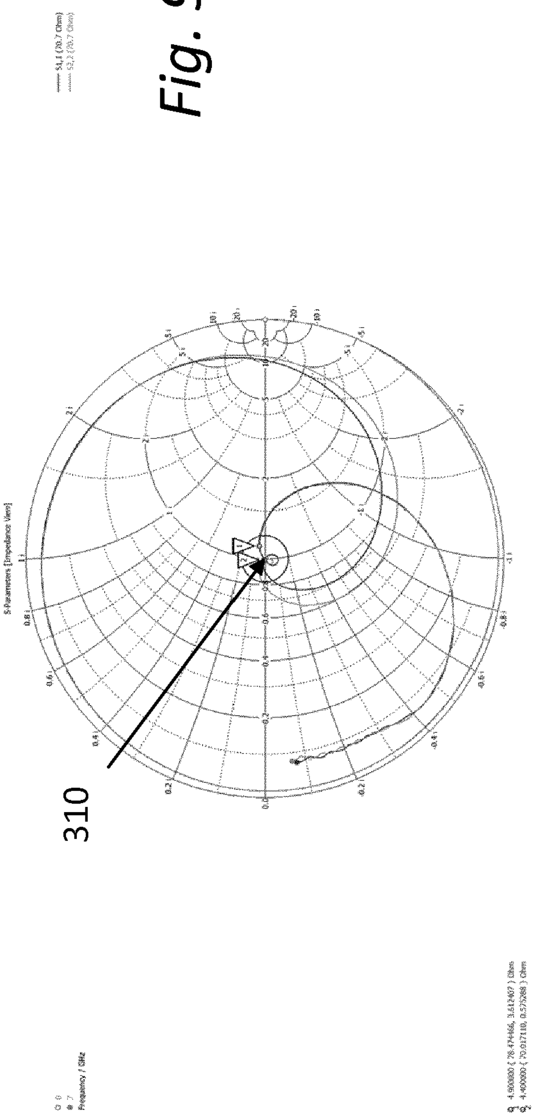

Fig. 9A

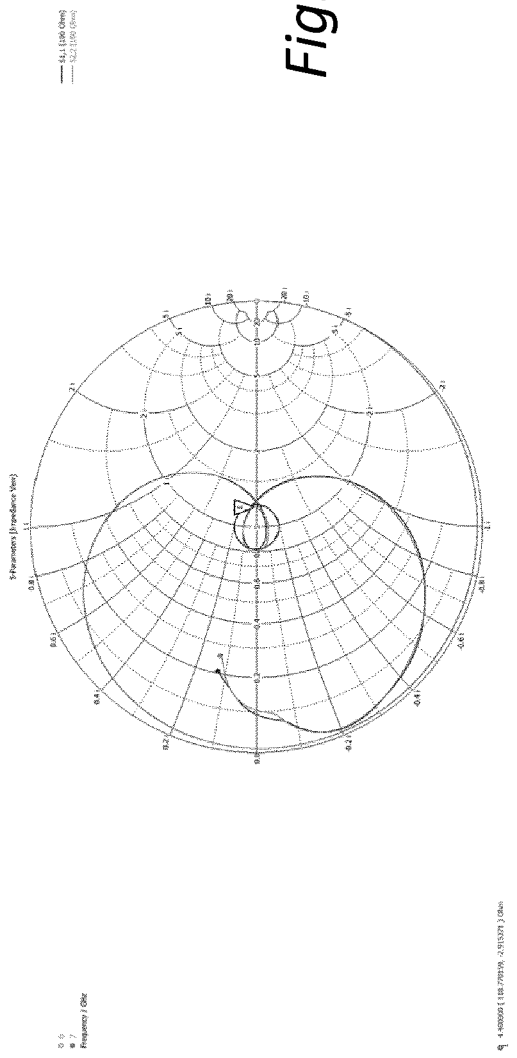

Fig. 9B

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European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 18 17 9474

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	EP 2 482 383 A2 (HUAWEI TECH CO LTD [CN]) 1 August 2012 (2012-08-01) * figures 3-5 * * paragraph [0005] - paragraph [0007] * * paragraph [0010] * * paragraph [0019] * * paragraph [0022] * -----	1-6, 10-12,15	INV. H01Q9/04
X	KIM D G ET AL: "A dual-polarization aperture coupled stacked microstrip patch antenna for wideband application", ANTENNAS AND PROPAGATION SOCIETY INTERNATIONAL SYMPOSIUM (APSURSI), 2010 IEEE, IEEE, PISCATAWAY, NJ, USA, 11 July 2010 (2010-07-11), pages 1-4, XP032146106, DOI: 10.1109/APS.2010.5562089 ISBN: 978-1-4244-4967-5	1,7,8, 11,14	
Y	* figure 1 * -----	9	
X	US 2014/253400 A1 (TIEZZI FERDINANDO [CH] ET AL) 11 September 2014 (2014-09-11) * figure 4 * * paragraph [0034] - paragraph [0035] * -----	1,11-13	TECHNICAL FIELDS SEARCHED (IPC) H01Q
Y	US 9 793 606 B2 (HUAWEI TECH CO LTD [CN]) 17 October 2017 (2017-10-17) * figure 4A * * paragraph [0072] - paragraph [0073] * -----	9	

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	10 December 2018	Yvonnet, Yannick

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 18 17 9474

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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10-12-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2482383 A2	01-08-2012	CN 102959801 A	06-03-2013
		EP 2482383 A2	01-08-2012
		WO 2011103841 A2	01-09-2011
US 2014253400 A1	11-09-2014	EP 2460230 A2	06-06-2012
		US 2011025574 A1	03-02-2011
		US 2014253400 A1	11-09-2014
		WO 2011014856 A2	03-02-2011
US 9793606 B2	17-10-2017	US 2017018848 A1	19-01-2017
		US 2018048064 A1	15-02-2018
		WO 2017008267 A1	19-01-2017

EPO FORM P0459

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