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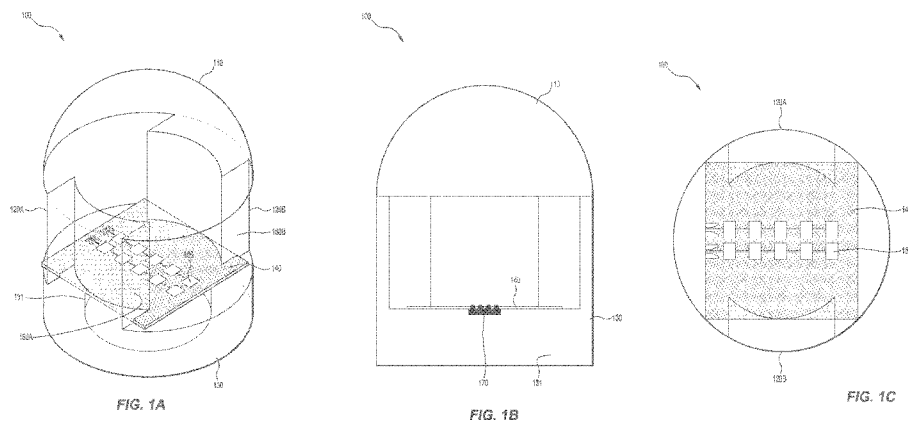
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(54) Title: AN ANTENNA UNIT



(57) Abstract: An antenna unit (100) comprises an antenna substrate (140) carrying one or more radiating elements (150), and a lens structure formed of a dielectric material, the lens structure comprising a lens (110) and at least one support member (120) arranged to support the antenna substrate (140) at a displacement relative to the lens (110).

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Title

AN ANTENNA UNIT

5 Field

The present invention relates to an antenna unit for use in a radar apparatus.

10 Background

Low power chip-based radars are becoming increasingly popular and widespread, especially in the automotive industry for safety and comfort applications such as collision avoidance or adaptive cruise control for motor vehicles.

Such chip-based radars have the potential to become more widespread if their cost can be lowered and/or if they can more easily integrated into motor vehicles or the like.

In order to achieve the necessary gain and angle resolution it has been proposed to use reflector and lens based antennas in automotive radar applications. These antenna types use a low-gain feed (such as a horn or planar patch) to illuminate a large, dielectric structure to diverge the primary rays so that they become a set of secondary rays that produce a desirable secondary radiation pattern for the transmitted radar signals. Lens antennas accomplish this by forward-scattering the primary rays of the transmitted radar signals, the basic process being one of diffraction. For this reason, lens antennas have one inherent advantage over reflector type antennas because the feed is not in the path of the secondary rays.

35 An offset to this advantage lies in the fact that lens antennas are typically thicker, heavier, and more

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difficult to construct than reflectors.

The present invention aims to provide an alternative antenna unit.

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Summary

In one aspect, the invention provides an antenna unit comprising:

10 an antenna substrate carrying one or more radiating elements; and

 a lens structure formed of a dielectric material, the lens structure comprising a lens and at least one support member arranged to support the antenna substrate at a
15 displacement relative to the lens.

In an embodiment, the support member is arranged to support the antenna substrate at a displacement relative to the lens where the plane of the antenna substrate
20 intersects the focus of the lens.

In an embodiment, the lens is a hemispherical lens.

In an embodiment, said lens structure comprises a pair of
25 walls extending from a base of the lens and joining the lens to a base member that provides the at least one support member.

In an embodiment, the antenna unit comprises a pair of
30 recesses in the integral lens structure where the walls meet the base member, each recess for receiving a portion of the antenna substrate.

In an embodiment, the base member is annular.

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In an embodiment, the one or more radiating elements are carried on an obverse, lens-facing side of the antenna

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substrate and at least one additional component is attached to a reverse side of the antenna substrate in a position where it extends into an interior of the annular base member.

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In an embodiment, the at least one additional component comprises a chip for driving the one or more radiating elements and/or processing signals received from the one or more radiating elements.

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In an embodiment, the lens is a hemicylindrical lens.

In an embodiment, said at least one support structure comprises a pair of walls extending from a base of the lens, each wall having a recess for receiving and supporting a portion of the antenna substrate.

15

In an embodiment, the one or more antenna elements are carried on an obverse, lens-facing side of the antenna substrate and at least one additional component is attached to a reverse side of the antenna substrate.

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In an embodiment, the at least one additional component comprises a chip for driving the one or more radiating elements and/or processing signals received from the one or more radiating elements.

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In an embodiment, the one or more radiating elements are provided by one or more series-fed patch arrays.

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In an embodiment, the one or more radiating elements are provided by at least one 2x2 patch array.

In an embodiment, the lens structure is formed from a low dielectric material such as Teflon or Rexolite.

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In another aspect, the invention provides a lens structure for an antenna unit, the lens structure being formed of a dielectric material, the lens structure comprising a lens and at least one support member arranged to support an
5 antenna substrate at a displacement relative to the lens.

In an embodiment, the support member is arranged to support the antenna substrate at a displacement relative to the lens where the plane of the antenna substrate will
10 intersect the focus of the lens.

In an embodiment, the lens is a hemispherical lens.

In an embodiment, the lens structure comprises a pair of
15 walls extending from a base of the lens and joining the lens to a base member that provides the at least one support member.

In an embodiment, the lens structure comprises a pair of
20 recesses in the lens structure where the walls meet the base member, each recess for receiving a portion of the antenna substrate.

In an embodiment, the base member is annular.
25

In an embodiment, the lens is a hemicylindrical lens.

In an embodiment, said at least one support structure comprises a pair of walls extending from a base of the
30 lens and, each wall having a recess for receiving and supporting a portion of the antenna substrate.

In an embodiment, the lens structure is formed from a low dielectric material such as Teflon or Rexolite.
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Brief Description of Drawings

Embodiments of the invention will now be described with reference to the accompanying drawings in which:

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Figure 1A is a partially transparent perspective view of an antenna unit of a first embodiment;

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Figure 1B is a partially transparent side view of an antenna unit of a first embodiment;

Figure 1C is a partially transparent top view of an antenna unit of a first embodiment;

15

Figure 2A is a partially transparent perspective view of an antenna unit of a second embodiment;

20

Figure 2B is an end view of an antenna unit of a second embodiment;

Figure 3 is a plan view of an antenna substrate with two series-fed patch arrays of radiating antenna elements;

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Figure 4 is a plan view of an antenna substrate with a 2x2 patch array of radiating antenna elements;

Figure 5 shows a hemispherical lens with two refracting surfaces; and

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Figure 6 shows a lens antenna radiation pattern in azimuth and elevation planes.

Detailed description

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In the embodiment, an improved antenna unit is provided by integrating a dielectric lens for an antenna into an lens structure formed of a dielectric material that

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incorporates both a lens and a support structure in a unitary body. The lens structure acts as a support (and in some embodiments as a housing) for an antenna substrate carrying radiating elements of the antenna, for example in the form of a primary printed array of radiating elements of the antenna. The antenna substrate is a planar substrate and may be a printed circuit board that provides baseband and digital signal circuits and may carry one or more additional components such as a CMOS chip for generating radar signals and/or processing reflected radar signals to obtain information about one or more targets.

The lens structure may be fabricated as a unitary body by using a 3-D printing or plastics moulding process.

In an embodiment suitable for automotive radar requirements, the radiating elements of the antenna may be a series-fed patch array. Such a series-fed patch array combined with a dielectric lens provided by the lens structure may provide high gain of above 20 dB.

As illustrated schematically in Figure 5, the gain and the 3dB beam width of the dielectric lens provided by the lens structure depends on its size. The correlation between the radius r of 10-30 mm, and the 3dB beam width (in the elevation plane) for a uniform illuminated circular lens can be estimated by:

$$\theta_{3dB} = 57 \frac{\lambda}{2r}$$

where λ is the wavelength at operating frequency and r is the radius of the lens. In order to achieve a high angle resolution and gain the 3dB - beam width has to be as small as possible since the gain (directivity) is related to the 3dB-beam width as:

$$D = \frac{41000}{\theta_{3dB} \phi_{3dB}}$$

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For example, to achieve the 20 dB directivity (gain) the 3dB-beam width should be 10° . This can be achieved by using a hemispherical lens (plano-convex) made of a dielectric material such as Teflon which is low loss material and
5 easy to manufacture and has a dielectric constant, $\epsilon_r=2.2$. Based on the above example, a lens that may be employed in an embodiment is one where the hemispherical lens portion of the lens structure is 20mm in diameter and the focal length is 10mm. Fig. 6 shows the predicted gain versus
10 angle in two principle planes for such a lens. As shown in Figure 6, the maximal gain of the antenna is 20 dB and the 3 dB beam width is 10° in elevation and 18° in azimuth plane. Side lobe suppression is 18 dB.

15 To achieve suitable gain while keeping the overall dimensions of the antenna unit to a reasonable size, employ lens portions of lens structures of advantageous embodiments of the invention have a radius in the range of 10mm to 15mm and more advantageously in the range of 10mm
20 to 12mm.

Persons skilled in the art will appreciate that materials other than Teflon may be employed for example, Rexolite ($\epsilon_r=2.53$), Foam ($\epsilon_r=1.69$), Silicon ($\epsilon_r=11.7$). In this
25 respect, while low dielectric constant materials are preferred, cost is a more significant consideration.

While microstrip series-fed patches may be used to produce a shaped pattern, without a lens the patch array would
30 have to be comprised of a considerably higher number of patch radiators. Accordingly, in the embodiment cascaded microstrip patch radiating elements are interconnected by half wavelength high-impedance T-lines. The design is based on the transmission line model and the equivalent
35 circuit concept. The shape of the radiation pattern (3 db beam width and gain) is directly related to the number of patches.

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Figures 1A to 1C show an antenna unit 100 of a first embodiment that has two series-fed antenna arrays 150 on an antenna substrate in the form of a printed circuit board (PCB) 140. As best seen in Figure 3, each of the antenna arrays 150A, 150B has five radiating antenna elements 321 that provide a primary radiation source for the antenna unit 100. In one example, the radiating antenna elements 321 are printed on a Taconic (PTFE) substrate of $\epsilon_r=2.2$ and thickness of 254 μ m. The width of the patches is 1.5 mm. The total length of the antenna including the feed line is 12 mm.

Referring to Figures 1A to 1C, it will be apparent that the lens structure of the antenna unit is formed from a hemispherical lens portion 110, a pair of opposing supporting walls 120A, 120B extend from the base of the lens portion 110 to meet an annular base member 130 on which the PCB 140 is supported. A pair of recesses 160A, 160B, where the walls 120 meet the base member 130, are adapted to receive the PCB 140 and hold it in place. The PCB 140 can be put in place by sliding it into the recesses. It will be appreciated that the base member is spaced from the lens 110 by the walls 120 such that the PCB 140 is supported at an appropriate displacement relative to the lens with the plane of the PCB intersecting the focal length of the lens 110.

The base member 130 is annular so as to define a hollow interior portion 132 within inner wall 131 that provides room for one or more additional components to be affixed to the PCB 140. In this example, a CMOS chip 170 for generating the radar signal and/or processing the return radar signal is affixed to the PCB 140 by ball soldering.

Figures 2A and 2B shows an antenna unit 200 of a second embodiment. In this embodiment, the lens structure has a

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cylindrical lens portion 210 supported by a pair of opposing walls 220A, 220B that extend from the base of the cylindrical lens portion 210. A pair of recesses 260A, 260B receive an antenna substrate in the form of PCB 240, in this example carrying radiating elements of one series-fed antenna array 250. The recesses 260 are positioned to appropriately space the radiating elements of the antenna from the lens 210.

Figure 4 illustrates an antenna array that may be used in another embodiment, in the form of 2x2 patch array 400 comprising four radiating elements of the antenna 410 on a PCB. Again array 400 is printed on Taconic (polytetrafluoroethylene) substrate of $\epsilon_r = 2.2$ and thickness of 254 μm . The size of the 2x2 patch array is 3.4mm x 3.85mm and the overall size of the structure including the ground plane is 4.5mm x 4.3mm. In order to obtain 50 Ω input impedance matching the antenna feeding line includes the transition from the coplanar waveguide to the microstrip line.

It will be understood to persons skilled in the art of the invention that many modifications may be made without departing from the spirit and scope of the invention, in particular it will be apparent that certain features of embodiments of the invention can be employed to form further embodiments. For example, while the above embodiments describe walls that support the lens, legs or a skirt could be used instead. Further, the embodiment of Figure 2 could have a third wall, closing one of the apertures between the pair of walls. Other variations will be apparent to those skilled in the art.

It is to be understood that, if any prior art is referred to herein, such reference does not constitute an admission that the prior art forms a part of the common general knowledge in the art in any country.

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In the claims which follow and in the preceding
description of the invention, except where the context
requires otherwise due to express language or necessary
5 implication, the word "comprise" or variations such as
"comprises" or "comprising" is used in an inclusive sense,
i.e. to specify the presence of the stated features but
not to preclude the presence or addition of further
features in various embodiments of the invention.

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CLAIMS:

1. An antenna unit comprising:
5 an antenna substrate carrying one or more radiating elements; and
a lens structure formed of a dielectric material, the lens structure comprising a lens and at least one support member arranged to support the antenna substrate at a
10 displacement relative to the lens.
2. An antenna unit as claimed in claim 1, wherein the support member is arranged to support the antenna substrate at a displacement relative to the lens where the
15 plane of the antenna substrate intersects the focus of the lens.
3. An antenna unit as claimed in claim 1 or claim 2, wherein the lens is a hemispherical lens.
20
4. An antenna unit as claimed in claim 3, wherein said lens structure comprises a pair of walls extending from a base of the lens and joining the lens to a base member that provides the at least one support member.
25
5. An antenna unit as claimed in claim 4, comprising a pair of recesses in the integral lens structure where the walls meet the base member, each recess for receiving a portion of the antenna substrate.
30
6. An antenna unit as claimed in claim 4 or claim 5, wherein the base member is annular.
7. An antenna unit as claimed in claim 6, wherein the
35 one or more radiating elements are carried on an obverse, lens-facing side of the antenna substrate and at least one additional component is attached to a reverse side of the

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antenna substrate in a position where it extends into an interior of the annular base member.

8. An antenna unit as claimed in claim 7, wherein the at least one additional component comprises a chip for driving the one or more radiating elements and/or processing signals received from the one or more radiating elements.

9. An antenna unit as claimed in claim 1, wherein the lens is a hemicylindrical lens.

10. An antenna unit as claimed in claim 1, wherein said at least one support structure comprises a pair of walls extending from a base of the lens, each wall having a recess for receiving and supporting a portion of the antenna substrate.

11. An antenna unit as claimed in claim 9 or claim 10, wherein the one or more antenna elements are carried on an obverse, lens-facing side of the antenna substrate and at least one additional component is attached to a reverse side of the antenna substrate.

12. An antenna unit as claimed in claim 11, wherein the at least one additional component comprises a chip for driving the one or more radiating elements and/or processing signals received from the one or more radiating elements.

13. An antenna unit as claimed in any one of claims 1 to 11, wherein the one or more radiating elements are provided by one or more series-fed patch arrays.

14. An antenna unit as claimed in any one of claims 1 to 11, wherein the one or more radiating elements are provided by at least one 2x2 patch array.

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15. An antenna unit as claimed in anyone of claims 1 to 14, wherein the lens structure is formed from a low dielectric material.

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16. An antenna unit as claimed in claim 15, wherein the dielectric material is selected from a group including Teflon and Rexolite.

10 17. A lens structure for an antenna unit, the lens structure being formed of a dielectric material, the lens structure comprising a lens and at least one support member arranged to support an antenna substrate at a displacement relative to the lens.

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18. A lens structure as claimed in claim 17, wherein the support member is arranged to support the antenna substrate at a displacement relative to the lens where the plane of the antenna substrate will intersect the focus of the lens.

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19. A lens structure as claimed in claim 17 or claim 18, wherein the lens is a hemispherical lens.

25 20. A lens structure as claimed in claim 19, wherein said lens structure comprises a pair of walls extending from a base of the lens and joining the lens to a base member that provides the at least one support member.

30 21. A lens structure as claimed in claim 20, comprising a pair of recesses in the lens structure where the walls meet the base member, each recess for receiving a portion of the antenna substrate.

35 22. A lens structure as claimed in claim 20 or claim 21, wherein the base member is annular.

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23. A lens structure as claimed in claim 17, wherein the lens is a hemicylindrical lens.

24. A lens structure as claimed in claim 23, wherein said
5 at least one support structure comprises a pair of walls extending from a base of the lens and, each wall having a recess for receiving and supporting a portion of the antenna substrate.

10 25. A lens structure as claimed in any one of claims 17 to 24, wherein the lens structure is formed from a low dielectric material.

15 26. A lens structure as claimed in claim 25, wherein the dielectric material is selected from a group including Teflon or Rexolite.

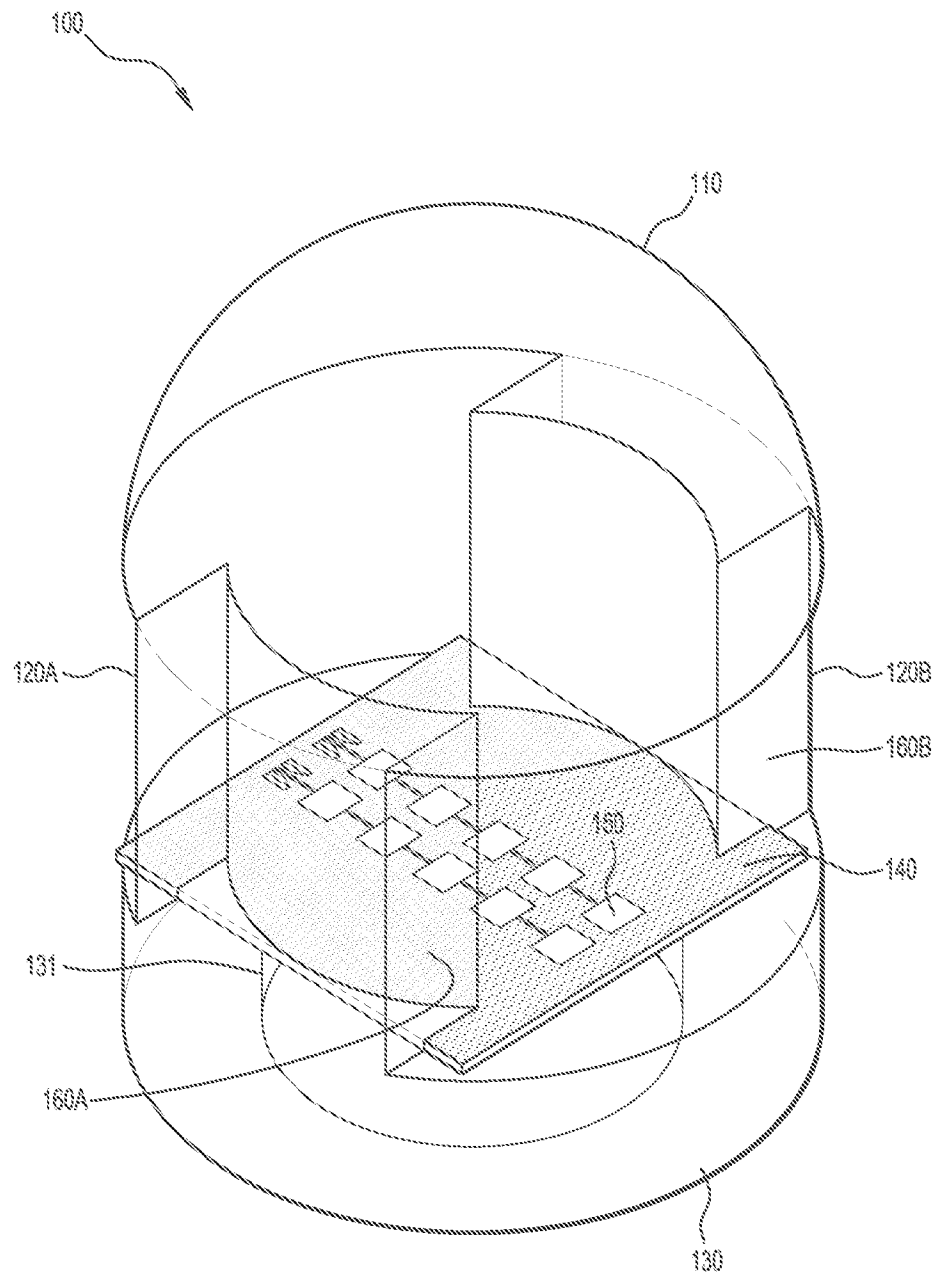


FIG. 1A

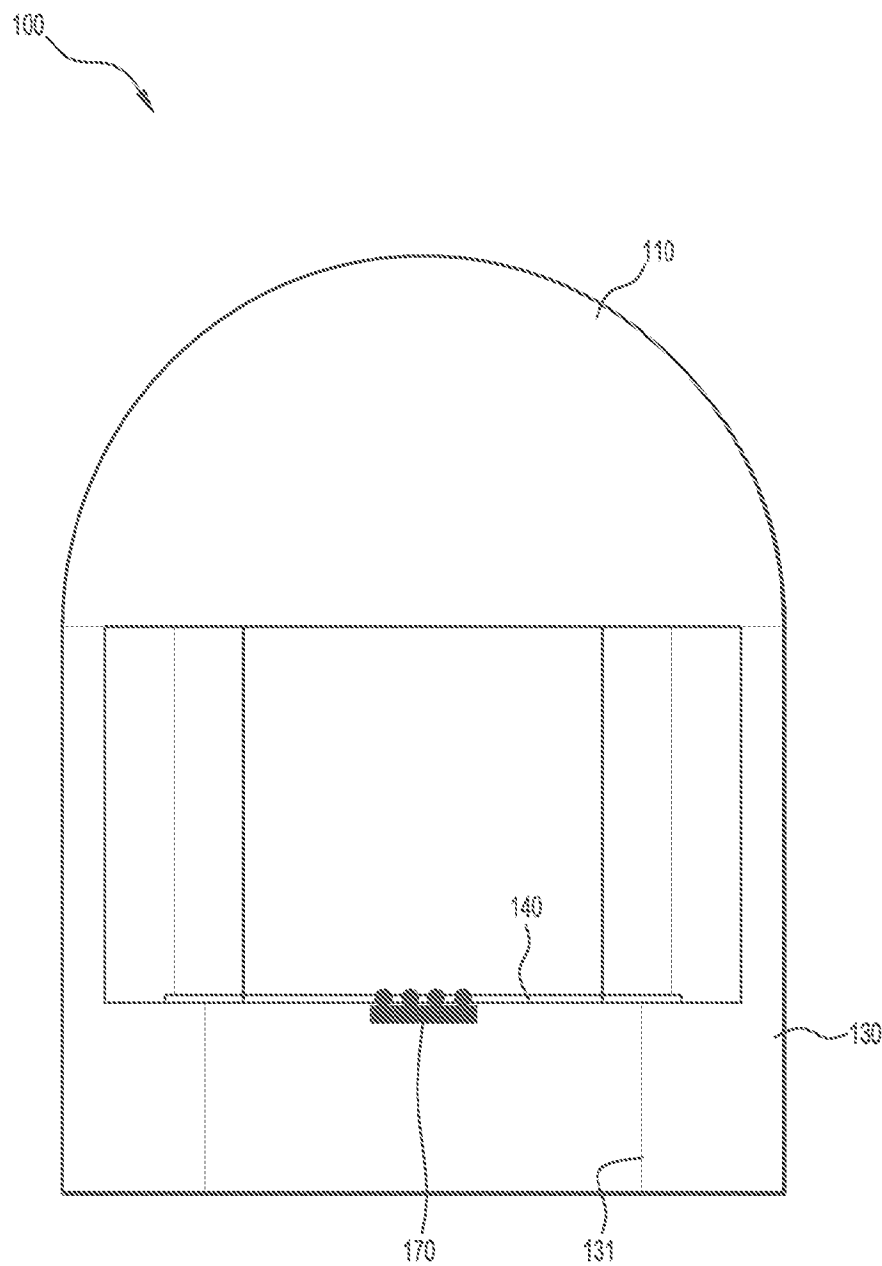


FIG. 1B

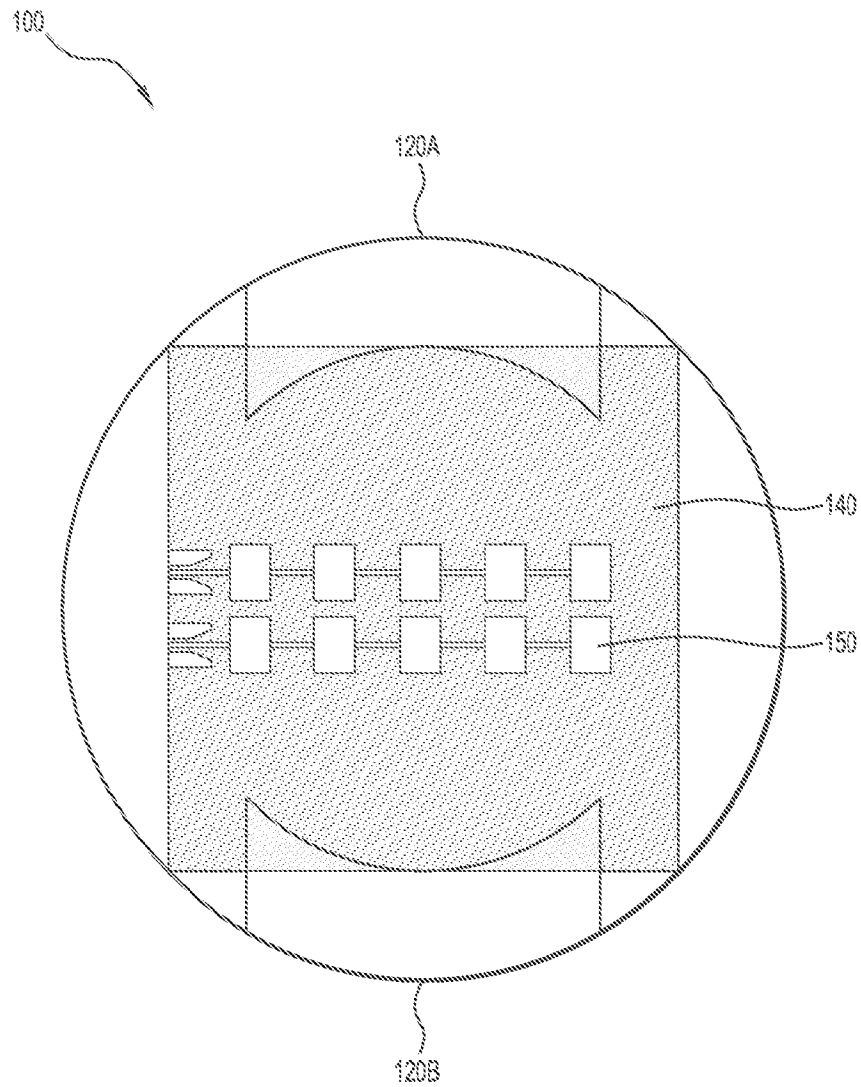


FIG. 1C

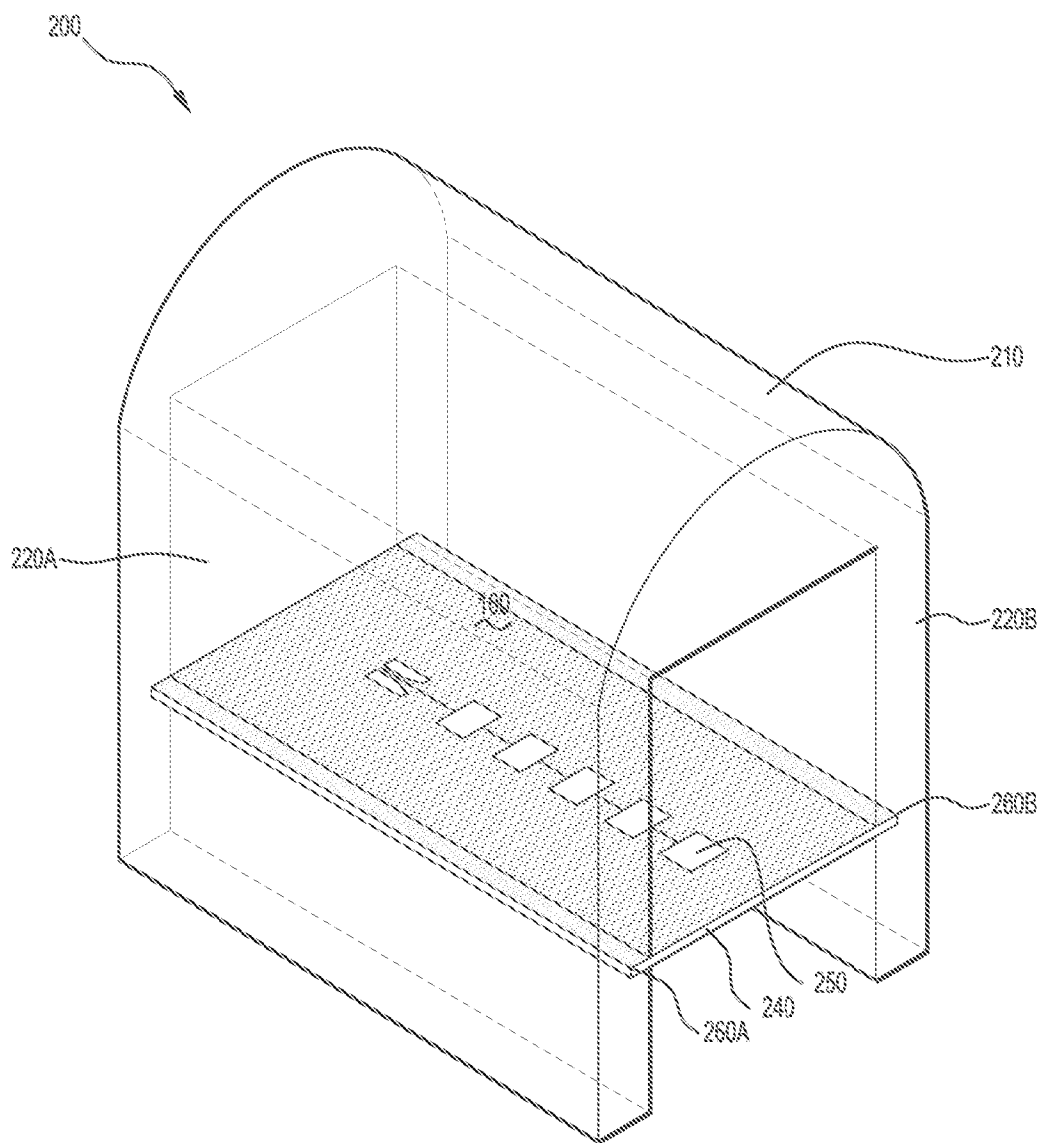


FIG. 2A

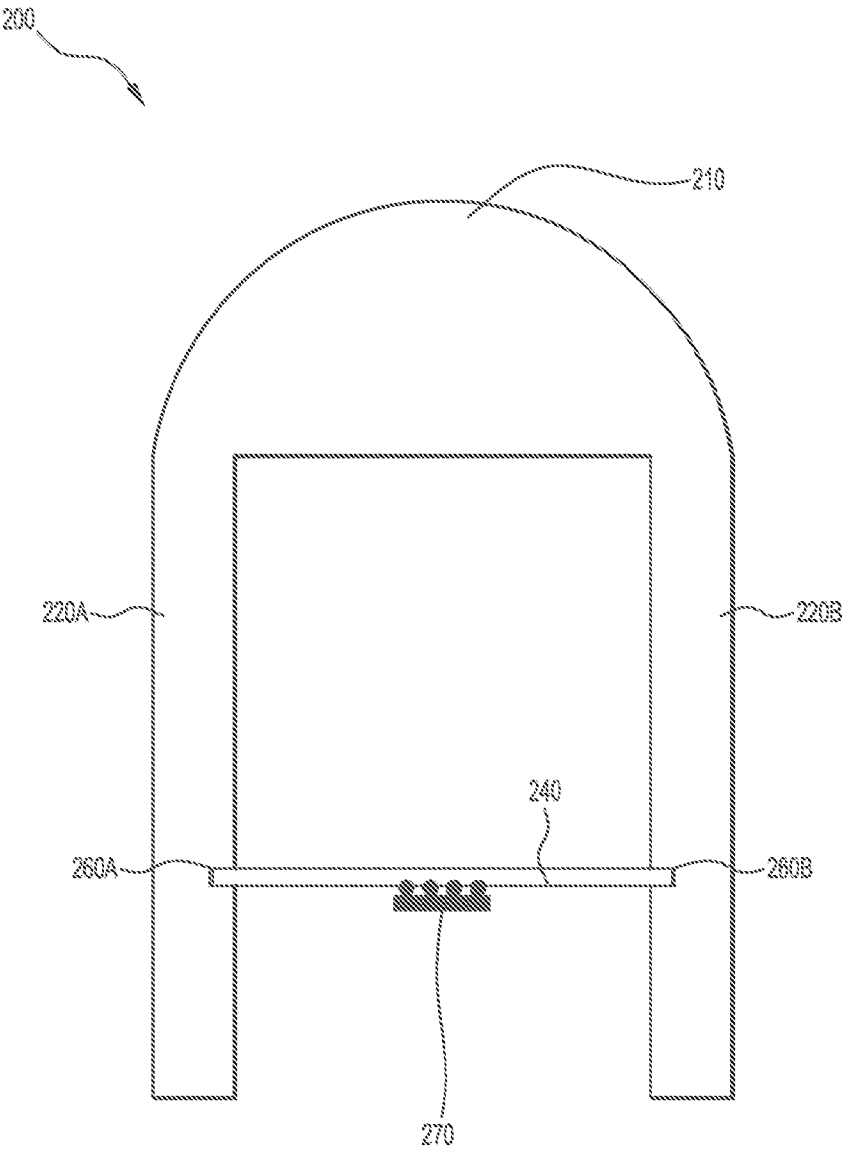


FIG. 2B

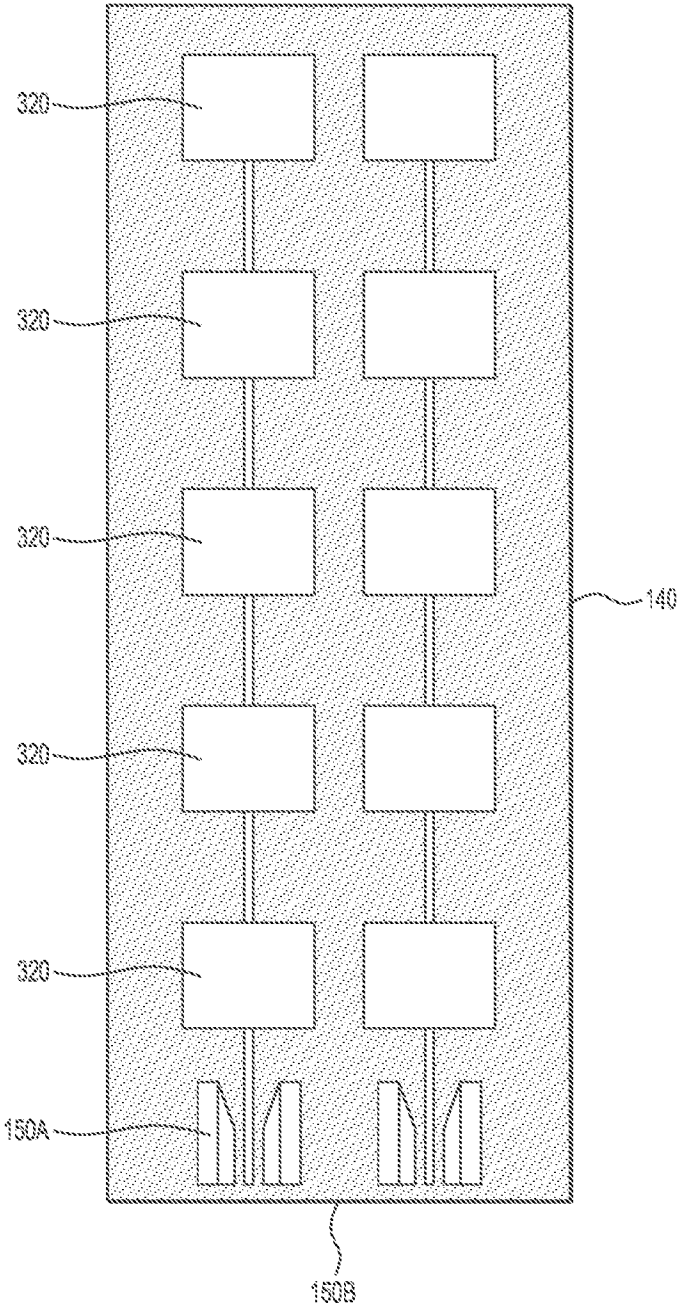


FIG. 3

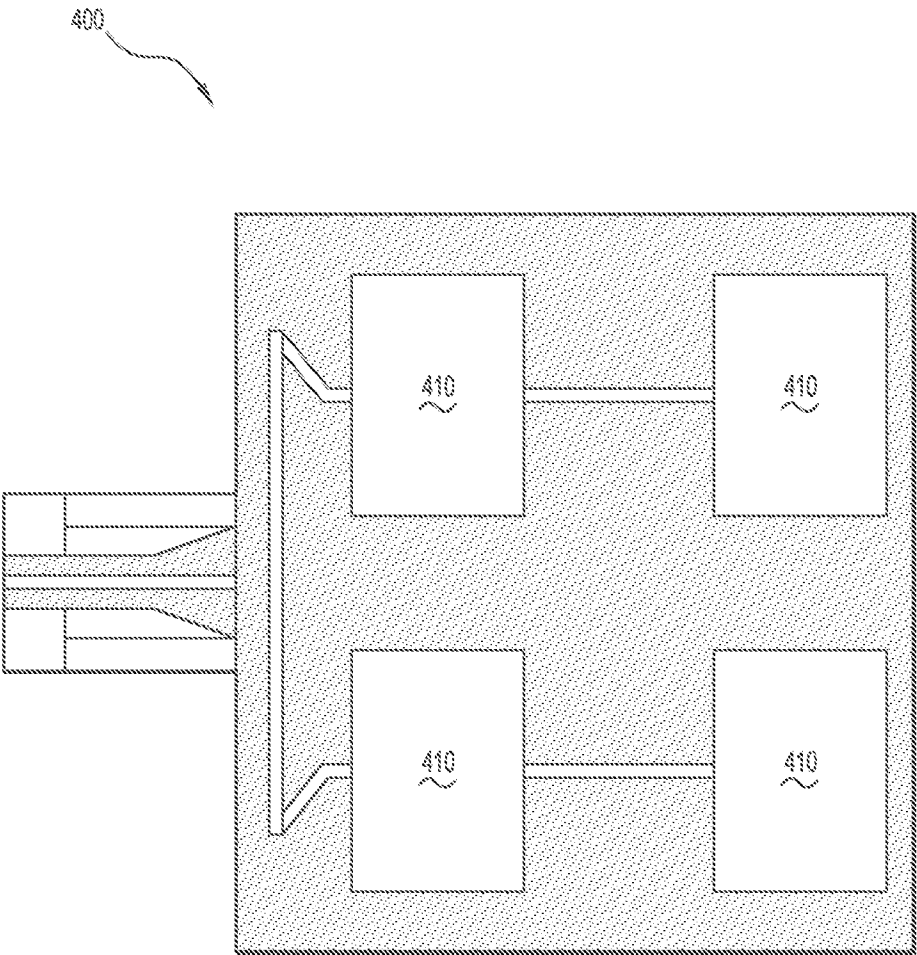


FIG. 4

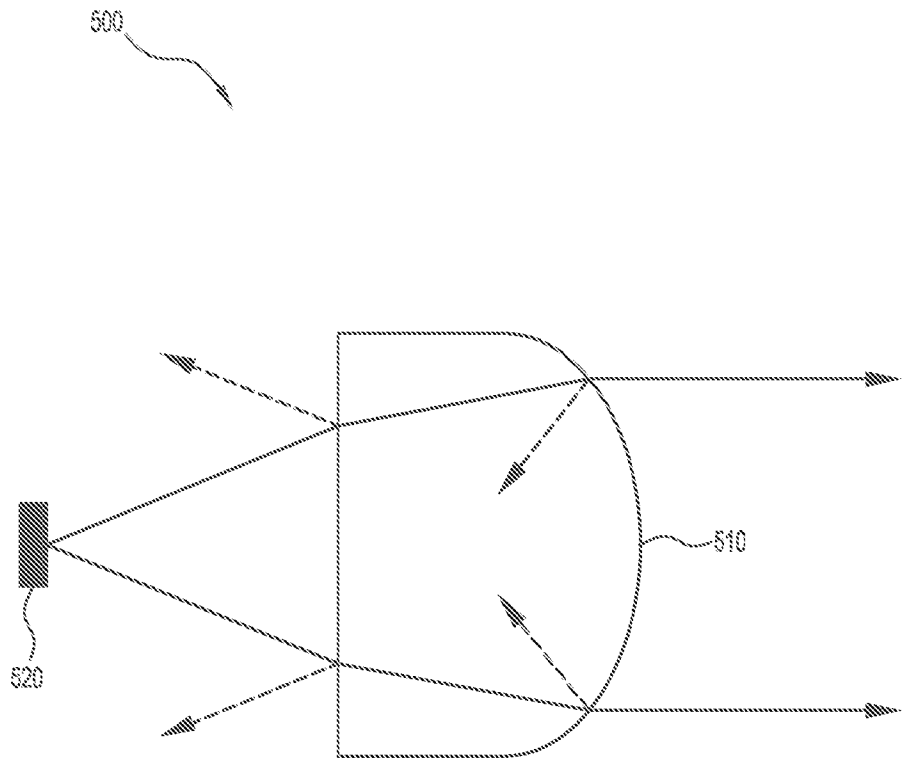


FIG. 5

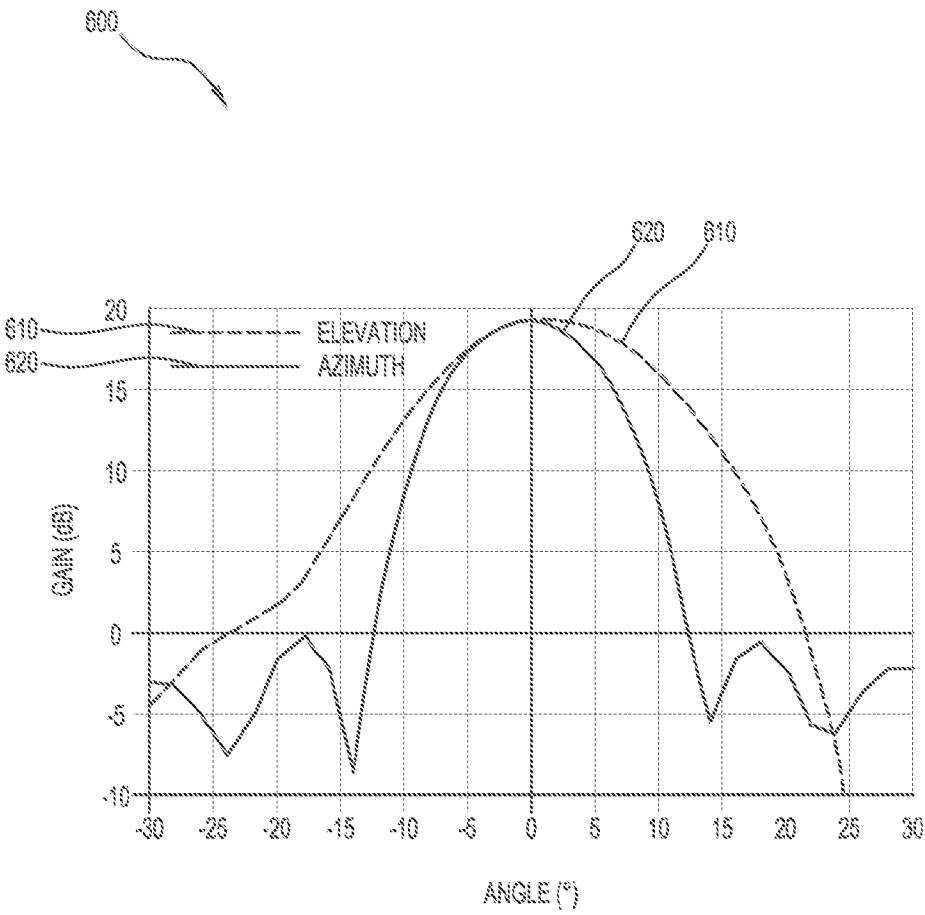


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2013/000827

A. CLASSIFICATION OF SUBJECT MATTER

H01Q 19/06 (2006.01) G01R 29/08 (2006.01)

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)

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)

EPOQUE Databases: EPODOC, WPI, INSPEC: Keywords (dielectric lens, Antenna array, wall, substrate, chip) & like terms.**INTERNET:** Google and Google Patents: Keywords (dielectric lens, Antenna array, wall, substrate, chip) & like terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

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"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
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Date of the actual completion of the international search
30 August 2013Date of mailing of the international search report
30 August 2013

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International application No.

DOCUMENTS CONSIDERED TO BE RELEVANT

PCT/AU2013/000827

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6590544 B1 (FILIPOVIC) 08 July 2003 Abstract, col. 2 lines 16-67, col. 4 lines 19-52, col. 11 line 39 – col. 12 line 61, Figs. 1, 2, 4, 5B, 5C, 8, 17A, 17B and 19, claim 1.	1-26
X	GB 2458723 B (QINETIQ Limited) 03 March 2010 Page 1 lines 1- 34, page 2 line 4 – page 3 line 35, page 5 lines 13-31, page 14 lines 20-32, page 15 lines 1-11, Figs. 1, 3, 10-12, 15,16.	1-26

INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/AU2013/000827	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
US 6590544 B1	08 Jul 2003	None	
GB 2458723 B	03 Mar 2010	GB 2458723 A	07 Oct 2009
		GB 2458723 B	03 Mar 2010
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			