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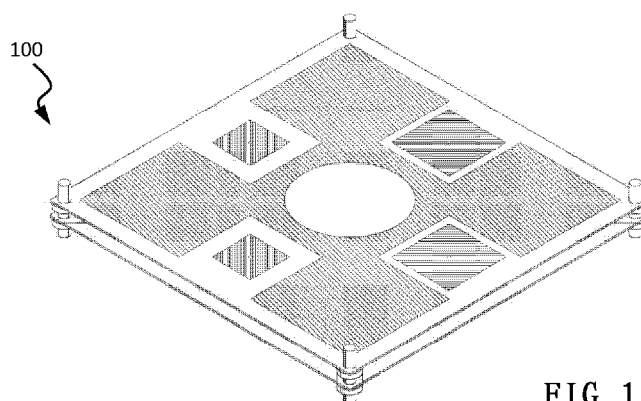


FIG. 1

(57) Abstract: Embodiments of the present disclosure provide a microstrip dual-polarized antenna for wireless transmission. The antenna comprises: a first dielectric substrate; a metal radiation sheet disposed on the first dielectric substrate, the metal radiation sheet defining a first square, each side of the first square defining a respective concave notch; a second dielectric substrate; a metal ground sheet disposed on the second dielectric substrate, the metal ground sheet defining a second square, the metal ground sheet defining four open slots, each of the open slots respectively dividing each corresponding right angle of the second square into two oblique angles; and at least one pillar respectively coupled to the first dielectric substrate and the second dielectric substrate, so that the first dielectric substrate and the metal ground sheet are separated by an air gap.



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# MICROSTRIP DUAL-POLARIZED ANTENNA FOR WIRELESS TRANSMISSION

## FIELD

[0001] Embodiments of the present disclosure generally relate to the field of wireless transmission, in particular a microstrip dual-polarized antenna for wireless transmission.

## BACKGROUND

[0002] The construction of new 5G infrastructure, the development of the Internet of Things and the wireless device boom bring severe challenges along therewith to the wireless transmission technology. Restricted by a size of a wireless device, an antenna occupies a small area and has a low profile, but the small size of the antenna leads to a decrease in radiation intensity. A microstrip patch antenna according to the prior art, which is taken an example, typically has a low gain. In order to attain the antenna gain as required, the antenna should be enlarged in physical size. However, this is contradictory with the trend of miniaturization, causing a failure in meeting the demand of market.

## SUMMARY

[0003] An antenna is disclosed herein to provide an effective solution to the aforesaid technical problem. The antenna is applicable to the Internet of Things, in particular an application scenario requiring a high gain and a low profile. There are disclosed herein a miniaturized microstrip dual-polarized antenna with a low profile and a large effective aperture for wireless transmission, and a method for improving a gain of a miniaturized low-profile microstrip antenna disposed on a small ground plate. It is noted that the size of the ground plate is small, which is one of the merits making the antenna of the invention superior to conventional solution with comparable antenna gain. By opening slots (e.g. cuts, openings, open slits) on the metal radiation sheet and the metal ground sheet, the overall area of the antenna is reduced while engineering the current distribution over the metal radiation sheet and the ground plate, thereby achieving effects of enhancing forward radiation and improving the gain. In the premise of keeping an extremely low profile, the antenna can have an effective-to-physical aperture ratio of 3.4 that is obviously higher than a miniaturized microstrip antenna similarly in size. The antenna is suitable for a miniaturized terminal for mid-to-long-range wireless power transfer and radio frequency identification and thus has a

wide application in intelligent and digital collection monitoring, warehousing logistics and transportation, and the like.

**[0004]** In a first aspect, a microstrip dual-polarized antenna for wireless transmission is disclosed in the present disclosure. The antenna comprises: a first dielectric substrate; a metal radiation sheet disposed on the first dielectric substrate, the metal radiation sheet defining a first square, each side of the first square defining a respective concave notch; a second dielectric substrate; a metal ground sheet disposed on the second dielectric substrate, the metal ground sheet defining a second square, the metal ground sheet defining four open slots, each of the open slots respectively dividing each corresponding right angle of the second square into two oblique angles; and at least one pillar respectively coupled to the first dielectric substrate and the second dielectric substrate, so that the first dielectric substrate and the metal ground sheet are separated by an air gap.

**[0005]** In one embodiment, the antenna further comprises: two metal feed patches respectively disposed in two of the concave notches, wherein the metal feed patches and the metal radiation sheet are electrically insulated from one another; and two metal parasitic patches respectively disposed in another two of the concave notches, wherein the metal parasitic patches and the metal radiation sheet are electrically insulated from one another.

**[0006]** Preferably, the metal feed patches and the metal parasitic patches are substantially equal in size.

**[0007]** Preferably, each of the metal feed patches is larger or smaller than each of the metal parasitic patches in size.

**[0008]** Preferably, the metal feed patches are respectively disposed in two adjacent ones of the concave notches, and the metal parasitic patches are respectively disposed in another two adjacent ones of the concave notches.

**[0009]** Preferably, the metal radiation sheet further defines a central opening (330).

**[0010]** In another embodiment, the antenna further comprises a microstrip feed line disposed on the second dielectric substrate, the microstrip feed line being in electrical contact with the metal feed patches. Preferably, the antenna further comprises a metal feed probe, wherein the metal feed probe extends in the air gap, and wherein the metal feed probe is in respective electrical contact with the microstrip feed line and corresponding metal feed patches. Preferably, the ground sheet is provided on a first surface of the second dielectric substrate, and the microstrip feed line is provided on a second surface of the second dielectric substrate.

[0011] In a further embodiment, the antenna further comprises a metal ground post, wherein the metal ground post extends in the air gap, and wherein the metal ground post is in respective electrical contact with corresponding metal parasitic patches and the metal ground sheet.

5 [0012] Preferably, the concave notches are symmetrically disposed at each of four sides of the first square, and wherein the concave notches are substantially of the same size.

[0013] Preferably, the four open slots are symmetrically disposed at each of four corners of the second square, and wherein the open slots are substantially of the same size, and wherein the open slots are spaced apart from one another.

10 [0014] Preferably, a ratio of an area defined by the first square to an area defined by the second square is at least 80%.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Fig. 1 is a perspective view of an antenna according to an embodiment;

[0016] Fig. 2 is an exploded view according to the embodiment of Fig. 1;

15 [0017] Fig. 3 is a side view according to the embodiment of Fig. 1;

[0018] Fig. 4 is a top view according to the embodiment of Fig. 1;

[0019] Fig. 5 is a bottom view according to the embodiment of Fig. 1;

[0020] Fig. 6 is a top view of a metal radiation sheet according to the embodiment of Fig. 1;

[0021] Fig. 7 is a top view of a metal ground sheet according to the embodiment of Fig. 1;

20 [0022] Fig. 8 is a sectional view according to the embodiment of Fig. 1;

[0023] Figs. 9A, 9B and 9C illustrate respective size parameters of the antenna according to the embodiment of Fig. 1;

[0024] Fig. 10 illustrates three example antennas (Antenna 1, Antenna 2, and Antenna 3) with respect to size, gain, and aperture area ratio

25 [0025] Fig. 11 illustrates a simulation S parameter and a radiation direction of Antenna 1;

[0026] Fig. 12 illustrates a simulation S parameter and a radiation direction of Antenna 2; and

[0027] Fig. 13 illustrates a simulation S parameter and a radiation direction of Antenna 3;

and

[0028] Fig. 14 illustrates a grounding current layout of the antenna according to the embodiment of Fig. 1.

## DETAILED DESCRIPTION OF EMBODIMENTS

5 [0029] It is to be understood that, except in the example embodiments described therein, the components as generally depicted and shown in the drawings can be arranged and designed in various manners. Accordingly, the example embodiments illustrated with reference to the drawings and the detailed description made below are merely provided as examples, rather than suggesting any limitations to the scope of protection.

10 [0030] As used herein, “an embodiment,” “another embodiment” or “embodiment” (or the similar terms) means that specific features, structure or characteristics as described with reference to the embodiment are covered in at least one embodiment. Therefore, as used herein, the expression “in an embodiment,” “in one embodiment” or the like may not refer to the same embodiment.

15 [0031] In addition, the features, structures or characteristics as described herein may be combined in one or more embodiments in any appropriate manner. More details will be provided below for thorough understanding on the embodiments. Nevertheless, those skilled in the art would realize that various embodiments can be implemented when one or more details are missing, or other methods, components, materials and the like are utilized. In  
20 other cases, some or all the known structures, materials or operations may not be demonstrated or described in detail for the sake of clarity.

[0032] Reference will now be made to the drawings to describe the present disclosure. To miniaturize a microstrip antenna, a miniaturized microstrip dual-polarized antenna having a low profile and a high gain is proposed. The microstrip dual-polarized antenna elaborated  
25 herein can guarantee the gain while miniaturizing the size of the microstrip antenna and its ground plate, to thus remarkably increase the effective-to-physical aperture ratio. By opening slots on the microstrip patch and the ground plate, the present disclosure can achieve effects of miniaturizing the antenna, manipulating the current distribution on the metal surface of the antenna, and enhancing forward gain.

30 [0033] Figs. 1-8 illustrate a microstrip dual-polarized antenna 100 for wireless transmission according to an embodiment of the present disclosure. The microstrip dual-polarized

antenna 100 includes: a first dielectric substrate 200; a metal radiation sheet 300 disposed on the first dielectric substrate 200; a second dielectric substrate 400; a metal ground sheet 500 disposed on the second dielectric substrate 400; and at least one pillar 700 respectively coupled to the first dielectric substrate 200 and the second dielectric substrate 400, where the first dielectric substrate 200 and the metal ground sheet 500 are separated by an air gap 800. The at least one pillar 700, the first dielectric substrate 200 and the second dielectric substrate 400 are formed of an insulating material, respectively. The first dielectric substrate 200 and the second dielectric substrate 400 may be formed of a material having a relative dielectric constant of 3.5 and a loss tangent of 0.001.

**[0034]** Wherein, the metal radiation sheet 300 defines a first square 380, and each side 380a/b/c/d of the first square 380 defines a respective concave notch 310a/b/c/d. For example, pairs of concave notches 310a/c, 310b/d are disposed symmetrically on four sides of the first square 380, where each concave notch 310a/b/c/d is substantially of the same size. The concave notch 310a/b/c/d may be a square notch. The metal radiation sheet further defines a central opening 330 which may be a round opening. In addition, the metal ground sheet defines a second square 580 and further defines four open slots 510a/b/c/d, where each of the open slots 510a/b/c/d divides the respective right angle 580a/b/c/d of the second square 580 into two oblique angles 530a/b/c/d and 532a/b/c/d. In other words, the respective pairs of oblique angles 530a/b/c/d and 532a/b/c/d are equal in size (e.g. 530a and 532a are equal in size). In an embodiment, the oblique angles 530a/b/c/d and 532a/b/c/d are equal in size (e.g. 530a and 530b are equal in size). The four open slots 510a/b/c/d are symmetrically disposed at four corners 580a/b/c/d of the second square 580, where the respective open slots 510a/b/c/d are substantially of the same size. Moreover, the open slots 510a/b/d/d are spaced apart from one another, and the open slots 510a/b/c/d are not joined to each other. For example, a ratio of an area defined the first square to an area defined by the second square is at least 80%.

**[0035]** For example, the first dielectric substrate 200 includes a first surface 202 and a second surface 204, and the metal radiation sheet 300 is disposed on the first surface 202 of the first dielectric substrate 200. The second dielectric substrate 400 includes a first surface 402 and a second surface 404, and the metal ground sheet is disposed on the first surface 402 of the second dielectric substrate 400; and a mcicrostrip feed line 710 is disposed on the second surface 404 of the second dielectric substrate 400. For example, the first dielectric substrate 200 has a thickness of 5 millimeters (mm), the second dielectric substrate 400 has a thickness

of 0.5 millimeters (mm), and the air gap has a thickness of 4 millimeters (mm).

**[0036]** The microstrip dual-polarized antenna 100 further includes two metal feed patches 610 respectively disposed in two concave notches 310a/b, wherein the metal feed patches 610 are electrically insulated from the metal radiation sheet 300. The microstrip dual-polarized antenna 100 further includes two parasitic patches 630 respectively disposed in another two concavity notches 310c/d, where the parasitic patches 630 are electrically insulated from the metal radiation sheet 300. The metal feed patches 610 and the parasitic patches 630 may be square. In this example, the metal feed patches 610 are disposed in two adjacent concave notches 310a/b, and the metal parasitic patches 630 are disposed in another two adjacent concave notches 310c/d. In another example, the metal feed patches 610 may be disposed opposite each other in two concave notches 310a/c, and the parasitic metal patches 630 may be disposed opposite each other in another two concave notches 310b/d. The size relation between the metal feed patch 610 and the parasitic metal patch 630 plays a role of tuning the operating frequency of the antenna and fulfilling input impedance matching. Therefore, the relation may be set below as required: the metal feed patch 610 is greater than, equal to, or less than the parasitic metal patch 630. For example, the metal feed patch 610 is less than the parasitic metal patch 630 in size. For another example, the metal feed patch 610 is greater than the parasitic metal path 630 in size. For further example, the metal feed patch 610 is substantially equal to the parasitic metal patch 630 in size.

**[0037]** The microstrip dual-polarized antenna 100 further includes two microstrip feed lines 710 depending on which dual-polarization can be accomplished. The microstrip feed lines 710 are disposed on the second dielectric substrate 400. The two microstrip feed lines 710 may be disposed on the second surface 404 of the second dielectric substrate 400. The microstrip feed lines 710 are in electrical contact with the metal feed patches 610. Referring to Fig. 8, the antenna 100 includes a metal feed probe 730 and a metal ground post 750, where the metal feed post 730 extends in the air gap and is in respective electric contact with the microstrip feed lines 710 and corresponding metal feed patches 610. Furthermore, the metal ground post 750 extends in the air gap and is in respective electric contact with corresponding metal parasitic patches 630 and the metal ground sheet 500.

**[0038]** The metal feed post 730 extends through the second dielectric substrate 400 and the first dielectric substrate 200 and is in respective electrical contact with the microstrip feed lines 710 and the corresponding metal feed patches 610. When extending through the second dielectric substrate 400, the metal feed post 730 is electrically insulated from the metal

ground sheet 500. After extending through the first dielectric substrate 200, the metal ground post 750 is in respective electrical contact with the parasitic metal patches 630 and the metal ground sheet 500.

**[0039]** In an embodiment, electromagnetic energy is effectively coupled to the metal radiation sheet 300 via the microstrip feed lines 710, the metal feed post 730 having a radius of 0.5 millimeters (mm), and the metal feed patches 610, to excite its main mode. With the inductive effect of the metal feed post 730 and the capacitive effect caused by the metal feed patches 610, the impedance matching of the antenna with the microstrip feed lines 710 having a characteristic impedance of 50 ohms can be adjusted, without a necessity for other matching structures.

**[0040]** By means of the two-point feeding mode and the overall square structure of the antenna, the dual-polarized antenna 100 fulfills dual-polarization in a pair of main modes orthogonal to each other. With the air gap between the metal radiation sheet 300 and the metal ground sheet 500, the present disclosure can miniaturize the antenna and manipulate a current distribution over the antenna. The cooperation between the concave notches 310a/b/c/d on the metal radiation sheet 300 and the open slots 510a/b/c/d on the metal ground sheet 500 of the antenna makes a positive contribution to forward radiation, thus improving the forward gain of the antenna and increasing an effective-to-physical ratio (EPAR) of the antenna. It is worth noting that an antenna provided only with concave notches 310a/b/c/d or open slots 510a/b/c/d cannot attain the forward gain and the EPAR as mentioned above.

**[0041]** In a further aspect, a method of arranging a microstrip dual-polarized antenna is disclosed, including adopting an antenna setting where an effective-to-physical aperture ratio (EPAR) is as great as possible whereas a ground sheet has an area as small as possible. As used herein, the term “an effective-to-physical aperture ratio (EPAR)” is to be read as a ratio of an effective aperture area ( $A_{\text{eff}}$ ) to a physical aperture area ( $A_{\text{phys}}$ ) of an antenna (i.e.,  $\text{EPAR} = A_{\text{eff}}/A_{\text{phys}}$ ).

**[0042]** According to an embodiment, the microstrip dual-polarized antenna is set based on the Equation 1.

**[0043]** In the Equation 1,  $N$  is an expansion order of an outfield spherical wave function,  $\lambda_0$  is a wavelength in a free space,  $G$  is a broadside gain of the antenna,  $a$  is a radius of a circumscribed sphere of the antenna, and  $k$  is a wave number in the free space.

**[0044]** Figs. 9A, 9B and 9C illustrate various size parameters of an antenna. Fig. 10

illustrates various parameters and values of example Antenna 1, Antenna 2, and Antenna 3. Figs. 11, 12 and 13 illustrate respective simulation S parameters and radiation directions of Antenna 1, Antenna 2, and Antenna 3.

**[0045]** Regarding Antenna 1: the metal feed patch ( $w_{fp}$ ) is less than the metal parasitic patch ( $w_{pp}$ ) in size. As can be seen from Fig. 11 which illustrates a simulation S parameter and a radiation direction, Antenna 1 has a high EPAR (3.2) but exhibits poor port isolation and a great cross-polarization level; the physical size of the antenna is only  $0.27\lambda*0.27\lambda*0.015\lambda$  (where  $\lambda$  is an electromagnetic wavelength in a free space).

**[0046]** Regarding Antenna 2: the metal feed patch ( $w_{fp}$ ) is equal to the metal parasitic path ( $w_{pp}$ ) in size. As can be seen from Fig. 12 which illustrates a simulation S parameter and a radiation direction, Antenna 2 has a high EPAR (3.4) and a high gain (6.0dBi) and exhibits satisfactory port isolation and a low cross-polarization level. Although the physical size of the antenna is only  $0.27\lambda*0.27\lambda*0.015\lambda$  (where  $\lambda$  is an electromagnetic wavelength in a free space), the antenna attains a forward gain of 6.0dBi and an EPAR of 3.4, superior to the existing microstrip dual-polarized antenna of the same size.

**[0047]** Regarding Antenna 3: the metal feed patch ( $w_{fp}$ ) is equal to the metal parasitic path ( $w_{pp}$ ) in size, and the antenna has a metal ground sheet with a large area. As can be seen from Fig. 13 which illustrates a simulation S parameter and a radiation direction, Antenna 3 has a low EPAR (2.9) but a high gain (6.8dBi), and exhibits satisfactory port isolation and a low cross-polarization level; the physical size of the antenna is only  $0.29\lambda*0.29\lambda*0.015\lambda$  (where  $\lambda$  is an electromagnetic wavelength in a free space).

**[0048]** As described above, among the three example antennas, if the antenna with the highest gain value is chosen according to the common sense, it should be Antenna 3, rather than Antenna 2. In other words, only from the gains of the antennas, a potential of further miniaturizing the antenna in the premise of satisfying the antenna gain requirement cannot be spotted. If the EPAR is further computed and used as a key factor according to an embodiment of the present disclosure, a better antenna configuration, such as Antenna 2, will be obtained. In this way, if the technical solution as described herein is applied in practice, respective parameters of the antenna can be set or adjusted according to actual application scenarios.

**[0049]** In a further aspect, a microstrip dual-polarized antenna set according to the above-mentioned method is disclosed herein, where a metal radiation sheet 300 and a metal

ground sheet 500 are separated by an air gap; and a ground current distribution of the metal ground sheet 500 of the antenna is set such that a current density over a central portion 910 is higher than a current density over a peripheral portion 920. Referring to Fig. 14, the ground current distribution is also dependent on the metal radiation sheet 300 and the metal ground sheet 500, and the technical effects of so doing include miniaturizing the antenna size, manipulating the current distribution over the metal surface of the antenna, and enhancing the forward gain. For clearly demonstrating the position of the metal ground sheet 500 relative to the metal radiation sheet 300, other components (e.g. the first dielectric substrate, the second dielectric substrate, and the like) are omitted in the figure. In this example, the ground current distribution is dependent on relative sizes, shapes and positions of the concave notches 310 of the metal radiation sheet 300, the central opening 330 of the metal radiation sheet 300, and the open slots 510 of the metal ground sheet 500. The central portions (i.e., the portions 910 indicated with slashes in Fig. 10) substantially surround the center of the antenna. The concave notches 310 of the metal radiation sheet 300, the central opening 330 of the metal radiation sheet 300, and the open slots 510 of the metal ground sheet 300 define the central portions 910 having a high current density. The peripheral portions 920 refer to other portions of the ground sheet 500 than the central portions 910, and have a substantially lower current density than the central portions 910. Similarly, with respect to the current over the metal radiation sheet 300, the current density over the central opening 330 is higher than the current density over the peripheral portions of the metal radiation sheet 300.

**[0050]** According to an example, the metal ground sheet 500 defines a plurality of open slots 510. The open slots extend from the edge 940 to the center portion 930 of the metal ground sheet 500, respectively, and are not in communication with one another, thereby causing the current path 950 of the metal ground sheet 500 prolonged and leading to a high current density over the center portion 910 of the metal ground sheet 500. In other words, as compared with a square metal ground sheet without open slots, the metal ground sheet 500 having open slots 510 according to the present disclosure has a long current path 950 and a small area.

**[0051]** As used herein, the singular form “a” or “one” is to be read as “one or more” unless the context clearly indicates otherwise.

**[0052]** The embodiments of the present disclosure are provided only for description and illustration, rather than being exhaustive or restrictive. Many modifications and variations would be obvious to those skilled in the art. The example embodiments are chosen and

described herein to elaborate principles and actual applications, making it clear to those skilled in the art that various modifications adapted to the embodiments of the present disclosure can achieve the anticipated particular technical effect.

5 **[0053]** Although the example embodiments have been described herein with reference to the drawings, it would be appreciated that the above description is not provided restrictively. Rather, without departing from the scope of disclosure or inventive idea and implementation solution of the present disclosure, those skilled in the art are allowed to make other variations and modifications.

**I/We Claim:**

1. A microstrip dual-polarized antenna for wireless transmission, the antenna comprising:

a first dielectric substrate;

5 a metal radiation sheet disposed on the first dielectric substrate, the metal radiation sheet defining a first square, each side of the first square defining a respective concave notch;

a second dielectric substrate;

a metal ground sheet disposed on the second dielectric substrate, the metal ground sheet defining a second square, the metal ground sheet defining four open slots, each of the  
10 open slots respectively dividing each corresponding right angle of the second square into two oblique angles; and

at least one pillar respectively coupled to the first dielectric substrate and the second dielectric substrate, so that the first dielectric substrate and the metal ground sheet are separated by an air gap.

15

2. The antenna as recited in claim 1, further comprising:

two metal feed patches respectively disposed in two of the concave notches, wherein the metal feed patches and the metal radiation sheet are electrically insulated from one another; and

20 two metal parasitic patches respectively disposed in another two of the concave notches, wherein the metal parasitic patches and the metal radiation sheet are electrically insulated from one another.

3. The antenna as recited in claim 2, wherein the metal feed patches and the metal  
25 parasitic patches are substantially equal in size.

4. The antenna as recited in claim 2, wherein each of the metal feed patches is larger or smaller than each of the metal parasitic patches in size.

30 5. The antenna as recited in claim 2, wherein the metal feed patches are respectively disposed in two adjacent ones of the concave notches, and the metal parasitic patches are respectively disposed in another two adjacent ones of the concave notches.

6. The antenna as recited in claim 2, wherein the metal radiation sheet further defines a central opening.

7. The antenna as recited in claim 2, further comprising:

5 a microstrip feed line disposed on the second dielectric substrate, the microstrip feed line being in electrical contact with the metal feed patches.

8. The antenna as recited in claim 7, further comprising:

10 a metal feed probe, wherein the metal feed probe extends in the air gap, and wherein the metal feed probe is in respective electrical contact with the microstrip feed line and corresponding metal feed patches.

9. The antenna as recited in claim 7, wherein the metal ground sheet is provided on a first surface of the second dielectric substrate, and the microstrip feed line is provided on a  
15 second surface of the second dielectric substrate.

10. The antenna as recited in claim 2, further comprising:

20 a metal ground post, wherein the metal ground post extends in the air gap, and wherein the metal ground post is in respective electrical contact with corresponding metal parasitic patches and the metal ground sheet.

11. The antenna as recited in claim 1, wherein the concave notches are symmetrically disposed at each of four sides of the first square, and wherein the concave notches are substantially of the same size.  
25

12. The antenna as recited in claim 1, wherein the four open slots are symmetrically disposed at each of four corners of the second square, and wherein the open slots are substantially of the same size, and wherein the open slots are spaced apart from one another.

30 13. The antenna as recited in claim 1, wherein a ratio of an area defined by the first square to an area defined by the second square is at least 80%.

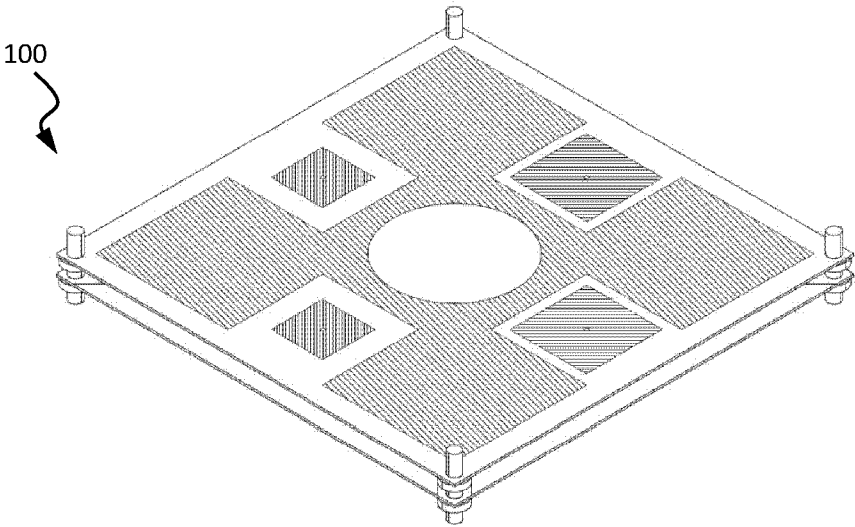


FIG. 1

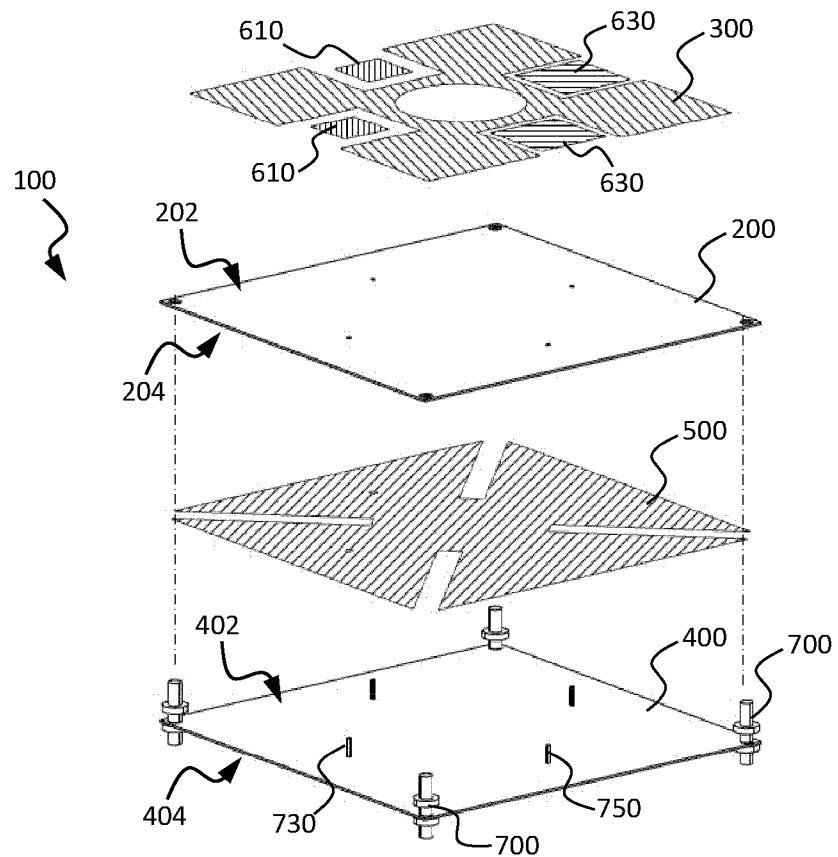


FIG. 2

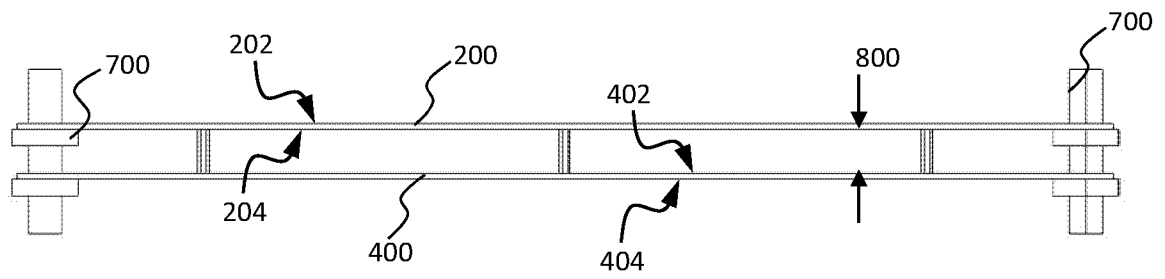


FIG. 3

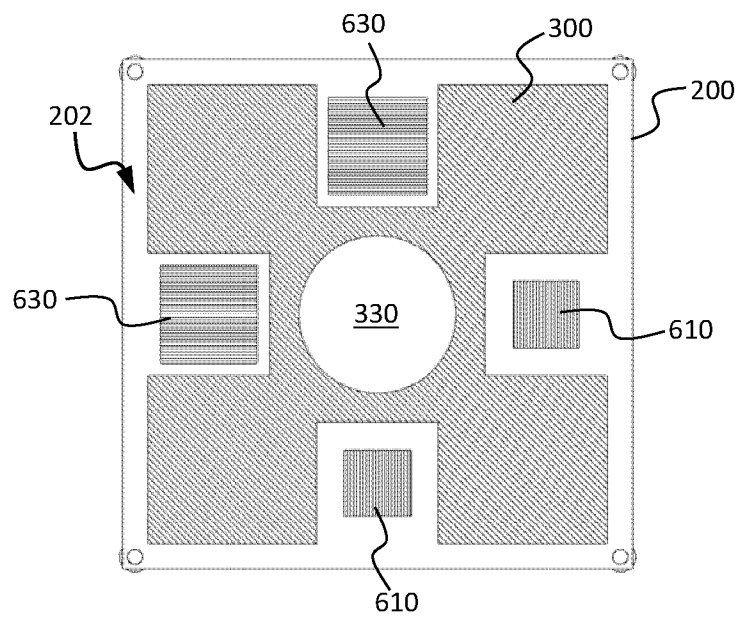


FIG. 4

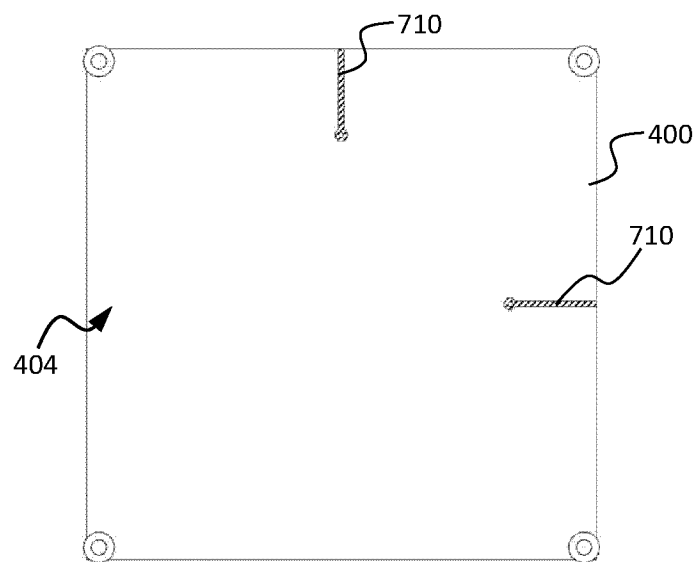


FIG. 5

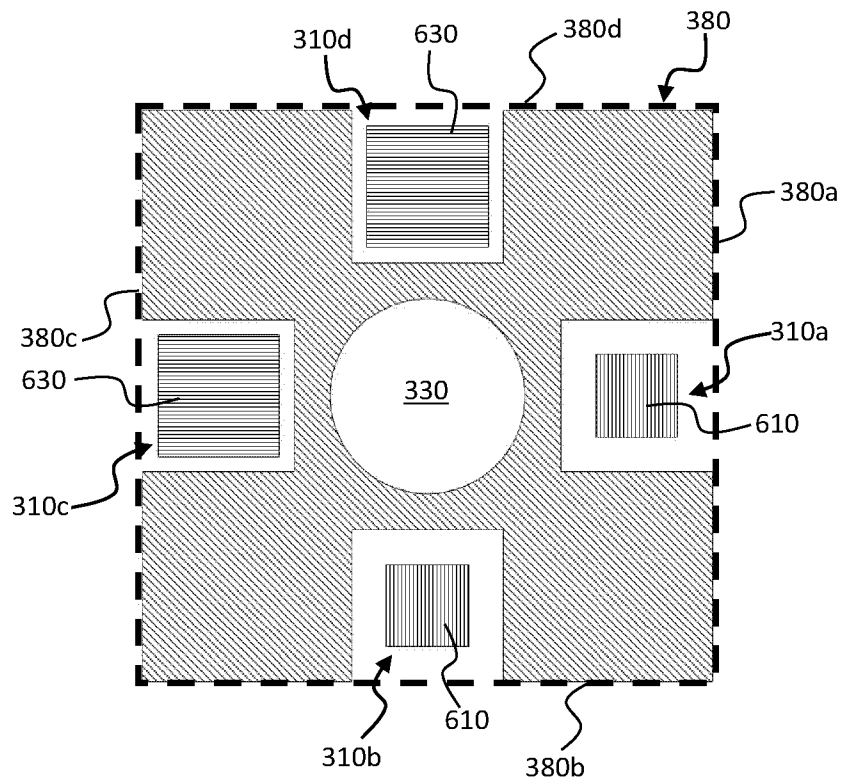


FIG. 6

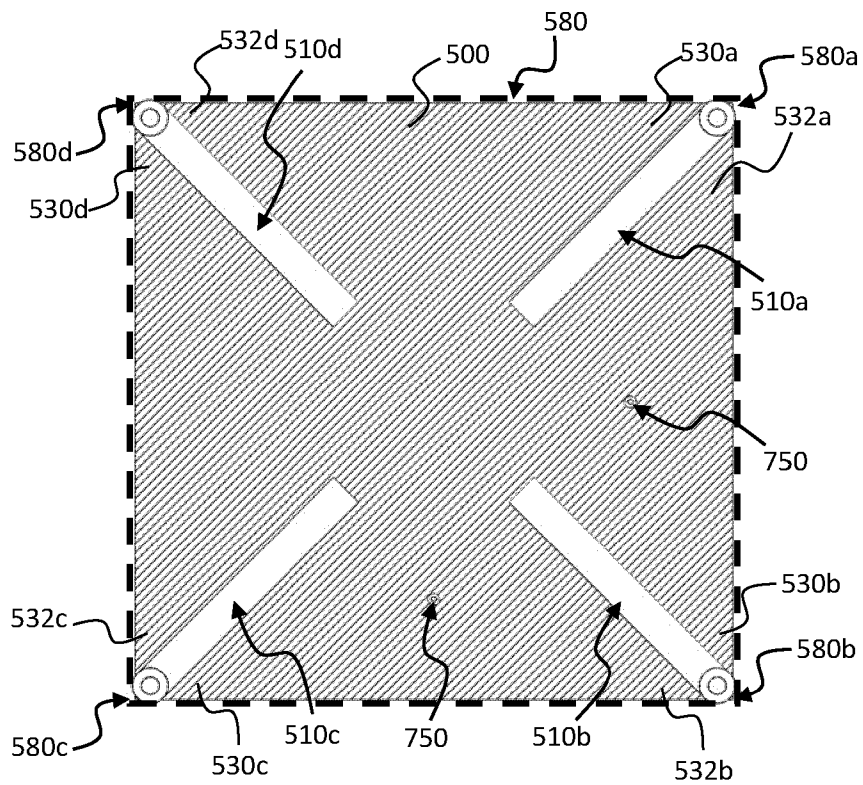


FIG. 7

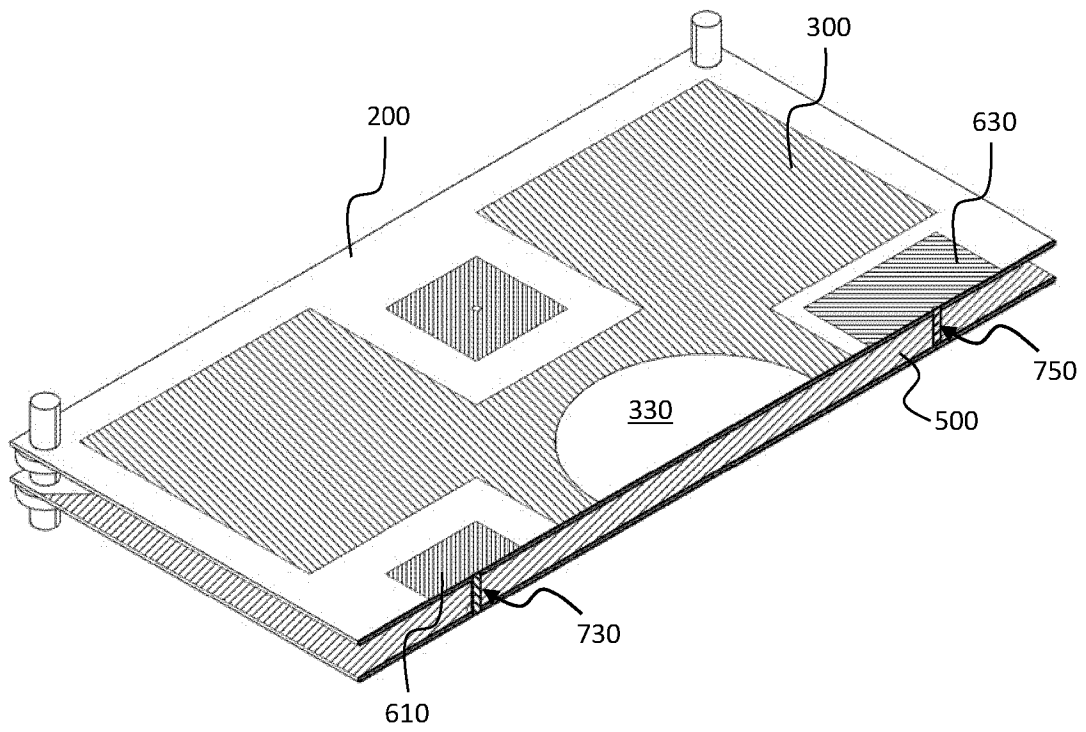


FIG. 8

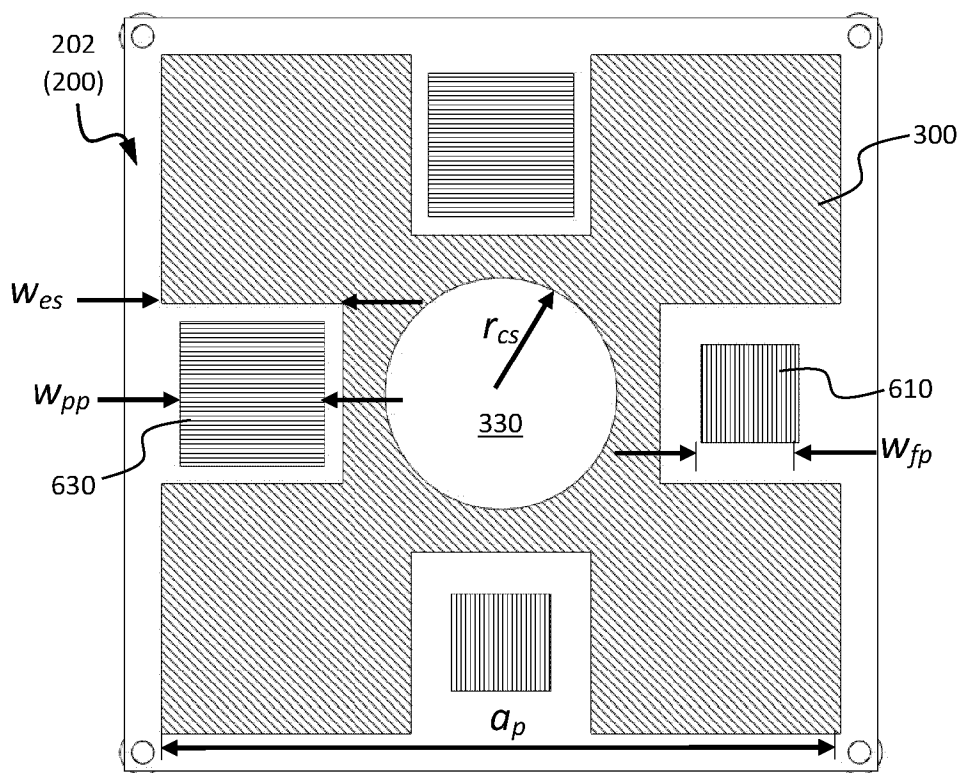


FIG. 9A

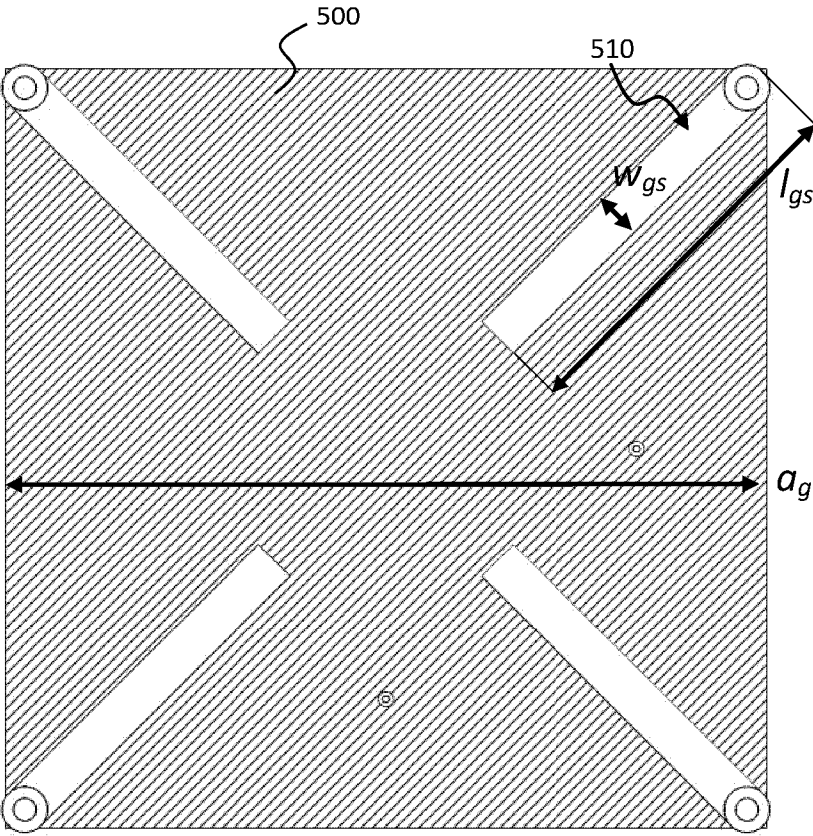


图 9B

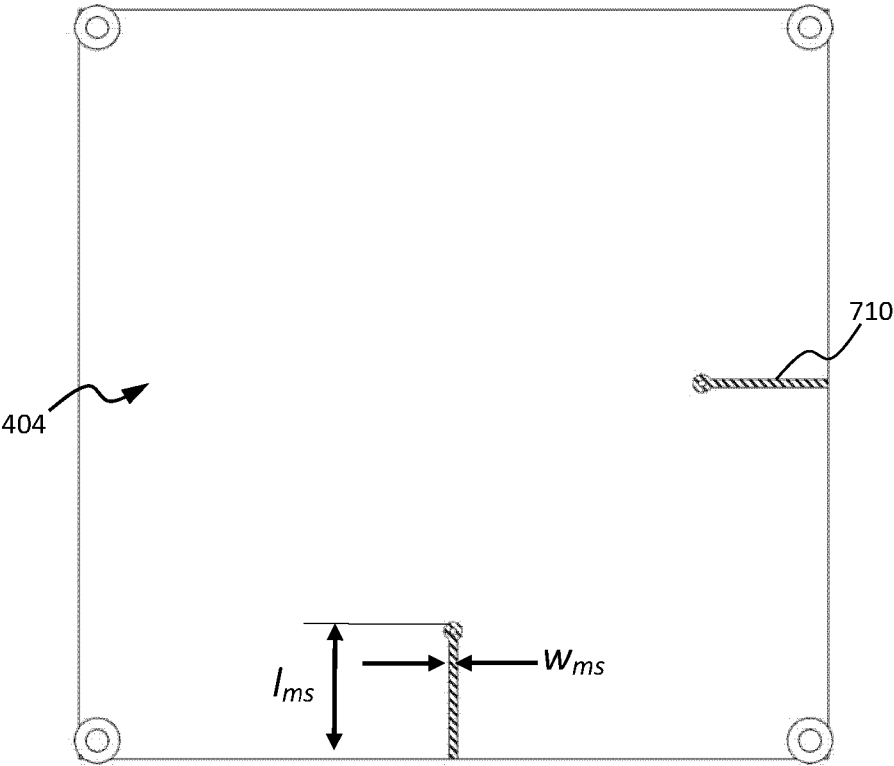


图 9C

|           | $a_g$<br>(Millimeter<br>/mm)    | $a_p$<br>(Millimeter<br>/mm)    | $w_{fp}$<br>(Millimeter<br>/mm) | $w_{pp}$<br>(Millimeter<br>/mm) | $w_{es}$<br>(Millimeter<br>/mm) | $r_{cs}$<br>(Millimeter<br>/mm)                                               |
|-----------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|-------------------------------------------------------------------------------|
| Antenna 1 | 100                             | 90                              | 13                              | 19                              | 24                              | 15.4                                                                          |
| Antenna 2 | 100                             | 90                              | 16.8                            | 16.8                            | 24                              | 14.65                                                                         |
| Antenna 3 | 120                             | 96                              | 19                              | 19                              | 25                              | 14.5                                                                          |
|           | $w_{gs}$<br>(Millimeter<br>/mm) | $l_{gs}$<br>(Millimeter<br>/mm) | $w_{ms}$<br>(Millimeter<br>/mm) | $l_{ms}$<br>(Millimeter<br>/mm) | Gain (dBi)                      | Effective-to-Physical<br>Aperture<br>Ratio<br>(EPAR =<br>$A_{eff}/A_{phys}$ ) |
| Antenna 1 | 6                               | 50                              | 1.1                             | 17                              | 5.7                             | 3.2                                                                           |
| Antenna 2 | 5                               | 52                              | 1.1                             | 17                              | 6.0                             | 3.4                                                                           |
| Antenna 3 | 4                               | 54                              | 1.1                             | 24.5                            | 6.8                             | 2.9                                                                           |

FIG. 10

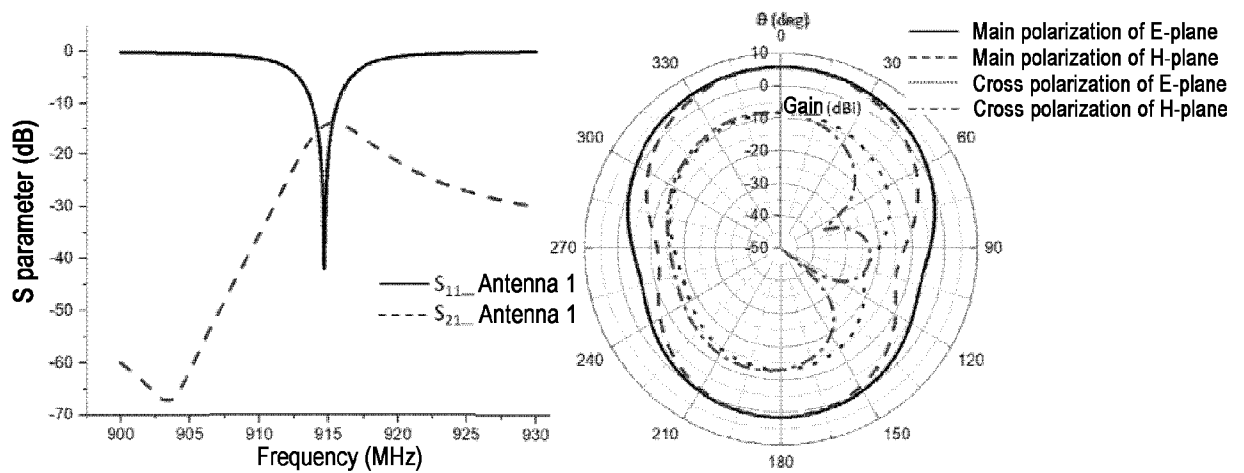


FIG. 11

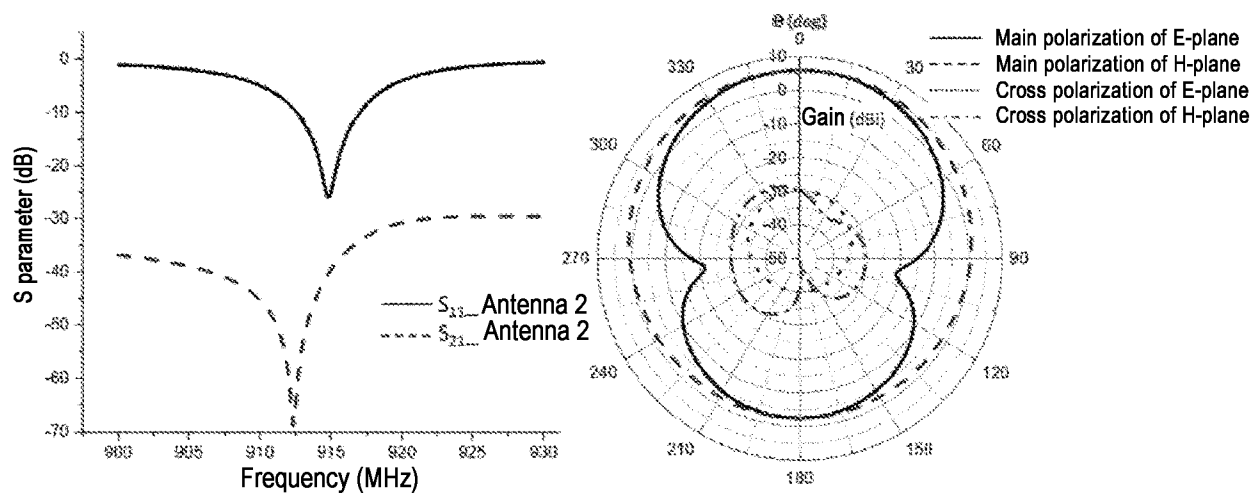


FIG. 12

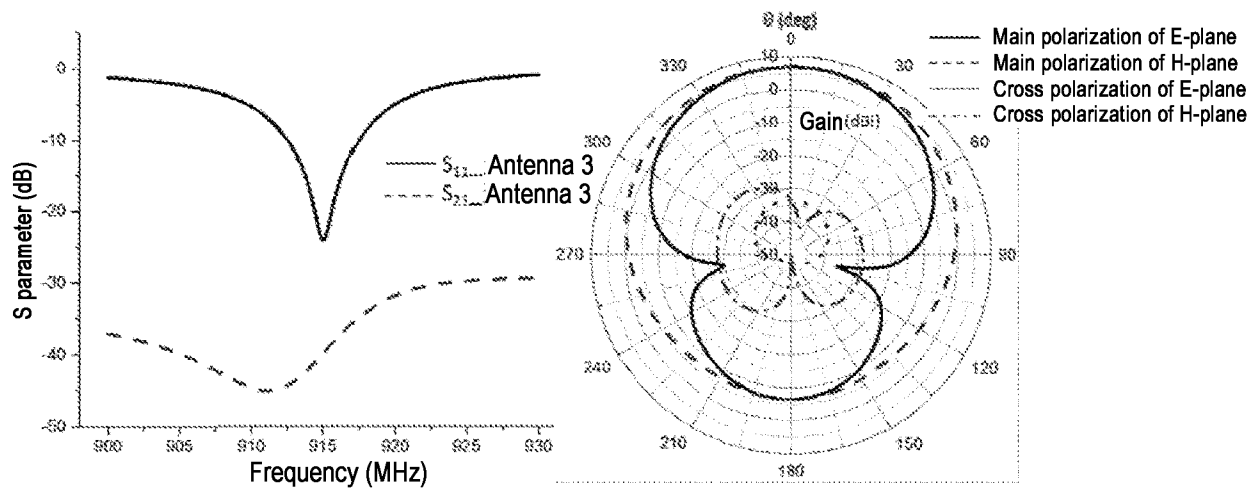


FIG. 13

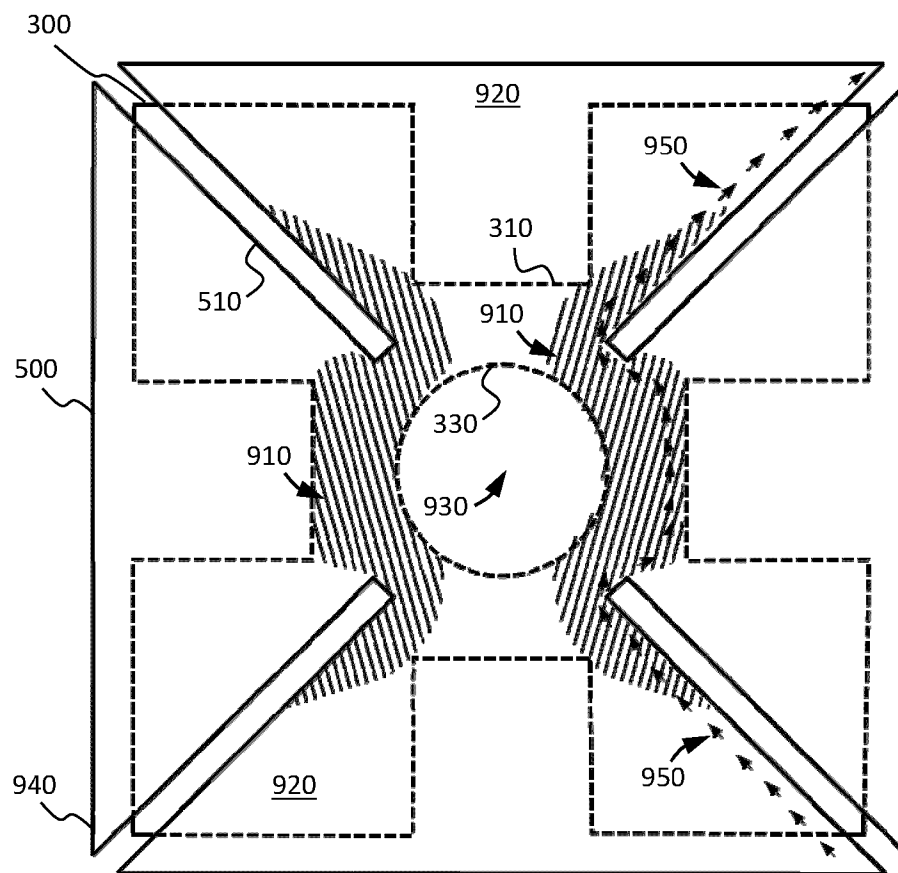


FIG. 14

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/CN2021/113593

A. CLASSIFICATION OF SUBJECT MATTER  
INV. H01Q1/48 H01Q9/04 H01Q19/00  
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)  
H01Q

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, 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         | YUAN JIADE ET AL: "A Compact Meandered Ring Antenna Loaded With Parasitic Patches and a Slotted Ground for Global Navigation Satellite Systems",<br>IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, IEEE, USA,<br>vol. 66, no. 12,<br>1 December 2018 (2018-12-01), pages<br>6835-6843, XP011702343,<br>ISSN: 0018-926X, DOI:<br>10.1109/TAP.2018.2869209<br>[retrieved on 2018-11-29] | 1,11-13               |
| A         | the whole document<br>-----<br>-/--                                                                                                                                                                                                                                                                                                                                                   | 2-10                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search

19 November 2021

Date of mailing of the international search report

29/11/2021

Name and mailing address of the ISA/

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## INTERNATIONAL SEARCH REPORT

International application No  
PCT/CN2021/113593

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                                                                                                                                                                               |                       |
|------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Category*                                            | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                            | Relevant to claim No. |
| X                                                    | PHONGCHAROENPANICH C ET AL: "Dual-band flat antenna for polarization diversity with high isolation", ANTENNAS AND PROPAGATION IN WIRELESS COMMUNICATIONS (APWC), 2012 IEEE-APS TOPICAL CONFERENCE ON, IEEE, 2 September 2012 (2012-09-02), pages 906-909, XP032456572, DOI: 10.1109/APWC.2012.6324943 ISBN: 978-1-4673-0404-7 | 1,11-13               |
| A                                                    | the whole document<br>-----                                                                                                                                                                                                                                                                                                   | 2-10                  |