(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
15 September 2016 (15.09.2016)

WIPO | PCT

(10) **International Publication Number**
WO 2016/144155 A1

(51) **International Patent Classification**:
H01Q 13/08 (2006.01)

(21) **International Application Number**:
PCT/MY2016/000011

(22) **International Filing Date**:
11 March 2016 (11.03.2016)

(25) **Filing Language**: English

(26) **Publication Language**: English

(30) **Priority Data**:
PI 2015700783 12 March 2015 (12.03.2015) MY

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU,

[Continued on next page]

(54) Title: A CIRCULARLY POLARIZED MICROSTRIP PATCH ANTENNA

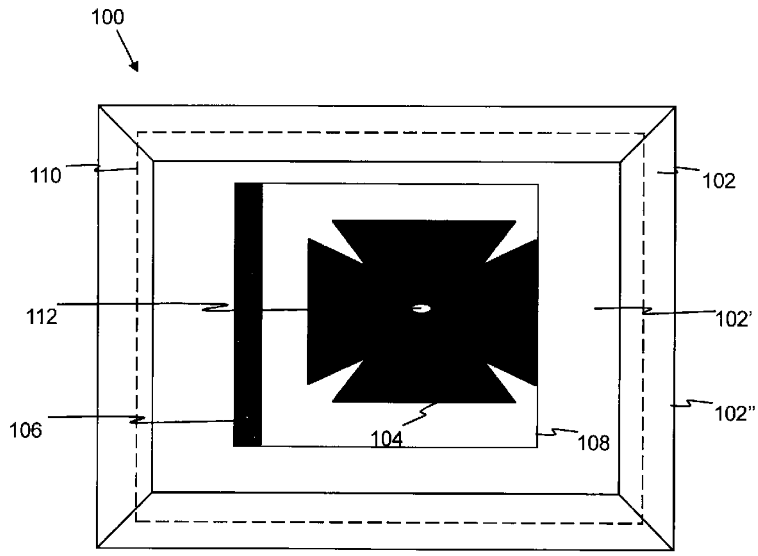

FIG. 1

(57) **Abstract**: A circularly polarized microstrip patch antenna (100) comprising a substrate (102) having a top surface (102') and a bottom surface (102"), four asymmetric slits (104), a passive thin strip (106) and a ground plane (110). The four asymmetric slits (104) and the passive thin strip (106) are disposed on the top surface (102') to form a patch (108) and the patch (108) is in electrical connection with the ground plane (110). Further, the substrate (102) having a hole (112) for enabling the electrical connection between the patch (108) and the ground plane (110). Also, the ground plane (110) is coupled with the bottom surface (102") of the substrate (102).

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TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

— *with amended claims (Art. 19(1))*

Title: A Circularly Polarized Microstrip Patch Antenna

Technical Field:

Embodiments of the present invention relate to a circularly polarized antenna and more particularly to a circularly polarized microstrip patch antenna which is developed to mount on Low Earth Orbit (LEO) small satellites and capable of operating in the S band transmission application. Also, the circularly polarized microstrip patch antenna is easy to integrate with metallic and nonmetallic surfaces of any shape.

Background Art:

In today's era of wireless communication, there has been increased need of high speed communication besides quality transfer of voice or video or data. Satellite communication is one of the most important modes of wireless communication and have significant role in the field of global telecommunications. There are approximately 2000 artificial satellites orbiting Earth and enable communication to and from multiple locations across the globe.

In general, a satellite has three main components namely communications system, power system and propulsion system. The communications system includes antennas and transponders enabling transfer of voice, video and data. The power system comprises of solar panels providing requisite power to drive the hardware of the satellite and other ancillary parts. Lastly, the propulsion system having rockets which drive the satellite in a desired orientation in the space.

The satellite communication technologies have been evolved rapidly in relatively short span of time. Today, the satellite communication technologies are very sophisticated and powerful. However, there is no dearth in demand for more refined technologies which are able to handle the ever increasing voice, video and data traffic. Therefore, there is a need of advanced satellites which can withstand such ever increasing demands of wireless communication. One of the advanced satellite technologies is ‘small satellites’ which enables accomplishing number of tasks and experiments in space.

Small satellites came into existence because of the evolved miniaturized technologies. Besides the advantages of small satellite it is a challenge to provide all necessary components within the physical limitations and restrictions. One of the main concerns for small satellite is to have adequate, efficient and economical antenna. For example, helical antennas were used in traditional satellite communication systems however they become unfit for small satellite. The small satellite antennas must have lightweight structure and high degree of integration. Further, the antennas are mostly provided on outer walls of the small satellite and are attached with a thermal blanket. Varied types of small antennas, low profile antennas or microstrip antennas have been developed to address critical requirements such as improved circular polarization, improved low angle radiation pattern, widen beams, enhanced gain at low angle , dual band operation etc. Such antenna have been developed by using slotted radiating patch, high dielectric material substrate, artificial magnetic conductor, electromagnetic band-gap (EBG) structure, metamaterial, and magnetodielectric materials etc.

Circularly polarized antennas have been developed by the researchers to be used in small satellite communication systems. Such types of antenna have a wide beam width and suitable to be used as global positioning system (GPS) receiving antennas, wireless local area network (LAN) antennas for ceiling installations, radio frequency identification (RFID) reader antennas for special use, and so forth. In other words, circularly polarized patch antennas are appropriate for satellite communication in order to achieve satisfactory received power and orientation independence of the base station antenna. Typically, in circularly polarized antennas, the structure of a patch antenna is frequently used. A patch antenna having a half wavelength size has a narrow beam width of about 70 degrees. To increase the beam width of the patch antenna, the size of the patch is reduced so as to be still smaller than the half wavelength using a high-k substrate, or a ground plane having a three-dimensional structure such as a pyramid is used. However, when the size of the patch is reduced, the return loss bandwidth of the antenna is reduced. When the ground plane having a three-dimensional structure is used, the thickness of the antenna is increased.

US 20120162021A1 talks about a circularly polarized antenna with a wide beam width, in which four U-shaped metal strips are disposed in a circular shape, and four signals having the same magnitude and phase difference intervals of 90 degrees are fed to the respective metal strips so as to transceive circularly polarized waves. The disclosed circularly polarized antenna includes a ground plane, a central patch formed in the center of an upper surface of the ground plane, and a plurality of radiation patches disposed above the ground plane and around the central patch in a circular shape, wherein signals having the same magnitude and preset phase differences are fed to respective radiation patches.

US 6181281B1 discloses another type of circularly polarized patch antenna which facilitates optimization of the axial ratio adjustment and impedance matching, and has an improved degree of freedom to optimize the axial ratio adjustment and the impedance matching. This antenna is comprised of a dielectric substrate, an approximately rectangular patch serving as a radiating element, a ground conductor serving as a ground plane formed on the substrate to be opposite to the patch and a feedpoint located on the patch for feeding or deriving electric power to or from the patch.

Though the above-mentioned documents and other state of the art miniature antennas have number of merits in terms of size, efficiency, compatibility etc. However, one still needs to put more research effort onto antenna miniaturization with improvement of bandwidth, gain, efficiency, and so forth.

Accordingly, there remains a need in the prior art to have an advanced circularly polarized antenna which overcomes the aforesaid problems and shortcomings.

However, there remains a need in the art for a circularly polarized microstrip patch antenna which eliminates the need of complicated deployable Ultra high frequency (UHF) / Very high frequency (VHF) antennas. Such antenna has simple design and easy to operate. Also, the circularly polarized microstrip patch antenna can be mounted on any metallic or non-metallic surface without any effect on performance of the antenna.

Disclosure of the invention:

Embodiments of the present invention aim to provide a circularly polarized microstrip patch antenna which has a low profile that adheres to the strictest nano-satellite launch policies. The proposed antenna utilizes unique asymmetric slits to achieve high gain circular polarization. Further, the asymmetric slits are employed to obtain circularly polarized radiation with a reduction in design size and complexity. Also, the disclosed antenna can be mounted on any metallic or non-metallic surface without any effect on performance and the geometric parameters of the same can be adjusted to tune the return loss and bandwidth over S band frequency using the Ramped Convergence Particle Swarm Optimization (RCPSO) algorithm. The present invention is provided with the features of claim 1, however the invention may additionally reside in any combination of features of claim 1.

In accordance with an embodiment of the present invention, the circularly polarized microstrip patch antenna comprising a substrate having a top surface and a bottom surface, four asymmetric slits, a passive thin strip and a ground plane. The four asymmetric slits and the passive thin strip are disposed on the top surface to form a patch and the patch is in electrical connection with the ground plane. Further, the substrate having a hole for enabling the electrical connection between the patch and the ground plane. Also, the ground plane is coupled with the bottom surface of the substrate.

In accordance with an embodiment of the present invention, the substrate is a, but not limited to, microwave dielectric substrate. Further, the substrate is having a thickness of 1.57 mm.

In accordance with an embodiment of the present invention, the substrate is having a dielectric constant of 2.2 and a dielectric loss tangent of 0.0009.

In accordance with an embodiment of the present invention, the four asymmetric slits are having, but not limited to, a V shape.

In accordance with an embodiment of the present invention, the passive thin strip is having, but not limited to, a rectangular shape.

In accordance with an embodiment of the present invention, the ground plane is coupled with the bottom surface of the substrate by means of, but not limited to, a surface mount technique.

While the present invention is described herein by way of example using embodiments and illustrative drawings, those skilled in the art will recognize that the invention is not limited to the embodiments of drawing or drawings described, and are not intended to represent the scale of the various components. Further, some components that may form a part of the invention may not be illustrated in certain figures, for ease of illustration, and such omissions do not limit the embodiments outlined in any way. It should be understood that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the invention is to cover all modification/s, equivalent/s and alternative/s falling within the scope of the present invention as defined by the appended claim. The headings used herein are for organizational purposes only and are not meant to be used to limit the scope of the description or the claim. As used throughout this description, the word "may" is used in a permissive sense (i.e. meaning having the potential to), rather than the mandatory sense (i.e. meaning must). Further, the words "a" or "an" mean "at least one" unless otherwise mentioned. Furthermore, the terminology and phraseology used herein is solely used for descriptive purposes and should not be construed as limiting in scope. Language such as "including," "comprising," "having," "containing," or "involving," and variations thereof, is intended to be broad and encompass the subject matter listed thereafter, equivalents, and additional subject matter not recited, and is not intended to exclude other additives, components, integers or steps. Likewise, the term "comprising" is considered synonymous with the terms "including" or "containing" for applicable legal purposes. Any discussion of documents, acts, materials, devices, articles and the like is included in the specification solely for the purpose of providing a context for the present invention. It is not suggested or represented that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present invention.

In this disclosure, whenever a composition or an element or a group of elements is preceded with the transitional phrase “comprising”, it is understood that we also contemplate the same composition, element or group of elements with transitional phrases “consisting of”, “consisting”, “selected from the group of consisting of, “including”, or “is” preceding the recitation of the composition, element or group of elements and vice versa.

Description of drawings and best mode for carrying out the invention:

So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawing illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

These and other features, benefits and advantages of the present invention will become apparent by reference to the following text figure, with like reference numbers referring to like structures across the views, wherein:

Fig. 1 illustrates a perspective view of a circularly polarized microstrip patch antenna in accordance with an embodiment of the present invention.

Fig. 2 illustrates a patch of the circularly polarized microstrip patch antenna in accordance with an embodiment of the present invention.

Fig. 3 illustrates a Smith chart of an experimental result in accordance with an embodiment of the present invention.

Fig. 4 illustrates an antenna axial ratio diagram of an experimental result in operation bandwidth in accordance with an embodiment of the present invention.

The present invention is described hereinafter by various embodiments with reference to the accompanying drawing, wherein reference numerals used in the accompanying drawing correspond to the like elements throughout the description. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiment set forth herein. Rather, the embodiment is provided so that this disclosure will be thorough and complete and will fully convey the scope of the invention to those skilled in the art. In the following detailed description, numeric values and ranges are provided for various aspects of the implementations described. These values and ranges are to be treated as examples only, and are not intended to limit the scope of the claims. In addition, a number of materials are identified as suitable for various facets of the implementations. These materials are to be treated as exemplary, and are not intended to limit the scope of the invention.

Embodiments of the present invention aim to provide a circularly polarized microstrip patch antenna which is capable of operating in the S band transmission application and can be easily mounted on LEO small satellites. The circularly polarized microstrip patch antenna has stable broadside radiation pattern with a high gain. Furthermore, the disclosed antenna utilizes robust microwave dielectric substrate that is resistant to harsh environment in outer space. The proposed antenna consists of coaxial probe fed asymmetric shaped patch with a passive rectangular strip. The disclosed antenna will be easy to integrate with metallic and nonmetallic surfaces of any shape.

Referring to the drawings, the invention will now be described in more detail. In accordance with an embodiment of the present invention, the circularly polarized microstrip patch antenna (100) as shown in figure 1, comprising a substrate (102), four asymmetric slits (104), a passive thin strip (106) and a ground plane (110).

In accordance with an embodiment of the present invention, the substrate (102) is a, but not limited to, microwave dielectric substrate and is resistant to harsh environment in outer space. The substrate (102) is having a thickness of 1.57 mm, a dielectric constant of 2.2 and a dielectric loss tangent of 0.0009.

Further, the substrate (102) may be in a shape of, but not limited to, triangle, rectangle, circle, elliptical and may consists of glass microfiber reinforced Polytetrafluoroethylene (PTFE) composite material. Also, the substrate (102) is having a top surface (102') and a bottom surface (102").

In accordance with an embodiment of the present invention, the four asymmetric slits (104) are having a V shape and the passive thin strip (106) is having a rectangular shape. The four asymmetric slits (104) and the passive thin strip (106) are disposed on the top surface (102') of the substrate (102) to form a patch (108). A top view of the patch (108) of the circularly polarized microstrip patch antenna (100) is shown in figure 2 having a rectangular shape.

As shown in figure 2, the four asymmetric slits (104) enables to achieve circularly polarized radiation. Further, the geometric parameters of the patch (108) can be adjusted to tune the return loss and bandwidth over S band frequency using the RCPSO algorithm. The RCPSO algorithm breaks down the optimization problem by considering only a subset of dimensions at a time and enable efficient gain optimization in antenna. Further, the electric connection of the patch (108) with the ground plane (110) is enabled through a hole (112) in the substrate (102).

In accordance with an embodiment of the present invention, the ground plane (110) is disposed on the bottom surface (102") of the substrate (102). Further, the ground plane (110) is completely covered in copper and contain no slots to achieve the high front to back radiation ratio.

As shown in figure 1, the patch (108) is in electrical connection with the ground plane (110) through a hole (112) in the substrate (102). Further, the circularly polarized microstrip patch antenna (100) comprises of a signal-fed component (not shown) and a system ground unit (not shown). The signal-fed component provides electrical signal to the bottom surface (102") of the substrate (102) which in-turn generates an electromagnetic signal in conjunction with the ground plane (110). The electromagnetic signal is then passed on to the patch (108) where it is circularly polarized by means of the four asymmetric slits (104) and radiated accordingly.

In accordance with an embodiment of the present invention, the signal-fed component may be a coaxial line, a coplanar line, or a SMA joint. Additionally, the system ground unit may be connected to the substrate by Surface Mount Technique (SMT), wherein the system ground unit may be a conductive metal structure in the shape of a rectangle, possibly a metal structure in a shape of a circle, ellipse, triangle, rectangle, or polygon.

Figure 3 illustrates a Smith chart (200) of an experimental result in accordance with an embodiment of the present invention showing that impedance bandwidth (VSWR≤2) of the proposed antenna is 60 MHz (2.24GHz-2.30 GHz).

Figure 4 illustrates an antenna axial ratio diagram (300) of an experimental result in operation bandwidth in accordance with an embodiment of the present invention showing that circularly polarized benefit in axial ratio bandwidth of 3-dB is 0.74% (2.278-2.295 GHz) in the operating band.

The above-mentioned circularly polarized microstrip patch antenna overcomes the problems and shortcomings of the existing circularly polarized antennas and also provides numerous advantages over them. In the present invention the four asymmetric slits enables to achieve high gain circular polarization. The four asymmetric slits are utilized to obtain circularly polarized radiation with a reduction in size and complexity of the whole antenna. Further, the asymmetric V-shaped slit and the rectangular shape of the patch provides a wide radiation beamwidth with significantly high gain. Also, the disclosed antenna is capable of operating in the S band transmission application and easily mounted on LEO small satellites. In addition, the proposed antenna is easy to integrate with metallic and nonmetallic surfaces of any shape.

The exemplary implementation described above is illustrated with specific shapes, dimensions, and other characteristics, but the scope of the invention also includes various other shapes, dimensions, and characteristics. For example, particular shape, size and attachment of the asymmetric slits, the thin strip, the substrate, and the ground plane. Also, the various attachments and the arrangement of the components such as substrate, ground plane, patch etc. The components as described in the present invention could be manufactured in various other ways and could include various other materials.

Various modifications to these embodiments are apparent to those skilled in the art from the description and the accompanying drawings. The principles associated with the various embodiments described herein may be applied to other embodiments. Therefore, the description is not intended to be limited to the embodiments shown along with the accompanying drawings but is to be providing broadest scope of consistent with the principles and the novel and inventive features disclosed or suggested herein. Accordingly, the invention is anticipated to hold on to all other such alternatives, modifications, and variations that fall within the scope of the present invention and appended claim.

Claims:

1. A circularly polarized microstrip patch antenna (100) comprising:

a substrate (102) having a top surface (102’) and a bottom surface (102”)

four asymmetric slits (104)

a passive thin strip (106)

a ground plane (110)

wherein said four asymmetric slits (104) and said passive thin strip (106) are disposed on said top surface (102’) to form a patch (108)

wherein said patch (108) is in electrical connection with said ground plane (110)

wherein said substrate (102) having a hole (112) for enabling said electrical connection between said patch (108) and said ground plane (110)

wherein said ground plane (110) is coupled with said bottom surface (102”) of said substrate (102).

2. The circularly polarized microstrip patch antenna (100) as claimed in claim 1, wherein said substrate (102) is a microwave dielectric substrate.

3. The circularly polarized microstrip patch antenna (100) as claimed in claim 2, wherein said substrate (102) is having a thickness of 1.57 mm.

4. The circularly polarized microstrip patch antenna (100) as claimed in claim 2, wherein said substrate (102) is having a dielectric constant of 2.2 and a

dielectric loss tangent of 0.0009.

5. The circularly polarized microstrip patch antenna (100) as claimed in claim 1, wherein said four asymmetric slits (104) are having a V shape.

6. The circularly polarized microstrip patch antenna (100) as claimed in claim 1, wherein said passive thin strip (106) is having a rectangular shape.

7. The circularly polarized microstrip patch antenna (100) as claimed in claim 1, wherein said ground plane (110) is coupled with said bottom surface (102") of said substrate (102) by means of a surface mount technique.

AMENDED CLAIMS
received by the International Bureau on 20 July 2016 (20.07.2016)

Claims:

1. A circularly polarized microstrip patch antenna (100) comprising:

a substrate (102) having a top surface (102') and a bottom surface (102")

four asymmetric slits (104)

a passive thin strip (106)

a ground plane (110)

wherein said four asymmetric slits (104) and said passive thin strip (106) are disposed on said top surface (102') to form a patch (108)

wherein said patch (108) is in electrical connection with said ground plane (110)

wherein said substrate (102) having a hole (112) for enabling said electrical connection between said patch (108) and said ground plane (110)

wherein said ground plane (110) is coupled with said bottom surface (102") of said substrate (102) by means of a surface mount technique and

wherein said substrate (102) is having a dielectric constant of 2.2 and a dielectric loss tangent of 0.0009.

2. The circularly polarized microstrip patch antenna (100) as claimed in claim 1, wherein said substrate (102) is a microwave dielectric substrate.

3. The circularly polarized microstrip patch antenna (100) as claimed in claim 2, wherein said substrate (102) is having a thickness of 1.57 mm.

4. (Cancelled)

5. The circularly polarized microstrip patch antenna (100) as claimed in claim 1, wherein said four asymmetric slits (104) are having a V shape.

6. The circularly polarized microstrip patch antenna (100) as claimed in claim 1, wherein said passive thin strip (106) is having a rectangular shape.

7. (Cancelled)

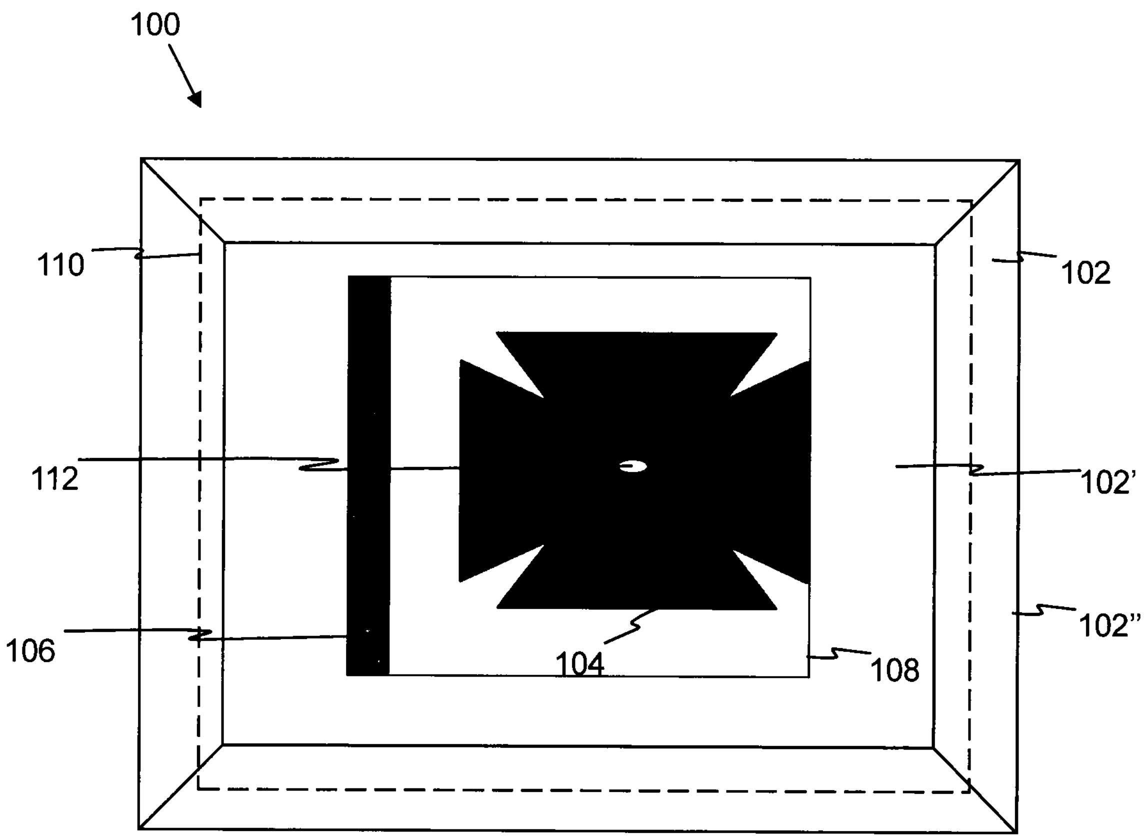

FIG. 1

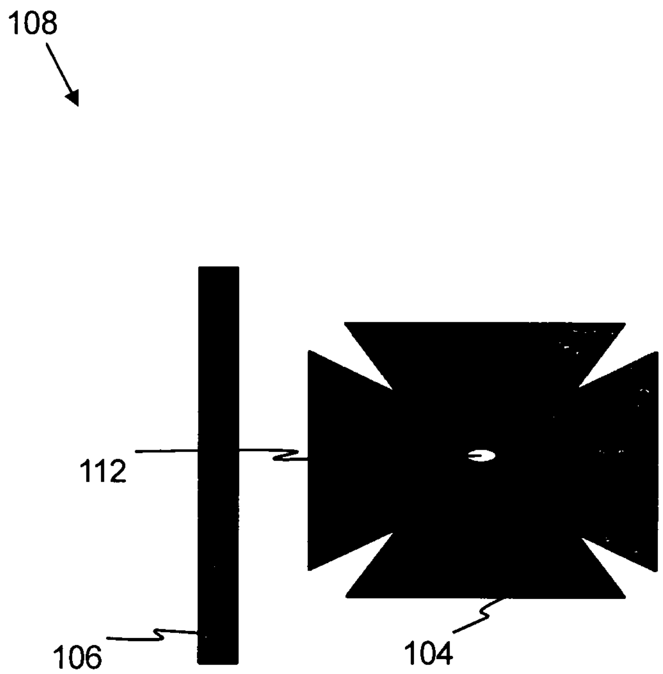

FIG. 2

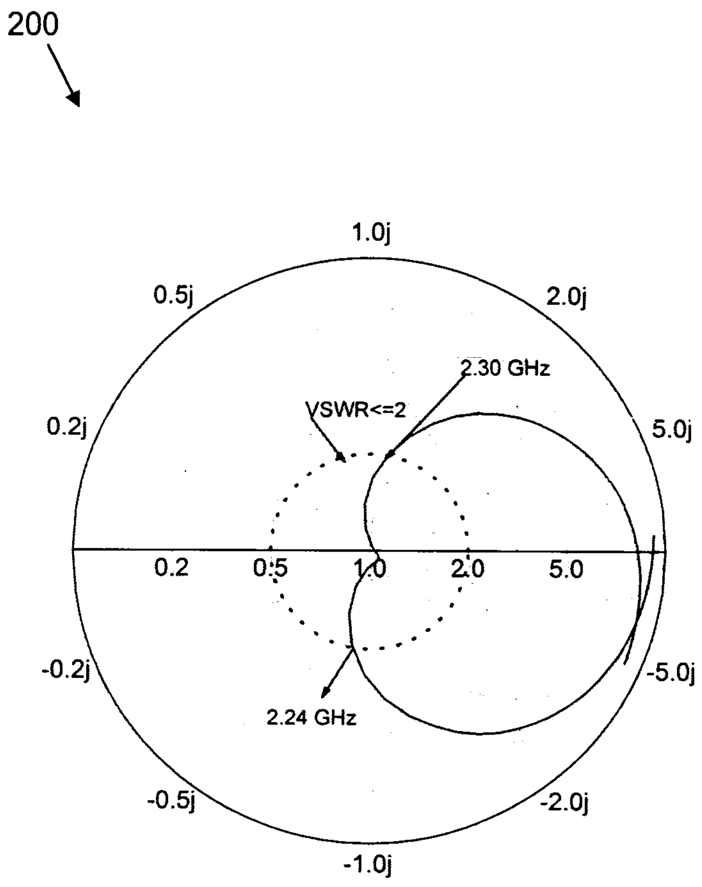
200
1.0j
0.5j
2.0j
2.30 GHz
VSWR<=2
0.2j
5.0j
0.2
0.5
1.0
2.0
5.0
-0.2j
-5.0j
2.24 GHz
-0.5j
-2.0j
-1.0j

FIG. 3

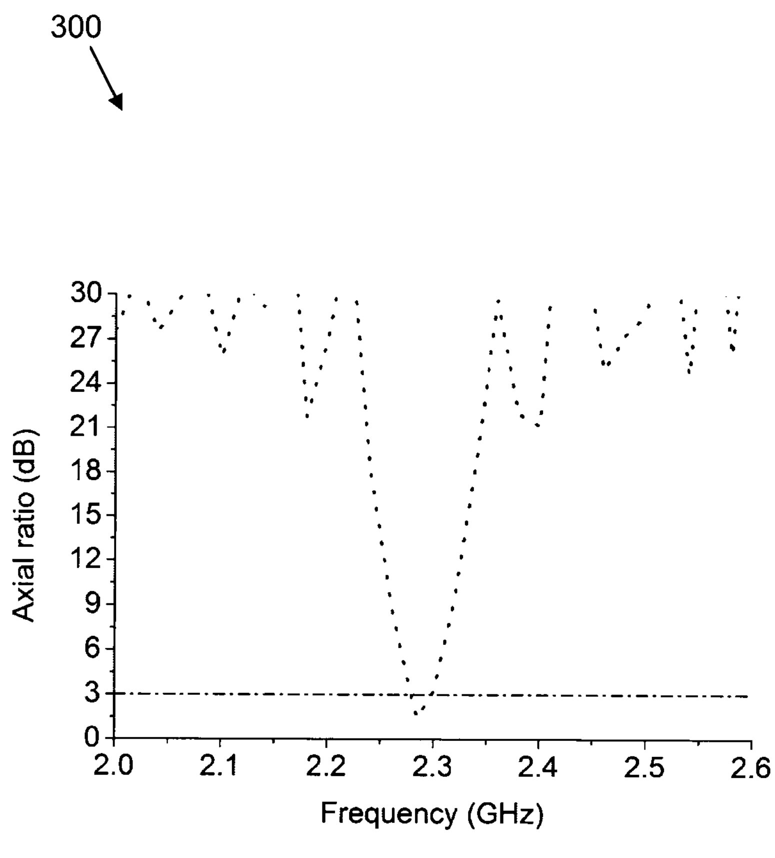
300
Axial ratio (dB)
30
27
24
21
18
15
12
9
6
3
0
2.0
2.1
2.2
2.3
2.4
2.5
2.6
Frequency (GHz)

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/MY2016/000011

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. H01Q13/08(2006.01)i

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)

Int.Cl. H01Q13/08

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2016
Registered utility model specifications of Japan 1996-2016
Published registered utility model applications of Japan 1994-2016

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

IEEE Xplore, CiNii

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	M. T. Islam et al., Development of S band antenna for Nanosatellite, 2014 IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE), 2014.12.08, pp.16-19	1-7
Y	WO 00/74172 A1 (ALLGON AB) 2000.12.07, p.4, line 15 - p.7, line 24, Fig. 1 & AU 5263400 A & CN 1353877 A	1-7

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13.05.2016	24.05.2016

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office	IWAI, Kazuhisa — 5K 5290
3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No. +81-3-3581-1101 Ext. 3556