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Hussain et al.

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(54) **SATELLITE ANTENNA WITH METAL FOIL ETCHED FILM LAYER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(51) **Int. Cl.**

H01Q 13/10	(2006.01)
H01Q 1/28	(2006.01)
H01Q 1/48	(2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 13/103*** (2013.01); ***H01Q 1/288*** (2013.01); ***H01Q 1/48*** (2013.01); ***H01Q 13/106*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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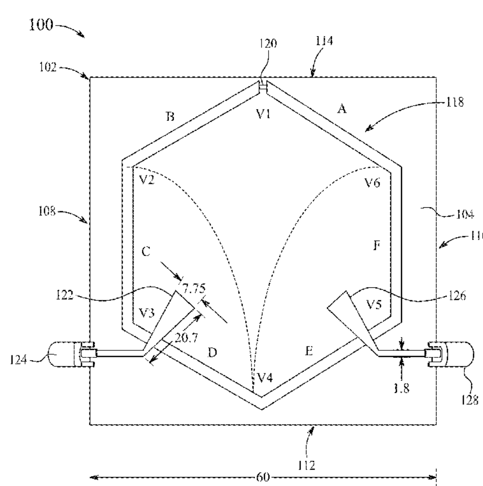
Primary Examiner — Dameon E Levi
Assistant Examiner — Aladdin Abdulbaki
(74) *Attorney, Agent, or Firm* — Oblon, McClelland, Maier & Neustadt, L.L.P.

(57) **ABSTRACT**

A dual feed slot-based circularly polarized wideband ultra high frequency (UHF) antenna for a cubic shaped satellite (Cube-Sat) is described. The UHF antenna includes a circuit board, a metallic layer, a hexagonal meandered slot, a capacitor, a first feed horn, and a second feed horn. The circuit board has a front side and a back side separated by a dielectric material. The metallic layer covers the back side of the circuit board. The hexagonal meandered slot symmetrically includes six legs of equal length and six vertexes. The capacitor is switchably connected to the metallic layer. The first feed horn is connected by a first feed line to a first edge of the front side of the circuit board. The second feed horn is connected by a second feed line to a second edge of the front side of the circuit board.

17 Claims, 12 Drawing Sheets



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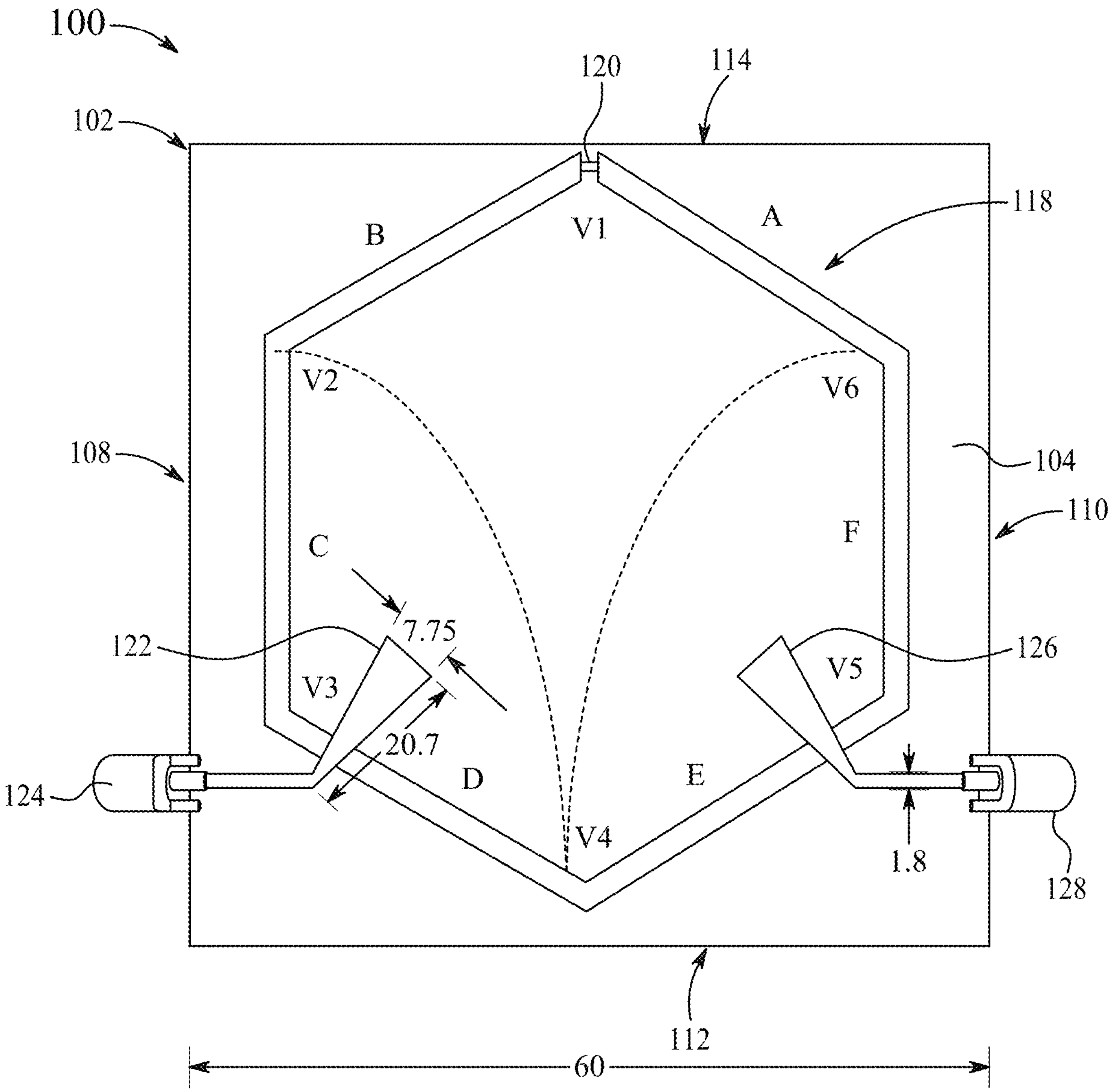

100
102
114
120
118
A
B
V1
V2
V6
108
104
110
C
F
7.75
122
126
V3
V5
124
128
20.7
D
E
V4
1.8
112
60

FIG. 1A

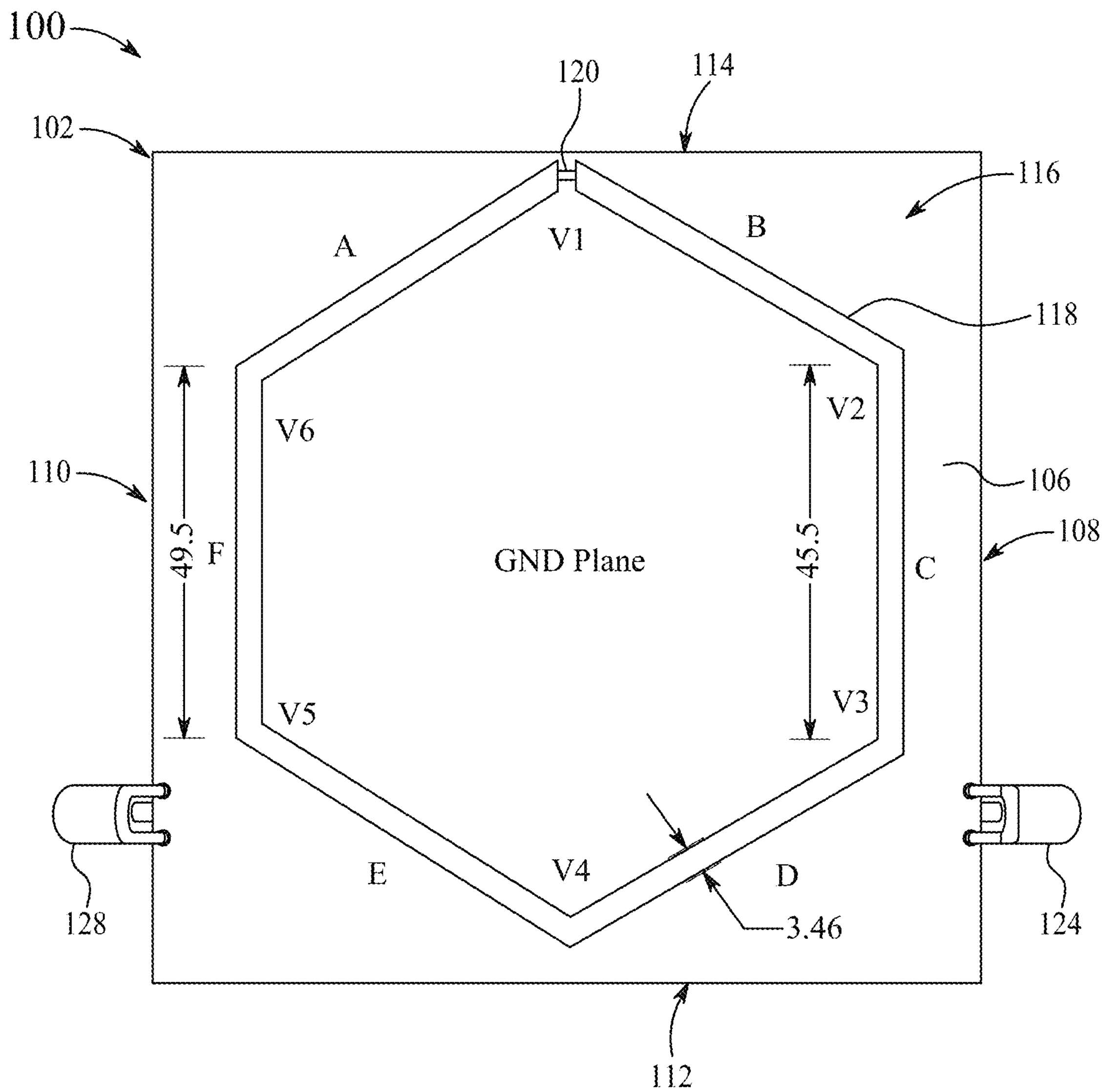

100
102
120
114
116
A
V1
B
118
V6
V2
110
106
108
49.5
F
GND Plane
45.5
C
V5
V3
E
V4
D
3.46
128
124
112

FIG. 1B

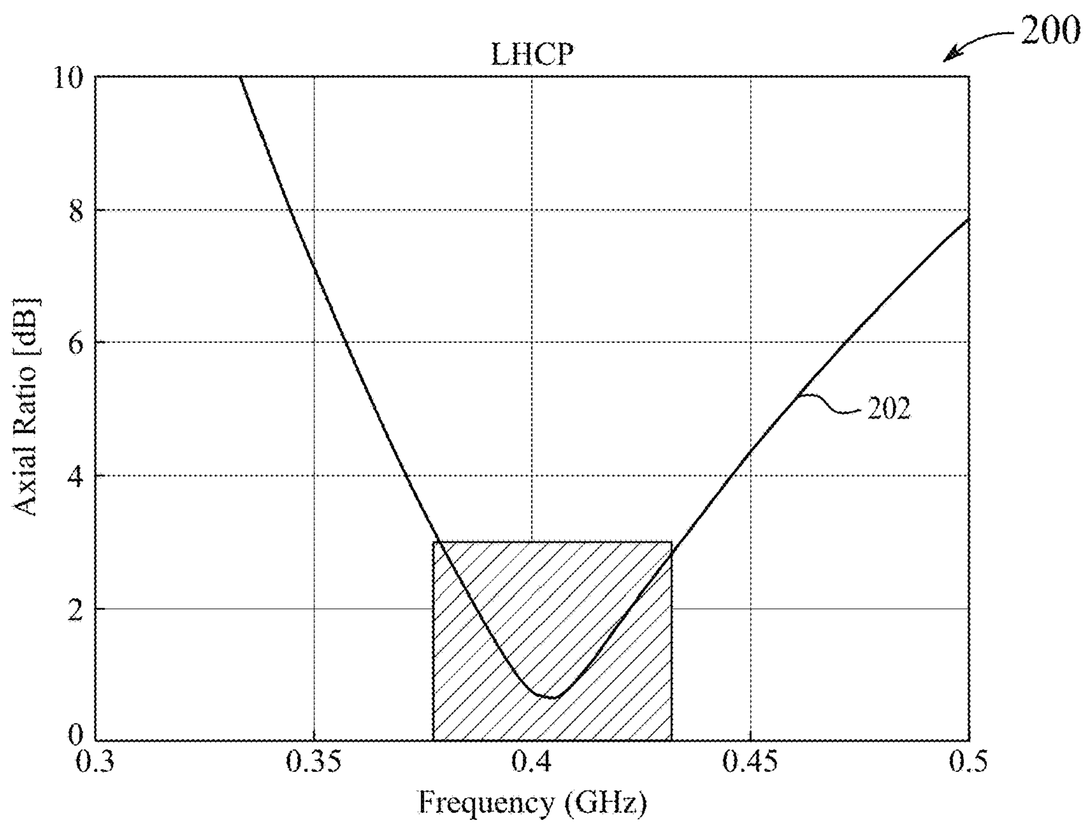

200
LHCP
10
8
6
4
2
0
0.3
0.35
0.4
0.45
0.5
Axial Ratio [dB]
Frequency (GHz)
202

FIG. 2

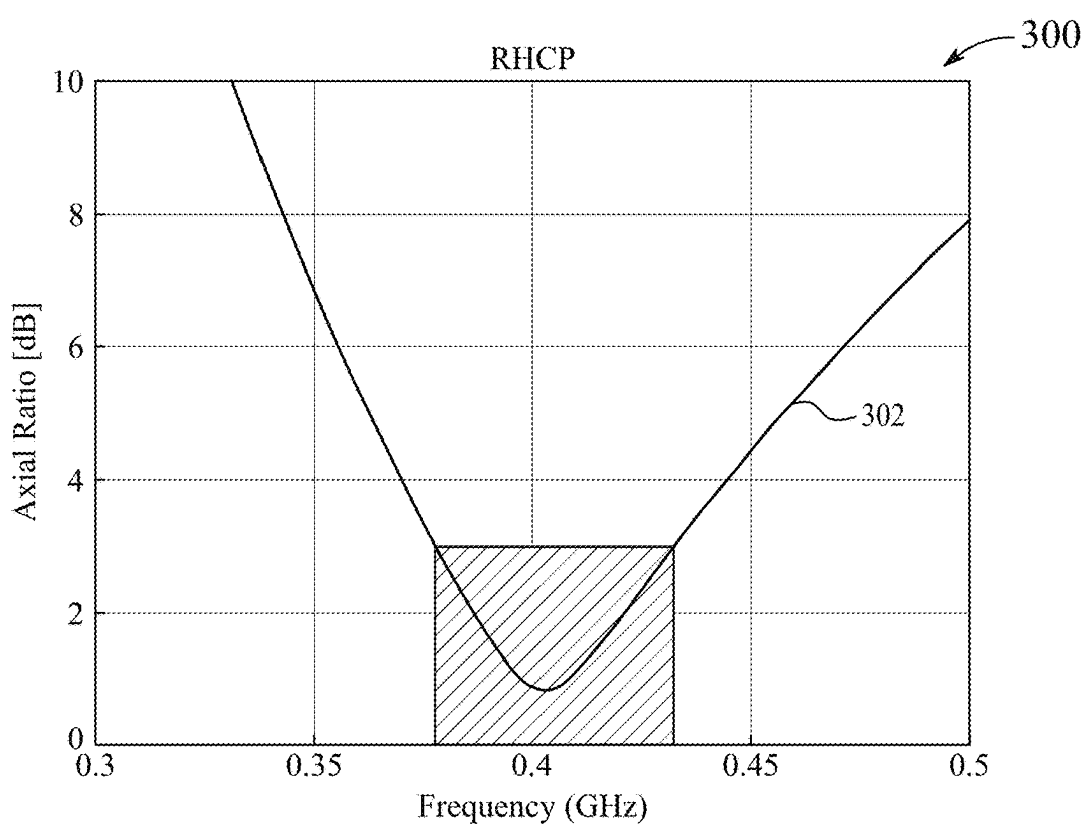

300
RHCP
10
8
6
4
2
0
0.3
0.35
0.4
0.45
0.5
Axial Ratio [dB]
Frequency (GHz)
302

FIG. 3

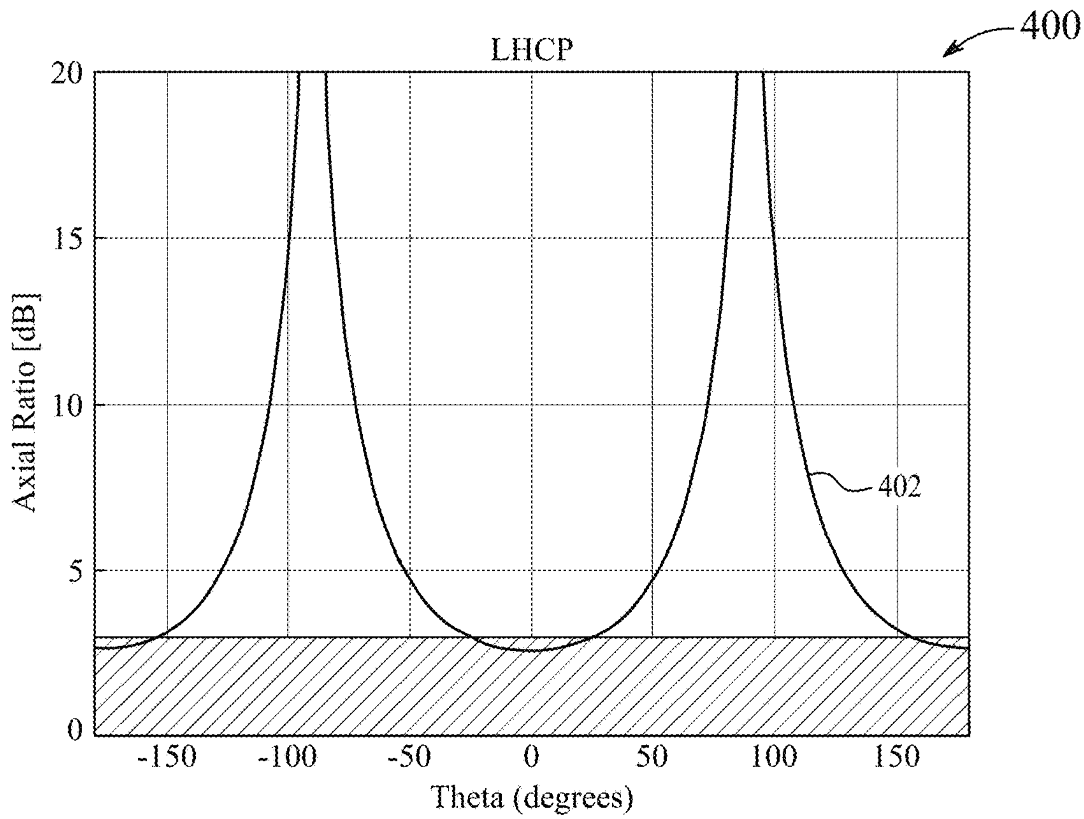

400
LHCP
20
15
10
5
0
Axial Ratio [dB]
402
-150 -100 -50 0 50 100 150
Theta (degrees)

FIG. 4

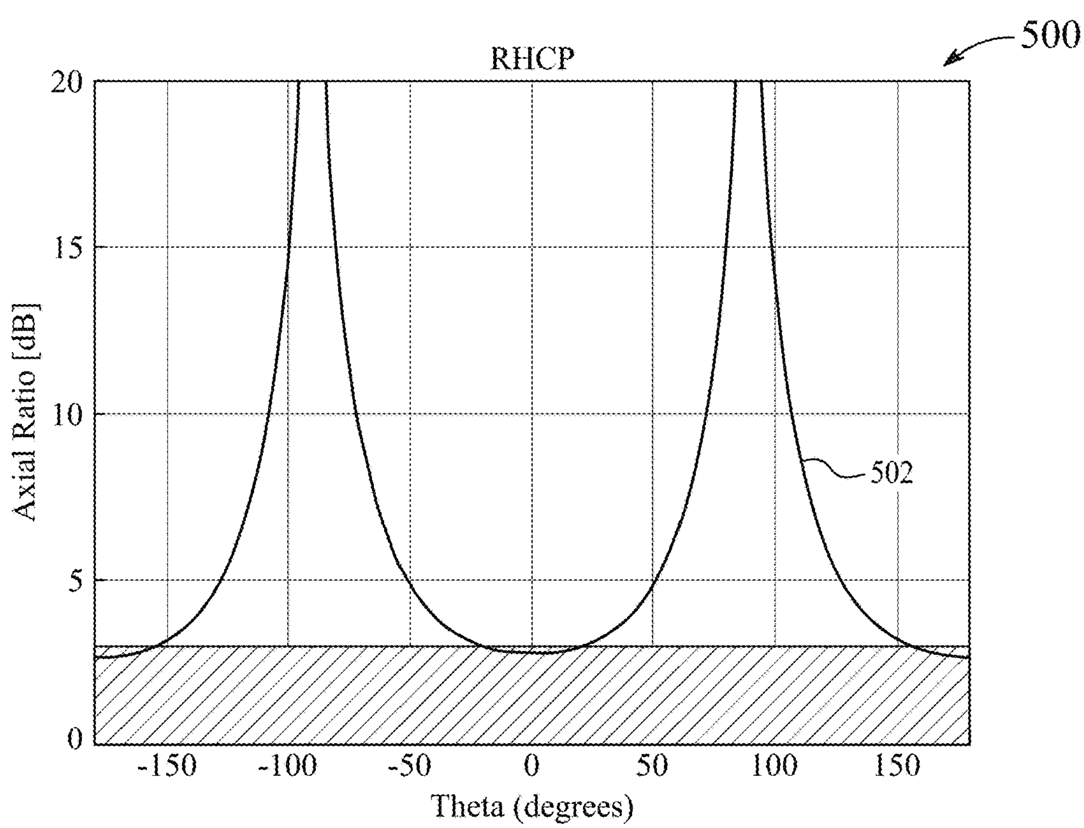

500
RHCP
20
15
10
5
0
Axial Ratio [dB]
502
-150 -100 -50 0 50 100 150
Theta (degrees)

FIG. 5

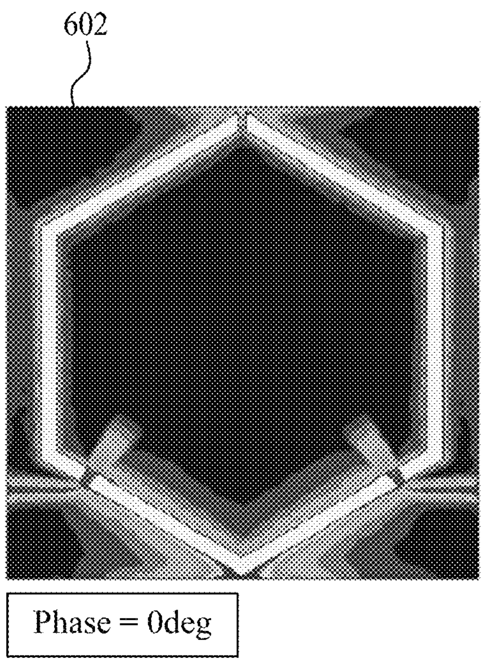


FIG. 6A

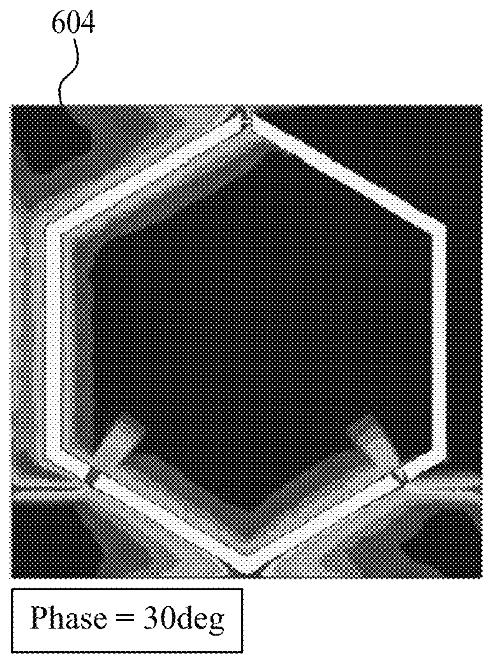


FIG. 6B

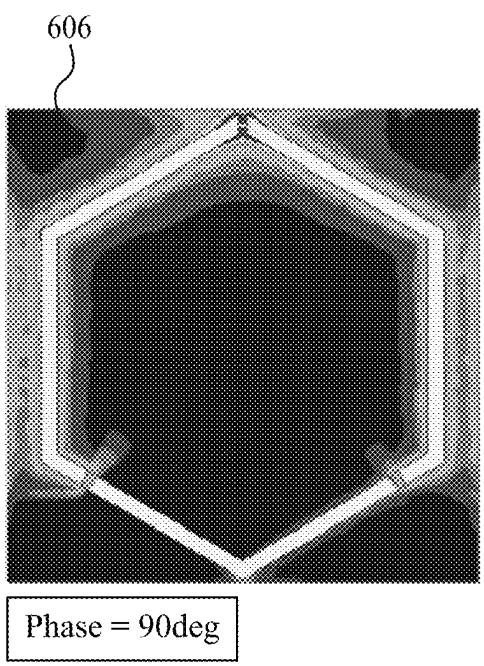


FIG. 6C

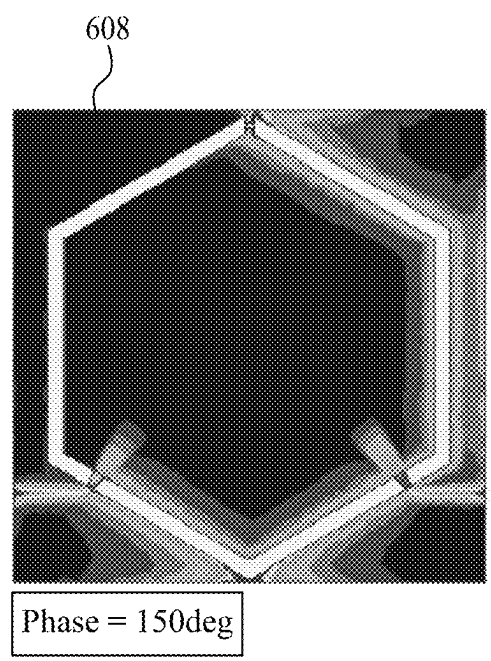
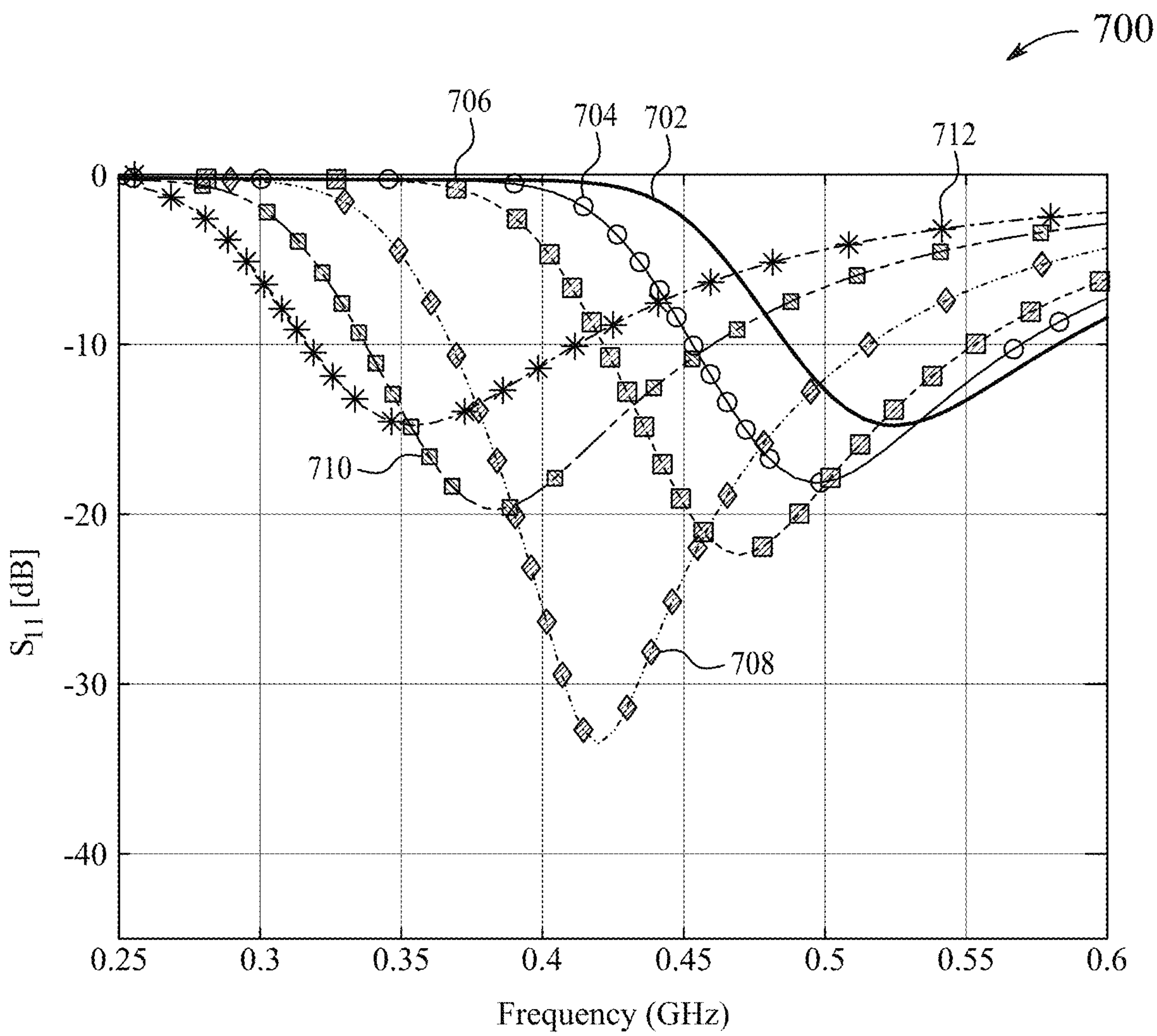


FIG. 6D



700
706
704
702
712
710
708
0
-10
-20
-30
-40
S_{11} [dB]
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
Frequency (GHz)

FIG. 7

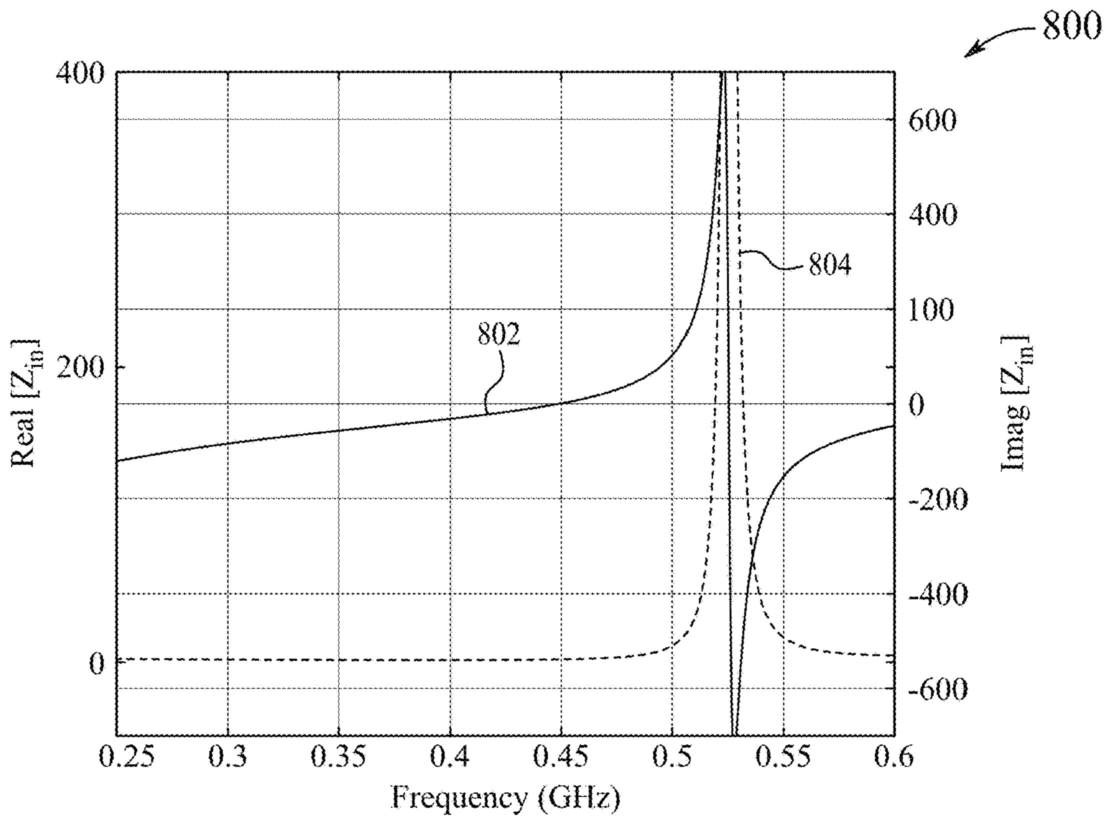

800
400
200
0
600
400
100
0
-200
-400
-600
802
804
Real [Z_{in}]
Imag [Z_{in}]
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
Frequency (GHz)

FIG. 8A

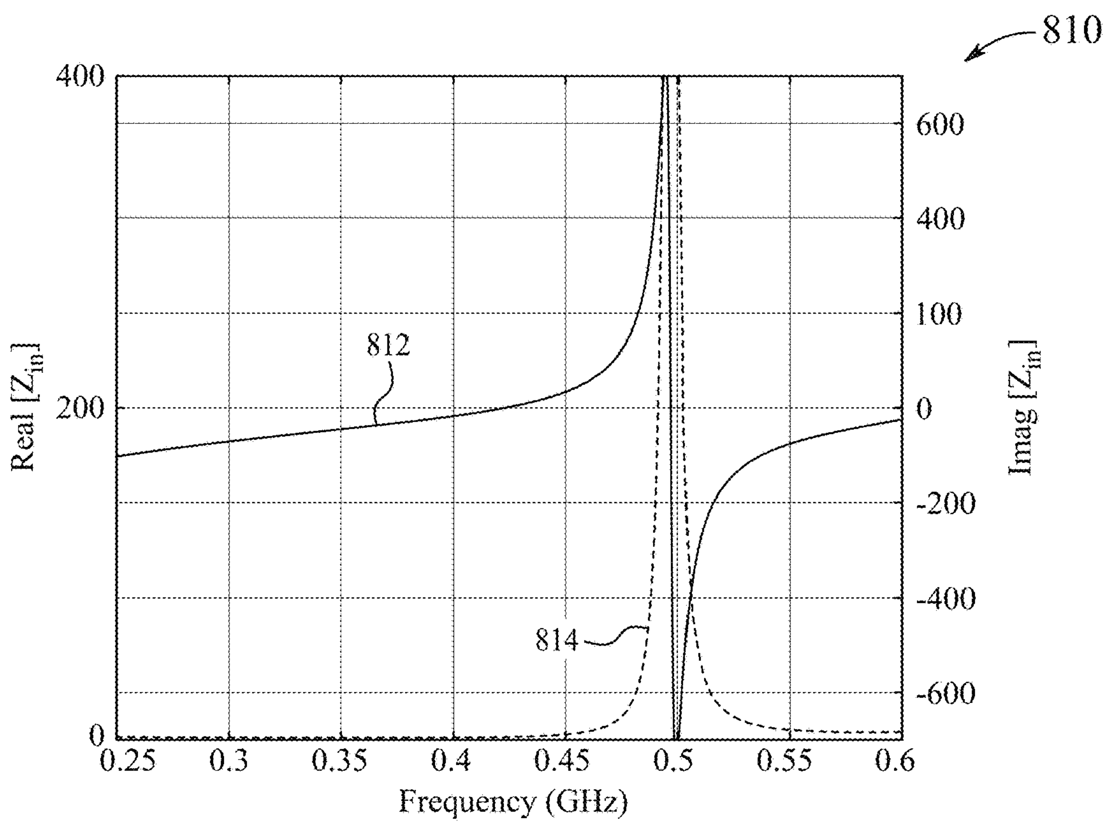

810
400
200
0
600
400
100
0
-200
-400
-600
812
814
Real [Z_{in}]
Imag [Z_{in}]
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
Frequency (GHz)

FIG. 8B

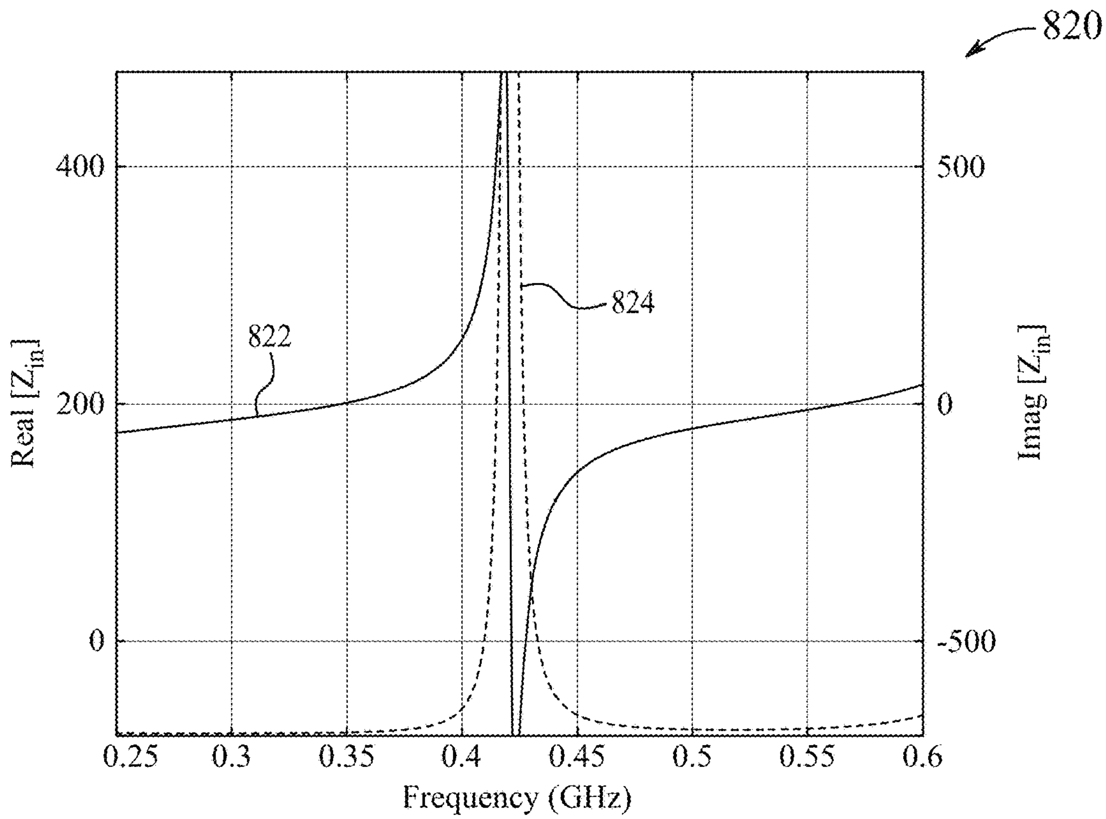

820
824
822
400
200
0
500
0
-500
Real [Z_{in}]
Imag [Z_{in}]
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
Frequency (GHz)

FIG. 8C

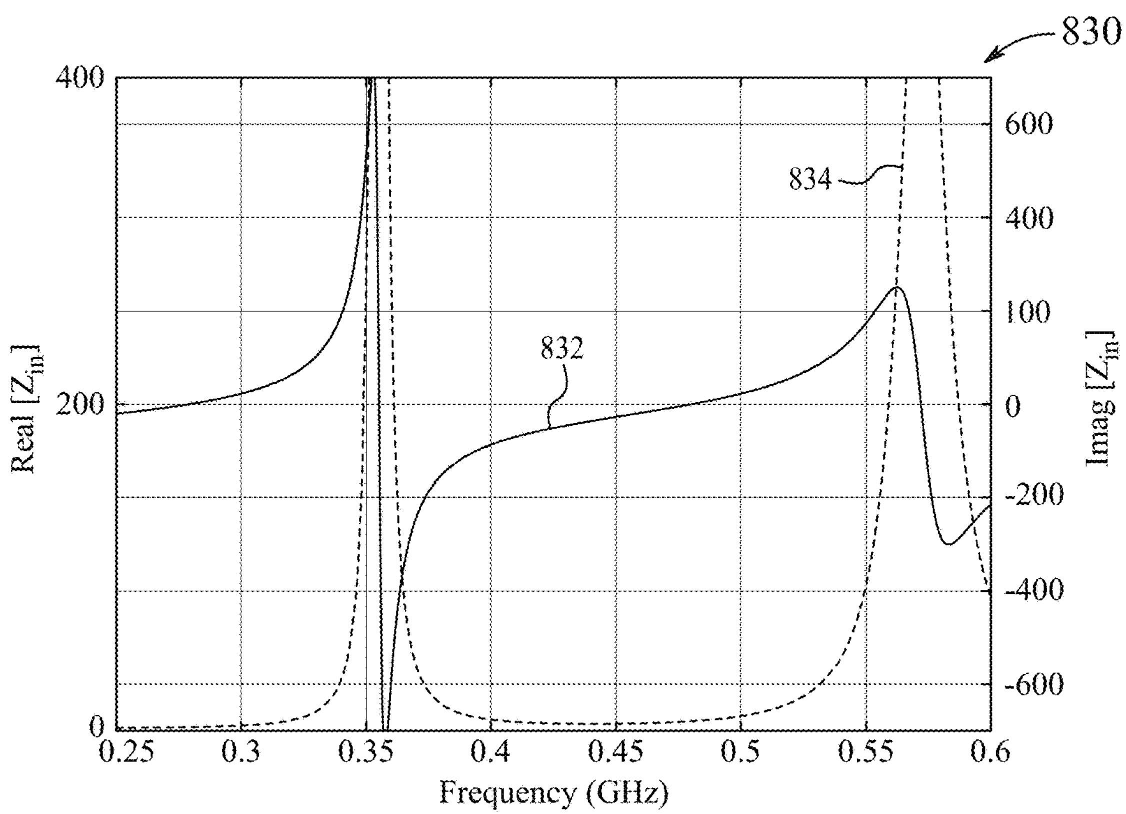

830
834
832
400
200
0
600
400
100
0
-200
-400
-600
Real [Z_{in}]
Imag [Z_{in}]
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
Frequency (GHz)

FIG. 8D

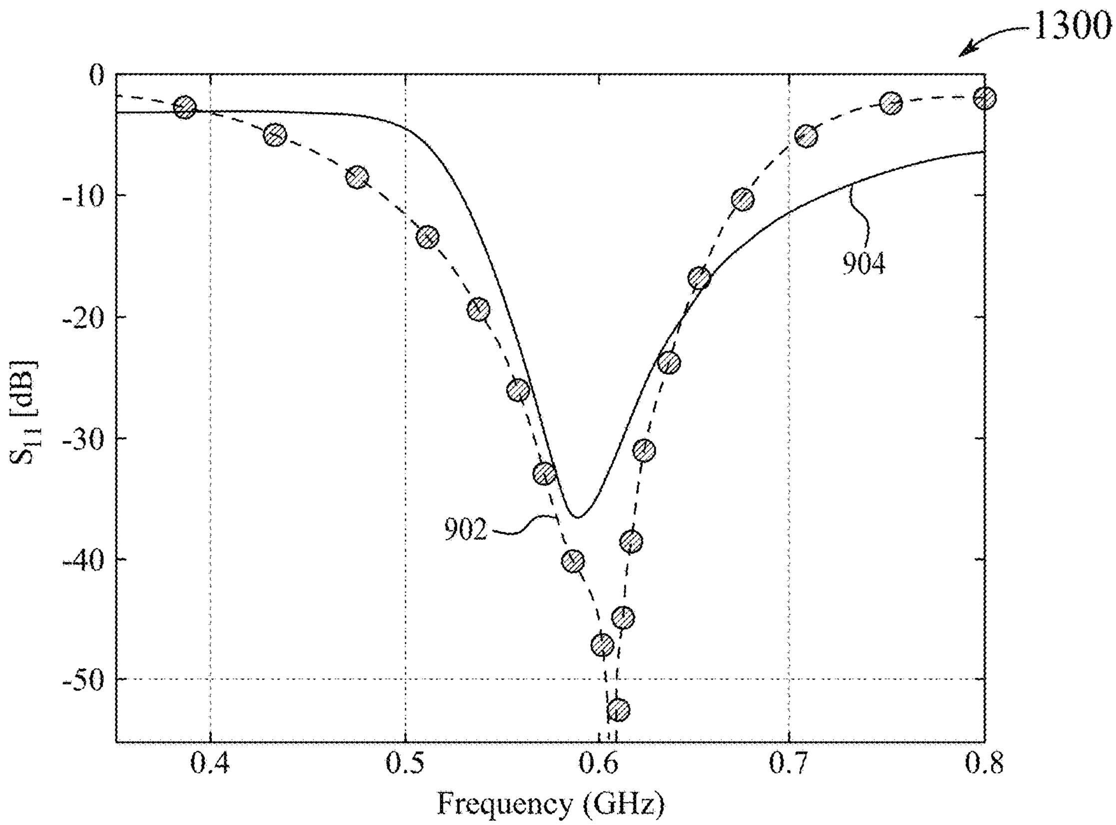

1300
0
-10
-20
-30
-40
-50
S_{11} [dB]
902
904
0.4
0.5
0.6
0.7
0.8
Frequency (GHz)

FIG. 9

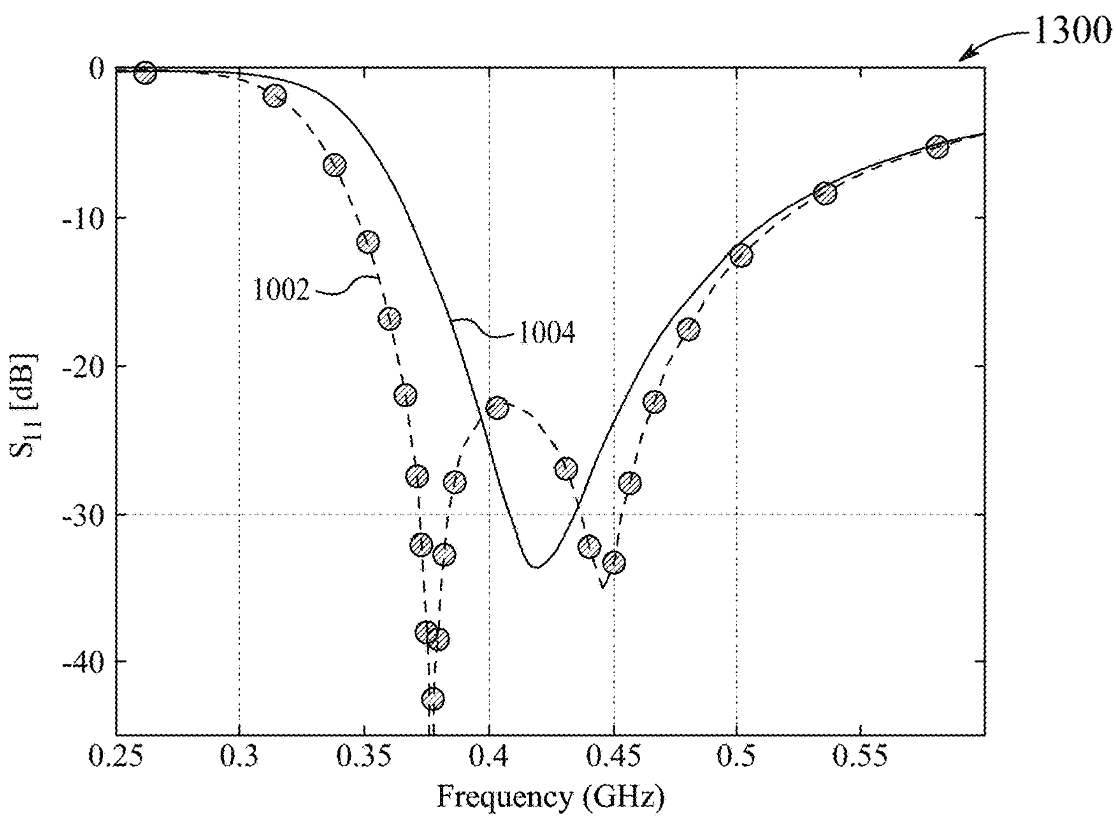

1300
0
-10
-20
-30
-40
S_{11} [dB]
1002
1004
0.25
0.3
0.35
0.4
0.45
0.5
0.55
Frequency (GHz)

FIG. 10

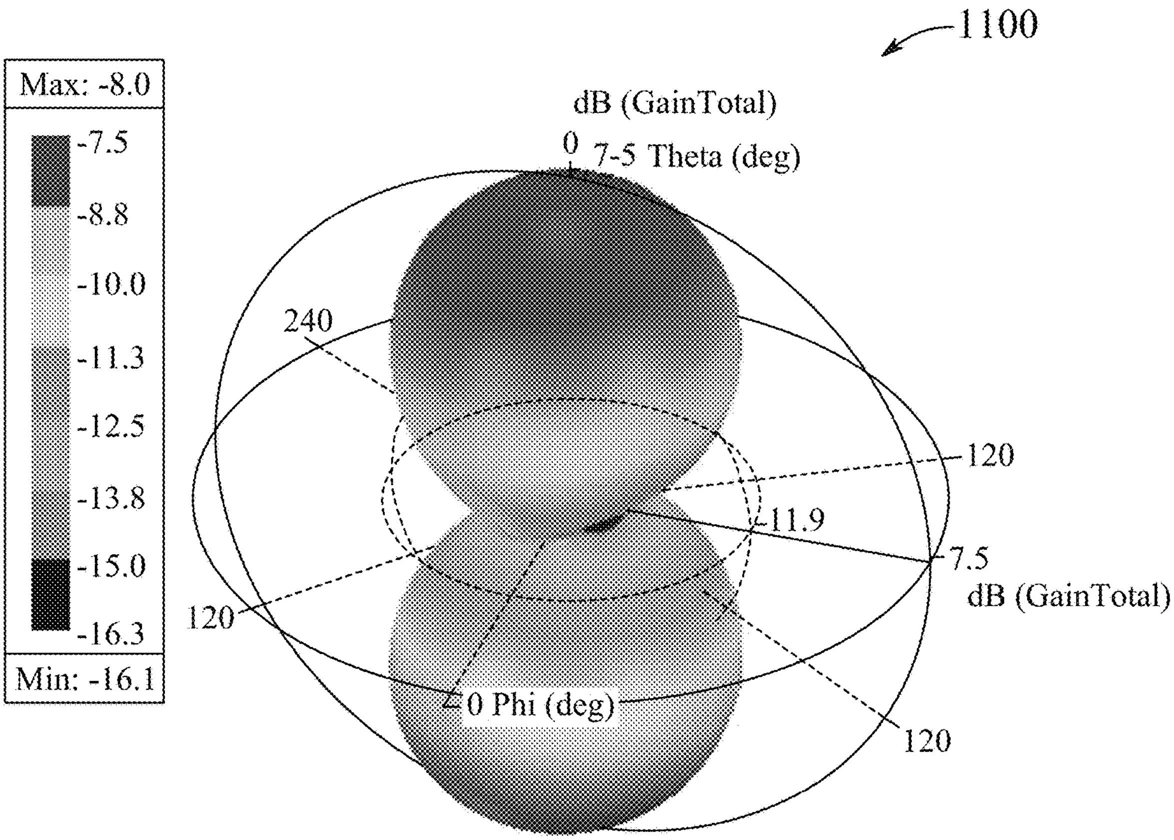
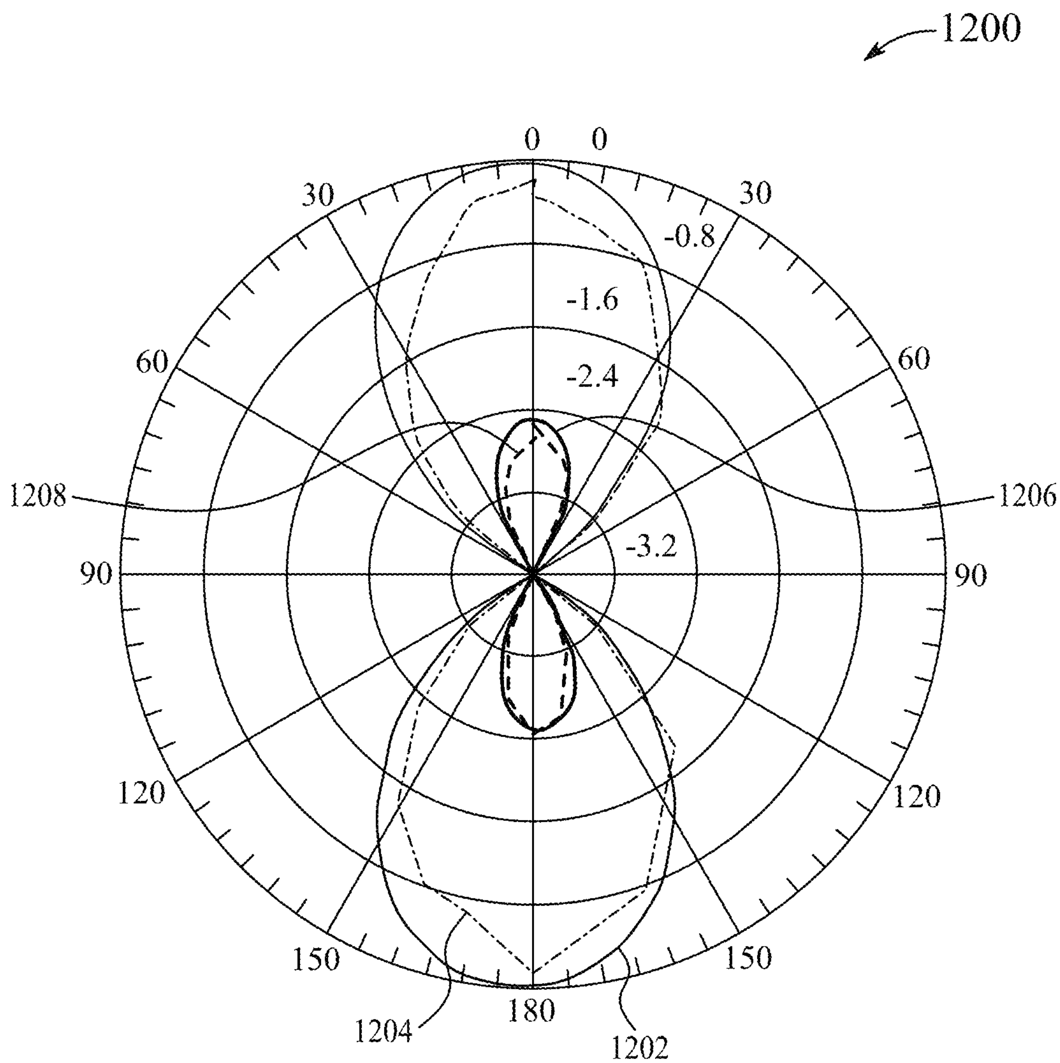

1100
Max: -8.0
-7.5
-8.8
-10.0
-11.3
-12.5
-13.8
-15.0
-16.3
Min: -16.1
dB (GainTotal)
0
7-5 Theta (deg)
240
120
-11.9
120
7.5
dB (GainTotal)
0 Phi (deg)
120

FIG. 11



1200
0
0
30
30
-0.8
-1.6
60
-2.4
60
1208
1206
-3.2
90
90
120
120
150
150
180
1204
1202

FIG. 12

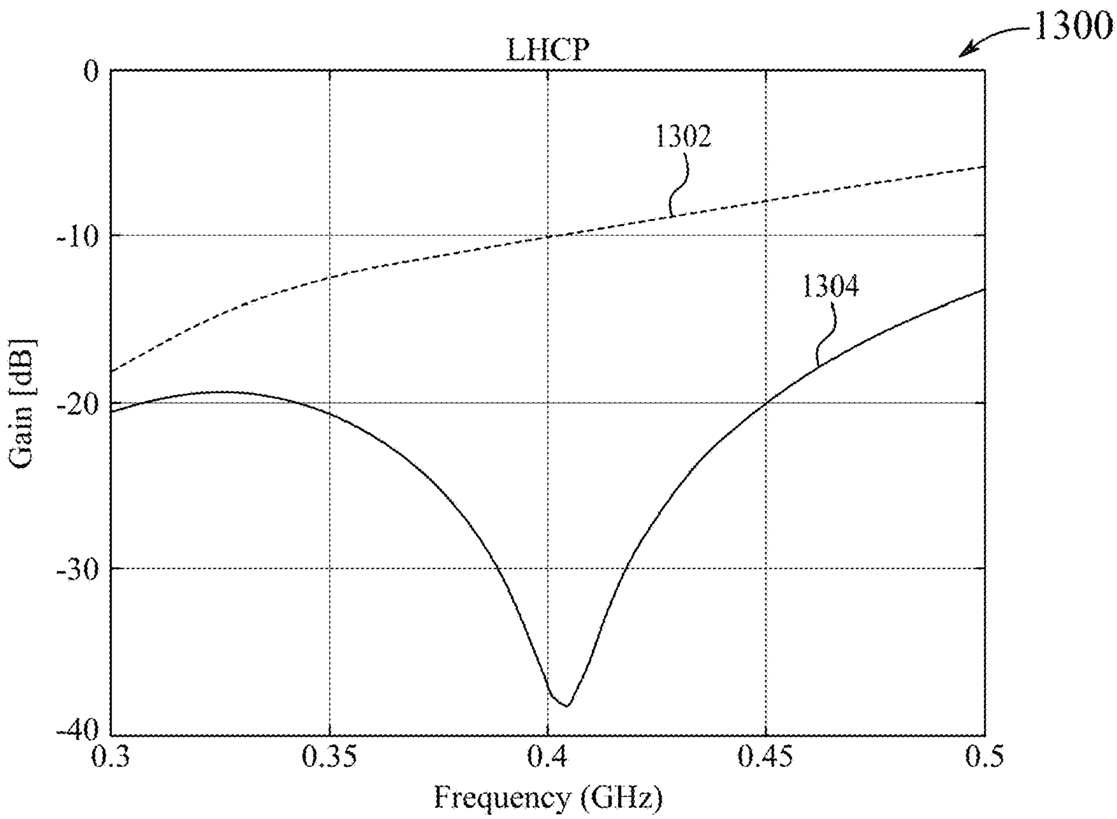

1300
LHCP
0
-10
-20
-30
-40
Gain [dB]
0.3
0.35
0.4
0.45
0.5
Frequency (GHz)
1302
1304

FIG. 13

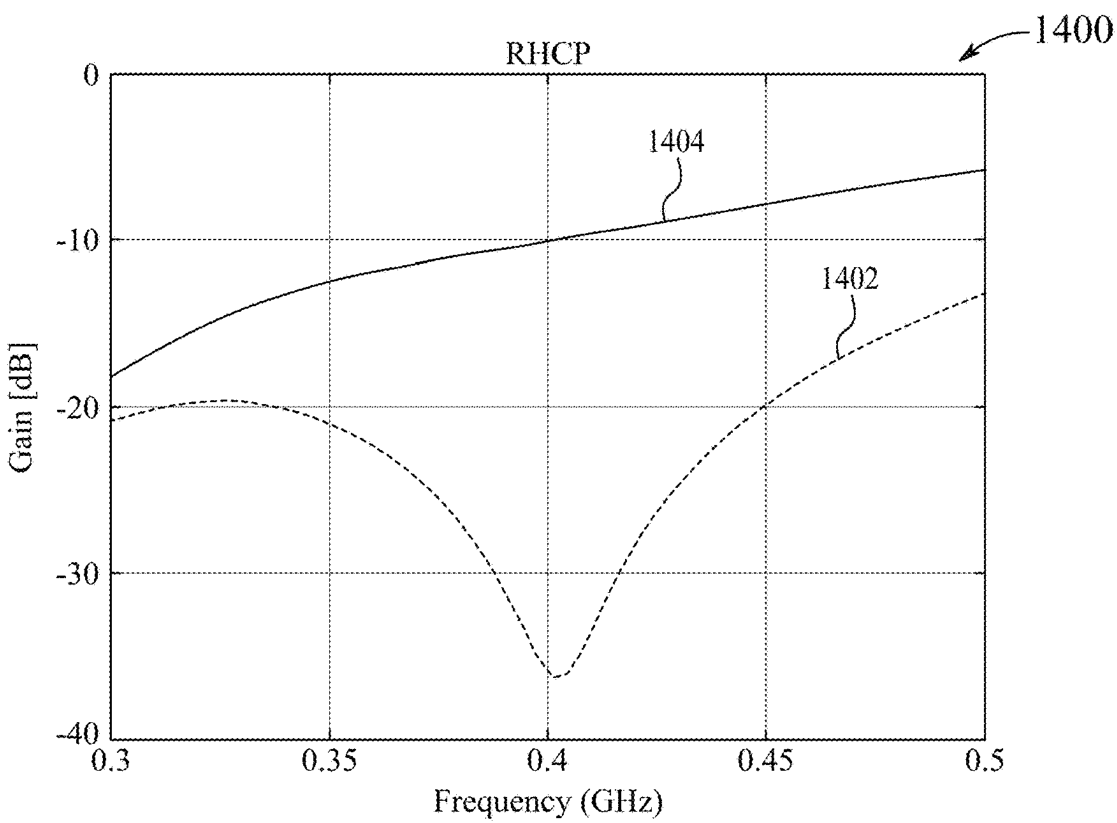

1400
RHCP
0
-10
-20
-30
-40
Gain [dB]
0.3
0.35
0.4
0.45
0.5
Frequency (GHz)
1404
1402

FIG. 14

SATELLITE ANTENNA WITH METAL FOIL ETCHED FILM LAYER

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a Continuation of U.S. application Ser. No. 18/181,964, now allowed, having a filing date of Mar. 10, 2023.

STATEMENT REGARDING PRIOR DISCLOSURE BY THE INVENTORS

Aspects of this technology are described in an article "Dual Sense Circularly Polarized Compact Slot Antenna For CubeSat Applications" published in IEEE Access, on Oct. 5, 2022, which is incorporated herein by reference in its entirety.

STATEMENT OF ACKNOWLEDGEMENT

The inventor(s) acknowledge the financial support provided by the King Fahd University of Petroleum and Minerals (KFUPM), Riyadh, Saudi Arabia through Project #SR201009.

BACKGROUND

Technical Field

The present disclosure is directed to a dual polarized ultra-high frequency (UHF) band CubeSat antenna.

Description of Related Art

The "background" description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description which may not otherwise qualify as prior art at the time of filing, are neither expressly or impliedly admitted as prior art against the present invention.

A Cube Satellite (CubeSat) is a class of nanosatellite that is an emerging alternative to conventional satellites for low-Earth orbit satellite communications and satellite missions. The CubeSat is cost-effective, small, and lightweight. CubeSats can communicate with each other in space and with ground stations to carry out various functions, such as remote sensing, space research, and wide-area measurements. The size of a 1-unit CubeSat is about 10×10×10 cm^3. The design of an antenna for the CubeSat has stringent limitations due to the size constraints that define its design space. A compact antenna is required for the CubeSat to maintain basic antenna characteristics, such as input impedance matching, bandwidth, and peak gain requirements.

Due to physical and structural requirements of the CubeSat, electrically small antennas with circular polarization (CP) and wideband characteristics are good candidates. The CubeSat requires a CP antenna with wide impedance matching bandwidth. The CP antenna offers more orientation flexibility and matching compared to a linear polarized antenna in many wireless communication applications, including satellites, 5G millimeter-wave, and radio frequency identification. It is a challenge to develop the CP antenna with wideband and compact size characteristics in the ultra-high frequency (UHF) spectrum, which are the core requirements in CubeSat communication.

In one conventional antenna design, a wideband and unidirectional loop antenna was partially loaded with mu-negative (MNG) metamaterial unit cells. To reduce the electrical size of the antenna, a first resonance of the antenna was formed by capacitively loading a conventional one-wavelength loop antenna to excite the mu-zero resonance that is independent of the resonator's size. However, this antenna design generated single linearly polarized waves.

An existing planar leaky-wave antenna (LWA) has been described (See: X. Li, J. Wang, G. Goussetis, and L. Wang, "*Circularly Polarized High Gain Leaky-Wave Antenna for CubeSat Communication*," IEEE Transactions on Antennas and Propagation, pp. 1-1, 2022, incorporated herein by reference in its entirety). The LWA was implemented by etching periodic fan-shaped slots on top of a substrate-integrated waveguide (SIW). These fan-shaped slots exhibited circular polarization radiation with high efficiency over a wide frequency band, however the LWA did not operate at UHF band.

A substrate-integrated waveguide (SIW) antenna utilized middle-point feeding and shorting walls to achieve broadside radiation in the far-field at two distinct frequencies (See: M. V. Kuznetcov, S. K. Podilchak, M. Poveda-Garcia, P. Hilario, C. A. Alistarh, G. Goussetis, and J. L. Gomez-Tornero, "*Compact Leaky-Wave SIW Antenna With Broadside Radiation and Dual-Band Operation for CubeSats*," IEEE Antennas and Wireless Propagation Letters, vol. 20, no. 11, pp. 2125-2129, 2021, is incorporated herein by reference in its entirety). The SIW antenna is matched from 23.2 to 23.5 GHz and 24.8 to 25.2 GHz with realized gains of 8 dBi and 6 dBi, respectively. The SIW antenna is prone to leaky waves and does not operate in the UHF band.

A conventional design of miniaturized slot antennas was described (See: R. Azadegan and K. Sarabandi, "*Design of miniaturized slot antennas*," IEEE Antennas and Propagation Society International Symposium. 2001 Digest. Held in conjunction with: USNC/URSI National Radio Science incorporated herein by reference in its entirety). The miniatured UHF band slot antenna achieved miniaturization by terminating a short slot by an inductor. Inductive loading was realized by coiling the shortened slot line with a length of less than a quarter wavelength. The directivity of the small dipole-slot antenna was equal to that of the infinitesimal Hertzian dipole, and its gain depended on the substrate material specifications and the antenna size. However, the antenna bandwidth, gain and efficiency were limited.

A compact multiband planar antenna was developed for mobile wireless terminals (See: Meeting, "*Cat. No.* 01*CH*37229, vol. 4, pp. 565-568", IEEE, 2001 is incorporated herein by reference in its entirety). However, the systems and methods described in these references and other conventional antennas suffer from various limitations including various leaky waves, poor bandwidth and limited gain.

Hence, there is a need for a CubeSat antenna that is compact in size, has wide bandwidth circularized polarization characteristics, and shows good impedance matching. It is one object of the present disclosure to provide a wideband ultra high frequency (UHF) antenna for use with a CubeSat.

SUMMARY

In an exemplary embodiment, a dual feed slot-based circularly polarized wideband ultra high frequency (UHF) antenna for a cubic shaped satellite (Cube-Sat) is described. The dual feed slot-based circularly polarized wideband ultra high frequency (UHF) antenna includes a circuit board having a front side and a back side separated by a dielectric material, a metallic layer configured to cover the back side of the circuit board, wherein the metallic layer is connected to a ground, a hexagonal meandered slot symmetrically formed in the metallic layer, wherein the hexagonal meandered slot includes six legs of equal length, wherein the six legs are configured such that the hexagonal meandered slot includes a first vertex located between a first leg and a second leg, a second vertex located between the second leg and a third leg, a third vertex located between the third leg and a fourth leg, a fourth vertex located between the fourth leg and a fifth leg, a fifth vertex located between the fifth leg and a sixth leg, and a sixth vertex located between the sixth leg and the first leg, a capacitor switchably connected to the metallic layer across the first vertex, a first feed horn connected by a first feed line to a first edge of the front side of the circuit board, wherein an open end of the first feed horn is directed into an inner area of the hexagonal meandered slot between the third vertex and the fourth vertex, and a second feed horn connected by a second feed line to a second edge of the front side of the circuit board, wherein the second edge is opposite the first edge, such that an opening of the second feed horn extends across the hexagonal meandered slot between the sixth vertex and the second vertex.

In another exemplary embodiment, a method for making a dual feed slot-based circularly polarized wideband UHF antenna of dimensions of less than 60 mm by 60 mm for cubic shaped satellites (Cube-Sat) is described. The method includes forming a metallic layer on the back side of a circuit board having a front side and a back side separated by a dielectric material, wherein the metallic layer is connected to a ground. The method includes symmetrically forming a hexagonal meandered slot in the metallic layer, the hexagonal meandered slot including six legs of equal length, and configuring the six legs such that the hexagonal meandered slot includes a first vertex located between a first leg and a second leg, a second vertex located between the second leg and a third leg, a third vertex located between the third leg and a fourth leg, a fourth vertex located between the fourth leg and a fifth leg, a fifth vertex located between the fifth leg and a sixth leg, and a sixth vertex located between the sixth leg and the first leg. The method includes switchably connecting a capacitor to the metallic layer across the first vertex. The method includes connecting a first feed line of a first feed horn to a first edge of the front side of the circuit board and directing an open end of the first feed horn into an inner area of the hexagonal meandered slot between the third vertex and the fourth vertex. The method includes connecting a second feed line of a second feed horn to a second edge of the front side of the circuit board, wherein the second edge is opposite the first edge, such that an opening of the second feed horn extends across the hexagonal meandered slot between the sixth vertex and the second vertex.

In another exemplary embodiment, a method for transmitting ultra high frequency (UHF) signals with a dual feed slot-based circularly polarized wideband UHF antenna of dimensions of less than 60 mm by 60 mm for cubic shaped satellites (Cube-Sat) is described. The method includes forming a first feed horn and a second feed horn in a front side dielectric circuit board, wherein a back side of the dielectric circuit board is covered with a grounded metallic sheet configured with a meandered hexagonal slot, wherein the hexagonal meandered slot is symmetrically formed in the metallic layer, wherein the hexagonal meandered slot includes six legs of equal length, wherein the six legs are configured such that the hexagonal meandered slot includes a first vertex located between a first leg and a second leg, a second vertex located between the second leg and a third leg, a third vertex located between the third leg and a fourth leg, a fourth vertex located between the fourth leg and a fifth leg, a fifth vertex located between the fifth leg and a sixth leg, and a sixth vertex located between the sixth leg and the first leg. The method includes switchably connecting a capacitor to the metallic layer across the first vertex. The method includes transmitting ultra high frequency (UHF) signals by applying signal frequencies in the range of 360 MHz to 470 MHz to the first feed horn and the second feed horn.

The foregoing general description of the illustrative embodiments and the following detailed description thereof are merely exemplary aspects of the teachings of this disclosure, and are not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of this disclosure and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

FIG. **1**A is a top view of a dual feed slot-based circularly polarized wideband ultra high frequency (UHF) antenna, according to certain embodiments.

FIG. **1**B is a bottom view of the dual feed slot-based circularly polarized wideband UHF antenna, according to certain embodiments.

FIG. **2** is an exemplary graph illustrating an axial ratio versus frequency curve for left hand circular polarization (LHCP) mode, according to certain embodiments.

FIG. **3** is an exemplary graph illustrating an axial ratio versus frequency curve for right hand circular polarization (RHCP) mode, according to certain embodiments.

FIG. **4** is an exemplary graph illustrating an axial ratio versus theta curve for LHCP mode, according to certain embodiments.

FIG. **5** is an exemplary graph illustrating an axial ratio versus theta curve for RHCP mode, according to certain embodiments.

FIG. **6**A is an exemplary illustration of surface current distributions at zero degree phase angle, according to certain embodiments.

FIG. **6**B is an exemplary illustration of surface current distributions at 30 degree phase angle, according to certain embodiments.

FIG. **6**C is an exemplary illustration of surface current distributions at 90 degree phase angle, according to certain embodiments.

FIG. **6**D is an exemplary illustration of surface current distributions at 150 degree phase angle, according to certain embodiments.

FIG. **7** is an exemplary illustration of measured S parameters (S_{11}) for different capacitance value, according to certain embodiments.

FIG. **8**A is an exemplary illustration of an input impedance (Z_{in}) curve when a capacitance value is 3 pF, according to certain embodiments.

FIG. **8**B is an exemplary illustration of the input impedance (Z_{in}) curve when the capacitance value is 8 pF, according to certain embodiments.

FIG. **8**C is an exemplary illustration of the input impedance (Z_{in}) curve when the capacitance value is 12 pF, according to certain embodiments.

FIG. **8**D is an exemplary illustration of the input impedance (Z_{in}) curve when the capacitance value is 16 pF, according to certain embodiments.

FIG. **9** is an exemplary graph illustrating simulated and measured S parameters (S_{11}) without capacitor loading, according to certain embodiments.

FIG. **10** is an exemplary graph illustrating simulated and measured S parameters (S_{11}) with capacitor loading, according to certain embodiments.

FIG. **11** is an illustration of 3-D gain pattern of the dual feed slot-based circularly polarized wideband UHF antenna, according to certain embodiments.

FIG. **12** is an illustration of 2-D simulated and measured radiation patterns of the dual feed slot-based circularly polarized wideband UHF antenna, according to certain embodiments.

FIG. **13** is an exemplary graph illustrating gain versus frequency curve for the LHCP mode, according to certain embodiments.

FIG. **14** is an exemplary graph illustrating gain versus frequency curve for the RHCP mode, according to certain embodiments.

DETAILED DESCRIPTION

In the drawings, like reference numerals designate identical or corresponding parts throughout the several views. Further, as used herein, the words "a," "an" and the like generally carry a meaning of "one or more," unless stated otherwise.

Furthermore, the terms "approximately," "approximate," "about," and similar terms generally refer to ranges that include the identified value within a margin of 20%, 10%, or preferably 5%, and any values therebetween.

CubeSats are a class of spacecraft called nanosatellites. CubeSats are built to standard dimensions (Units or "U") of about 10 cm×10 cm×10 cm. CubeSats can be 1 U, 2 U, 3 U, or 6 U in size, and typically weigh less than 1.33 kg (3 lbs.) per U.

Aspects of this disclosure are directed to a dual feed slot-based circularly polarized wideband ultra-high frequency (UHF) antenna and a method for making the dual feed slot-based circularly polarized wideband UHF antenna. A Cubesat equipped with the antenna is also described, as are methods of transmitting and receiving signals with a CubeSat having the dual feed slot-based circularly polarized wideband UHF antenna. The antenna of the present disclosure has a compact structure, which makes the antenna a suitable candidate for CubeSat applications. The antenna includes a thin hexagonal slot and two feeding transmission lines. In order to achieve a circular polarized (CP) antenna, the two feeding transmission lines are placed symmetrically with respect to the hexagonal slot. The shape and location of the feeding transmission lines, and the hexagonal slot are determined using a parametric analysis. To achieve wideband characteristics with a compact size, the hexagonal slot is constructed with capacitive loading. The antenna is configured to provide both right-hand circular polarization and left-hand circular polarization. The antenna provides a good impedance matching bandwidth from 360 MHz to 470 MHz with a 3 dB axial ratio.

In various aspects of the disclosure, definitions of one or more terms that will be used in the document are provided below.

The term "decibel (or dB)" is a unit used to measure the ratio of input to output power. dB measures the intensity of the power level of an electrical signal by comparing it to a given scale. For example, an amplifier causes a gain in power measured in decibels and it is indicated by a positive number. In another example, cables can cause a loss of power. This is measured in negative dB.

The term "dBi" is defined as the gain of an antenna system relative to an isotropic radiator at radio frequencies. The dBi is an abbreviation for "decibels relative to isotropic". The dBi is based on the decibel, a logarithm i measure of relative power. Antenna manufacturers use dBi to measure antenna performance.

FIG. **1**A to FIG. **1**B illustrate an overall configuration of the dual feed slot-based circularly polarized wideband UHF antenna for a cube-shaped satellite (CubeSat).

FIG. **1**A illustrates a top view of the dual feed slot-based circularly polarized wideband UHF antenna, according to certain embodiments (hereinafter interchangeably referred to as "the UHF antenna **100**"), according to one or more aspects of the present disclosure. FIG. **1**B is a bottom view of the UHF antenna **100**, according to certain embodiments. In an aspect, the UHF antenna **100** has dimensions of less than 60 mm by 60 mm. FIG. **1**A may be read in conjunction with FIG. **1**B for a better understanding. In the drawings of FIG. **1**A, and FIG. **1**B, dimensions shown are for the example of a 60×60 mm^2 circuit board and should not be construed as limiting. For a circuit board less than or greater than 60×60 mm^2, the dimensions are proportionately smaller or greater respectively. In an aspect, the total length or width of the UHF antenna **100** is 0.082, at 435 MHz which is very compact compared to the conventional antennas.

As shown in FIG. **1**A-FIG. **1**B, the UHF antenna **100** includes a circuit board **102**, a metallic layer **116**, a hexagonal meandered slot **118**, a capacitor **120**, a first feed horn **122**, and a second feed horn **126**.

The circuit board **102** has a front side **104** and a back side **106**. In an aspect, the front side **104** and the back side **106** are separated by a dielectric material. The circuit board **102** has a first edge **108**, a second edge **110**, a third edge **112**, and a fourth edge **114**. In an example, the circuit board **102** is a Rogers RO4350 substrate (fabricated by Rogers Corporation, located at 2225 W Chandler Blvd, Chandler, Arizona, United States). In an example, the circuit board **102** uses a substrate material having a relative permittivity (ε_r) of 3.48 and loss tangent of 0.0036. The dimensions of the circuit board **102** are less than or equal to 60×60 mm^2. The dimensions of FIGS. **1**A-**1**B are based on a circuit board of 60×60 mm^2 and are merely exemplary. For a circuit board less than 60×60 mm^2, the dimensions are proportionately smaller. In an aspect, the Rogers RO4350 has a size of 60×60×1.52 mm^3.

The metallic layer **116** is configured to cover the back side **106** of the circuit board **102**. The metallic layer **116** is connected to a ground terminal. The metallic layer **116** is a material which can conduct an electric field, selected from the group of copper, aluminum, silver, metal copper foils, and combinations thereof. In a non-limiting example, the metallic layer **116** has a thickness of 18 microns and is made of copper. In the metallic layer **116**, the hexagonal meandered slot **118** is formed. For example, the hexagonal meandered slot **118** is fabricated in the metallic layer **116** using a PCB laser etching and milling machine (See: LPKF Prototyping machine manufactured by LPKF Laser & Electronics, located at Osteriede 7, 30827 Garbsen, Germany). In an aspect, the hexagonal meandered slot **118** is covered with an epoxy coating that protects the surface edges of the hexagonal meandered slot **118** from any damage.

The hexagonal meandered slot **118** is symmetrically formed in the metallic layer **116** and is preferably equiangular. The hexagonal meandered slot **118** includes six legs (A-F) preferably of substantially equal length. In an aspect, each interior angle between the two adjacent legs is 120 degrees. For example, the six legs (A-F) include a first leg (A), a second leg (B), a third leg (C), a fourth leg (D), a fifth leg (E), and a sixth leg (F). The six legs (A-F) are configured such that the hexagonal meandered slot **118** includes six vertices (V**1**-V**6**). In an exemplary connection implementation, a first vertex V**1** is located between the first leg (A) and the second leg (B). A second vertex V**2** is located between the second leg (B) and a third leg (C). A third vertex V**3** is located between the third leg (C) and a fourth leg (D). A fourth vertex V**4** is located between the fourth leg (D) and a fifth leg (E). A fifth vertex V**5** is located between the fifth leg (E) and a sixth leg (F). A sixth vertex V**6** is located between the sixth leg (F) and the first leg (A). In an aspect, the hexagonal meandered slot **118** has a width in the range of 3 mm to 4 mm. For example, the hexagonal meandered slot **118** has a width of 3.5±0.2 mm or 3.46 mm. In an aspect, the inner length of leg of the hexagonal meandered slot **118** is 43-47 mm, preferably 45±1 mm, or 45.5±0.2 mm. In an example, the outer length of each leg of the hexagonal meandered slot **118** is 48-50 mm, preferably 49±0.5 mm or 49.5±0.1 mm. Each leg is of equal length.

The hexagonal meandered slot **118** is configured to resonate at a signal frequency selected from a group of signal frequencies. For example, the signal frequencies are dependent on a value of capacitance of the capacitor **120**. By varying the capacitance value of the capacitor **120**, the signal frequency may be changed, and as a result, the UHF antenna **100** is able to be tuned to different signal frequencies.

The capacitor **120** is switchably connected to the metallic layer **116** across the first vertex V**1**. In an aspect, the capacitor **120** is connected to the hexagonal meandered slot **118**. In an aspect, the capacitor **120** has a capacitance value selected from a group consisting of 3 pF, 5 pF, 8 pF, 12 pF, 14 pF, and 16 pF. For example, the capacitance value of the capacitor **120** is selected to be 12 pF. In some examples, the capacitor **120** is a variable capacitor. The capacitor **120** is configured to reduce an electrical size of the hexagonal meandered slot **118** and improves the impedance matching bandwidth. In an aspect, the UHF antenna **100** is configured to operate in a range of 550 MHz to 650 MHz frequency band without capacitive loading. In an example, the UHF antenna **100** is configured to operate in a range of 360 MHz to 470 MHz frequency band with capacitive loading. In an aspect, the UHF antenna **100** is configured to operate in a left hand circular polarization (LHCP) mode, and a right hand circular polarization (RHCP) mode.

As shown in FIG. **1**A, the first feed horn **122** includes a first feed line **124**, a first feed end, and a first horn end. The first feed line **124** is connected to the first edge **108** of the front side **104** of the circuit board **102**. The first feed end of the first feed horn **122** is connected to the first feed line **124**. The first feed horn **122** is connected to the first edge **108** of the front side **104** of the circuit board **102** by the first feed line **124**. In an aspect, an open end of the first feed horn **122** is directed into an inner area of the hexagonal meandered slot **118** between the third vertex V**3** and the fourth vertex V**4**. In an aspect, the horn end of the first feed horn **122** makes an angle of 50 to 55 degrees with the first feed line **124**. In an example, the first horn end has an opening of 7.75 mm. In some examples, the first horn end has a length of 20.7 mm. In another example, the first feed line **124** has a width of 1.8 mm. In an aspect, the first feed horn **122** is configured to act as a left feed (Feed-1). When the first feed horn **122** is excited and the second feed horn **126** is terminated with a matched load, the UHF antenna **100** operates in the LHCP mode and generates a left hand circular polarized wave (output). The dimensions of the first feed horn are exemplary only and may vary by ±2%.

As shown in FIG. **1**B, the second feed horn **126** includes a second feed line **128**, a second feed end, and a second horn end. The second feed line **128** is connected to the second edge **110** of the front side **104** of the circuit board **102**. The second feed end of the second feed horn **126** is connected to the second feed line. The second feed horn **126** is connected to the second edge **110** of the front side **104** of the circuit board **102** by the second feed line **128**. In an aspect, the second edge **110** is opposite the first edge **104**, such that an opening of the second feed horn **126** extends across the hexagonal meandered slot **118** between the sixth vertex V**6** and the second vertex V**2**. In an example, the second horn end has an opening of 7.75 mm. In some examples, the second horn end has a length of 20.7 mm. In another example, the second feed line **128** has a width of 1.8 mm. In an aspect, the horn end of the second feed horn **126** makes an angle of 50 degrees with the second feed line. In an aspect, the second feed horn **126** is configured to act as a right feed (Feed-2). When the second feed horn **126** is excited and the first feed horn **122** is terminated with a matched load, the UHF antenna **100** operates in the RHCP mode and generates a right hand circular polarized wave (output). In an example, the feeding transmission lines (the first feed line **124**, and the second feed line **128**) are modified and optimized to achieve a wideband impedance matching bandwidth. In an operative mode, the hexagonal meandered slot **118** of the UHF antenna **100** is configured to transmit or receive frequency (RF) waves between two points in space. The UHF antenna **100** is configured to either transmit a signal or receive a signal at a time. When the UHF antenna **100** acts as a transmitting antenna, a voltage is applied to the transmitting antenna, the hexagonal meandered slot **118** with the capacitor **120** is configured to generate radio signals which travel to a receiving antenna where the signal is converted back into electrical energy in the form of information. The UHF signals are applied to the first feed horn **122** and the second feed horn **126** formed in the circuit board **102**. The UHF signals are transmitted by the ground stations towards the CubeSat. Based upon the excitation of the feed horns, the UHF antenna **100** operates either in the RHCP mode or in the LHCP mode.

When the UHF antenna **100** is working as the receiving antenna, then a propagating electromagnetic field interacts with it. The propagating electromagnetic field generates a varying electric voltage signal at the center of the UHF antenna **100**. This voltage signal is an output when the antenna works as a receiver. The frequency of the output voltage signal is the same as the frequency of the receiving EM wave.

In an aspect, the UHF antenna **100** is configured to resonate at a signal frequency selected from the range of 360 MHz to 470 MHz with less than a 3 dB axial ratio when the capacitor **120** is switched ON. In some examples, the UHF antenna **100** is configured to resonate at a signal frequency selected from the range of 560 MHz to 650 MHz when the capacitor **120** is switched OFF.

The capacitor is connected to the metallic material on either side of the slot. One terminal is connected an outer area of the hexagonal slot and the other terminal is connected to an inner area of the hexagonal slot.

In an example, the UHF antenna **100** is configured to resonate at a signal frequency of 435 MHz when the capacitance value of the capacitor **120** is 12 pF.

In an operative aspect, the UHF antenna **100** is a slot based antenna, that is configured to resonate at 435 MHz frequency for UHF band CubeSat communications. The slot based antenna of the present disclosure is easily fabricated, easily integratable with CubeSat structure, has planar structure, has wideband characteristics and omnidirectional radiation patterns which are suitable for UHF band CubeSat communications.

FIG. **2** is an exemplary graph **200** illustrating an axial ratio versus frequency curve for the LHCP mode, according to certain embodiments. When the UHF antenna **100** operates in the LHCP mode, curve **202** illustrates the axial ratio curve of the UHF antenna **100** with respect to the different frequencies. In an example, the axial ratio, for any structure or shape with two or more axes, is the ratio of the length (or magnitude) of those axes to each other, i. e., the longer axis divided by the shorter axis. By measuring the received signals of the UHF antenna **100**, when the UHF antenna **100** works in the LHCP or RHCP modes at two different angles, the axial ratio of the UHF antenna **100** can be determined.

As shown in the FIG. **2**, the axial ratio decreases with a substantial rise in the frequency. The UHF antenna **100** has a stable axial ratio below 3 dB from 360 MHz to 470 MHz frequency band for the LHCP mode.

FIG. **3** is an exemplary graph **300** illustrating an axial ratio versus frequency curve for the RHCP mode, according to certain embodiments. When the UHF antenna **100** operates in the RHCP mode, curve **302** illustrates the axial ratio curve of the UHF antenna **100** with respect to the different frequencies. As shown, the axial ratio decreases with a substantial rise in the frequency. The UHF antenna **100** has a stable axial ratio below 3 dB from 360 MHz to 470 MHz frequency band for the RHCP mode.

FIG. **4** is an exemplary graph **400** illustrating an axial ratio versus theta (degrees) curve for the LHCP mode, according to certain embodiments. When the UHF antenna **100** operates in the LHCP mode, curve **402** illustrates the axial ratio of the UHF antenna **100** with respect to the various theta values. In an aspect, the UHF antenna **100** employs a spherical coordinate system. The spherical coordinate system is a coordinate system having a spherical symmetry. The spherical coordinates system utilizes three distinct spherical coordinates:

- R—a magnitude of a distance between an origin and a point (always positive),
- θ (theta values)—a polar angle in spherical coordinates—an angle between the z-axis and the vector from the origin to the point (ranges from 0 to 180 degrees), and
- ϕ (phi values)—an azimuth angle in spherical coordinates—an angle between the x-axis and the projection of the point onto the x-y plane (ranges from 0 to 360 degrees).

The spherical coordinates are useful in determining a response of the UHF antenna **100** in a particular direction. The spherical coordinates are employed in analyzing a radiation pattern that defines the variation of the power radiated by an antenna as a function of the direction away from the antenna.

FIG. **5** is an exemplary graph **500** illustrating an axial ratio versus a theta curve for the RHCP mode, according to certain embodiments. When the UHF antenna **100** operates in the RHCP mode, curve **502** illustrates the axial ratio curve of the UHF antenna **100** with respect to the various theta values. The stability of the axial ratio can also be verified from FIG. **4** and FIG. **5**.

FIG. **6**A to FIG. **6**D illustrate current distributions for the UHF antenna **100** at various phase angles. In order to analyze the antenna's radiation pattern, it is required to measure the magnitude of the power received or transmitted, and the phase angle of the antenna. These measurements should be specified in two orthogonal directions in order to capture all the components (polarizations) of the antenna. The electric fields (E-fields) are orthogonal to the direction of travel in the far field region. For example, the magnitude of the x-component of the E-field is A and the magnitude of the z-component of the E-field is B. The phase of the x-component is D, and the phase of the z-component is F (relative to the oscillation at frequency f). If D=F, the components are in phase and the polarization is linear. If D and F are separated by 90 degrees and the amplitudes are equal, the E-field is circularly polarized.

In an aspect, the current distributions are plotted at 430 MHz with the phase values of 0°, 30°, 90°, and 150°. FIG. **6**A is an exemplary illustration **602** of surface current distributions at a 0° phase angle. FIG. **6**B is an exemplary illustration **604** of surface current distributions at a 30° phase angle. FIG. **6**C is an exemplary illustration **606** of surface current distributions at a 90° phase angle. FIG. **6**D is an exemplary illustration **608** of surface current distributions at a 150° phase angle. It can be seen from FIG. **6**A-FIG. **6**D, when feeding is carried out via the two feeding ports (the first feed line **124**, and the second feed line **128**), the surface currents of the hexagonal meandered slot **118** (main radiating part) change with the phase angle.

The following examples are provided to illustrate further and to facilitate the understanding of the present disclosure.

During experimentation, a parametric analysis of the UHF antenna **100** was performed which helped in achieving a better performance in terms of size reduction and widening the bandwidth. In an aspect, the UHF antenna **100** was stimulated using a HFSS (High Frequency Structure Simulator). The UHF antenna **100** was fabricated using a laser milling machine (for example, the LPKF S**103**, manufactured by LPKF Laser & Electronics, located at Osteriede 7, 30827 Garbsen, Germany). The fabricated UHF antenna **100** was characterized for S-parameters using a vector network analyzer (for example, Agilent FieldFox RF Vector Network Analyzer manufactured by Agilent Technologies, Inc., located at 5301 Stevens Creek Blvd. Santa Clara, CA, United States of America).

FIG. **7** is an exemplary illustration **700** of measured S parameters (S_{11}) for different capacitance values, according to certain embodiments. In an aspect, the S-parameters describe the input-output relationship between ports (or terminals) in an electrical system. S_{11} represents how much power is reflected from the antenna, and hence is known as the reflection coefficient. If S_{11}=0 dB, then all the power is reflected from the antenna, and nothing is radiated. The capacitor **120** is loaded with the UHF antenna **100**. The values of the capacitance of the capacitor **120** are varied to see the effect on the antenna. The reflection coefficient S_{11} curves for the first feed horn **122** are shown in FIG. **7**. It can be seen that the S_{11} are dependent on the capacitance values. Signal **702** represents the values of s-parameter (S_{11}) when the capacitance value is 3 pF. Further, signal **704** represents values of S_{11} when the capacitance value is 5 pF. Signal **706** represents values of S_{11} when the capacitance value is 8 pF. Signal **708** represents values of S_{11} when the capacitance value is 12 pF. Signal **710** represents values of S_{11} when the capacitance value is 14 pF. Signal **712** represents values of S_{11} when the capacitance value is 16 pF. The UHF antenna **100** may be tuned at other lower frequency bands by changing the capacitance values, thereby making the UHF antenna **100** more flexible to tune at other frequency bands.

By employing the capacitor **120**, the UHF antenna **100** provides a better performance in terms of size reduction and widening the bandwidth.

FIG. **8**A-FIG. **8**D illustrate different input impedance (Z_{in}) curves for the UHF antenna **100** for different capacitance value. FIG. **8**A is an exemplary illustration **800** of an input impedance (Z_{in}) curve when the capacitance value is 3 pF. Signal **802** illustrates an imaginary part of the impedance when the capacitance value is 3 pF. Signal **804** illustrates a real part of the impedance when the capacitance value is 3 pF. FIG. **8**B is an exemplary illustration **810** of the input impedance (Z_{in}) curve when the capacitance value is 8 pF, according to certain embodiments. Signal **812** illustrates an imaginary part of the impedance when the capacitance value is 8 pF. Signal **814** illustrates a real part of the impedance when the capacitance value is 8 pF.

FIG. **8**C is an exemplary illustration **820** of the input impedance (Z_{in}) curve when the capacitance value is 12 pF. Signal **822** illustrates an imaginary part of the impedance when the capacitance value is 12 pF. Signal **824** illustrates a real part of the impedance when the capacitance value is 12 pF. FIG. **8**D is an exemplary illustration **830** of the input impedance (Z_{in}) curve when capacitance value is 16 pF. Signal **832** illustrates an imaginary part of the impedance when the capacitance value is 16 pF. Signal **834** illustrates a real part of the impedance when the capacitance value is 16 pF.

It can be seen from the FIG. **8**A-FIG. **8**D, with increasing the capacitance values from 3 pF to 16 pF, the resonance frequency is shifted to the lower frequency. The increased capacitance values will increase the effective electrical length of the UHF antenna **100**, lowering the resonance frequency. FIG. **8**A-FIG. **8**D show curves for 3 pF, 5 pF, 8 pF, 12 pF, 14 pF, and 16 pF. In an aspect, the 12 pF capacitance value is selected for the UHF antenna **100** to operate at 435 MHz. From FIG. **8**A-FIG. **8**D, it can also be observed that the 12 pF capacitance also improves the impedance matching bandwidth compared to without capacitor loading structure.

FIG. **9** is an exemplary graph **900** illustrating simulated and measured S parameters (S_{11}) of the UHF antenna **100** without capacitor loading, according to certain embodiments. Signal **902** represents the simulated values of S_{11}. Further, signal **904** represents the measured values of S_{11}. As shown in FIG. **9**, the measured results are in good agreement with the simulated results. The UHF antenna **100** is configured to cover 550 MHz to 650 MHz for both LHCP and RHCP modes.

FIG. **10** is an exemplary graph **1000** illustrating simulated and measured S parameters (S_{11}) of the UHF antenna **100** with capacitor loading, according to certain embodiments. Signal **1002** represents the simulated values of S_{11} with capacitor loading. Further, signal **1004** represents the measured values of S_{11} with capacitor loading. As shown in FIG. **10**, the measured results are in good agreement with the simulated results. The UHF antenna **100** is configured to cover 360 MHz to 470 MHz for both left and right-handed circular polarizations cases. In an example, the 10 dB impedancematching bandwidth is 110 MHz which is very wide at UHF band. In an aspect, due to the symmetry of the UHF antenna **100**, the S_{11} and S_{22} are similar.

The UHF antenna **100** was characterized for its far-field radiation patterns parameters. To understand the antenna's radiation pattern, in experimentation, the UHF antenna **100** was provided with input signals. FIG. **11** is an exemplary illustration **1100** of the 3-D gain pattern of the UHF antenna **100**. In an example, the UHF antenna **100** is also characterized for far-field radiation patterns in an anechoic chamber. The anechoic chamber is a shielded room that has radio-wave absorbing material applied to the walls, ceiling, and floor. The simulated 3D radiation patterns, given in FIG. **11**, show omnidirectional patterns at 435 MHz.

FIG. **12** is an exemplary illustration **1200** of 2-D simulated and measured radiation patterns of the dual feed slot-based circularly polarized wideband UHF antenna **100** at 435 MHZ, according to certain embodiments. In an aspect, the simulated and measured2D radiation patterns for the first feed horn **122** is tuned at 435 MHz are shown in FIG. **12**. Signal **1202** represents the simulated radiation pattern for the UHF antenna **100** in XZ plane. Signal **1204** represents the measured radiation pattern for the UHF antenna **100** in XZ plane. Signal **1206** represents the simulated radiation pattern for the UHF antenna **100** in XY plane. Signal **1208** represents the measured radiation pattern for the UHF antenna **100** in XY plane. As shown in FIG. **12**, a cross polarization (signals **1206** and **1208**) is lower than the cross polarization (signals **1202** and **1204**). As shown in FIG. **12**, the measured results are in good agreement with the simulated results.

FIG. **13** is an exemplary graph **1300** illustrating the gain versus frequency curve for the LHCP mode, according to certain embodiments. Signal **1302** represents a LHCP gain. Signal **1304** represents a RHCP gain. When the first feed horn **122** is excited and the second feed horn **126** is terminated with a matched load, the UHF antenna **100** operates as a left-hand polarized UHF antenna as shown in FIG. **13**. The LHCP gain (gain in LHCP mode) is much higher than the RHCP gain (gain in RHCP mode) which verifies that the UHF antenna **100** is circular polarized.

FIG. **14** is an exemplary graph **1400** illustrating a gain versus frequency curve for the RHCP mode, according to certain embodiments. Signal **1402** represents the LHCP gain. Signal **1404** represents the RHCP gain. When the second feed horn **126** is excited and the first feed horn **122** is terminated with the matched load, the UHF antenna **100** operates as a right-hand polarized antenna as shown in FIG. **14**. The RHCP gain is much higher than the LHCP gain which verifies that the UHF antenna **100** is also a circular polarized antenna. In an aspect, the UHF antenna **100** has gain in the range of 8 dBi to 10 dBi in the covered band.

The performance of the UHF antenna **100** of the present disclosure was compared with the aforementioned existing antenna designs and is summarized in Table 1. It is observed from the Table 1 that the UHF antenna **100** is efficient in comparison to conventional antenna designs.

It can be noticed from the Table 1 that the UHF antenna **100** is very compact in size and provides wideband characteristics at 435 MHz UHF band. Moreover, the UHF antenna **100** is a right and left hand circular polarized while the conventional antennas are only linear polarized.

TABLE 1

Summary of performance comparison						
References	Frequency	Size (mm^2)	S_{11} BW	Polarization Sense	CP BW	Antenna Type
X. Li, J. Wang et. al	28 GHz	98 × 6	≅10 GHz	LHCP & RHCP	10 GHz	Leaky wave
M. V. Kuznetcov et. al	24 GHz	26 × 33	≅3 GHz	Linear	NA	Leaky wave
R. Azadegan et. al	300 MHz	55 × 55	≅2 MHz	Linear	NA	Slot
Meeting IEEE, 2001	800 MHz	335 × 230	Not given	Linear	NA	Slot
The present UHF antenna 100	435 MHz	60 × 60	110 MHz	LHCP & RHCP	100 MHz	Slot

In an aspect, the present disclosure describes an antenna design procedure having following steps:

1. Selecting a resonating frequency, i.e. 435 MHz.
2. Selecting a hexagonal meandered slot **118** as a resonating structure.
3. Adding and optimizing the location of the feeding structure.
4. Selecting and adding an capacitor **120** to the hexagonal meandered slot **118**.
5. Performing a parametric analysis of the antenna structure to achieve wideband axial ratio bandwidth.

The advantages of the present UHF antenna **100** over existing CubeSat antennas include:

1. Compatible with nano avionics UHF antenna systems,
2. Planar structure,
3. No deployable mechanism is required,
4. Circularly polarized antenna design,
5. Switching between LHCP and RHCP.

In an operative aspect, the UHF antenna **100** may be installed in the CubeSat in any of the following different manners:

1. Fit the UHF antenna **100** on a top panel or on a bottom panel of a CubeSat structure;
2. Fit the UHF antenna **100** on a long side of a 3 U CubeSat structure;
3. Add a substrate between the UHF antenna **100** and a ground plane of the CubeSat structure.

The integration of the UHF antenna **100** with the solar panel of the CubeSat structure is described below.

Solar panels represent the main source of power for the CubeSat, and thus it is important to reserve available space for their installation on the satellite's body. On the other hand, the antenna is another subsystem of the CubeSat that requires space for installation and is also of great importance in terms of communication. Consequently, integrating antennas with solar panels has proven to be a very efficient approach to using a CubeSat's available space. An integrated solar panel-antenna system keeps the received solar energy loss low. In an aspect, the slot antennas are created, and solar cells are deposited directly on top of the antennas.

The first embodiment is illustrated with respect to FIG. **1**A-FIG. **1**B. The first embodiment describes a dual feed slot-based circularly polarized wideband ultra high frequency (UHF) antenna **100** for a cubic shaped satellite (Cube-Sat). The UHF antenna **100** includes a circuit board **102** having a front side **104** and a back side **106** separated by a dielectric material; a metallic layer **116** configured to cover the back side of the circuit board **102**, wherein the metallic layer **116** is connected to a ground; a hexagonal meandered slot **118** symmetrically formed in the metallic layer **116**, wherein the hexagonal meandered slot **118** includes six legs of equal length, wherein the six legs are configured such that the hexagonal meandered slot **118** includes a first vertex V**1** located between a first leg and a second leg, a second vertex located between the second leg and a third leg, a third vertex located between the third leg and a fourth leg, a fourth vertex located between the fourth leg and a fifth leg, a fifth vertex located between the fifth leg and a sixth leg, and a sixth vertex located between the sixth leg and the first leg; a capacitor **120** switchably connected to the metallic layer across the first vertex; a first feed horn **122** connected by a first feed line to a first edge **106** of the front side **104** of the circuit board **102**, wherein an open end of the first feed horn **122** is directed into an inner area of the hexagonal meandered slot **118** between the third vertex and the fourth vertex; and a second feed horn **126** connected by a second feed line to a second edge **108** of the front side of the circuit board **102**, wherein the second edge is opposite the first edge, such that an opening of the second feed horn **126** extends across the hexagonal meandered slot **118** between the sixth vertex and the second vertex.

In an aspect, the capacitor **120** has a capacitance value selected from a group consisting of 3 pF, 5 pF, 8 pF, 12 pF, 14 pF, and 16 pF.

In an aspect, a capacitance value of the capacitor **120** is selected to be 12 pF.

In an aspect, the UHF antenna **100** has dimensions of less than 60 mm by 60 mm.

In an aspect, each feed horn has a length of 20.7 mm and a horn opening of 7.75 mm.

In an aspect, the hexagonal meandered slot **118** has a width in the range of 3 mm to 4 mm.

In an aspect, the UHF antenna **100** is configured to resonate at signal frequencies in the range of 360 MHz to 470 MHz with less than a 3 dB axial ratio when the capacitor **120** is switched ON.

In an aspect, the UHF antenna **100** is configured to resonate at a signal frequency of 435 MHz when a capacitance value of the capacitor **120** is selected to be 12 pF.

In an aspect, the UHF antenna **100** is configured to resonate at signal frequencies in the range of 560 MHz to 650 MHz when the capacitor **120** when the capacitor **120** is switched OFF.

In an aspect, the horn end of the first feed horn makes an angle of 50 degrees with the first feed line.

In an aspect, the horn end of the second feed horn makes an angle of 50 degrees with the second feed line.

The second embodiment is illustrated with respect to FIG. 1A-FIG. 1B. The second embodiment describes a method for making the dual feed slot-based circularly polarized wideband UHF antenna **100** of dimensions of less than 60 mm by 60 mm for cubic shaped satellites (Cube-Sat). The method includes forming a metallic layer **116** on the back side of a circuit board **102** having a front side **104** and a back side **106** separated by a dielectric material, wherein the metallic layer is connected to a ground. The method includes symmetrically forming a hexagonal meandered slot **118** in the metallic layer, the hexagonal meandered slot **118** including six legs of equal length, and configuring the six legs such that the hexagonal meandered slot **118** includes a first vertex located between a first leg and a second leg, a second vertex located between the second leg and a third leg, a third vertex located between the third leg and a fourth leg, a fourth vertex located between the fourth leg and a fifth leg, a fifth vertex located between the fifth leg and a sixth leg, and a sixth vertex located between the sixth leg and the first leg. The method includes switchably connecting a capacitor **120** to the metallic layer across the first vertex. The method includes connecting a first feed line **124** of a first feed horn **122** to a first edge of the front side **104** of the circuit board **102** and directing an open end of the first feed horn **122** into an inner area of the hexagonal meandered slot **118** between the third vertex and the fourth vertex. The method includes connecting a second feed line **128** of a second feed horn **126** to a second edge of the front side **104** of the circuit board **102**, wherein the second edge is opposite the first edge, such that an opening of the second feed horn **126** extends across the hexagonal meandered slot **118** between the sixth vertex and the second vertex.

In an aspect, the method further includes selecting a capacitance value of the capacitor **120** from a group consisting of 3 pF, 5 pF, 8 pF, 12 pF, 14 pF, and 16 pF.

In an aspect, the method further includes selecting a capacitance value of the capacitor **120** to be 12 pF.

In an aspect, the method further includes forming each feed horn to have a length of 20.7 mm and a horn opening of 7.75 mm.

In an aspect, the method further includes forming, by laser milling, a width of the hexagonal meandered slot **118** to be in the range of 3 mm to 4 mm.

In an aspect, the method further includes switching the capacitor **120** ON; applying signal frequencies to the first feed line and the second feed line; and configuring the dual feed slot-based circularly polarized wideband UHF antenna to resonate in the range of 360 MHz to 470 MHz with less than a 3 dB axial ratio.

In an aspect, the method further includes selecting a capacitance value of the capacitor **120** to be 12 pF; switching the capacitor **120** ON; and applying signal frequencies to the first feed line and the second feed line which resonate the dual feed slot-based circularly polarized wideband UHF antenna **100** at a 435 MHz.

In an aspect, the method further includes switching the capacitor **120** OFF, applying signal frequencies to the first feed line and the second feed line, and resonating the dual feed slot-based circularly polarized wideband UHF antenna **100** in the range of 360 MHz to 470 MHz with less than a 3 dB axial ratio.

The third embodiment is illustrated with respect to FIG. 1A-FIG. 1B. The third embodiment describes a method for transmitting ultra high frequency (UHF) signals with a dual feed slot-based circularly polarized wideband UHF antenna **100** of dimensions of less than 60 mm by 60 mm for cubic shaped satellites (Cube-Sat). The method includes forming a first feed horn **122** and a second feed horn **126** in a front side **104** dielectric circuit board **102**, wherein a back side of the dielectric circuit board **102** is covered with a grounded metallic sheet configured with a meandered hexagonal slot, wherein the hexagonal meandered slot **118** is symmetrically formed in the metallic layer, wherein the hexagonal meandered slot **118** includes six legs of equal length, wherein the six legs are configured such that the hexagonal meandered slot **118** includes a first vertex located between a first leg and a second leg, a second vertex located between the second leg and a third leg, a third vertex located between the third leg and a fourth leg, a fourth vertex located between the fourth leg and a fifth leg, a fifth vertex located between the fifth leg and a sixth leg, and a sixth vertex located between the sixth leg and the first leg. The method further includes switchably connecting a capacitor **120** to the metallic layer across the first vertex. The method further includes transmitting ultra high frequency (UHF) signals by applying signal frequencies in the range of 360 MHz to 470 MHz to the first feed horn **122** and the second feed horn **126**.

Obviously, numerous modifications and variations of the present disclosure are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

The invention claimed is:

1. A dual feed slot-based circularly polarized wideband ultra high frequency (UHF) antenna for a cubic shaped satellite, comprising:

a circuit board having a front side and a back side separated by a dielectric material;

a metallic layer configured to cover the back side of the circuit board, wherein the metallic layer is connected to a ground, wherein the metallic layer is a metallic foil made from copper, aluminum or silver;

a hexagonal meandered slot symmetrically etched in the metallic layer, wherein the hexagonal meandered slot includes six legs of equal length, wherein the six legs are configured such that the hexagonal meandered slot includes a first vertex located between a first leg and a second leg, a second vertex located between the second leg and a third leg, a third vertex located between the third leg and a fourth leg, a fourth vertex located between the fourth leg and a fifth leg, a fifth vertex located between the fifth leg and a sixth leg, and a sixth vertex located between the sixth leg and the first leg;

a capacitor switchably connected to the metallic layer across the first vertex;

a first feed horn connected by a first feed line to a first edge of the front side of the circuit board, wherein an open end of the first feed horn is directed into an inner area of the hexagonal meandered slot between the third vertex and the fourth vertex; and

a second feed horn connected by a second feed line to a second edge of the front side of the circuit board, wherein the second edge is opposite the first edge, such that an opening of the second feed horn extends across the hexagonal meandered slot between the sixth vertex and the second vertex.

2. The dual feed slot-based circularly polarized wideband UHF antenna of claim **1**, wherein the capacitor has a capacitance value selected from a group consisting of 3 pF, 5 pF, 8 pF, 12 pF, 14 pF and 16 pF.

3. The dual feed slot-based circularly polarized wideband UHF antenna of claim 1, wherein the antenna has dimensions of less than about 60 mm by about 60 mm.

4. The dual feed slot-based circularly polarized wideband UHF antenna of claim 1, wherein each feed horn has a length of about 20.7 mm and a horn opening of about 7.75 mm.

5. The dual feed slot-based circularly polarized wideband UHF antenna of claim 1, wherein the hexagonal meandered slot has a width in the range of about 3 mm to about 4 mm.

6. The dual feed slot-based circularly polarized wideband UHF antenna of claim 1, wherein the antenna is configured to resonate at signal frequencies in the range of 360 MHz to 470 MHz with less than a 3 dB axial ratio when the capacitor is switched ON.

7. The dual feed slot-based circularly polarized wideband UHF antenna of claim 1, wherein the antenna is configured to resonate at a signal frequency of 435 MHz when a capacitance value of the capacitor is selected to be about 12 pF.

8. The dual feed slot-based circularly polarized wideband UHF antenna of claim 1, wherein the antenna is configured to resonate at signal frequencies in the range of 560 MHz to 650 MHz when the capacitor is switched OFF.

9. The dual feed slot-based circularly polarized wideband UHF antenna of claim 1,

wherein a horn end of the first feed horn makes an angle of 50 degrees with the first feed line.

10. The dual feed slot-based circularly polarized wideband UHF antenna of claim 1,

wherein a horn end of the second feed horn makes an angle of 50 degrees with the second feed line.

11. A method for making a dual feed slot-based circularly polarized wideband UHF antenna of dimensions of less than 60 mm by 60 mm for cubic shaped satellites, comprising:

etching a metallic layer on the back side of a circuit board having a front side and a back side separated by a dielectric material, wherein the metallic layer is connected to a ground and is made from copper, aluminum or silver;

symmetrically forming a hexagonal meandered slot in the metallic layer, the hexagonal meandered slot including six legs of equal length, and configuring the six legs such that the hexagonal meandered slot includes a first vertex located between a first leg and a second leg, a second vertex located between the second leg and a third leg, a third vertex located between the third leg and a fourth leg, a fourth vertex located between the fourth leg and a fifth leg, a fifth vertex located between the fifth leg and a sixth leg, and a sixth vertex located between the sixth leg and the first leg;

switchably connecting a capacitor to the metallic layer across the first vertex;

connecting a first feed line of a first feed horn to a first edge of the front side of the circuit board and directing an open end of the first feed horn into an inner area of the hexagonal meandered slot between the third vertex and the fourth vertex; and

connecting a second feed line of a second feed horn to a second edge of the front side of the circuit board, wherein the second edge is opposite the first edge, such that an opening of the second feed horn extends across the hexagonal meandered slot between the sixth vertex and the second vertex.

12. The method for making a dual feed slot-based circularly polarized wideband UHF antenna of claim 11, further comprising selecting a capacitance value of the capacitor from a group consisting of 3 pF, 5 pF, 8 pF, 12 pF, 14 pF and 16 pF.

13. The method for making a dual feed slot-based circularly polarized wideband UHF antenna of claim 11, further comprising forming each feed horn to have a length of about 20.7 mm and a horn opening of about 7.75 mm.

14. The method for making a dual feed slot-based circularly polarized wideband UHF antenna of claim 11, wherein the hexagonal meandered slot has a width in the range of about 3 mm to about 4 mm.

15. The method for making a dual feed slot-based circularly polarized wideband UHF antenna of claim 11, further comprising:

switching the capacitor ON;

applying signal frequencies to the first feed line and the second feed line; and

configuring the dual feed slot-based circularly polarized wideband UHF antenna to resonate in the range of 360 MHz to 470 MHz with less than a 3 dB axial ratio.

16. The method for making a dual feed slot-based circularly polarized wideband UHF antenna of claim 11, further comprising:

selecting a capacitance value of the capacitor to be about 12 pF;

switching the capacitor ON; and

applying signal frequencies to the first feed line and the second feed line which resonate the dual feed slot-based circularly polarized wideband UHF antenna at a 435 MHz.

17. The method for making a dual feed slot-based circularly polarized wideband UHF antenna of claim 11, further comprising:

switching the capacitor OFF;

applying signal frequencies to the first feed line and the second feed line; and

resonating the dual feed slot-based circularly polarized wideband UHF antenna in the range of 360 MHz to 470 MHz with less than a 3 dB axial ratio.

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