Broad-band Circularly Polarized Patch Antenna for Multi-Mode Navigation Application

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Abstract

A broad-band circularly polarized, patch antenna is developed for GPS/ GLONASS/ BEIDOU/ GALILEO systems. The antenna includes four L-probes, a circular patch with four edges trimming and a feed network. The four L-probes are excited by a feed network in equal magnitude and successive 90 phase difference. The edge cutting method is used to improve the axial ratio, impedance bandwidth and reduced the size of the antenna. The measured gains at 1227 and 1575 MHz are about 8 and 10 dB respectively. The 10 dB return loss bandwidth of the antenna is 42.9% from 1.1 to 1.7 GHz; the 3 dB axial ratio bandwidth of the antenna is 30% from 1.19 to 1.61 GHz. Low multipath effects have been observed of the antenna.

Keywords: *circularly polarized antenna, broad-band antenna, multi-mode navigation, patch antenna.*

1. Introduction

The Global Navigation Satellite System (GNSS) mainly includes GPS, GLONASS, BeiDou are widely used for navigation, location, and precise position measurement [1-3]. The center frequencies of GPS, GLONASS are 1575.42 /1227.60MHz and 1602/1246MHz. Frequency range of BeiDou system are: 1559.052MHz ~ 1591.788MHz, 1166.22MHz ~ 1217.37MHz, and 1250.618MHz ~ 1286.423MHz. Antenna performance plays an important role in GNSS application. With the rapid growth of GNSS application, broad-band circularly polarized (CP) antennas are needed [4, 5].

Conventional microstrip antennas have many advantages, such as low cost and easy fabrication; they also have the disadvantages of narrow impedance and axial ratio (AR) bandwidth [6, 7]. To obtain a wider axial ratio bandwidth, some methods have been presented [8, 9], for example, the proximity-coupled L-probe feeding method [10, 11].

In this letter, a broad-band circularly polarized patch antenna for GNSS, by using L-probes coupling feed technology and edge cutting method is proposed. The dimensions of the patch, L-probes and feed network are optimized to achieve good axial ratio and impedance bandwidth using ANSOFT HFSS 10. Multipath occurs when a signal reaches the receiving antenna via more than one path. In high-precision GNSS applications, the antenna performance has important influence on the multipath of GNSS receiver; therefore, multipath of the antenna is discussed in this letter.

2. Antenna Structure and Design

2.1 Antenna geometry

The geometry of the proposed broad-band antenna is shown in Fig.1. The antenna includes three parts: four L-probes that are connected to feed network, a circular patch with four edges trimming and a feed network in equal magnitude and successive 90 phase difference.

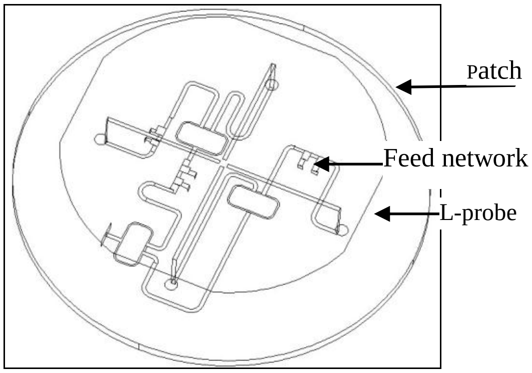


Fig.1 Overall shape of the patch antenna

In the design of this antenna, the energy of electromagnetic wave could be coupled to circular patch through the L-probes. The circular patch with four equal edges trimming can improve axial ratio and impedance bandwidth of antenna. The medium of this antenna is air. The radius of antenna patch is defined as “a”, the value from circle center to edge trimming is defined as “a - b”, which are shown in Fig.2.

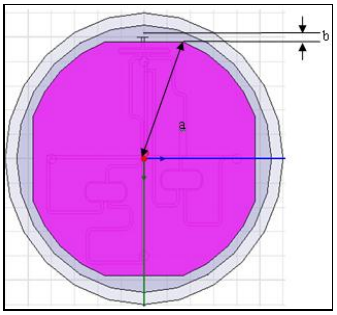


Fig.2 Main view of the antenna

2.2 Design of feed network.

In order to receive right-hand circularly polarized (RHCP) signal, feed network is the key design. A feed network in equal magnitude and successive 90 phase difference is designed to realize the circular polarization; the geometry of the feed network is shown in Fig.3.

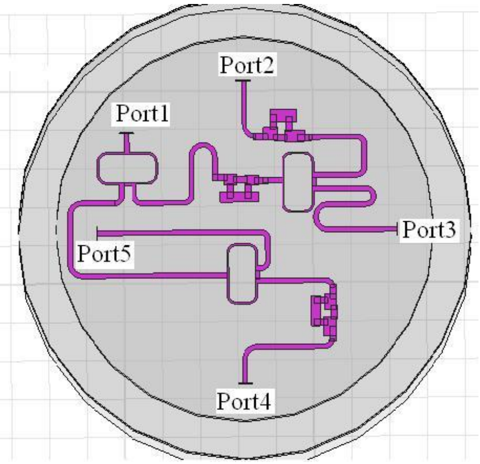


Fig.3 Feed network on the bottom

The power divider and phase shifter is printed on the top of Rogers RT substrate that has a dielectric constant of 10.2 and a thickness of 2.8 mm. Port1 is input port, Port2, 3, 4, 5 are output ports. The magnitudes of Port2, 3, 4, 5 are equal, the phase difference of Port2, 3, 4, 5 are 0 °, 90 °, 180 °and 270 °using Port1 as reference. In order to achieve the phase shifter among output ports, we added Composite Right/Left-handed Transmission Lines (CRLH-TLs) [12] in one of the outputs, it's a simple structure that is shown in Fig.4, the other output ports are connected with microstrip line; phase shifter of 90 °and 180 ° can be obtained by adjusting the value of the inductance, capacitance and the length of the microstrip line.

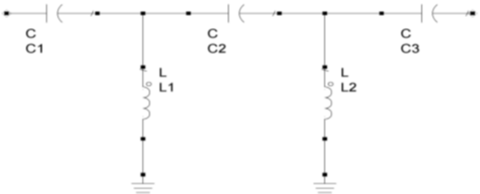


Fig.4 The structure of CRLH-TLs

2.3 Design of patch antenna

Resonance frequency of antenna is very important. We discuss the s11 variation with different heights of patch and different radiuses of patch, Fig.5 and Fig.6 give the results. Axial ratio variation with different radiuses of patch is shown in Fig.7

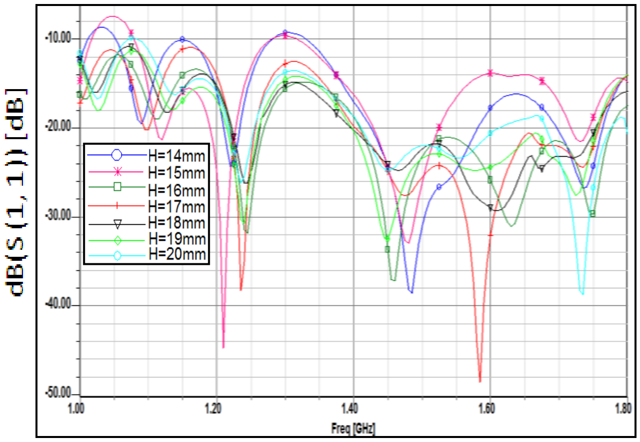


Fig.5 S11 variation with different heights of patch

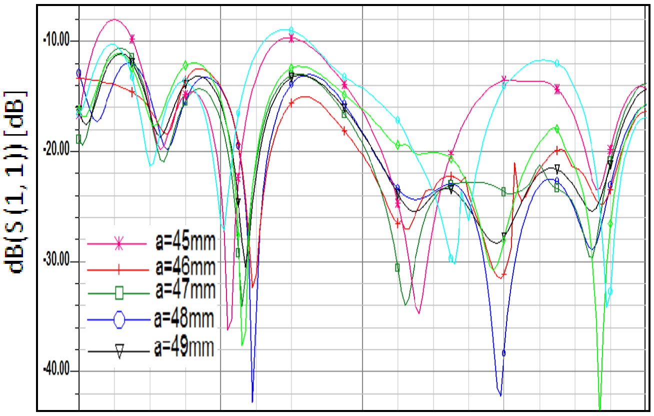


Fig.6 S11 variation with different radiuses of patch

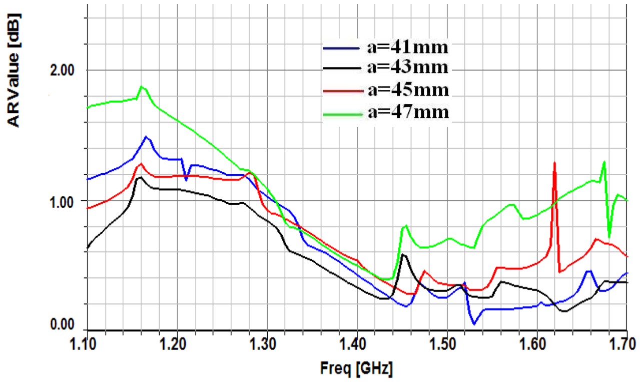


Fig.7 Axial ratio variation with different radiuses of patch

By simulation and optimization, the final values of this antenna are: the circular patch's radius is 48mm; the value of "b" is 3mm, the height and length of L-probe are 12.35mm and 39mm respectively, the height of patch is 17mm. The simulated radiation patterns at 1227/1575 MHz are listed in Fig.8

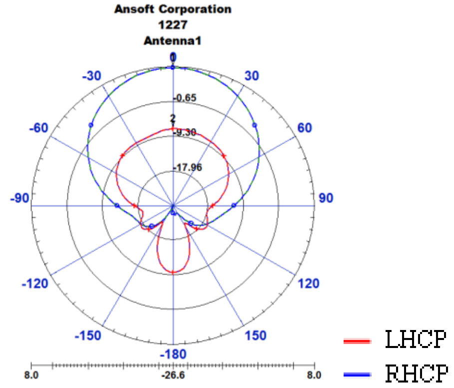


Fig.8 (a) Simulated radiation patterns at 1227 MHz

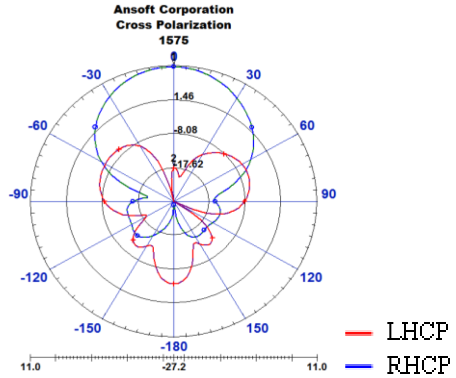


Fig.8 (b) Simulated radiation patterns at 1575 MHz.

3. Measurement Results

According to the simulation, the proposed antenna is fabricated and measured. Fig.9 is the photograph of this antenna with four L-probes and feed network. Fig.10 is the photo of the whole antenna. The return loss and VSWR of this antenna is shown in Fig.11. Fig.12 is the measured normalized radiation pattern at 1227MHz and 1575MHz.

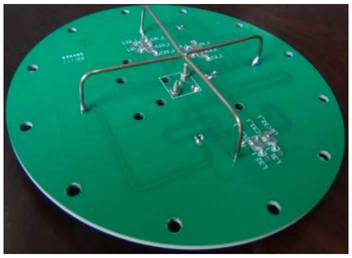


Fig.9 Photograph of the antenna with feed network and four L-probes

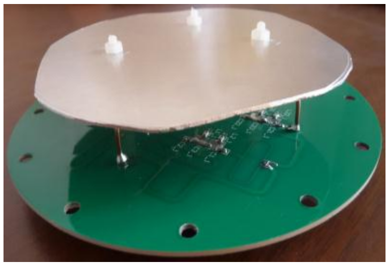


Fig.10 Photograph of the fabricated antenna

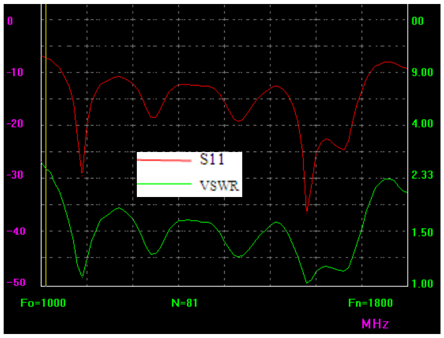


Fig.11 Measured s11and VSWR of this antenna

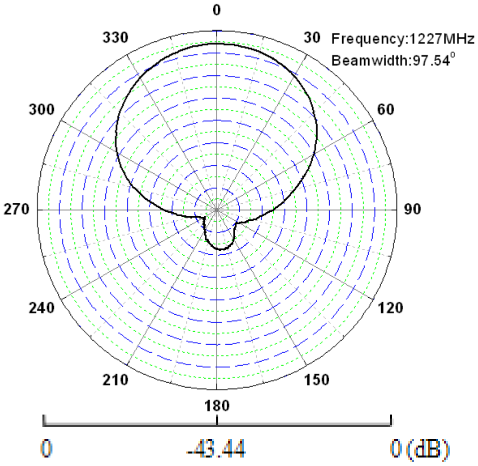


Fig.12 (a) Measured radiation pattern at 1227MHz

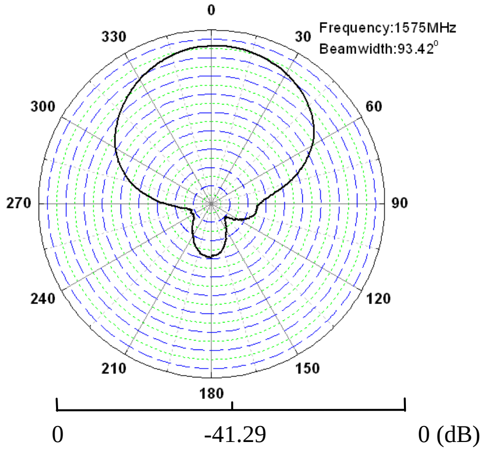


Fig.12 (b) Measured radiation pattern at 1575MHz

The gains of the antenna in other frequency points are listed in table 1. The axial ratio of the antenna are measured and listed in table 2.

TABLE .1 GAIN OF THE ANTENNA

Freq (GHz)	1.1	1.227	1.3	1.4	1.5	1.575	1.7
Gain (dB)	6.28	7.95	8.46	9.71	9.92	10.04	8.28

TABLE.2 Axial ratio of the antenna

Freq (GHz)	1.1	1.19	1.227	1.4	1.5	1.575	1.61	1.7
AR (dB)	4.0	2.95	2.68	1.24	1.98	2.45	3.01	4.25

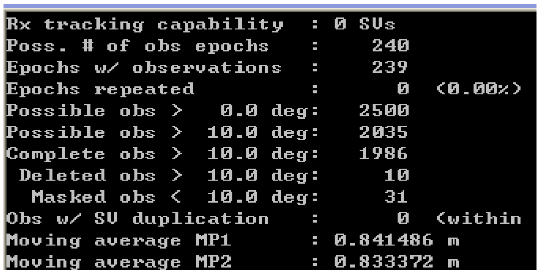
From table.1 and table.2, we can see that the 10 dB return loss bandwidth of the antenna is 42.9% from 1.1 to 1.7 GHz; the 3 dB axial ratio bandwidth of the antenna is 30% from 1.19 to 1.61 GHz, which can meet the requirements of multi-mode navigation application. As can be seen, the simulation and measurement results are in good agreement. In Table 3, comparisons of the proposed antenna to those reported in [1, 2, 3, and 13] on antenna impedance bandwidth, axial-ratio bandwidths and gain are given.

TABLE.3 Comparisons of the antenna with other navigation

Published literature	***Impedance bandwidth (GHz)***	***axial-ratio bandwidth(GHz)***	***Gain (dB)***
[1]J.-H. Oh, et al.	1.50-1.576	1.54-1.59	at GPS L1: 2.3
[2]K. Geary, et al.	1.552-1.568	not mention	at GPS L1: 5.2
[3]X.F. Peng,et al.	1.221-1233; 1.499-1.577	1.217-1.235; 1.567-1.597	at GPS L1:5.5 at GPS L2:2.9
[13]Sergey N et al.	1.15-1.60	1.15-1.60	6-8dB
Proposed	1.1-1.7GHz	1.19-1.61	at GPS L1: 10.04

A major source of error in high-accuracy GPS is the interference of multiple reflections with the direct GPS signal, known as multipath [14]. A variety of techniques (e.g., the narrow correlator spacing, multipath estimating delay lock loop, and strobe techniques) have been developed to mitigate multipath errors. For long delay multipath, the receiver itself can recognize the delayed (or reflected) GPS signal and discard it. However, shorter delay multipath from signals reflected by the ground or other nearby reflectors is harder to filter because it interferes with the direct GPS signal, causing effects almost indistinguishable from routine fluctuations in atmospheric delay. Alternative methodologies for the mitigation of multipath at reception include the design of high precision antenna [15], [16].

The fabricated antenna has been applied in GPS receiver and the values of multipath have been tested, Fig.13 gives the MP1/MP2 calculated by TEQC (Translation, Editing and Quality Checking), which is a powerful GNSS data pre-processing software; the MP1/MP2 of the antenna is 0.84/0.83 in urban district.



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Rx tracking capability   : 0 SVs
Poss. # of obs epochs    :    240
Epochs w/ observations   :    239
Epochs repeated          :      0  (0.00%)
Possible obs >   0.0 deg:   2500
Possible obs >  10.0 deg:   2035
Complete obs >  10.0 deg:   1986
 Deleted obs >  10.0 deg:     10
  Masked obs <  10.0 deg:     31
Obs w/ SV duplication    :      0  (within
Moving average MP1       : 0.841486 m
Moving average MP2       : 0.833372 m
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Fig.13 MP1/MP2 of this antenna in urban

4. Conclusions

This letter presents an antenna design with high performances for the applications of GNSS, by using L-probes coupling feed technology and edge cutting method. The 10 dB return loss bandwidth of the antenna is 42.9% from 1.1 to 1.7 GHz; the 3 dB axial ratio bandwidth of the antenna is 30% from 1.19 to 1.61 GHz; low multipath effects have been observed. The experimental results show that this design is ideally practical for multi-mode navigation application.

Acknowledgments

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