Stacked Tri-Band Circularly Polarized Microstrip Patch Antenna for CNSS Applications

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Abstract—**This paper proposes a novel stacked tri-band circularly polarized antenna which has three independent ports. To obtain tri-band operation, a stacked three layers of microstrip antenna working at different frequency is presented. Each of them is fed by dual feed probes. The simulated results show that the antenna can cover Compass Navigation Satellite System CNSS B3 1.268 GHz, L band 1.615 GHz and S band 2.49 GHz. The proposed antenna has achieved a bandwidth of 3.1%, 6.8% and 2.3% at each band, respectively. It exhibits small axial ratio under 3dB in three bands for the CNSS applications. Details of the proposed antenna design and results for the obtained tri-band circularly polarized performances are presented and discussed.**

Keywords- tri-band; circularly polarized; CNSS; microstrip patch antenna; stacked.

I. INTRODUCTION

With the rapid development of navigation system , many new applications of the wireless communications and sensor systems devices have been growing dramatically. In China, Compass Navigation Satellite System (CNSS), or "BeiDou" in its Chinese name, began to provide navigation and positioning services in the latest years. According to Chinese officials, the CNSS can cover three frequency band , 1258-1278MHz, 1610-1626MHz and 2483-2500MHz. Thus, an antenna which can operate at all of the CNSS frequency is required.

The microstrip antenna has the advantages of low profile, lightweight and low fabrication cost and ease of fabrication [1]. So it is obvious that microstrip antenna has been widely used in communication system. In practice, a circularly polarized (CP) microstrip antenna is needed for the antenna to stably receive signal especially for multi-band CP antenna. In order to achieve multi-band CP antenna, many scholars have done a lot of research. Various types of designs related to multi-band CP antennas have been reported [3]-[10]. CP antennas have been achieved using both single and dual feed techniques. A single-fed CP antenna has the disadvantages of both narrow AR bandwidth and impedance bandwidth [2], so it is necessary to adopt multi-feed techniques [3]. And recently stacked microstrip antennas have been developed to obtain dual-band or tri-band radiation. Some dual-band CP stacked microstrip patch antennas were achieved, like using an aperture couple feed [4] [5], by two different types of stacked patched [6], and by carving an asymmetric S-shaped slot [7]. In [8], a stacked patch technique with a high permittivity dielectric material is used to achieve a compact triple band antenna design. In [9], a three-layer stacked single feed CP microstrip antenna was designed to achieve tri-band CP radiation. Also, a tri-band CP stacked design was introduced in [10] for GPS and CNSS applications. The CP radiations were achieved by inserting the two pairs of narrow slots parallel to the edges of the top square patch and cutting a slit in the bottom square patch.

In this paper, a three ports tri-band CP stacked microstrip antenna for CNSS applications is presented. The tri-band characteristic is achieved by three stacked square patch, and each band of CP radiation is achieved by two probes feeding. This can be realized by use a 90-deg hybrid coupler to generate two orthogonal modes of the patch for the circularly polarized. So three independent ports working with different sense of CP performance is realized by adjusting the feeding location. The proposed antenna can find useful application in "BeiDou" 2nd generation satellite system.

II. ANTENNA DESIGN

The desired CNSS antenna must have the following specifications:

1. Multiband operation (B3: 1.268GHz ; L: 1.615GHz ; S: 2.49GHz);
2. RHCP radiation for B3 and S band, LHCP radiation for L band, Gain greater than 2.5 dBi;
3. Axial ratio (AR) is less than 3 dB at the frequency (B3/L/S);
4. Feed matched to 50 Ω ;

The geometry of the proposed stacked tri-band CP microstrip antenna for CNSS applications is shown in Fig.1

The antenna is made up of three square patches stacked on one another. The three square patches are etched on separate substrates which have the thickness of h_1,h_2,h_3, .In order to reduce the geometry of antenna patch, we choose relative permittivity $\varepsilon_1 = 3.5$, $\varepsilon_2 = 6$, $\varepsilon_3 = 10$. And a substrate made of Rogers 5880 material ($\varepsilon_4 = 2.2$) has been chosen to accommodate the feeding network. The top, middle and bottom square patches have different side length of L_i respectively.

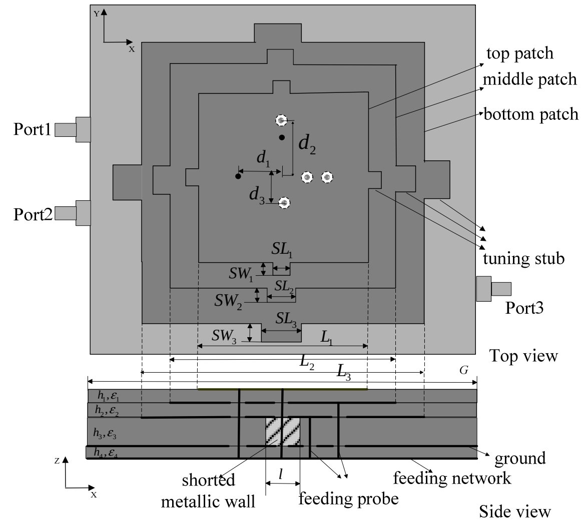


Figure 1. Geometry of the proposed stacked tri-band CP antenna.

In general, the side length is usually about half-wavelength, that is

$$L_i = \frac{c}{2\sqrt{\varepsilon_e f_i}}$$

Where i=1,2,3, c is the speed of the light, ε_e is the approximated effective dielectric constant, and f_i is the free space resonant frequency of the antenna. Each patch is excited by two probes feeding, which are connected to the patch through two via holes in the other patch. To optimize the antenna performance, four tuning stubs were added to the patch. Experiments shows the shortening of either stub will decrease the effective electromagnetic length of the dominant mode cavity formed by the patch, thereby increasing its resonant frequency. In order to improve the gain at 1.268GHz, a 3×3mm square hole was cut in the bottom substrate which add a shorted metallic wall around it. Owing to the adding of the shorted metallic wall, the gain at low frequency can increase about 1dB, thus it can satisfy the design

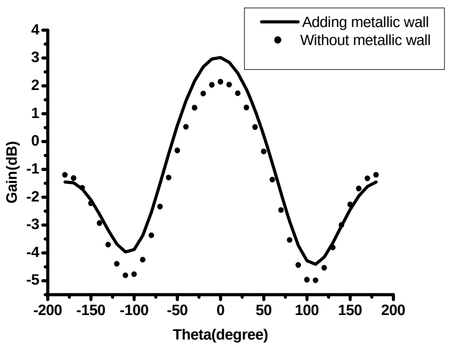


Figure 2. The comparison of gain with different structure at 1.268 GHz

The antenna feeding network has to provide 90-deg phase difference between two probes at each band. To achieve this, a compact wideband 90-deg hybrid coupler has been used to supply two probes with balanced signals of equal magnitude and 90-deg phase difference. For the feed position at port 1 and port 3, right-hand CP (RHCP) operation is obtained. Through adjust the phase difference between the two probes, left-hand CP (LHCP) operation is obtained by feeding the patch at port 2. Hence, a tri-frequency circularly-polarized antenna is achieved by choosing the different feed port on the antenna. The final dimensions of the parameters are listed in Table I. The proposed antenna is fabricated and measured. The overall ground plane size is 50×50mm.

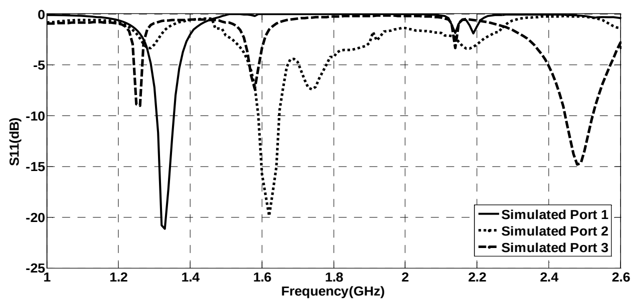
TABLE I Dimensions of The Proposed Antenna

parameter	value	parameter	value	parameter	value
h_1	3mm	L_3	34mm	SW_3	2mm
h_2	2mm	d_1	5.5mm	SL_1	1mm
h_3	2mm	d_2	10mm	SL_2	4mm
h_4	1mm	d_3	7.2mm	SL_3	5mm
L_1	31mm	SW_1	2mm	l	3mm
L_2	33.5mm	SW_2	5mm		

III. Measurement Results and Discussions

The characteristics of the proposed tri-band CP antenna are simulated by software Ansoft HFSS 10. The reflection coefficients are measured using a vector network analyzer, and radiation characteristics are measured in the anechoic chamber. The reflection coefficient, axial radio (AR), and radiation patterns measured at the three feeding ports of the antenna are presented in Fig.3,4,and 5, along with the simulated results.

Fig.3 shows the return loss of different port which indicates that the three bands are: 1.268 GHz, 1.615 GHz and 2.49 GHz. A good agreement is obtained between simulation and measurement. The measured impedance bandwidths (S_{11} < -10) are 3.15% with respect to 1.268 GHz (from 1.25 GHz to 1.29 GHz) for the low band, 6.3% with respect to 1.615 GHz (from 1.53 GHz to 1.63 GHz) for the middle band and 2.8% with respect to 2.49 GHz from 2.47 GHz to 2.54 GHz for the upper band.



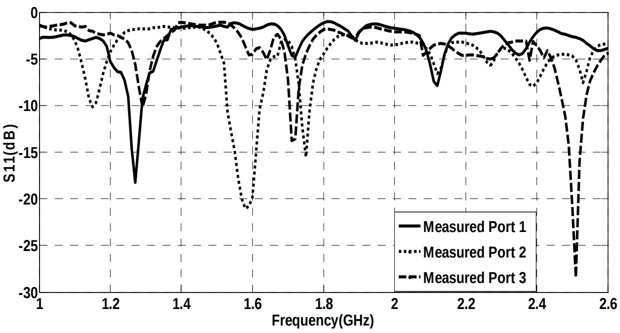


Figure 3. Simulated and measured S_{11} of the proposed stacked tri-band CP antenna

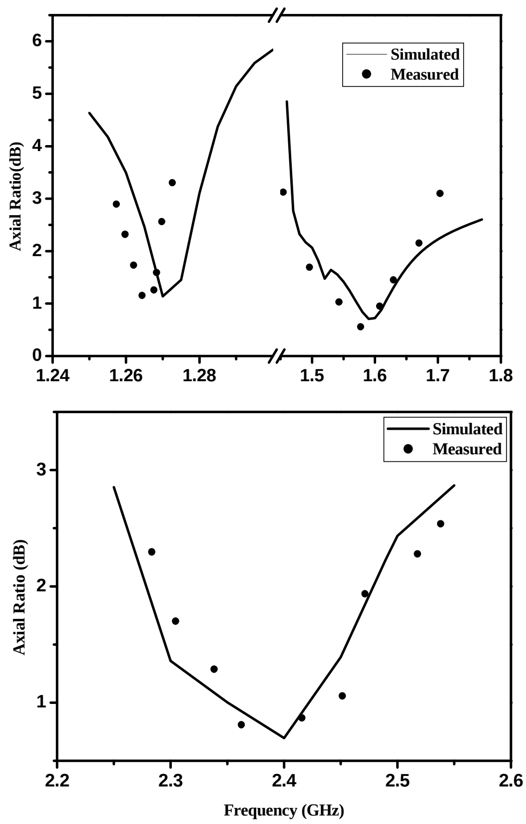


Figure 4. Simulated and measured axis ratio of the proposed stacked tri-band CP antenna.

The simulated axial ratio against frequency in the broadside direction is shown in Fig. 4. The measured 3 dB axial ratio bandwidth for the first band is 15 MHz, from 1.258 to 1.273 GHz for RHCP, corresponding to about 1.2% with respect to 1.268 GHz for CNSS B3 application. The measured axial ratio bandwidth for the second band is 180MHz, from 1.5 to 1.68 GHz for LHCP, corresponding to about 11% with respect to 1.615GHz for CNSS L band, and the measured axial ratio bandwidth for the third band is 240 MHz, from 2.28 to 2.52GHz for RHCP, corresponding to about 9.6% with respect to 2.49GHz for CNSS application.

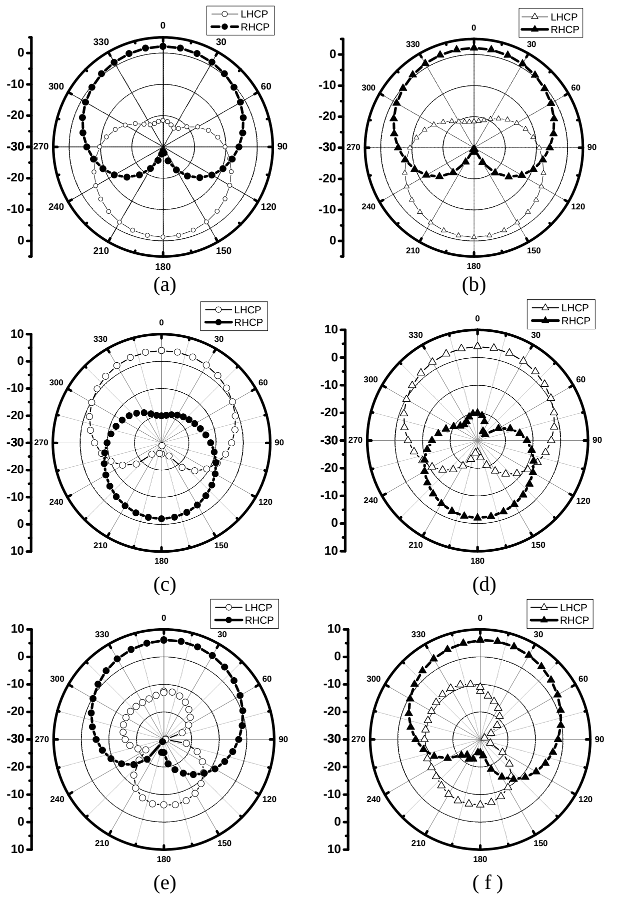


Figure 5. Measured radiation pattern: (a) XoZ plane at 1.268GHz, (b) YoZ plane at 1.268 GHz, (c) XoZ plane at 1.615 GHz, (d) YoZ plane at 1.615 GHz, (e) XoZ plane at 2.49 GHz, (f) YoZ plane at 2.49 GHz.

Fig.5 show the measured radiation patterns in XoZ-plane and YoZ-plane at three frequency. According to the measured radiation patterns, RHCP radiation patterns at the low and high band and LHCP radiation patterns at the second band are excited in respectively. The radiation patterns are symmetrical at 1.268 GHz for the XoZ-plane with a 3-dB beamwidth of 96°and the YoZ-plane with a beamwidth of 92°. At the second and third bands, the beamwidth is narrower than that of the first band. Also, the radiation patterns are tilted slightly at the high frequency bands. The measured gain values at the all three bands of the proposed antenna are 3.0 dBi at 1.268 GHz, 3.95 dBi at 1.615GHz and 6.3 dBi at 2.49 GHz, respectively.

IV. CONCLUSION

A novel triple-band circularly polarized stacked patch antenna is proposed in this paper and fabricated. The proposed antenna can be used in CNSS systems, since its bands of operation are: 1.268 GHz, 1.615GHz and 2.49 GHz. The radiation is circularly polarized at each band. For the low and high bands the wave is RHCP, while for the medium band it is LHCP. The broad beamwidth , small size and high gain of this antenna makes it suitable for the CNSS applications.

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