Compact Multi-band Circularly Polarized Antenna for GNSS Applications

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***Abstract*-A novel compact multi-band stacked patch antenna with circularly polarization is proposed for GNSS applications. The antenna has been designed to operate at the satellite navigation frequency bands including GPS L1, GLONASS L1, BDS-1 L, BDS-1 S, and BDS-2 B3. The proposed antenna comprises of four layer stub-loaded circular microstrip patches, all of which are dual probe-fed. The feed network which includes four broadband baluns for the antenna is also designed. The antenna has been designed and fabricated. Details of the design considerations are described. Both simulated and measured results are presented and discussed.**

I. INTRODUCTION

Global navigation satellite systems (GNSS) can provides reliable positioning, navigation, and timing services for users on a continuous basis in all weather, day and night, anywhere on or near the Earth which has four or more visible GNSS satellites. Therefore, nowadays satellite navigation systems have been intensively used both in civilian and military areas. At present, GNSS includes GPS (USA), GLONASS (Russia), Galileo (Europe), BDS-1/-2 (China), etc. The American GPS and the Russian GLONASS are already operable worldwide. In 2012, it has been announced that Chinese BDS began to provide service for Asia-Pacific region (55°E-180°E, 55°S-55°N) [1]. In the future, satellite navigation receivers will provide multi-mode operation using different satellite navigation systems to improve positioning accuracy and reliability. So it is practically desirable to design terminal antenna for multi-mode satellite navigation systems.

Recently, GNSS antenna has attracted great research attention and kinds of GNSS antennas have been reported, including microstrip antennas, quadrifilar helix antennas, and many other type antennas [2-7]. However, most of GNSS antennas developed can only cover a single band [2-4], or operate in a single mode [5- 6]. The antenna proposed in [7] is able to operate at GPS, GLONASS, Galileo, and BDS-2 bands. However, the bands for BDS-1 which can provide both navigation and communication services has not been covered.

In this paper, a multi-band circularly polarized (CP) antenna is proposed. The proposed antenna has right hand circularly polarized (RHCP) radiation patterns for GPS L1 (1575 ± 5 MHz), GLONASS L1 (1602 ± 8 MHz), BDS-1 S (2492 ± 5 MHz), and BDS-2 B3 (1268 ± 10 MHz) bands, while left hand circularly polarized (LHCP) radiation patterns for BDS-1 L (1616 ± 5 MHz) band. In the proposed antenna, due to its advantage of low profile, easy fabrication, and easy integration with passive and active devices, four layer stub-loaded circular microstrip patches are stacked to achieve multi-band operation. Details of the design considerations and experimental results will be presented and discussed in the following sections.

II. ANTENNA DESIGN

The geometry of the proposed multi-band GNSS antenna is presented in Fig. 1. The four stub-loaded circular patches overlap each other without any air gaps, which usually result in an increase of antenna thickness, fabrication complexity and cost [8]. From top to bottom, the patches are deigned to operate at BDS-1 S, BDS-1 L, BDS-2 B3, and GPS L1 and GLONASS L1 successively. The top and bottom substrates have thickness of h_1 and relative permittivity of ε_{r1}, while the second and third substrates have thickness of h_2 and relative permittivity of ε_{r2}. Stubs are loaded for each patch for the convenience of tuning the impedance matching. The commercial electromagnetic simulation software Ansoft HFSS is used to design and optimize the geometric parameters of the proposed antenna. In the end, the optimal antenna parameters are determined as follows: h_1 = 3.2 mm, h_2 = 2.5 mm, r_{s1} = 17.0 mm, r_{s2} = 22.5 mm, r_{s3} = 30.0 mm, r_{s4} = 35.0 mm, r_{p1} = 12.5 mm, r_{p2} = 18.0 mm, r_{p3} = 26.0 mm, r_{p4} = 31.5 mm, ε_{r1} = 6.15, ε_{r2} = 10.0, d_{f1} = 3.5 mm, d_{f2} = 7.5 mm, d_{f3} = 12.5 mm, d_{f4} = 17.8 mm. A ladder-type cylindrical station and a screw were employed to fix and support the microstrip patches.

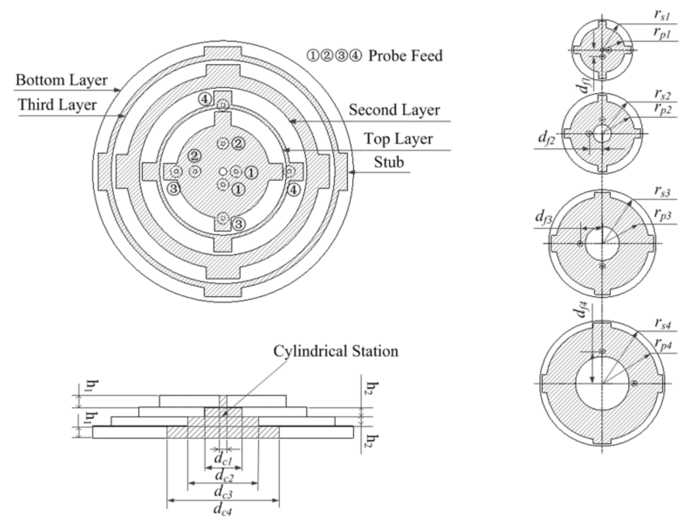


Figure 1. Geometry of the proposed GNSS antenna

The proposed structure of the feed network is shown in Fig. 2. It includes four broadband baluns, each of which comprises of a cascade of 3-dB Wilkinson power divider and a 90° broadband phase shifter. The feed network is printed on substrate with thickness of h_1 = 1.0 mm and relative permittivity of ε_{r2} = 2.65. To decrease the coupling between the patches and the feed network, the baluns are printed on the opposite side of the ground plane of the patches. Certain amounts of grounding holes are adopted to enhance the amplitude balance and phase orthogonality of the outputs for each balun.

The return loss parameters of the proposed antenna with and without the feed work are simulated, which are respectively shown in Fig. 3. It can be seen that good performance of return loss has been obtained. The return loss is less than -15 dB over all the operating frequency bands, which attributes to the adoption of the broadband baluns of the feed network.

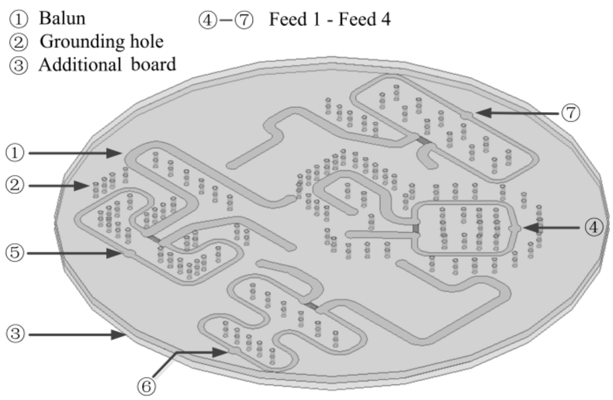
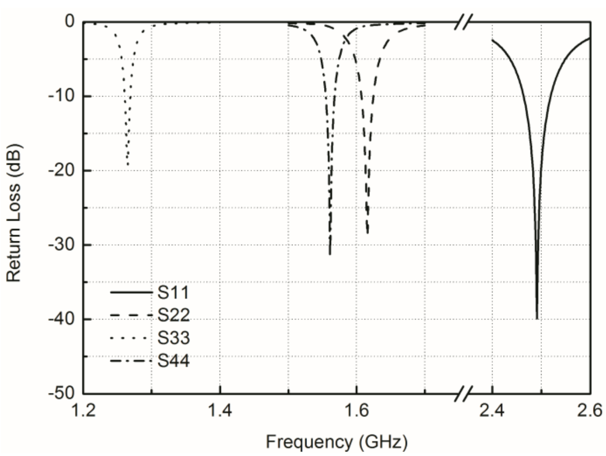
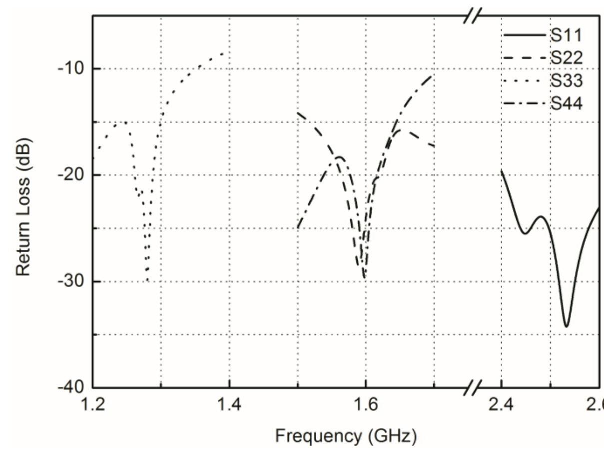


Figure 2. Structure of the proposed feed network



(a)



(b)

Figure 3. Simulated return loss parameters: (a) without feed network, (b) with feed network

III. RESULTS AND DISCUSSIONS

The proposed GNSS antenna integrated with the feed network is fabricated as shown in Fig. 4. Fig. 5 shows the measured return loss parameters. As seen, the measured return loss demonstrates high performance of less than -15 dB (corresponding to VSWR < 1.5) for all the operating bands. Compared with Fig. 3(b), it can be observed that the measured results agree well with the simulated ones, and good impedance matching performance has been achieved.

Fig. 6 presents the normalized measured far-field radiation patterns respectively at 1268 MHz, 1575 MHz, 1616 MHz and 2492 MHz. It shows that good RHCP performance is achieved for 1268 MHz, 1575 MHz and 2492 MHz, and good LHCP performance is achieved for 1616 MHz. The CP isolation is above 12 dB for all designed bands. The measured peak gain is 0.38 dBi, 2.93 dBi, 2.62 dBi, and 3.56 dBi for 1268 MHz, 1575 MHz, 1616 MHz and 2492 MHz. The axial ratio in the broadside direction also have been measured, which is 2.1 dB at 1268 MHz, 1.8 dB at 1575 MHz, 1.9 dB at 1616 MHz and 2.3 dB at 2492 MHz.

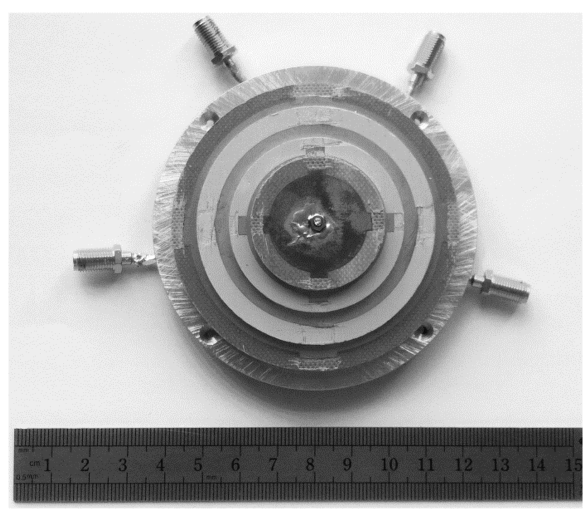


Figure 4. The fabricated multi-band GNSS antenna

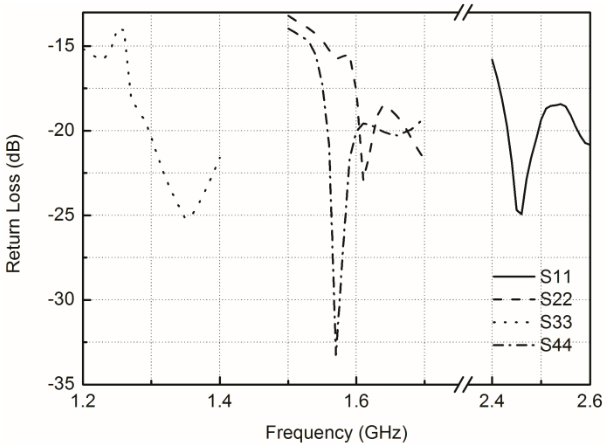
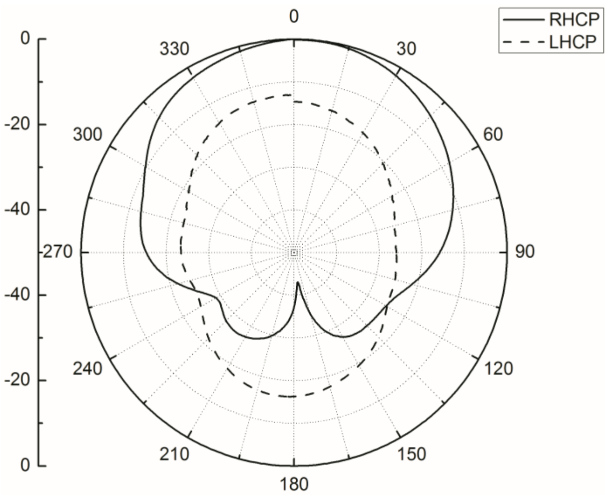
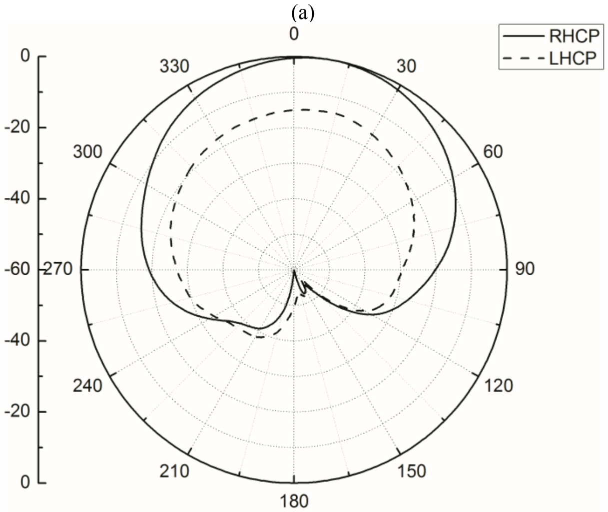


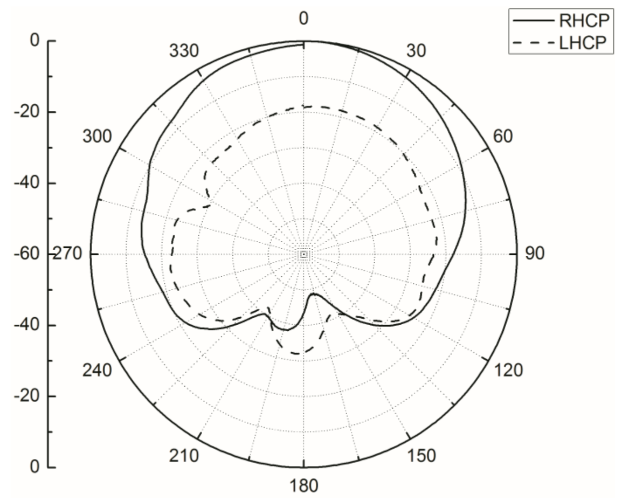
Figure 5. Measured return loss parameters of the fabricated antenna



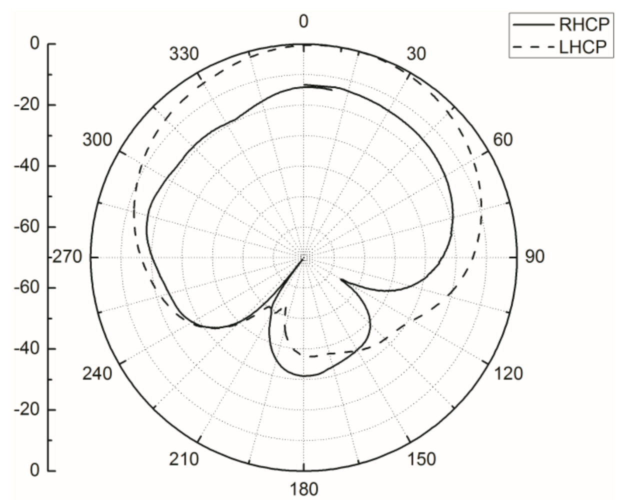
(a)



(b)



(c)



(d)

Figure 6. Measured normalized radiation patterns at: (a) 1268 MHz, (b) 1575 MHz, (c) 2492 MHz, and (d) 1616 MHz

IV. Conclusion

In this paper, a novel compact multi-band stacked patch antenna for GNSS applications is proposed. The antenna can achieve good impedance matching performance and circularly polarized radiation patterns within GPS L1, GLONASS L1, BDS-1 L, BDS-1 S, and BDS-2 B3 bands. A prototype has been developed and measured to verify the concept. Both the simulated and the measured results demonstrate the high performance of the proposed antenna.

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