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# Wideband Circular Polarization Cavity-Backed Slot Antenna for GNSS Applications

**Chunhong Chen*, Xinpeng Zhang, Shishan Qi, and Wen Wu**

**Abstract**—This paper presents a wideband circular polarization antenna for Global Navigation Satellite System (GNSS). By exciting four slots etched along each edge of a square ground with equal amplitude and 90° phase difference, good circular polarization performance is achieved. A novel radiation element, composed of back-side slot and front-side monopole, is proposed to realize a wideband radiation. Meanwhile, the feed network composed of Schiffman phase shifters and Wilkinson power dividers maintains this wideband performance. A backed cavity is used to suppress the backward radiation, therefore enhances the frontward gain. Measured results of the fabricated antenna show good agreement with the simulated ones. The main advantages of this antenna include its wide bandwidth, good circular polarization, high front to back ratio, low cost, and easy fabrication, which make it very attractive for GNSS terrestrial applications.

## 1. INTRODUCTION

Global Navigation Satellite System (GNSS) has been developed by leaps and bounds, along with the booming of numerous satellite positioning and navigation systems such as GPS, GLONASS, Galileo, and Beidou. In order to cover those systems' working bands, the GNSS spectra spread over 1.164–1.614 GHz. Therefore, a wideband circular polarization antenna is required for its applications. A variety of single-feed wideband GNSS antenna designs have been reported in literatures. Among them, a lot of researches involve the spiral antenna, which exhibits good circular polarization and wideband properties [1–7]. Another common approach is the stacked construction, where a wideband feed network is always used [8–13]. In addition, there are some special-structure antennas, for example, small radiating element with parasitic elements around [14], convex reference station antenna with straight pins and convex impedance ground planes [15], rectangular microstrip antenna with two different slots [16], and the rectangular hybrid dielectric resonator antenna [17], etc.. With more and more extensive applications of microstrip-fed slot antenna, it is becoming a good candidate for GNSS antenna, due to its performances of wide bandwidth and slight interaction of surface waves. Meanwhile, it also has the features of low cost and light weight. However, unfortunately, a slot cut in the ground plane of a microstrip line will have a broadside radiation. It is well known that the ideal GNSS antenna should provide right-handed circular polarized (RHCP) radiation pattern with low backlobe and high cross-polarization rejection ratio, because the polarization of reflected EM wave on the ground is changed to the left-handed circular polarization (LHCP). In this case, a cavity-backed slot (CBS) antenna [18–21] with suppressed backward radiation is an economical solution of GNSS antennas for terrestrial applications.

In this paper, a wideband circular polarization GNSS antenna based on the CBS antenna is designed. By exciting four slots etched along each edge of a square ground, with equal amplitude

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and 90° phase difference, circular polarization is generated. Both the back-side slots and the front-side microstrip monopoles have wideband radiation performances, and their resonant frequencies are slightly different, which leads to a more wideband radiating element. Moreover, the wideband feed network maintains wideband antenna performance. On the other hand, the inverted configuration and the cavity enhance the forward radiation, so the antenna gain is improved. Details of the antenna design are described, and experimental results are presented.

## 2. ANTENNA DESIGN CONSIDERATIONS

Figure 1 shows the configuration of the proposed antenna. Four centrosymmetric dumbbell-shaped slots are etched on the backside of an RO4003 PCB with dielectric constant of 3.38 and substrate thickness of 0.813 mm. The corresponding four feed probes (microstrip monopoles) and feed network are printed on the front side. The feed network provides the excitations for the feed probes with equal amplitude and 90° phase difference, therefore the circular polarization radiation modes are excited. A square cavity of length $D$ and height $H$ is soldered to the ground plane under the PCB to suppress the backward radiation and enhance the bandwidth.

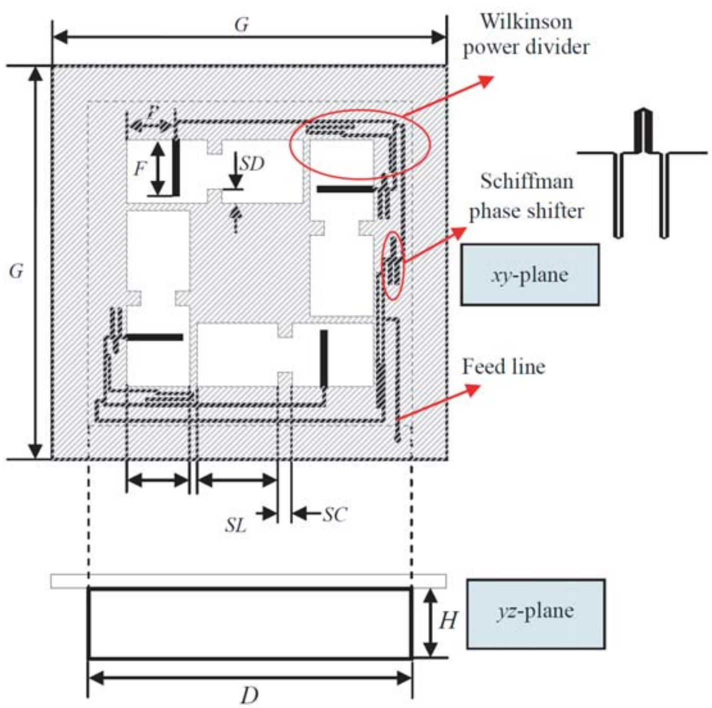



**Figure 1.** Configuration of the proposed antenna ($G = 250$ mm, $SL = 57.5$ mm, $SW = 45$ mm, $SC = 10$ mm, $SD = 10$ mm, $F = 39$ mm, $P = 35$ mm, $D = 220$ mm, $H = 50$ mm).

As we know, the resonance frequency of a slot antenna is mainly determined by the length of slot. In general, the length of the slot is about half resonant wavelength. In order to miniature the size of slot, a dumbbell slot is adopted. Besides, the resonant frequency of the slot antenna will decrease with an increasing width of slot, which also means a miniaturization. However, the wide slot will lead to higher cross polarization. So the slot width should be properly chosen.

The microstrip feed line in Fig. 1 can be considered as a microstrip monopole with a length about one quarter wavelength, which introduces another resonance. According to the theory of monopole antenna, the wider monopole has wider band and better impedance matching; however, its shade area over the slot radiation increases, too. Thus the width of feed line should be chosen for a compromise.

Note that the cavity will also introduce an extra resonance, so it is important to choose a proper cavity size to ensure its resonant frequency far away from the operating frequency range. The height of the cavity can be changed to compromise the backward reflection and forward radiation energies, at the same time adjust the reactance of the input impedance. It is worth noting that because of the cavity, the size of the ground plane has little effect on the performance of the antenna.

The bandwidth of the feed network and the isolation between the feeding ports are key factors on the performance of the antenna for wideband applications. The feed network composed of wideband branch-line couplers can provide the desired amplitude and phase distribution, but its size is unacceptable for a single-layer PCB. So power dividers with phase shifters are more applicable to this kind of antenna, due to its layout flexibility. In some designs, transmission line (TL) was used to realize phase shift, and T-junction was used as power divider. However, the phase deviation of transmission line caused by frequency offset will deteriorate the polarization performance. Schiffman phase shifter (as shown in Fig. 1) is a good candidate for wideband application, which can provide fairly constant relative phase shift in a wide frequency range. Table 1 shows the axial ratio values of the GNSS antenna without phase shifters (original), with TL phase shifters, and with Schiffman phase shifters, respectively. As shown, the axial ratio bandwidth of the antenna with TL phase shifters is too narrow to satisfy the bandwidth requirement of GNSS antenna, while the antenna with Schiffman phase shifters generates favourable circular polarization in the GNSS band.

**Table 1.** Axial ratio values of the GNSS antenna.

| Frequency/GHz | Original/dB | With TL/dB | With Schiffman/dB |
|---|---|---|---|
| 1.19 | 0.37 | 4.5 | 0.75 |
| 1.26 | 0.59 | 2.7 | 1.35 |
| 1.39 | 0.03 | 0.68 | 1.55 |
| 1.58 | 0.71 | 2.6 | 1.55 |

It should be pointed out that T-junction is a lossless three-port network, so there is no isolation between the two input ports. Meanwhile, there is a mismatch when looking into the input ports. Like TL phase shifter, T-junction can only be used for the narrow band applications. Otherwise the performance of circular polarization will become worsen because the reflected power is not dissipated. For example, when T-junctions are added behind Schiffman phase shifters, the antenna radiates linear polarization at certain frequencies in GNSS band. On the other hand, Wilkinson power divider is a lossy three-port network, and has all ports matched with isolation between input ports. Therefore, Wilkinson power divider is applicable for GNSS antenna. Fig. 2 shows the simulated axial ratio values and RHCP gains at boresight of the GNSS antenna with Schiffman phase shifters and Wilkinson power divider. We can see that axial ratio values in GNSS band are lower than 3 dB, and gains are more than 7.8 dB, so we can say the antenna has the good circular polarization performance.

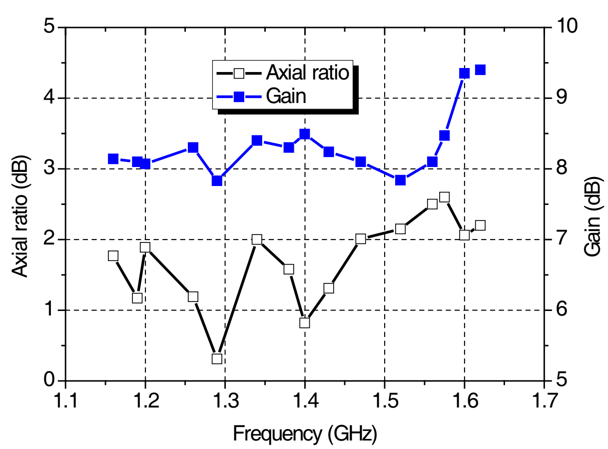



**Figure 2.** Simulated axial ratio values and gains at boresight of the designed antenna.

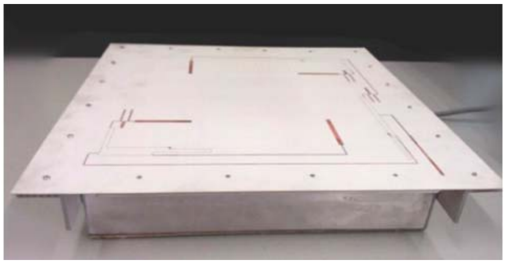


Figure 3. Photo of the fabricated antenna.

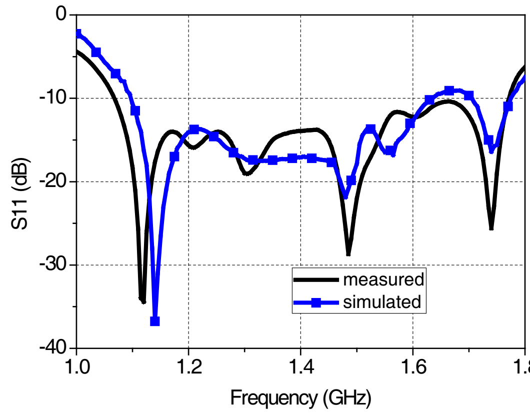
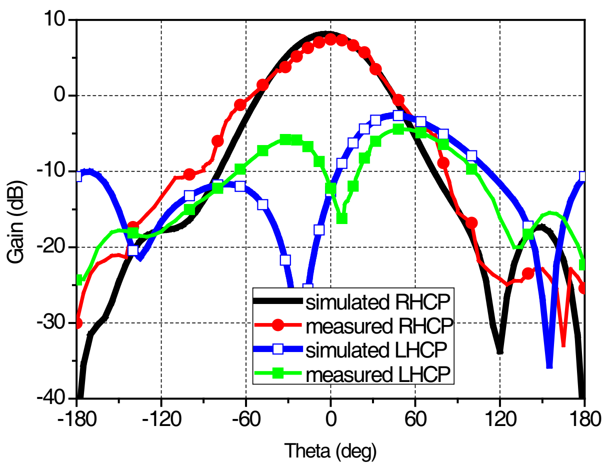
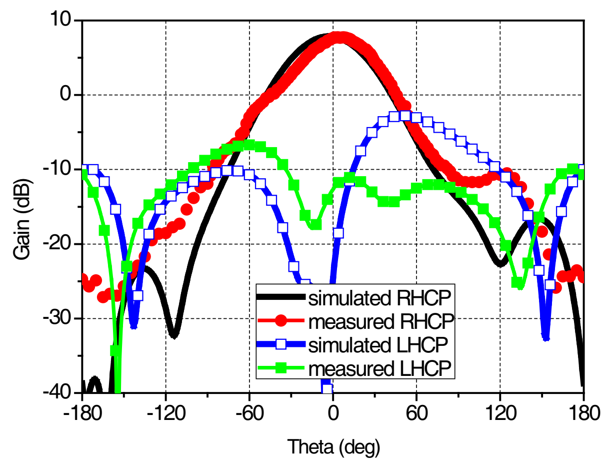


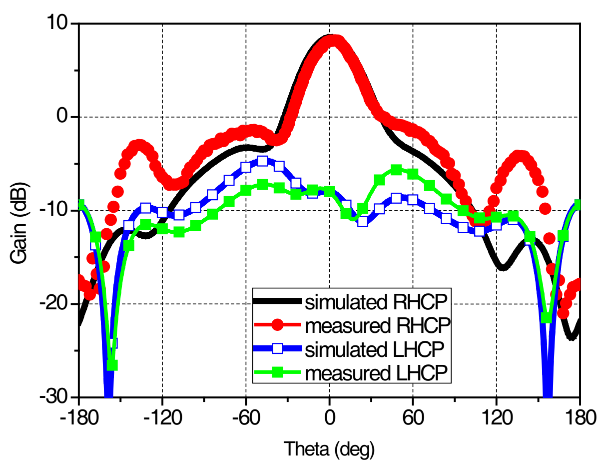

**Figure 4.** Simulated and measured reflection coefficients of our fabricated antenna.




(a)




(b)




(c)

**Figure 5.** Simulated and measured radiation patterns. (a) 1.19 GHz, (b) 1.26 GHz, (c) 1.575 GHz.

## 3. EXPERIMENTAL RESULTS

Figure 3 shows a photo of the fabricated antenna. The simulated and measured reflection coefficients of our fabricated antenna are shown in Fig. 4. We can see that the impedance bandwidth is over 38%, which covers the whole GNSS band. For a typical application, the radiation patterns at three center frequencies of Beidou receive system are shown in Fig. 5. It can be seen that the measured RHCP gains are higher than 7.4 dB, the cross polarizations are lower than −16 dB, and the backlobe levels of the RHCP patterns are lower than −25 dB. Meanwhile, the measured results are in good agreement with the simulated ones, which verify the feasibility of this design.

## 4. CONCLUSION

A wideband RHCP GNSS antenna with suppressed backward radiation has been designed, fabricated, and measured. The wideband performance of the antenna is due to the wideband radiation element composed of a back-side slot and front-side microstrip monopole, and the wideband feed network, in which Schiffman phase shifter is adopted to ensure 90° phase difference between ports over the whole GNSS band. Meanwhile, Wilkinson power divider also provides good port isolation, and therefore, wideband circular polarization characteristics have been obtained. Moreover, the backed cavity suppresses the backward radiation, leading to a gain enhancement. Simulated and measured results of the reflection coefficients and radiation patterns demonstrate a good agreement over the band of 1.164–1.614 GHz. The main features of this antenna include its wide bandwidth, good circular polarization performance, low cost, and easy fabrication. All these characteristics make this antenna potentially very useful for GPS, GLONASS, Galileo, or Beidou system.

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