Progress In Electromagnetics Research Letters, Vol. 26, 97–104, 2011

COMPACT CIRCULARLY POLARIZED PRINTED ANTENNA USING MAGNETIC COUPLING-FED AND CAPACITIVELY-LOADED STRUCTURE

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Abstract—A compact circularly polarized (CP) printed antenna for global positioning system (GPS) is proposed. The antenna adopts a two-layered stacked structure, in which a diagonally positioned rectangular patch is used as the driven part and capacitively-loaded patch-based crossed dipoles are used as the main radiators. Good impedance matching is obtained conveniently by using magnetic-coupling feeding technique, and antenna size reduction is realized by using capacitively-loaded structure (50% size reduction in comparison with the conventional half-wave dipole antennas). A prototype of the antenna with the size of 46 mm × 46 mm is fabricated and tested. Good agreement is achieved between the simulated and measured results, which shows that the impedance bandwidth defined by 10 dB return loss is 34.8 MHz. In addition, the 3 dB-axial-ratio bandwidth is 8 MHz, and the antenna gain is about 7 dB.

1. INTRODUCTION

For the mobile global positioning system (GPS) antenna, compact size and circularly polarization are usually the fundamental requirements. Traditional CP antennas for personal communication systems are turnstile dipole antenna (TDA) and microstrip antennas [1–5]. Turnstile dipole antenna is commonly used for its simple structure and easy fabrication. However, when we design an antenna operating at the frequency of 1.575 GHz using a traditional TDA, the size of the antenna, according to the reference [1], is about 95 mm × 95 mm ($0.5\lambda \times 0.5\lambda$). It is difficult to be integrated into a portable device. Circularly polarized (CP) microstrip antennas with compact size [2, 3]

Received 3 July 2011, Accepted 23 August 2011, Scheduled 31 August 2011
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have been proposed. The single-fed CP patch antenna [2] operating at GPS band adopts a substrate with the permittivity of 10.2 to reduce the antenna size, and the circular polarization is achieved by using the diagonally positioned feeding probe. In [3], a small double-fed CP patch antenna is presented, and the fabrication of this antenna is not cost effective due to its complex feeding network. A single-layer CP microstrip antenna for GPS applications is reported in [4], in which the antenna has four switches on four slots on the path. This antenna has a problem that it needs a control circuit for switches. The antenna configuration in [5] needs two perpendicular ports and two power dividers to provide 90° phase shift. For microstrip antennas, which are widely used in mobile communications due to its advantages of low profile, light weight, low-cost and easy fabrication, high-permittivity substrates are usually used to reduce the antenna size, but high-permittivity substrate also results in high-cost, narrow bandwidths for its high Q factor and low radiation efficiency [6].

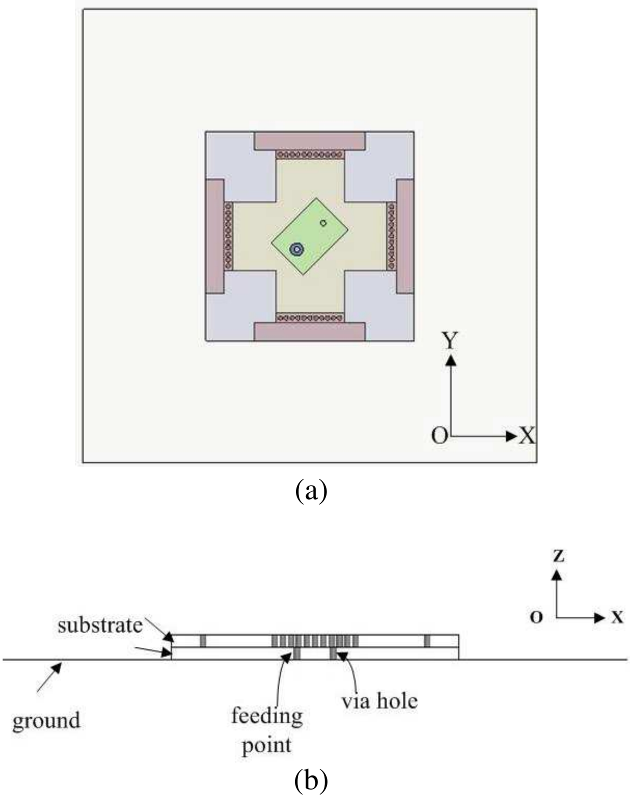
An electrically small CP antenna operating at GPS L1-band is proposed in [7]. It is composed of two orthogonal, two-gap capacitively-loaded wire loop antennas with a rotated coaxial-fed semi-loop driven structure. Size reduction is realized by simply increasing the capacitive gaps. However, the wire structure limits the antenna to be integrated into a small mobile GPS terminal.

In this paper, a compact printed CP antenna for GPS L1 (1.5754 GHz) band is proposed. The antenna adopts a two-layered stacked structure, in which a diagonally positioned rectangular patch is used as the driven part, and capacitively-loaded patch-based crossed dipoles are used as the main radiators. Good impedance matching is obtained conveniently by using magnetic-coupling feeding technique, and antenna size reduction is realized by using capacitively-loaded structure (50% size reduction in comparison with the conventional half-wave dipoles). The radiant crossed dipoles are driven in phase quadrature by diagonally positioning the feeding probe to obtain CP performance.

2. ANTENNA DESIGN

The configuration and photograph of the proposed antenna are shown in Figure 1. It adopts a two-layered stacked structure of 46 mm × 46 mm and a large ground plane of 100 mm × 100 mm. Substrates of the two layers are the same with relatively dielectric constant of 2.65 and height of 2 mm. The lower layer is a diagonally positioned rectangular patch with the size of 10 mm × 14 mm and is coaxially fed through a finite ground plane. A via hole symmetrical with the feeding probe is inserted into the lower layer, which makes the excitation process magnetic-coupling. The upper layer is capacitively-loaded patch-based crossed dipoles with the same size of 38 mm × 15 mm, which are the main radiators excited directly by the magnetic flux produced by the lower rectangular patch. Two pairs of capacitive patches with different but approximate size are printed on back of the substrate, which are connected to the front radiant crossed dipoles by via holes with the radius of 1 mm. The two radiant crossed dipoles are driven in phase quadrature by diagonally positioning the feeding probe to obtain CP performance.

The equivalent circuit model of the antenna is shown in Figure 2. As observed, the driven rectangular patch and radiant crossed dipoles form an impedance transformer. Good impedance matching can be obtained by adjusting the sizes of the rectangular patch and the crossed dipoles, i.e., we adjust the ratio of the impedance transformer to obtain impedance matching. With different sizes for the two pair



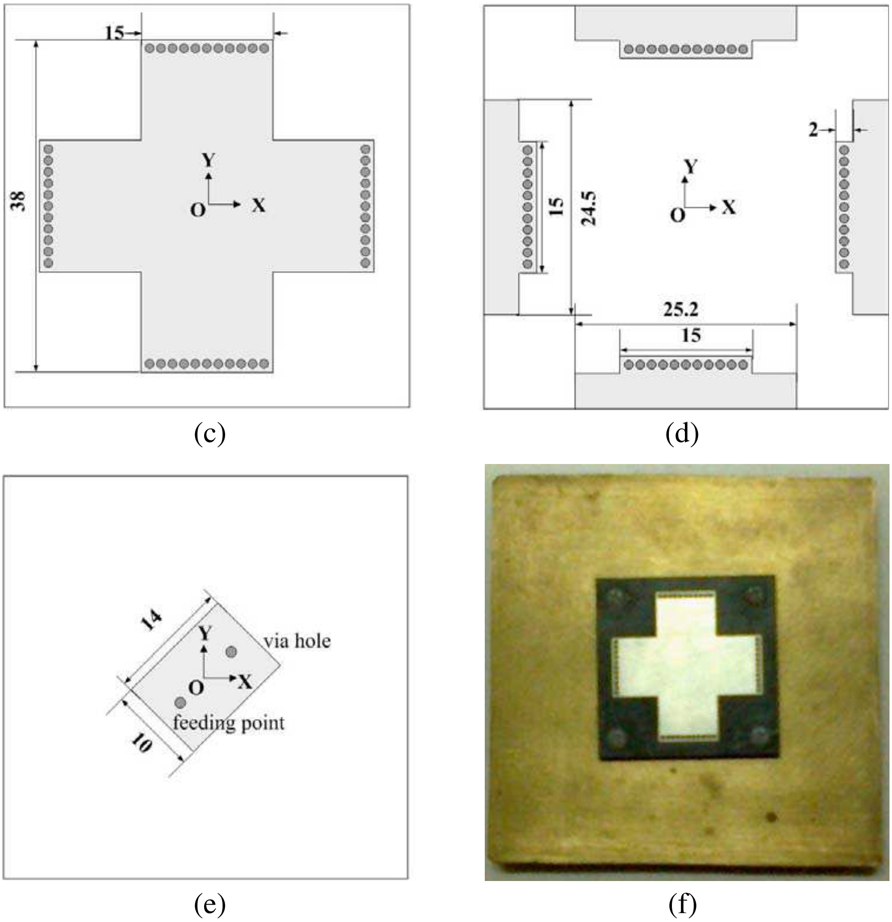


Figure 1. Configuration and the photograph of the proposed antenna (Unit: mm). (a) Front view of the antenna. (b) Side view of the antenna. (c) Front of upper layer. (d) Back of upper layer. (e) Front of lower layer. (f) Photograph of the antenna.

capacitive patches, the capacitive values of Cg1 and Cg2 are unequal but approximate. The capacitively-loaded patch-based crossed dipoles are designed to resonate at different frequencies by adjusting the sizes of their capacitive patches, which leads to a circular polarization similar to turnstile dipole antenna [1]. The capacitively-loaded structure makes the antenna have a smaller size in comparison with the conventional half-wave dipole antennas at a given operating frequency.

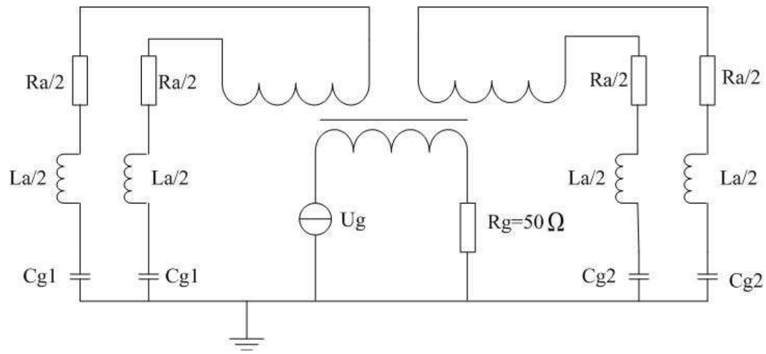


Figure 2. Equivalent circuit model of presented antenna.

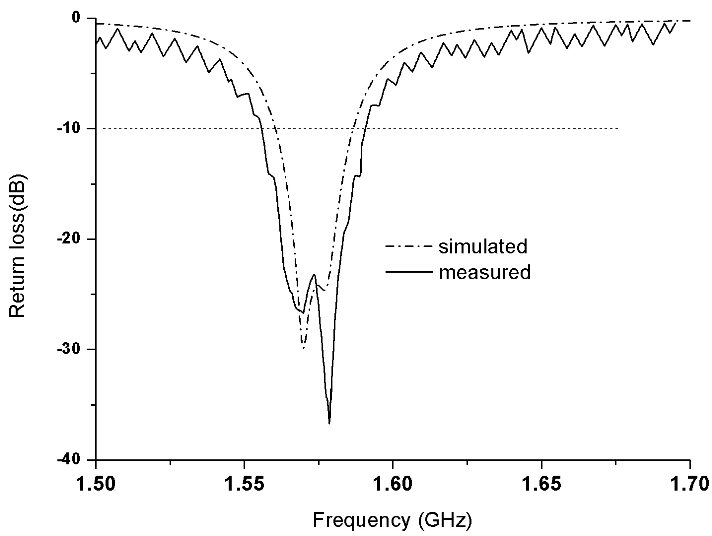


Figure 3. Simulated and measured return losses of presented antenna.

3. RESULTS AND DISCUSSIONS

In our research, the simulated and measured results are obtained with the help of the high frequency structure simulation software (HFSS) and WILTRON-37269A vector network analyzer. Figure 3 illustrates the return loss characteristic of the proposed antenna. As shown in this figure, the measured impedance bandwidth ($S_{11} < -10\,\mathrm{dB}$) is 34.8 MHz (1.5558 GHz to 1.5906 GHz). It can be seen that there is a little discrepancy between the simulated and measured results

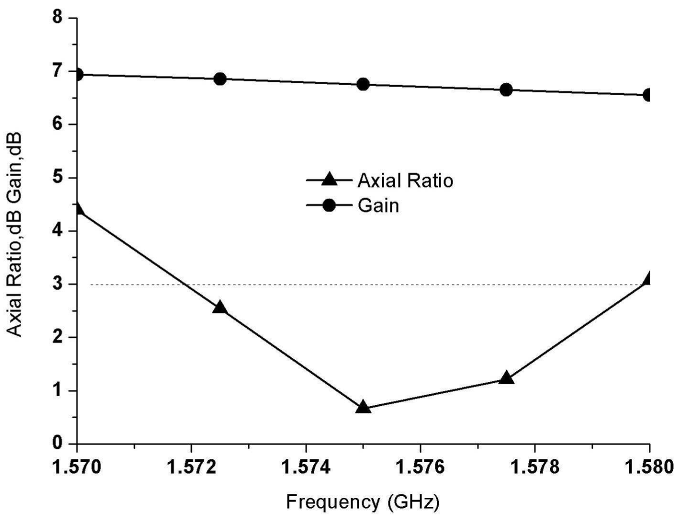


Figure 4. Axial ratio and gain.

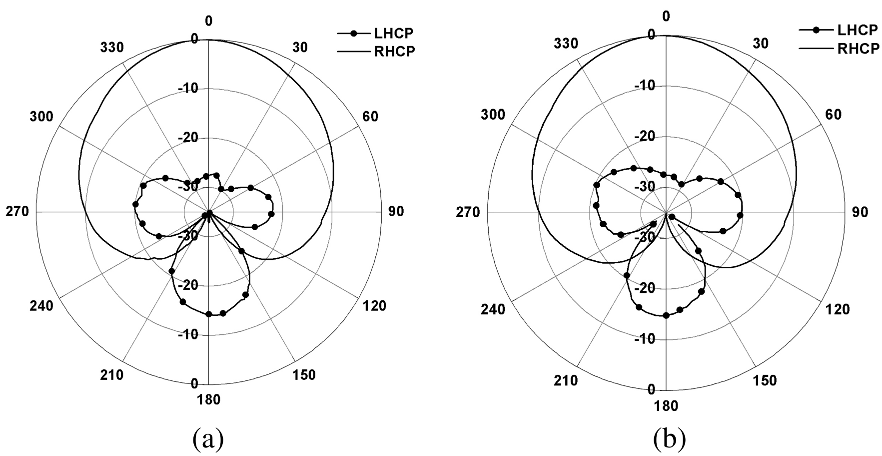


Figure 5. Radiation patterns at 1.5754 GHz. (a) $\varphi = 0°$. (b) $\varphi = 90°$.

because of the manual processing error and the effect of experimental instruments.

Figure 4 shows the simulated axial ratio and the gain of the antenna, and it can be observed that the axial ratio equals 0.83 dB at 1.5754 GHz. Besides, the bandwidth (AR < 3 dB) is 8 MHz (centered at 1.5754 GHz), and the gain is about 7 dB with variation less than

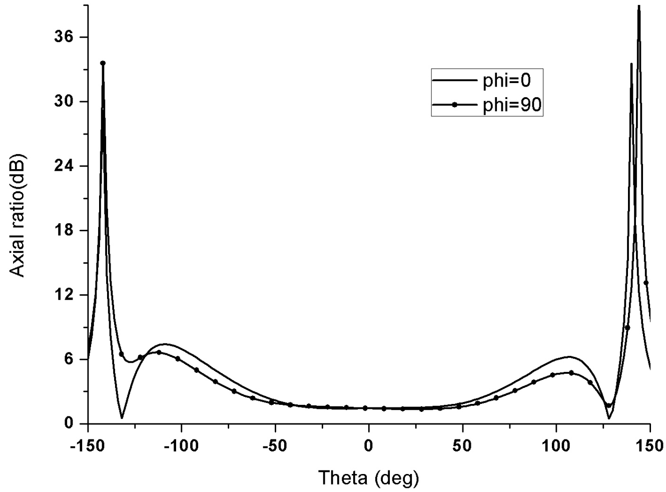


Figure 6. Axial ratio beam width of the antenna.

0.5 dB. The simulated far-field radiation patterns at 1.5754 GHz of the two principal planes, $\varphi = 0°$ and $\varphi = 90°$, are shown in Figure 5. It is clear that the antenna is RHCP with a small LHCP level of -27.2 dB in both the principal planes. The half power beam width (HPBW) is around 87° at the two principal planes. Figure 6 shows the simulated axial ratio beam width of the two principal planes: $\varphi = 0°$ and $\varphi = 90°$. These results demonstrate that the antenna can obtain a axial ratio beam width of $\theta = \pm 50°$.

4. CONCLUSION

A compact printed CP antenna for GPS L1-band is proposed in this paper. The antenna adopts a two-layered stacked structure, in which a diagonally positioned rectangular patch is used as the driven part, and capacitively-loaded patch-based crossed dipoles are used as the main radiators. Good impedance matching is obtained conveniently by using magnetic-coupling feeding technique, and antenna size reduction is realized by using capacitively-loaded structure (50% size reduction in comparison with the conventional half-wave dipole antennas). The measured return loss curve is sufficient to encompass the GPS L1-band. Besides, the radiation pattern figures show that the antenna has good radiation patterns and CP performance. With low profile, small size and good CP radiation, the proposed antenna can be widely used in many applications.

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