Low Profile Circularly Polarized Magnetic Dipole Antenna for L1 Band of GPS

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Abstract

A low-profile circularly polarized magnetic dipole antenna operating at the GPS band is proposed in this paper. In this antenna, the metal patches with the rectangular slot printed on the upper and lower surfaces of the dielectric substrate are used as magnetic dipoles. The surrounding vertical metal posts pass through the dielectric substrate to connect the metal patch to ground. The right-handed circular polarization of proposed antenna is achieved by using a quarter-wavelength metal ring. Based on this method, the profile of the antenna is reduced to $0.056\lambda_0$. The simulation results show that the antenna obtained the 16% of impedance bandwidth (1.41-1.66GHz), 6.38dBi of peak gain and the 5.7% of axial ratio bandwidth (<3dB). It coveres the L1 band of GPS.

Keywords

Circularly Polarized; Low Profile; Magnetic Dipole Antenna; GPS.

1. Introduction

Global Positioning System (GPS) are widely used in the world. Therefore, the design of GPS band antenna is also very important [1]. However, in some studies, the size or profile height of these antennas is often larger or greatly complicated due to the low frequency [2, 3], so it is also meaningful to reduce the profile height of the GPS band antenna. Especially in some special scenario, it is necessary to require the antenna to have a low profile. In [4], the antenna uses a ME-dipole antenna to achieve the bandwidth of the GPS band, but due to its vertical printing structure, the antenna has a higher profile, so its scenarios are limited.

In order to reduce the antenna profile, a lot of efforts have also been made. In [5], the author designed the antenna to obtain bandwidth of 1.15-1.6 GHz and axial ratio bandwidth of about 28%, but the antenna has a height of 0.16λ (λ is wavelength at center frequency). In [6], the author introduces a method for realizing a low-profile GPS dual-band antenna using a four-arm helix. By adding a ring and a metal strip above the cylinder, the profile of the antenna is reduced to 0.097λ. However, the design method of this antenna is very complicated, which increases the design cost of antenna fabrication. In [7], a broadband crossed dipole antenna is proposed. The antenna achieves impedance bandwidth of 66% and axial ratio bandwidth of 41%. But it has a high profile.

In this paper, a low profile magnetic dipole circularly polarized antenna working at 1.575GHz is proposed. The antenna has an impedance bandwidth of 16% and a peak gain of 6.38dBi. The antenna uses a $\lambda/4$ ring to make the antenna have a right-hand circularly polarized 3dB axial ratio bandwidth of 5.7%, which improves the error tolerance rate of antenna reception or transmission. The most important aspect of antenna is that the profile of the antenna is reduced to 0.056λ, which is very meaningful in some special scenes.

2. Antenna Structure and Principle

2.1 Antenna Structure

The configuration of proposed antenna is shown in Fig.1. The structure of the antenna are consists of three parts. The first part is a ground with reflection cavity, which is composed of an aluminum ground and a rectangular reflection wall around it. The second part is the magnetic dipole antenna. In this part, four trapezoidal metal patches printed on the upper and lower surfaces of the dielectric substrate respectively and it through the surrounding metal posts to connect to ground. The metal patches with slot equivalence magnetic dipoles. The dielectric substrate is Rogers duroid 5880. The third part is the feeding structure, as shown in Fig.1. (c). In this part, two quarter-wavelength rings are printed on the upper and lower surfaces of the dielectric substrate, respectively, which are connected to the inner probe and outer surface of the coaxial line. The metal ring is connected to the surrounding trapezoidal patch through metal strips, and the circular polarization of this antenna is excited by the phase delay of the ring. The specific parameters of the antenna are shown in Table 1.
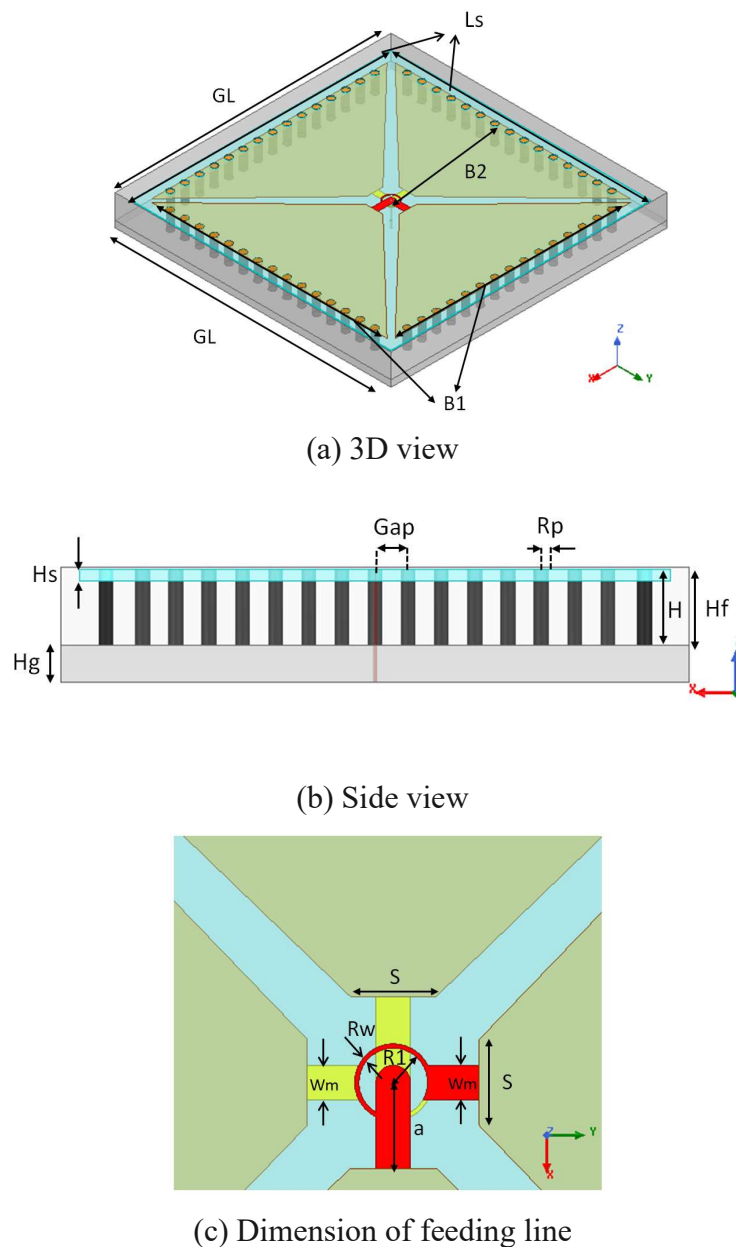

(a) 3D view

(b) Side view

(c) Dimension of feeding line

Fig. 1 Configuration of proposed antenna.

Table 1. Specific Parameters of Proposed Antenna

| Parameters	Value/mm	Parameters	Value/mm
GL	170	Hf	11.79
Ls	160	Hs	0.5
B1	150	H	10.79
B2	140	Wm	4
S	10	R1	4
a	10	Rw	0.3

2.2 Principle of Design

It can be seen from Fig.2 that the energy intensity of the slots between the metal patches of upper and lower of dielectric plates in the antenna (marked as No. 1 and No. 2) is the largest, so it represents the magnetic dipole equivalent to the slot between the patches is working at 1.48GHz. At 1.62GHz, the energy distribution on the metal patch (marked as number 3 and 4) connected by the yellow metal strip in the antenna is the stronger, so the radiation at this frequency is caused by the pair of patches on the lower surface of the dielectric substrate . Under the resonance of the two frequency points, the bandwidth of the antenna is expanded. In addition, due to the reverse current flow in the inner probe and outer layer of the coaxial line, and the 90° phase difference caused by the λ/4 ring, the patch radiation on the upper and lower surfaces differs by 180°, and the adjacent patches differ by 90°on the same surface, resulting in the circular polarization effect of the antenna as shown in Fig.2. (c).
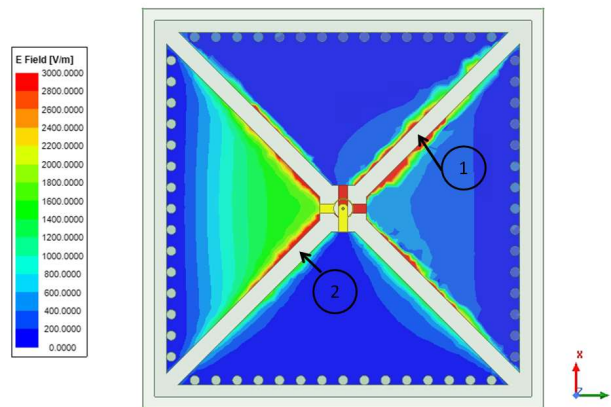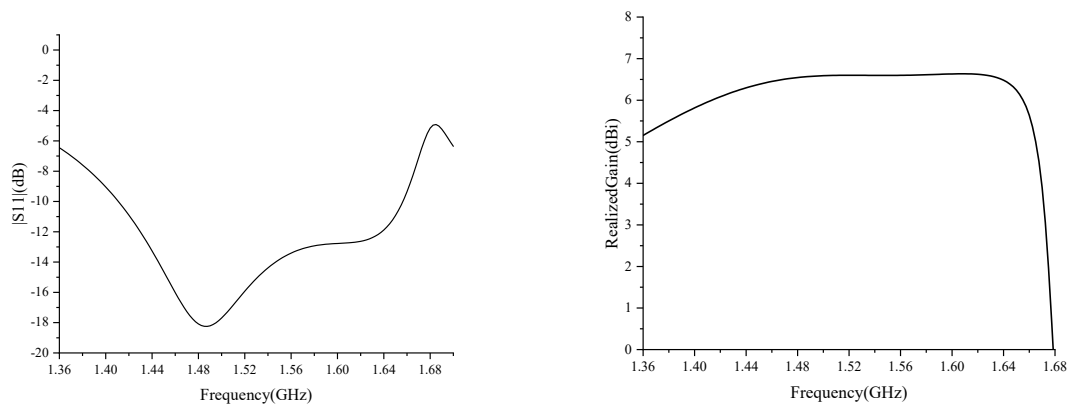

(a) at 1.48GHz
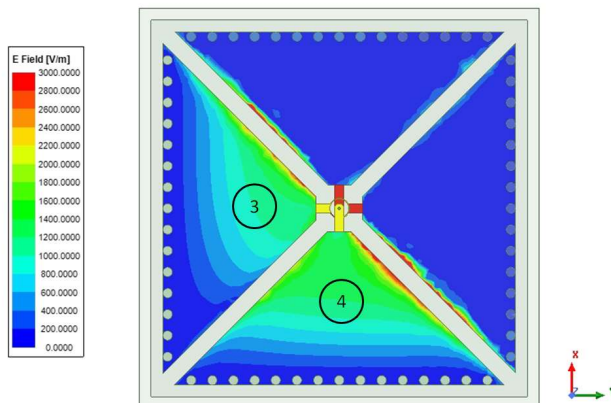
(b) at 1.62GHz
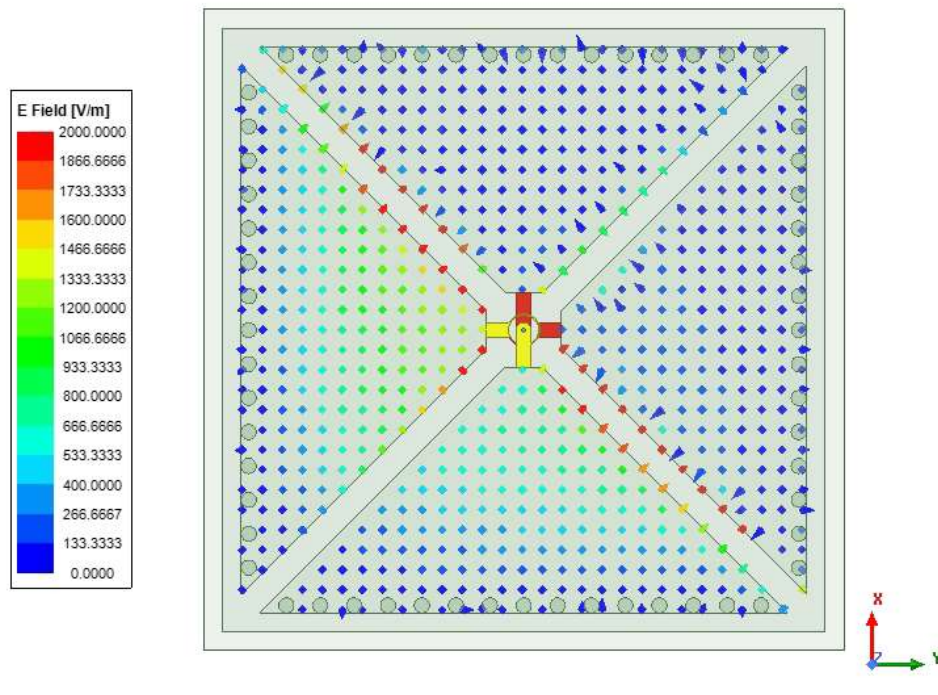
(c) Circular polarization electric field at 1.575GHz

Fig. 2 Electric field distribution of antenna.

3. Result

The simulation of proposed antenna in this paper is completed by using the commercial software HFSS of ANSYS Company. The simulation results of the antenna are shown in Fig. 3. Fig.3. (a) and Fig.3.(b) show the return loss of antenna and its gain respectively. The figure shows that the impedance bandwidth of the antenna is 16% (1.41-1.66GHz) and the average gain of the antenna is 6.47dBi.The circular ring of λ/4 makes the antenna realize right-hand circular polarization (RHCP). Fig.4. shows the axial ratio bandwidth of the antenna. The axial ratio bandwidth (<3dB) is 5.7% (1.52-1.61GHz), which can cover the L1 working frequency band of GPS.

(a) Return loss (S11<-10dB)   (b) Gain

Fig. 3 Simulate result of proposed antenna.
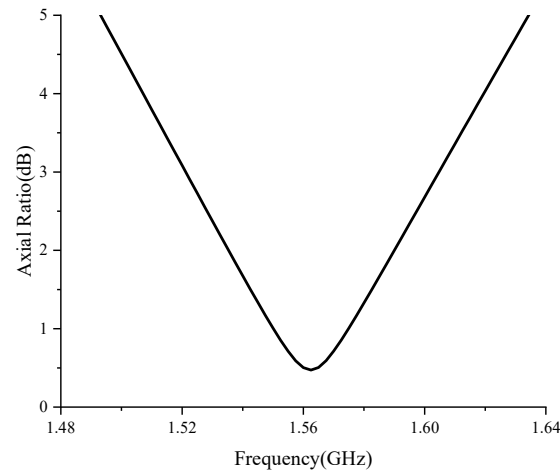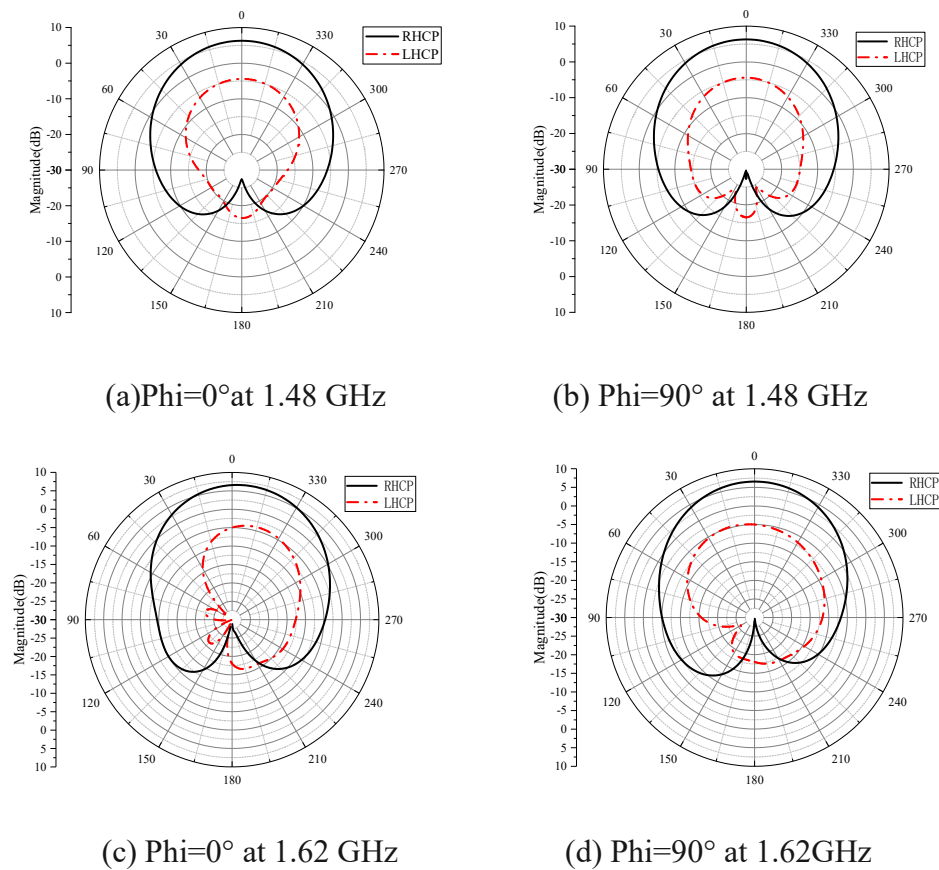
Fig. 4 Axial ratio of proposed antenna

(a)Phi=0°at 1.48 GHz

(b) Phi=90° at 1.48 GHz

(c) Phi=0° at 1.62 GHz

(d) Phi=90° at 1.62GHz

Fig. 5 simulated radiation patterns of proposed antenna when phi=0°and phi=90°.

The radiation patterns of the antenna at 1.48GHz and 1.62GHz are shown in Fig.5. The antenna realizes RHCP. At 1.48GHzthe cross-polarization of the antenna is less than -10.7dB, when phi=0° and phi=90°.The cross-polarization of the antenna is less than -11.4 dB and -11.5 dB when phi=0° and phi=90° at 1.62GHz, respectively. It can meet the performance requirements of the antenna.

4. Conclusion

In this paper, a low-profile magnetic dipole circularly polarized antenna working at the GPS band is proposed. The metal patches (equivalent magnetic dipoles) are printed on the upper and lower sides of the dielectric plates, and the metal posts are distributed around to connect the magnetic dipoles and the ground. The metal posts can also sustain the dielectric substrate. The right-hand circular polarization of the antenna is realized by using coaxial line with $\lambda/4$ ring. The simulation results show that the proposed antennas obtained impedance bandwidth of 16% and a peak gain of 6.38dBi, respectively. Furthermore, the antenna has a circularly polarized radiation effect at the frequency of 1.575GHz, and the axial ratio bandwidth (<3dB) is 5.7%. The antenna described in this paper can work in applications for GPS, and the circularly polarized radiation improves the applicability of the antenna.

Acknowledgments

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