A Compact Circular Polarized Tag Antenna in UHF Band for Metallic Object Application

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Abstract— In this article, a compact RFID tag antenna operated on UHF band with circular polarization is proposed. The antenna is comprised of a radiating square with two pairs of unequal crossed slots to produce a circularly polarized (CP) radiation and a simple quarter-wave microstrip line to feed the patch. A tag chip is embedded between the microstrip line and a short-circuited stub line. The simulated result for −3-dB power reflection coefficient (PRC) is about 27 MHz (904–931 MHz) that covers the RFID bands of North and South America and Taiwan (920–928 MHz) and its corresponding simulated 3-dB axial-ratio (AR) bandwidth is about 7 MHz (910–917 MHz). The overall antenna size is 75 mm × 75 mm × 1.6 mm at 915 MHz. The results show a perfect circularly polarized radiation.

1. INTRODUCTION

In recent years, applications for radio frequency identification (RFID) systems in the ultra-high frequency (UHF) band has been received much interest in several service industries, such as, purchasing, distribution logistics, and animal tracking applications [1]. For a commercial RFID system, it usually consists of a reader and many tags. The reader antenna generally has a circular polarization radiation pattern to increase the orientation diversity. However, most of RFID tags are linear polarization (LP) in the UHF frequency band. Therefore, the polarization mismatch between them would result in that only half of the transmission power is received by tags. But, if the tag antenna is also circularly polarized, the power received by the CP tag antenna can be improved by 3 dB, and the maximum reading range can thus be increased by 41%, theoretically [2].

Currentlya few antennas for RFID tag in UHF band with CP radiation are presented [3–5]. A compact circularly polarized tag antenna with a dimension of 80 mm × 80 mm × 1.6 mm at 915 MHz and a 3-dB AR bandwidth of 6 MHz is proposed in [3]. In [4], a circular microstrip RFID tag antenna for CP radiation has been presented. The antenna has a dimension of 74 mm × 74 mm × 1.6 mm at 915 MHz and a 3-dB AR bandwidth of 6 MHz. In [5], a circular polarization tag antenna with two diagonal dipoles is presented. The antenna has a dimension of 68 mm × 68 mm × 1 mm at 915 MHz and a wide 3-dB AR bandwidth of 31 MHz. But it is not used for metallic objects.

In this paper, a square-shaped CP tag antenna fed by a microstrip line is proposed in the UHF band. The proposed antenna exhibits a surface area of 75 mm × 75 mm × 1.6 mm at 915 MHz. And the antenna has a 3-dB AR bandwidth of 7 MHz, and its corresponding simulated −3-dB power reflection coefficient is 27 MHz (904–931 MHz). The antenna presents a good performance when it mounts on a ground plane.

2. ANTENNA DESIGN PROCESS

The final structure and dimensions of the proposed compact circularly polarized tag antenna is shown in Fig. 1. The antenna is fabricated on a FR4 substrate (ε_r=4.4, $\tan\delta = 0.02$) and has a thickness of H ($H = 1.6$ mm). The ground plane has a size of 75 mm × 75 mm. While the radiating patch has a length of L ($L = 58$ mm), and the radiating patch is loaded with two pairs of crossed slots which have unequal lengths, and equal width W ($W = 4$ mm). The crossed slots embedded to the patch at corners along the direction of $\phi = \pm 45°$ is used to produce a CP radiating pattern. The antenna is fed by a microstrip line at point of A. An IC chip is attached between the microstrip line and the short-circuited stub line, which is the red area as shown in Fig. 1.

In the proposed antenna, first, the radiating patch is loaded with four slits at the corners along the direction of $\phi = \pm 45°$. In order to reduce the size of the antenna, other slits are added to lengthen the resonant length. Then the antenna with four cross-shaped slits is presented, and a better circular polarization radiation is achieved. Here, an Alien Higgs chip with an input impedance of $13 - j111\Omega$ and a threshold power sensitivity of −18.5 dBm at 915 MHz is provided. The conjugate impedance of the antenna is achieved by turning the parameters L_1, L_2, t_1, and t_2. The parameters S_1, S_2, b and d are used as variables to optimize the circular polarization.

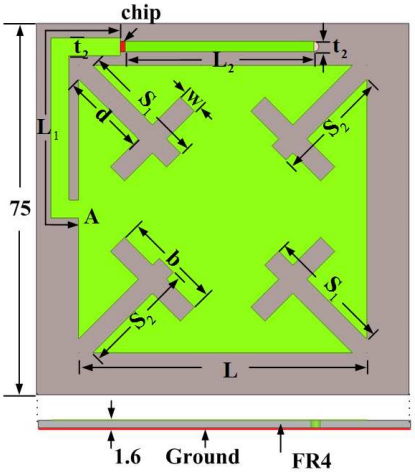

Figure 1: Geometry of the circularly polarized antenna.

3. RESULTS AND DISCUSSIONS

Note that the commercially available simulation software, Ansoft High Frequency Simulator Structure (HFSS) 14 is used for the simulated results. The simulated input impedance When $L_1 = 56\,\text{mm}$, $L_2 = 38\,\text{mm}$, $t_1 = 3.6\,\text{mm}$ and $t_2 = 2\,\text{mm}$ is presented in Fig. 2. The simulated input impedance is $13.2 + j112.4\Omega$ at approximately the center frequency 915 MHz. It is conjugately matched to the chip. The simulated power reflection coefficient of the proposed antenna is given in Fig. 3. The simulated −3-dB PRC bandwidth of the tag antenna is about 27 MHz (904–931 MHz). It completely covers the North and South American UHF RFID band which ranges from 902 to 928 MHz. When $S_1 = 56\,\text{mm}$, $S_2 = 38\,\text{mm}$, $b = 24\,\text{mm}$ and $d = 16\,\text{mm}$, the simulated CP bandwidth determined by the 3-dB axial ratio, is 7 MHz (910–917 MHz) and best at 913 MHz with $AR = 0.9\,\text{dB}$. The maximum simulated gain for the proposed antenna is about $-15\,\text{dB}$. The gain will be better when the antenna is mounted on a bigger metal plane.

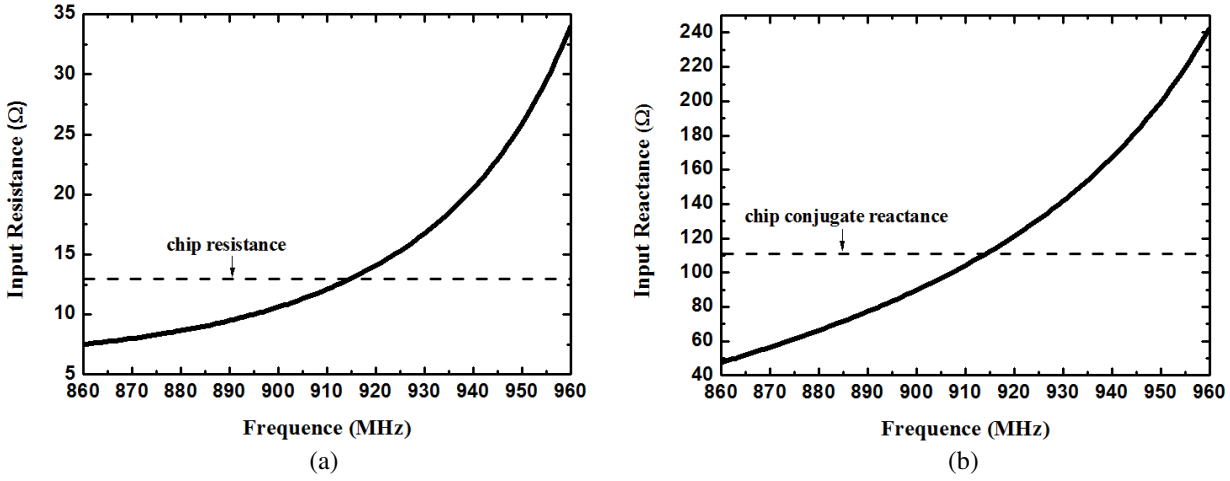

Figure 2: Simulated input impedance. (a) Input resistance. (b) Input reactance.

Here, a theoretical prediction for the reading range by considering the Friis transmission equation is presented as follow [6]:

$$r_{\max} = \frac{\lambda_0}{4\pi}\sqrt{\frac{P_t G_t G_r \rho\left(1-|\Gamma|^2\right)}{P_{th}}} \tag{1}$$

where λ_0 is the wavelength, P_t is the transmit power of the reader, G_t is the gain of reader antenna, P_{th} is the minimum threshold power required by the tag chip to respond, G_r is the gain of tag antenna, ρ is the polarization factor, and Γ is the reflection coefficient of tag antenna. In this case,

both the reader antenna and the proposed antenna are circularly polarized, thus $\rho = 1$. The total transmitted power is 4.0 W effective isotropic radiated power (EIRP). The calculated reading range of the proposed tag antenna is about 2.4 m at 915 MHz.

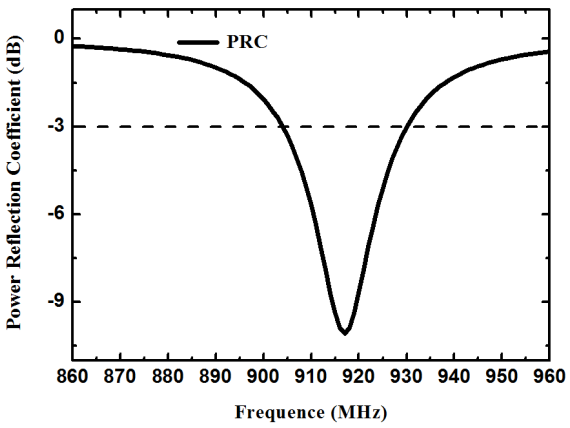

Figure 3: The simulated PRC of the proposed tag antenna.

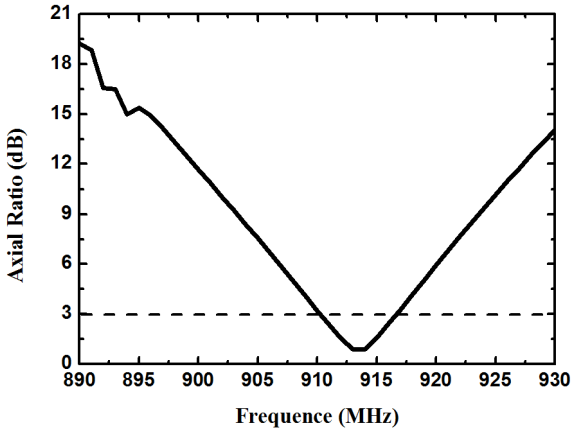

Figure 4: The simulated axial ratio.

4. CONCLUSION

A compact square-shaped tag antenna with excellent circular polarization has been designed. The circularly polarized bandwidth (910–917 MHz) obtained in this paper is determined by unequal crossed slots embed to the radiation patch. The complex impedance matching of the proposed tag antenna can be achieved by properly selecting the dimensions of the microstrip line and the short-circuited stub line. The power reflection coefficient is 27 MHz (904–931 MHz). The overall antenna size is 75 mm × 75 mm × 1.6 mm at 915 MHz. The simulated results verified a good CP radiation when it mounts on a metal plane. With smaller size, lower weight, and lower cost, the proposed tag antenna is a good candidate for metallic object application in the UHF band.

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