Proceedings of ISAP 2014, Kaohsiung, Taiwan, Dec. 2-5, 2014

Inverted-Z RFID Tag Antenna for Circularly Polarized Operation

Horng-Dean Chen, Ruenn-Bo Tsai, Ching-Han Tsai, and Ting-Yuan Liu
Department of Optoelectronics and Communication Engineering, National Kaohsiung Normal University, Kaohsiung, Taiwan

***Abstract* - A novel inverted-Z tag antenna for circularly polarized operation in the UHF band RFID application is proposed. The structure of the proposed tag antenna comprises two inverted-Z strips, one printed on top side and the other on bottom side of the substrate, perpendicularly to each other. The measured 10-dB impedance bandwidth of the tag antenna is 33 MHz (897–930 MHz), and its 3-dB axial-ratio bandwidth is 32 MHz (899–931 MHz). The antenna gain and reading range of about 1.38 dBic and 14 m, respectively, were also demonstrated.**

***Index Terms* — Tag antenna, circular polarization, radio frequency identification (RFID).**

I. Introduction

At present, the use of commercial RFID system operating in the UHF band (902–928 MHz) usually requires a circularly polarized (CP) reader antenna for orientation diversity, and the available RFID tags are commonly designed as dipole- or microstrip-type with linear polarization (LP) [1, 2]. Obviously, only half of the power transmitted by a CP reader antenna is received by a LP tag because of the polarization mismatch. However, if a CP tag antenna with the same polarized orientation as a CP reader antenna is used, the maximum reading range of a CP tag can be improved by approximately 41% as compared with a LP tag. Hence, the design of a tag antenna with CP radiation is a very important topic in the RFID community. To date, a few CP tag antennas have been studied [3]–[5].

In this paper, an alternative design for exciting a CP tag antenna using two identical inverted-Z strips is proposed. To obtain the desired input impedance, the technique of loading a matching stub across the antenna's feed point is introduced. Furthermore, CP radiation can be achieved by adjusting the length of the open gap between the two inverted-Z strips. The various parametric designs through simulation and measurement were carried out.

II. Antenna Structure and Design

As shown in Fig. 1, the proposed antenna comprises two identical inverted-Z strips, which are fabricated on the top and bottom sides of an FR4 substrate with 85 × 85 mm^2 size and 0.4 mm thickness, respectively. The top inverted-Z strip has a feed point at the distance s from the y-axis. A matching stub with dimensions $L_x \times L_y$ is loaded across the feed point. The width of the gaps at the right-upper and left-lower corners of the substrate is g.

In this design, the tag chip (Alien Higgs IC) has an impedance of 13 – j111 Ω at 915 MHz. Therefore, the input impedance of the proposed antenna must be 13 + j111 Ω, so that optimal power transfer between the antenna and the tag chip can be achieved. By properly selecting the feed distance s and the parameters L_x, L_y and t of the matching stub, good conjugate impedance matching can be realized. Also, by tuning the gap width g, good CP radiation can be excited.

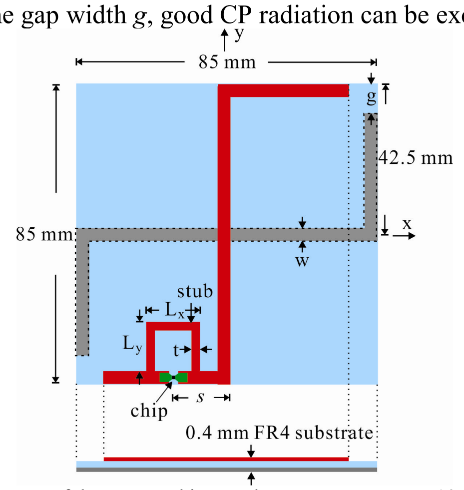
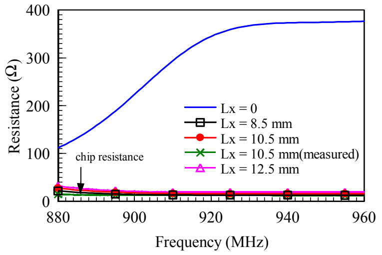


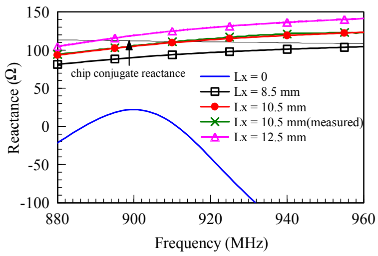
Fig. 1 Structure of the proposed inverted-Z tag antenna; L_x = 10.5 mm, L_y = 6.8 mm, t = 0.6 mm, s = 15 mm, g = 7.3 mm, w = 2 mm.

III. Results and Discussions

The design of the proposed tag antenna was achieved by using the commercially electromagnetic simulation software HFSS. Fig. 2 shows the simulated input impedances of the proposed tag antenna for various values of L_x. It is first seen that for the case without the matching stub (L_x = 0), the input reactance at 915 MHz is about −16 Ω, which is much smaller than the desired reactance of 111 Ω. At L_x = 10.5 mm, the antenna has an input impedance of 15 + j112 Ω at 915 MHz. This completes the conjugate impedance matching between the antenna and the chip. Fig. 3 shows the measured and simulated power reflection coefficients for the case of L_x = 10.5 mm. Good agreement between the measurement and the simulation is observed. The measured impedance bandwidth, determined from −10 dB power reflection coefficient, is 33 MHz (897–930 MHz, 3.6%) and it can cover the RFID UHF band (902–928 MHz). The effects of the gap width g on the CP performances were studied, and the simulated axial ratio (AR) is shown in Fig. 4. It is observed that the decrease of g has resulted in moving the CP operating frequency to the lower frequency. When g = 7.3 mm, a right-hand CP wave with a 3-dB AR bandwidth of 32 MHz (899–931 MHz, 3.5%) was obtained. Fig. 5 presents the simulated radiation patterns of the proposed antenna. The typical bidirectional patterns with maximum radiation at $\theta = 0^\circ$ and 180° are exhibited in the two principal planes. As both E_θ and E_ϕ at $\theta = 0^\circ$ and 180° are nearly equal, it also shows that the proposed antenna has good CP radiation. Fig. 6 presents the simulated gains of the proposed antenna. The gain of 1.38 dBic at 915 MHz was attained.



(a)



(b)

Fig. 2 Simulated and measured input impedances by tuning L_x. (a) Input resistance; (b) Input reactance.

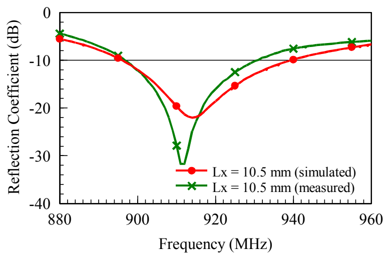


Fig. 3 Simulated and measured reflection coefficient of the proposed antenna.

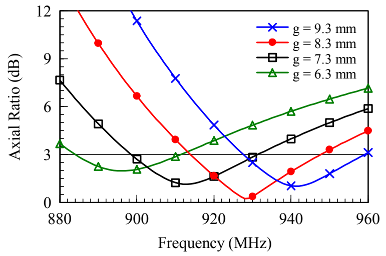


Fig. 4 Simulated axial ratio by tuning the gap width g.

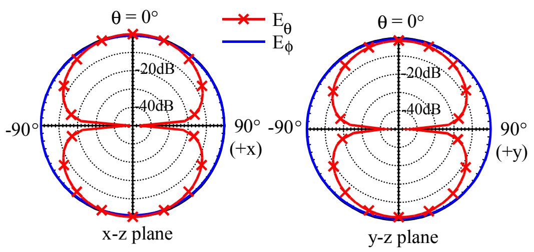


Fig. 5 Simulated radiation patterns at 915 MHz for the proposed antenna.

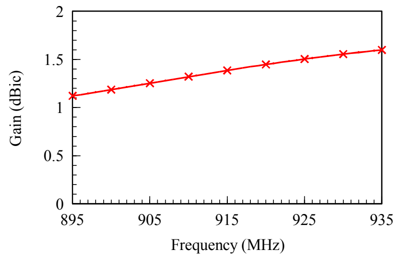


Fig. 6 Simulated antenna gain of the proposed antenna.

To perform the reading range measurement, an RFID reader module (Favite FS-GM201) with operating frequency of 902–928 MHz and 30 dBm output power was used, and LP and CP reader antennas were separately attached to this reader module. Here, the gain of the LP reader antenna (Favite, FS-GA203) is 10 dBi, while the gain of CP reader antenna (Motorola, AN400) is 9 dBic. The measurements of the reading ranges were performed by rotating the proposed tag antenna along the ϕ direction. The reading ranges measured by the LP reader antenna are between 10.6 and 11 m at all ϕ angles. As for the CP reader antenna, the reading ranges around 14 m are obtained at all ϕ angles, which is approximately 3 m longer than the LP type, even though the gain of CP reader antenna (9 dBic) is smaller. This is due to good polarization matching between the reader antenna and the proposed tag antenna.

IV. Conclusion

A novel CP RFID tag antenna with two identical Z-inverted strips has been successfully implemented and studied. The measured impedance bandwidth and CP bandwidth of the proposed tag antenna were 33 MHz (897–930 MHz) and 32 MHz (899–931 MHz), respectively. Furthermore, the reading range measured by using CP reader antenna was about 14 m. Therefore, the proposed antenna is suitable for long reading distance RFID applications in the UHF band.

References

[1] G. Marrocco, “The art of UHF RFID antenna design: impedance-matching and size-reduction techniques,” *IEEE Antennas Propag. Mag.*, vol. 50, no. 1, pp. 66–79, 2008.

[2] S. L. Chen and K. H. Lin, “A slim RFID tag antenna design for metallic object applications,” *IEEE Antennas Wireless Propag. Lett.*, vol. 7, 729–732, 2008.

[3] D. D. Deavours, “A circularly polarized planar antenna modified for passive UHF RFID,” in *Proc. 2009 IEEE Int. Conf. RFID*, pp. 265–269.

[4] C. Cho, I. Park, and H. Choo, “Design of a circularly polarized tag antenna for increased reading range,” *IEEE Trans. Antennas Propag.*, vol. 57, no. 10, pp. 3418–3422, 2009.

[5] H. D. Chen, S. H. Kuo, C. Y. D. Sim, and C. H. Tsai, “Coupling-feed circularly polarized RFID tag antenna mountable on metallic surface,” *IEEE Trans. Antennas Propag.*, vol. 60, no. 5, pp. 2166–2174, 2012.