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INTEGRATED COMPACT CIRCULAR POLARIZATION ANNULAR RING SLOT ANTENNA DESIGN FOR RFID READER

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Abstract—An integrated compact circular-polarized annular ring slot antenna is proposed in this paper. It consists of an annular ring slot radiator and a hybrid patch coupler. The hybrid patch coupler is integrated with the annular ring slot antenna to radiate the circular-polarized wave, while size of the antenna remains the same. Both the impedance bandwidth and axial ratio bandwidth of the proposed design almost cover the entire UHF band of RFID system and it has the features of easy fabrication and low cost. To verify the proposed design, a prototype is fabricated. Measured results agree well with the simulated results.

1. INTRODUCTION

Radio frequency identification (RFID) mainly consists of a reader and a tag. For the reader antenna, circular polarization (CP) is preferred because it can reduce the loss caused by the multi-path effects between the reader and the tag antenna [1–3]. In addition, a compact size is often required because of the limited space in the portable devices.

CP can be realized by the perturbation method or the orthogonal feed technique. CP is formed by the perturbation method in [4–6]. By introducing asymmetry in the ring slot and arranging the feeding point in [4], CP is realized for the annular and rectangular ring slot antennas. The CP is realized by selecting a proper length of the shorted section in the ring slot in [5]. In [6], CP is realized by placing a metal strip across the diagonal line of the aperture. However, the axial ratio bandwidth is very narrow using this method. To address this issue, power divider or coupler, which generates the same amplitude but 90°

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phase differences at the two output port, is used to feed the antenna to obtain wide AR bandwidth in [1, 7–9]. Wilkson power divider is place inside the rectangular ring antenna to obtain CP in [1] and an additional matching network is needed for this method. Dual-Fed method is used to form CP in [7]. Circular ring slot antenna is fed by stripline hybrid coupler in [8]. Since multilayer structure is used in [8], it is not easy to fabricate. Patch hybrid coupler is integrated with the rectangular ring antenna in [9] to achieve a compact circular polarized antenna, but the radiation bandwidth is narrow for this design. In addition, because of the compact size of the ring and ring slot antenna, it has been widely used for different antenna designs such as UWB [10] and dual band applications [11–13].

In this paper, annular ring slot antenna is integrated with the hybrid patch coupler to radiate the circular polarized wave. Meanwhile, because hybrid patch coupler is at the bottom of the annular ring slot antenna, the inner ground of the ring slot antenna can be considered as the ground plane of the hybrid patch coupler. With this novel configuration, CP is realized with broad bandwidth. In addition, the antenna size is not affected by the additional patch coupler and a very compact structure is obtained. Both the impedance bandwidth and axial ratio bandwidth of the proposed antenna almost cover the entire UHF band for RFID system.

2. THE PROPOSED ANTENNA DESIGN

As shown in Figure 1, the proposed antenna consists of an annular ring slot radiator on the top layer and a hybrid patch coupler on the bottom layer. When the annular ring slot antenna operates at its fundamental mode TM_{11}, circumference of the annular ring should be one free space wavelength [14], which means the radius of the annular ring slot antenna is only about 0.32 free space wavelength. To match the antenna to the 50-ohms feed line, the coupled open-ended microstrip line is used here to feed the slot ring antenna, as shown in Figure 2. By tuning l_f and w_f, the input impedance of this antenna can be changed easily, and a good matching condition can be achieved.

Following the design guideline in [15], a miniaturized hybrid patch coupler is designed to feed the antenna. It is employed here to provide power assignment with the same amplitude but 90° phase difference and is placed on the bottom of the FR4 substrate. By this arrangement, the inner ground plane on the top layer can be considered as the ground plane of the hybrid coupler. As a result, the proposed antenna can radiate circular polarized wave with an integrated compact configuration.

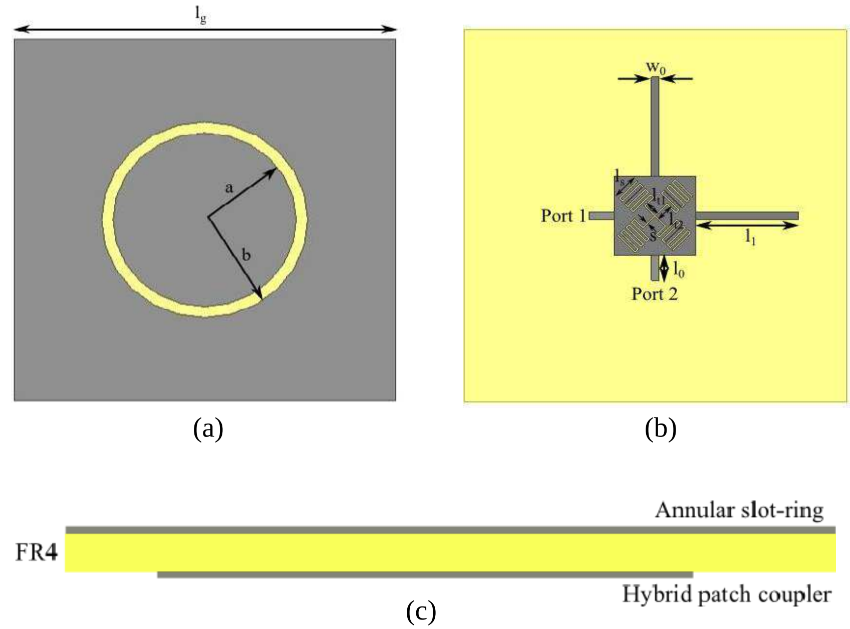


Figure 1. Configuration of the proposed antenna. (a) Top view. (b) Bottom view. (c) Cross view.

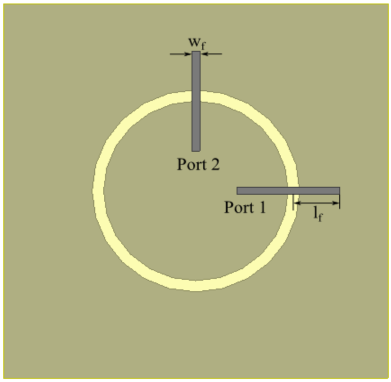


Figure 2. Annular ring slot antenna with open-ended matching microstrip line.

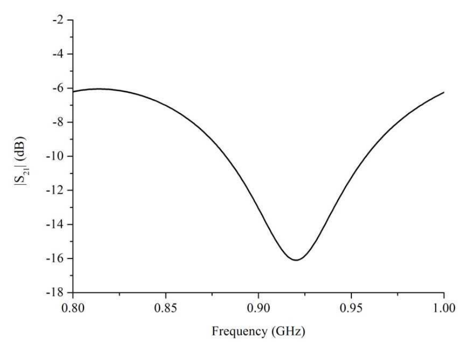


Figure 3. Isolation between two input ports of the annular ring slot antenna.

The proposed antenna is simulated with the commercial full wave solver HFSS, and the final dimensions of the proposed antenna are shown in Table 1. Figure 3 shows the isolation between the two input ports of the annular ring slot antenna. As can be seen, isolation between the two ports is almost lower than -10 dB within the operating bandwidth. The performances of the hybrid patch coupler are depicted in Figure 4 too. It is found that there is a good amplitude balance with 90° phase difference at two output ports. Then the annular ring slot antenna and the hybrid patch coupler are integrated together to radiate the circular polarized wave with compact size. The simulated $|S_{11}|$ of the integrated antenna is shown in Figure 5. It is found the proposed antenna operated from 830 MHz–950 MHz ($|S_{11}| < -10$ dB) and almost covers the entire UHF band. As shown in Figure 6, a bidirectional radiation pattern is obtained. Gain of the

Table 1. Final dimensions of the proposed antenna (unit: mm).

Parameters	value	Parameters	value
a	36	s	0.5
b	40.5	l_s	10
l_g	150	l_{t1}	5.25
w_0	3	l_{t2}	6.25
l_0	10	h	1.6
l_1	40		

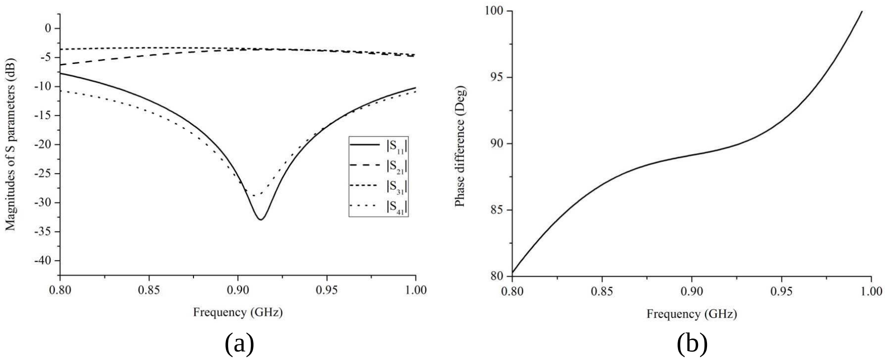


Figure 4. Performances of the hybrid patch coupler. (a) Magnitudes of S parameters of hybrid patch coupler. (b) Phase difference of two output ports of hybrid patch coupler.

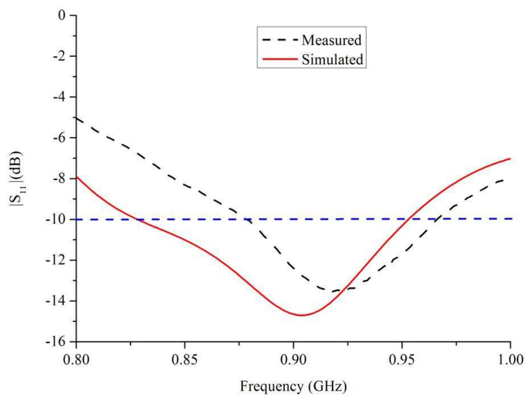


Figure 5. Simulated and measured magnitudes of $|S_{11}|$.

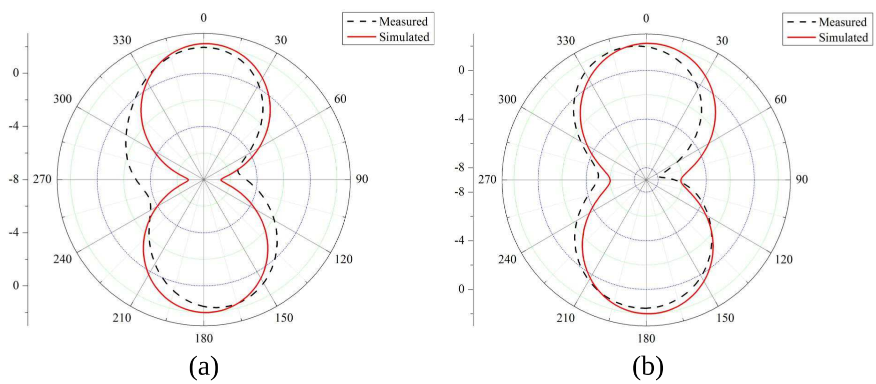


Figure 6. Simulated and measured radiation @ 915 MHz. (a) E plane. (b) H plane.

proposed antenna at the operating band is shown in Figure 7. The peak gain over the entire UHF band is from 1 dBi to 2.2 dBi. Figure 8 shows the simulated axial ratio of the proposed antenna, the bandwidth of axial ratio (AR < 3 dB) is 870 MHz–960 MHz. Based on the simulated results, the proposed antenna has a good performance in the entire UHF band and is a good candidate for the RFID reader antenna.

3. EXPERIMENTAL RESULTS AND DISCUSSION

To verify the proposed antenna, a prototype is fabricated and measured. Photograph of the fabricated antenna is shown in Figure 9.

Measure $|S_{11}|$ is shown in Figure 5. It agrees well with the simulated results except a slightly frequency shift, which is mainly caused by the poor characteristics of the cheap FR4 substrate. The radiation pattern of this antenna is measured in a microwave chamber, and a good symmetry of the bidirectional radiation pattern is observed, as shown in Figure 6.

Figure 7 shows the measured gain of the proposed antenna, good agreement is obtained between the simulated and measured results. The measured gain is larger than 1 dB in the entire UHF RFID band with small fluctuation. However, there is a discrepancy between the simulated axial ratio and measured axial ratio. It is because that axial

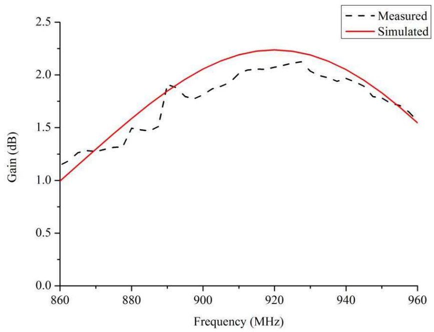


Figure 7. Simulated and measured gain of the proposed antenna.

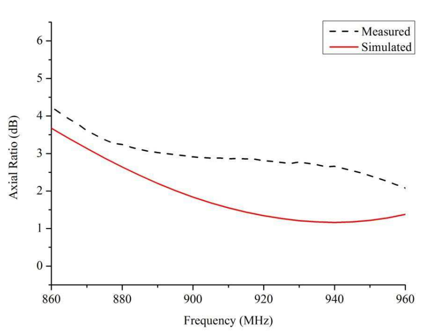
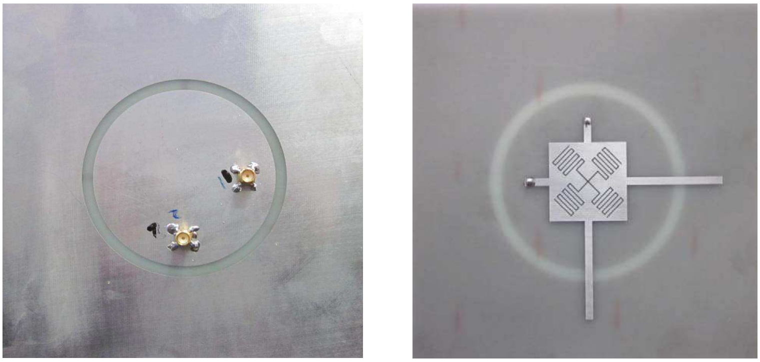


Figure 8. Simulated and measured axial ratio of the proposed antenna.



(a) (b)

Figure 9. Photograph of the fabricated antenna. (a) Top view. (b) Bottom view.

ratio is sensitive to the amplitude balance and phase differences, and both of them are related to the unstable FR4 substrate. The axial ratio bandwidth with AR < 3 dB for the simulated result covers from 870 MHz–960 MHz, while the measured one is 885 MHz–960 MHz.

4. CONCLUSION

A compact bidirectional radiated circular polarized annular ring slot antenna is designed, fabricated and measured in this paper. The measured results show that the proposed antenna not only has a wide impedance bandwidth, but also has a wide axial ratio bandwidth. It almost covers the entire UHF band of the RFID system. In addition, the proposed antenna has the features of easy fabrication and low cost and is suitable for mass production.

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