Design of Broadband Circularly Polarized Antenna for UHF-RFID Reader

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ABSTRACT

A new planar broadband circularly polarized reader antenna that operates within the ultra-high frequency (UHF) band is proposed for global UHF radio frequency identification (RFID) applications. By modifying the ground plane, two orthogonal modes that have equal amplitude and are 90^{o} out of phase are simultaneously excited. Broadband characteristics can be achieved using the symmetrical cross-shaped coplanar waveguide (CPW) feed line. The simulated and measured 10-dB impedance bandwidths are 242MHz (813-1055MHz) and 246MHz (805-1051MHz), while their 3-dB axial ratio (AR) bandwidths are 124MHz (856-980MHz) and 155MHz (815-970MHz), respectively.

1. INTRODUCTION

RFID system operation at UHF has gained considerable interests in many commercial applications, such as logistics management, inventory control and vehicle management [1]. There are several standards that regulate the use of RFID systems depending on region. For example, the UHF-RFID system operates at the bands of north and south of America (902-928 MHz), China (920.5-924.5 MHz), Europe (866-869 MHz) and Japan (952-955 MHz). In RFID system, the reader antenna plays an important role in the information exchange between the RFID reader and tag, and the reader antenna should be designed with circular polarization and broadband, since the tags are always arbitrarily oriented in practical usage and tag antennas are normally linearly polarized, circularly polarized reader antenna can receive the linearly polarized signal from arbitrarily oriented tag and improve the reliability of communication between reader and tag [2]. Meanwhile, due to the differences in operating frequencies, a broadband circularly polarized reader antenna is needed to meet the overall bandwidth specification of global RFID system.

Numerous circularly polarized reader antennas for UHF-RFID system have been presented, such as single-layer printed planar type [3]-[4] and broadband stacked type [5]-[6]. Although, the single-layer printed type enjoys the advantages such as low profile, low cost and ease in manufacturing, its circular polarization bandwidth is usually narrow [3]-[4] and cannot meet requirements of global UHF-RFID system. Hence, a number of broadband circularly polarized reader antennas with top loading design for UHF-RFID applications have been studied [5]-[6]. However, those stacked antenna designs have disadvantage of complex structure. To improve the operating bandwidth and not increase the antenna complexity, a novel simple slot antenna fed by a CPW is proposed in this paper. The structure is made of copper plate with FR-4 substrate, the circular polarization and broadband characteristics can be obtained by employing asymmetrical ground plane and symmetrical cross-shaped feed line into the slot antenna, respectively. The proposed antenna is designed to cover the UHF-RFID band of 860-960 MHz with acceptable performance in terms of gain, AR, impedance matching and reading-range. Meanwhile, the antenna configuration is simple and easy for fabrication. Detail

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of the antenna design is described and its simulation and measurement results are presented and discussed as well.

2. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed broadband circularly polarized antenna. The slot antenna with width W and length L is fabricated on an FR4 substrate of relative permittivity $\varepsilon_r = 4.4$ and height $h = 0.8$ mm. The symmetrical cross-shaped feed line with width W_f and length (L_{f1}, L_{f2}) is used for impedance matching. Its horizontal section is located 5mm (D_g) away from the edge of ground plane. The radiator is electromagnetically coupled to a 50Ω CPW located along the vertical center line of the patch. The end of the line is symmetrical cross-shaped to increase its impedance. The other end of CPW connected to an SMA connector directly. The asymmetrical ground plane with width (W_g) and length (L_{g1}, L_{g2}) is used to obtain circularly polarized characteristic. To achieve excellent broadband circularly polarized characteristics, these antenna dimensions need to be carefully adjusted. The antenna was simulated using the HFSS simulation software. The parameter values are: $W = 115$ mm, $L = 97$ mm, $W_f = 1.9$ mm, $L_{f1} = 84$ mm, $L_{f2} = 91$ mm, $D_g = 5.5$ mm, $W_g = 56.35$ mm, $L_{g1} = 58$ mm, $L_{g2} = 38$ mm.

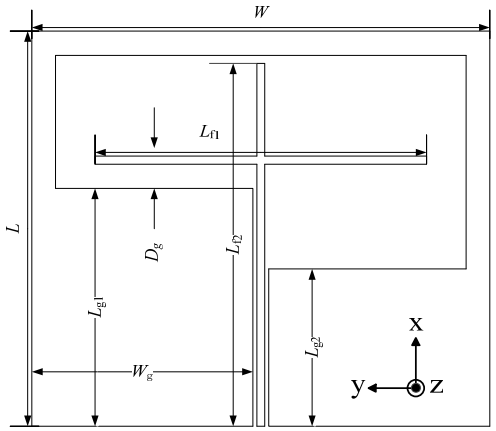
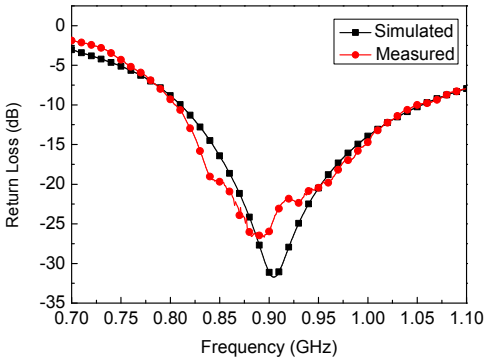
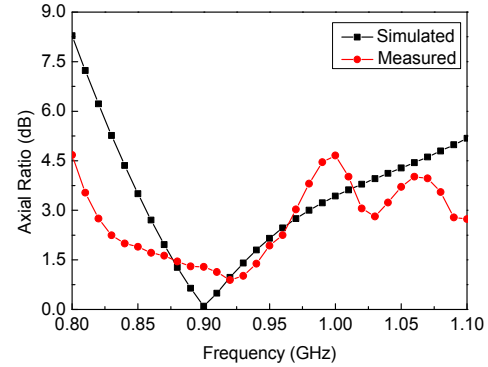


Figure 1 Geometry of the proposed broadband circularly polarized antenna for UHF-RFID reader

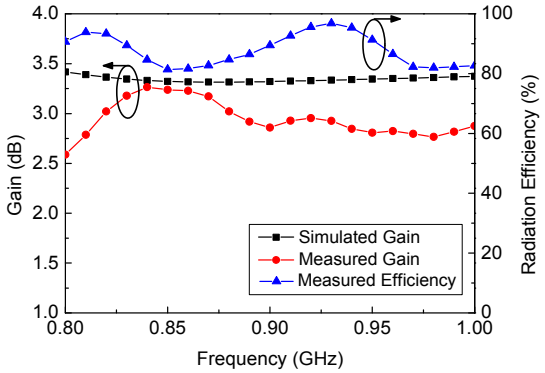
The proposed circularly polarized antenna is designed to operate at the centre frequency of about 900 MHz in the UHF band for the RFID reader. The return loss is measured using an N5230C vector network analyzer, and AR and radiation patterns are evaluated in an anechoic chamber using the Satimo antenna measurement system. Figure 2 (a) shows the simulated and measured return loss of the proposed antenna, which has broad impedance bandwidth owing to the good impedance matching. The measured impedance bandwidth for 10-dB return loss is 26.5%, ranging from 805 to 1051 MHz, and agrees well with the HFSS simulated results (813-1055 MHz). Figure 2 (b) exhibits the simulated and measured AR of the antenna at boresight. The measured AR bandwidth is less than 3dB over the frequency range of 815-970 MHz (17.4%), which covers the entire UHF-RFID band, and agrees well with the simulated results (856-980 MHz). Note that the measured minimum AR value is about 1 dB at 920 MHz, indicating that the circular polarization is very pure. The gain and efficiency versus frequency compared between the simulation and the measurement is shown in Figure 2 (c). It can be observed that the measured peak gain and radiation efficiency is more than 2.7 dB and 80% over the 860-960 MHz. The measured and simulated circularly polarized radiation pattern at 900 MHz is plotted in Figure 3. In the X-Z and Y-Z planes, symmetrical patterns and wide-angle AR characteristics have been observed. The HPBW (half power beam width) and 3-dB AR beamwidth of the antenna prototype at 900 MHz are about 104^o and 95^o (X-Z plane) and about 95^o and 110^o (Y-Z plane). To validate the superior features of proposed antenna in practical usage, the reading-range a measurement was carried out. The proposed antenna was attached to a Kaile RFID reader (KL9007T) with operating frequency 902-928 MHz and 30 dBm output power. A standard tag (ALN-9640) is introduced for the measurement. From the measured results, maximum reading-range (at boresight) in free space is maintained between 1.6-2 meters.



(a)

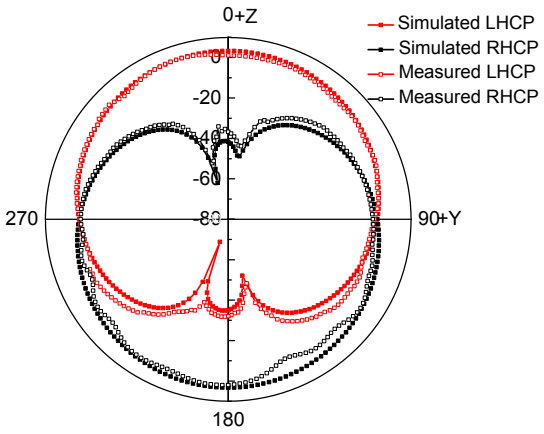


(b)

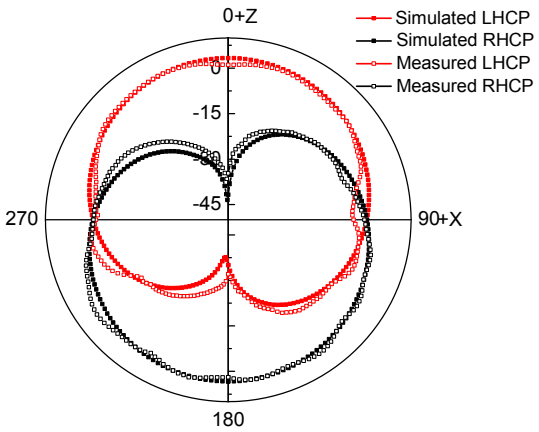


(c)

Figure 2 Simulated and measured results against frequency for the proposed broadband circularly polarized antenna. (a) Return Loss (b) Axial Ratio and (c) Gain



(a)



(b)

Figure 3 Simulated and measured LHCP/RHCP radiation patterns for the proposed broadband circularly polarized antenna at 900 MHz (a) X-Z plane and (b) Y-Z plane

3. CONCLUSIONS

In this paper, a new microstrip slot antenna was shown to provide wide circular polarization over UHF-RFID band. The structure employs an asymmetrical ground plane and symmetrical cross-shaped CPW feed line which enable the generation of circular polarization and broadband characteristics, respectively. Furthermore, the proposed compact antenna uses a simple design, with lower weight, smaller volume and low cost. It is very likely to confirm that the antenna can be applicable for wireless terminals of global UHF-RFID system.

4. ACKNOWLEDGEMENT

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