

# Compact Circularly Polarized RFID Tag Antenna with an Embedded L-shaped Feedline for Metallic Objects

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**Abstract**— An ultra-high frequency (UHF) passive radio frequency identification (RFID) tag antenna with circular polarization for metallic objects is proposed. Using a novel and embedded L shape microstrip line to feed, a good performance of impedance matching is achieved. The proposed antenna can cover the whole operating frequency of UHF RFID system from 860 MHz to 960 MHz. The 3-dB circular polarization bandwidth is 7 MHz (from 916 to 923 MHz). The optimized antenna has a high gain of  $-5.5$  dBi in 0 degree direction. The main parameters of the antenna are also discussed.

## 1. INTRODUCTION

In recent years, the applications of radio frequency identification (RFID) operating in the ultrahigh frequency (UHF) become more and more extensive. Long reading distance, high data rate transfer, and small tag size are needed to achieve a good RFID system. As the majority of reader antennas are designed with circular polarization (CP) for orientation diversity in a commercial RFID application, the polarization mismatch occurs if the tag antenna uses a linear polarization (LP) such as in [1] and [2]. The polarization mismatch will result in that only half of the transmitted power can be received by the LP tag and the reading range decreases. To provide high directivity and narrow beamwidth in certain areas, some RFID readers are designed with linear polarization. In this case, if the LP tag is attached inadequately to the targeted object with different direction, the polarization will mismatch, and the RFID reader will not identify the targeted object. Thus, to resolve the polarization mismatch problem, the study of CP tag antenna is necessary.

Many studies have been done about the CP tag antenna. In [3–5], the tag antenna is designed with a good circular polarization, impedance matching and an excellent performance when the tag antenna is mounted on metallic plates. However, all the feedlines are outside the radiator and consequently the size of the tag antenna is big.

A center frequency of 920 MHz broadband RFID tag antenna with circular polarization for metallic objects is proposed in this paper. The antenna is used a novel L-shape feedline embedded in two cross rectangular slots of unequal lengths. To get a smaller size of antenna, another two L-shape slots are designed in opposite corner of patch. The parameters of this antenna are simulated and discussed in this paper.

## 2. ANTENNA DESIGN

The substrate we used is FR4 layer (relative permittivity of 4.4, loss tangent of 0.02) with a thickness of  $h = 1.6$  mm. The two L-shaped slots with width of 2 mm, length of  $S_1$  and  $S_2$  in opposite corners are etched on the  $60 \text{ mm} \times 60 \text{ mm}$  radiating patch to produce CP. The ground plane size is  $86 \text{ mm} \times 86 \text{ mm}$  and the operating frequency band is from 695 MHz to 1060 MHz. A terminal grounded L-shaped feedline is embedded in two cross rectangular slots to couple and excite the patch antenna. The impedance of the welded Monza4 tag chip is  $11 + j143K$  at 920 MHz. The length of the feedline should be set to 27.9 mm according to the theory of short-circuited transmission line in [6]. Considering the electromagnetic coupling effect [7], the feed line length should be slightly tuned to 37.5 mm to ensure the antenna impedance is matched to the impedance of the tag chip. The geometry of the proposed tag antenna is shown in Fig. 1. Table 1 shows the detailed dimension of the designed antenna.

## 3. RESULTS AND DISCUSSIONS

In this paper, the tag antenna is simulated and optimized by the ANSYS HFSS. Since the tag chip has the feature of low impedance and high reactance, the impedance matching is an important part of the tag antenna design. Fig. 2 shows the simulated input impedance. At 920 MHz, the input impedance is  $37 + j142 \Omega$ , which matches to the tag chip impedance. As shown in Fig. 3, the return

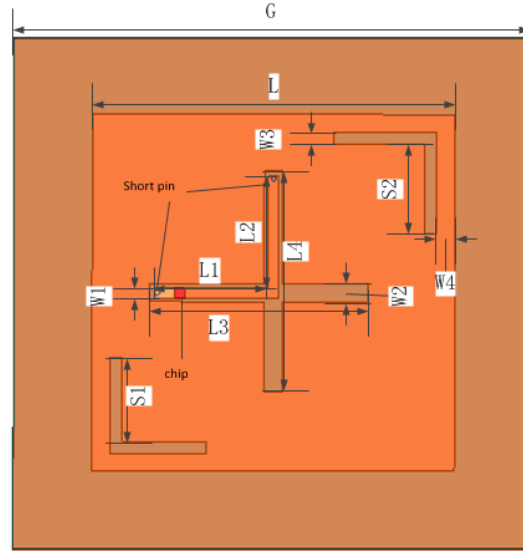


Figure 1: Geometry of the tag antenna.

Table 1: Detailed dimensions of the proposed antenna (Unit: mm).

$G$	$L$	$L1$	$L2$	$L3$	$L4$
86	60	18.75	18.75	36.2	37.2
$W1$	$W2$	$W3$	$W4$	$S1$	$S2$
1.7	3	2	3	14	15

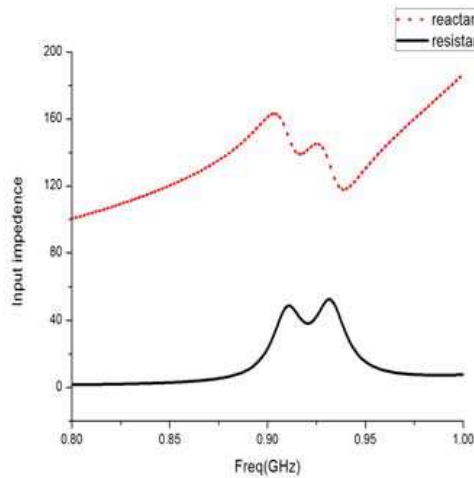
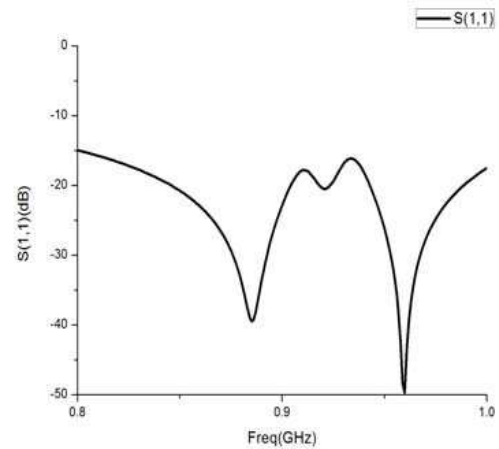


Figure 2: Input impedance of the antenna.

Figure 3: The  $S_{11}$  of the antenna.

loss ( $S_{11}$  parameter) of the antenna in the entire RFID ultra-high frequency 860 MHz  $\sim$  960 MHz are below  $-10$  dB, and the return loss parameter is below  $-21$  dB at 920 MHz.

Figure 4 shows the simulated CP radiation patterns at 920 MHz. In Fig. 4, the 3-dB axial ratio is from 916 MHz to 923 MHz. Compared the situation without the two L-shaped slots, the center frequency of the axial ratio moves from 955 MHz (without L-shaped slots) to move 920 MHz (with the L-shaped slots). Fig. 5 also shows the simulated gains of our tag antenna in different placement environment (mounted on metal plates of various sizes). On the metal surface, our tag antenna still has a good gain characteristic. Since the metal surface of the antenna can increase the current area, it also plays a role in increasing the antenna gain. Fig. 6 shows the simulated 2-D and 3-D

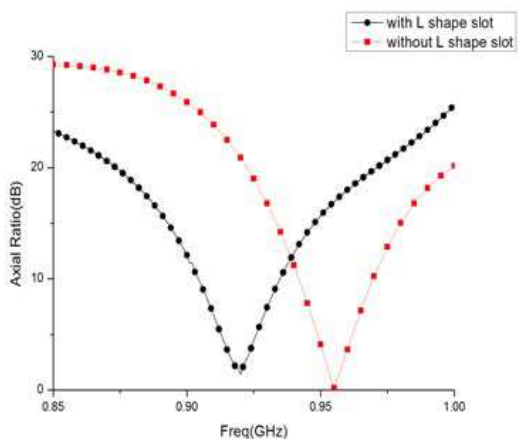


Figure 4: Simulated axial ratio of the antenna.

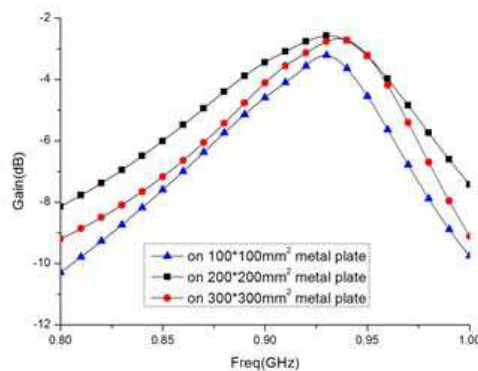


Figure 5: Simulated gains of the antenna mounted on a metal plate of various sizes.

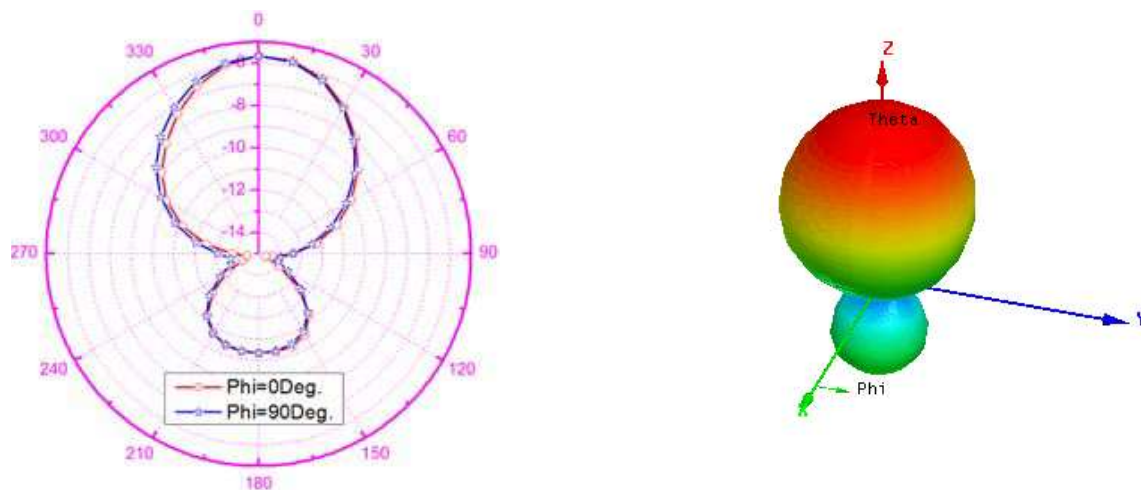


Figure 6: Simulated radiation patterns at 920 MHz.

Table 2: Comparison of antenna performances between the proposed antenna and the antennas in [4] and [8].

Proposed optimal antennas with different ground plane sizes (mm <sup>2</sup> )	Simulated Gain (Gr)	AR bandwidth
Proposed antenna (80 × 80)	-6.15 dBic	7 MHz
[4] (80 × 80)	-11.4 dBic	6 MHz
Proposed antenna (100 × 100)	-3.22 dBic	8 MHz
[8] (100 × 100)	-8 dBic	8 MHz

radiation pattern of the antenna at 920 MHz, and the max gains is about -5.5 dBi in 0 degree direction. The radiation gains on the *XOY* and *YOZ* planes are good.

To further illustrate the advantages of our antenna compared to [8] and [9], we discuss in detail the differences in gain and AR bandwidth with the same ground size. As we can see from Table 2, our optimized antenna has a higher gain and a wider AR bandwidth.

#### 4. CONCLUSION

A compact circularly polarized RFID tag antenna was proposed with an embedded L-shaped feed-line for metallic objects. The impedance matching, return loss, axial ratio and gain of the proposed

antenna had been analyzed and discussed. The Monza4 tag chip was selected. The proposed antenna can achieve a good impedance conjugate matching at the 920 MHz, realize circular polarization at 920 MHz and also has a stable gain on a metal surface of different size.

#### ACKNOWLEDGMENT

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