A Novel Antenna Design for UHF RFID Tag on Metallic Objects

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Abstract— A novel microstrip patch RFID tag antenna with wideband characteristic is proposed. It has less sensitive characteristic against size of metallic object, wide impedance bandwidth and long reading distance. The antenna consists of shorting strip, open stubs, tag IC and radiating patch having I-shaped slits. The proposed antenna is located on the finite ground plane and is constructed on FR4 substrate ($\varepsilon_r = 4.4, \tan\delta = 0.02$). Overall dimension of the antenna is $100\,\text{mm}\times 26\,\text{mm}\times 6\,\text{mm}$. The tag IC has input impedance of $43 - j800\,\Omega$ at 915 MHz. The -3 dB impedance bandwidth is from 696 MHz to 978 MHz. When the antenna is placed in free space and mounted on $200\,\text{mm}\times 200\,\text{mm}$, $400\,\text{mm}\times 400\,\text{mm}$ and $600\,\text{mm}\times 600\,\text{mm}$ metallic plates, the peak gains are 4.7 dBi, 2.4 dBi, 2.3 dBi and 1.7 dBi, respectively. The radiation efficiencies are 69%, 40%, 38% and 38%, respectively, and the maximum reading distances are 5.13 m, 6 m, 5.75 m and 4.75 m, respectively.

1. INTRODUCTION

Recently, radio frequency identification (RFID) in the UHF band has gained popularity in many applications, since it provided a broad readable range, fast reading speed, and large information storage capability. In RFID system, tags are usually attached to objects having various material properties. Among them, metallic objects strongly affect the performance of antenna including radiation efficiency, gain, etc.. Planar inverted-F and microstrip patch antennas have been proposed for RFID tag application. However, these antennas have narrow impedance bandwidth and resonant frequency can be easily shifted due to the characteristics of objects that tag antennas are attached to.

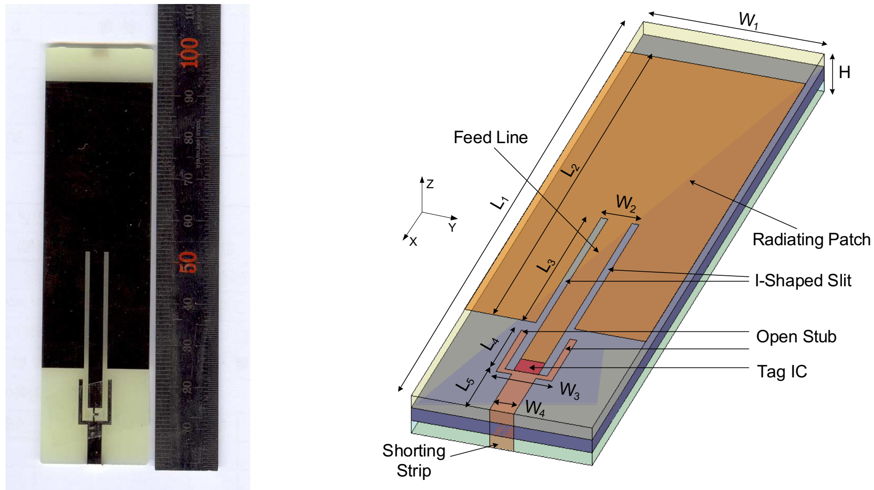
In this paper, a novel microstrip patch RFID tag antenna with wideband characteristic is proposed. It has a less sensitive characteristic against size of metallic object, wide impedance bandwidth and a long reading distance. The resonant frequency and impedance bandwidth can be controlled by adjusting the lengthes of I-shaped slits and open stubs, and a gap distance between the open stub and feed line. High radiation efficiency and peak gain are achieved by using shorting strip.

2. STRUCTURE AND DESIGN

The geometry of the proposed antenna is shown in Fig. 1. The antenna consists of shorting strip, open stubs, tag IC and radiating patch having I-shaped slits. The values of parameters are listed in Table 1. The width of open stubs and I-Shaped slits is 1 mm. The radiating patch is a metal plate with length L_2 and width W_1. The length L_1, L_2 and width W_1 are optimized to a tag chip with an impedance $Z_c = (43 - j800)\,\Omega$ at 915 MHz. It means that the load antenna impedance should be $43 + j800\,\Omega$ for conjugate matching and to transmit the maximum power between the antenna and the microchip. The tag chip feed is placed at one end of the feed line, and the other end is terminated by shorting strip and ground. The radiating patch is constructed on FR4 substrate ($\varepsilon_r = 4.4$, $\tan\delta = 0.02$) with thickness H. Thickness H is used to achieve a high gain and less

Table 1: Final design parameters (Unit: mm).

Parameters	Values	Parameters	Values
L_1	100	W_1	26
L_2	69	W_2	5.5
L_3	22	W_3	8
L_4	11	W_4	3.5
L_5	9.5	H	6



(a) (b)

Figure 1: Proposed RFID tag antenna: (a) fabricated antenna, (b) 3D view.

sensitive characteristic against size of a metallic object. The microstrip feed line is inset into the patch. Generally, the edge-coupled feed suffers from a limitation of impedance mismatch because the input impedance of the patch at its radiating edge is very high compared to that of the feed line. Therefore, an inset microstrip feed line is used in radiating patch to mitigate this problem. The open stubs are used for impedance matching. Resonant frequency can be controlled by adjusting the gap length between feed line and open stub, and the length of open stub.

3. RESULTS AND MEASUREMENT

The antenna performance is analyzed by Ansoft HFSS simulator. Return loss, peak gain, radiation pattern, radiation efficiency and maximum reading distance are simulated and measured in free space, on 200 mm×200 mm, 400 mm×400 mm and 600 mm×600 mm metallic plates. The maximum reading distance is measured in RFID Test Bed, E.M.W Antenna Co., Ltd..

Figure 2 shows return loss characteristic of the antenna. The bandwidth is measured to be about 282 MHz (696 MHz ∼ 978 MHz) which satisfies UHF band (908 MHz ∼ 914 MHz) of RFID system. I-shaped slits and open stubs can control resonant frequency of antenna. Length of I-shaped slits and open stubs can be interpreted as series inductance. Therefore, the longer their lengthes are, the lower resonant frequency of the antenna becomes. Fig. 3 shows radiation patterns. As listed in Table 2, radiation patterns, peak gains and radiation efficiencies are less sensitive against metallic sizes.

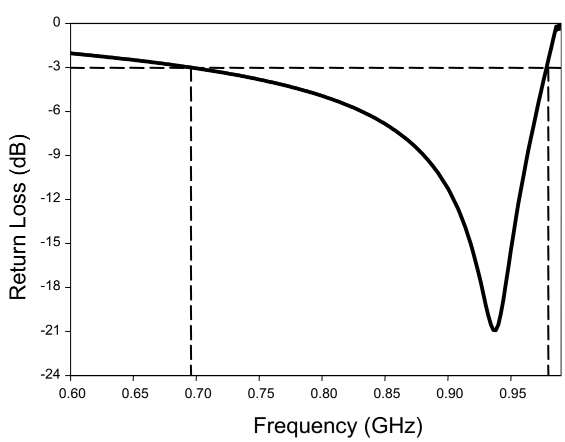


Figure 2: Return loss characteristic.

The proposed antenna is combined with the commercial tag chip. Then, using the commercial

Table 2: Peak gain and radiation efficiency.

Metallic Plate Size	Free Space	200 mm×200 mm	400 mm×400 mm	600 mm×600 mm
Peak Gain (dBi)	4.7	2.4	2.3	1.7
Radiation Efficiency (%)	69	40	38	38

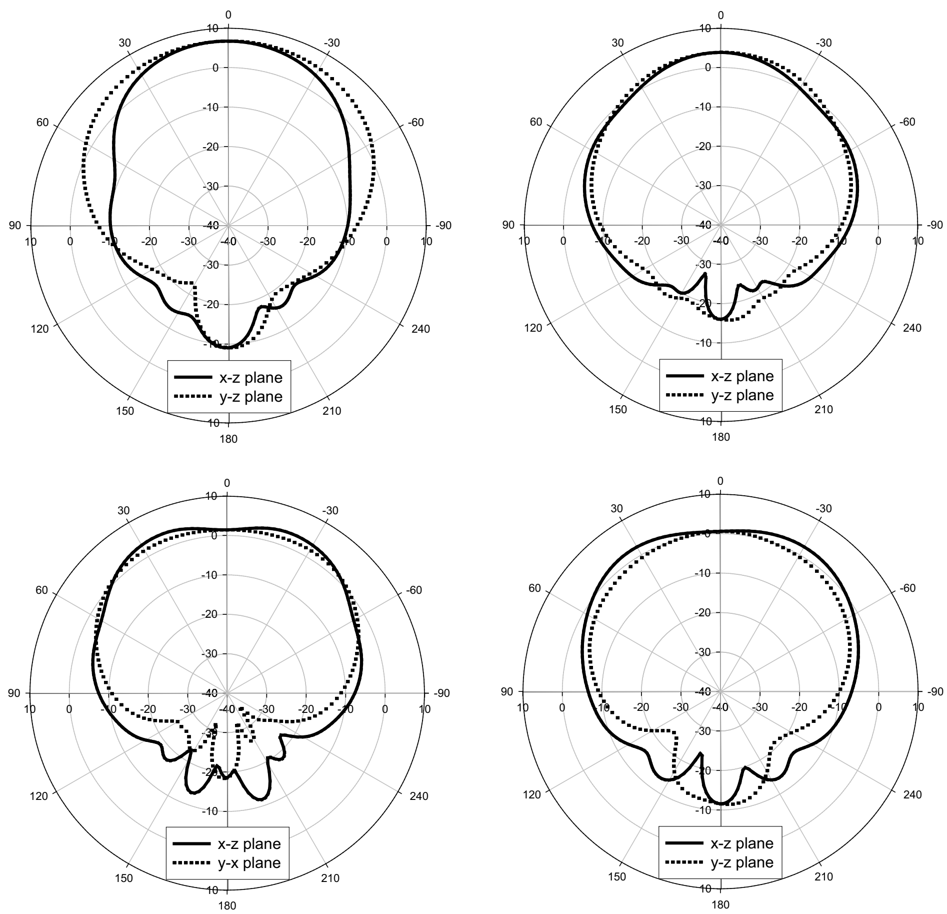


Figure 3: Radiation pattern at 910 MHz.

RFID reader, its performances are measured based on the back-scattering method in an RFID Test bed. The measurement setup consists of the transmission and receiving parts. The transmission part includes a computer, RFID reader (ALIEN, ALR-9800-KOR), reader antenna (EMW Antenna, FSDC-07) and variable attenuator. The minimum power signal from the reader is sent to wake up the tag. The reader output power is 32 dBm. The maximum reading distances of the proposed antenna are listed in Table 3.

Table 3: Measured maximum reading distance for metallic plate sizes (Unit: m).

	Sample 1	Sample 2	Average
Free Space	5	5.25	5.13
200 mm×200 mm	5.5	6.5	6
400 mm×400 mm	5.5	6	5.75
600 mm×600 mm	4.5	5	4.75

4. CONCLUSION AND FUTURE WORK

In this paper, a novel microstrip patch RFID tag antenna with wideband characteristic is proposed. It has a less sensitive characteristic against size of metallic objects, wide impedance bandwidth and a long reading distance. The performance of proposed antenna is not sensitive to the metallic size of object and can be applied to RFID systems whose tags are mounted on metallic objects. In the future, the height and size of the proposed antenna will be further reduced.

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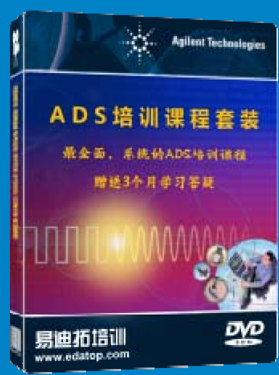

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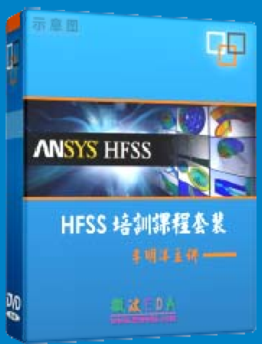

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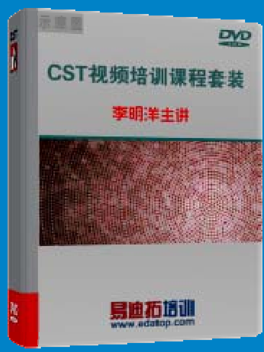

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