A Low-profile Wideband RFID Tag Antenna Attached to Metallic Surfaces

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Abstract— In this paper, a low-profile dipole-type broadband tag antenna is proposed and it can be mounted on metallic objects for UHF RFID systems. The meandering technique, capacitive-tip loading structure, and T-matching network are wisely hybridized to improve the impedance matching and radiation patterns of the RFID tag antenna. For low-cost fabrication, the antenna is etched on a single-layer substrate without a ground plane or shorting pins. The simulated impedance bandwidth of the proposed antenna is 635 MHz (i.e., from 615 MHz to 1250 MHz) which can entirely cover the frequency band of the worldwide UHF RFID (i.e., from 860 MHz to 960 MHz) and the simulated radiation patterns show a good feature.

1. INTRODUCTION

The radio frequency identification (RFID) system in the ultra high frequency (UHF) band from 860 MHz to 960 MHz has become more popular in recent years and has been widely used in the labels of products and services. Compared to the RFID system working in the frequency band lower than the UHF, the system has several benefits such as the safer security mechanism, larger data storage, and better stability [1]. Furthermore, it can read several tags simultaneously and rapidly, making it become the preferred choice in many applications. There are usually four important aspects that should be considered in the design of tag antenna, i.e., size, impedance matching, radiation pattern, and gain [2]. Also, the RFID tags have to be attached to various materials in practical situations and the cancellation of electric current on the surface of antenna will significantly worsen the performance of tags if they are attached to metallic objects. Aiming to the problem, some solutions have been proposed, such as embedding a slotted via-patch in the middle of the dual layer RFID tag antenna, incorporating an artificial magnetic conductor (AMC) with a printed meander monopole tag antenna, and applying a proximity-coupled feed to a radiating patch [3, 4].

In this work, we propose a different design for the UHF-RFID tag antenna which will be attached to metallic objects. The meandering technique, capacitive-tip loading structure, and T-matching network are wisely hybridized to improve the impedance matching of the RFID tag antenna. The simulated results show that the design can remarkably enhance the performance of tag antenna in both bandwidth and gain when it is attached to a metal sheet. Moreover, compared to the same-type antenna presented in [5, 6], the impedance bandwidth is much larger (from 615 MHz to 1250 MHz) and the overall size is much smaller (50 mm × 20 mm × 1.6 mm).

2. ANTENNA DESIGN

The configuration of the proposed tag antenna is shown in Figure 1. The proposed antenna is symmetrical and includes a T-matching network, two bent microstrips, and two loading bars. The T-matching network is used for conjugate matching between tag antenna and RFID chip by adjusting H_2 and L_1 [7]. The meandering structure is formed by bending the arms of the diploe antenna to finely tune the impedance of the proposed antenna and improve the radiation pattern. Two loading bars are introduced to increase the area of antenna radiation element. For the satisfactory gain and easy fabrication, the Rogers RT/duroid 5880 ($\epsilon_r = 2.2$ and $\tan\delta = 0.0009$) is used as the substrate when the tag is attached to a dielectric block. In the antenna design, the return loss is used to check the energy transfer between the tag antenna and the chip, which can be calculated by:

$$RL = -S_{11} = 20\log|\Gamma| = 20\log\left|\frac{Z_c - Z_a}{Z_c + Z_a}\right| \quad (1)$$

where $Z_c = R_c + jX_c$ is the microchip's input impedance and $Z_a = R_a + jX_a$ is the antenna's input impedance. Generally, the efficient RL value is below -10 dB and the conjugate match happens when $R_a = R_c$ and $X_a = -X_c$. The tag antenna is designed for the RFID chip Impinj Monza 4, whose impedance is $11 - j143\,\Omega$ at 915 MHz. To get a conjugate impedance of the RFID chip,

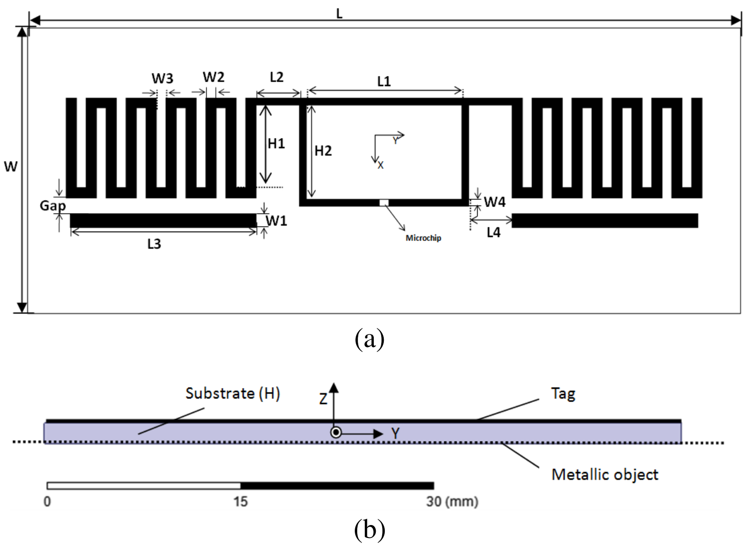


Figure 1: Configuration of the proposed RFID tag antenna. (a) Top view. (b) Side view.

the antenna's impedance should be adjusted to be $11 + j143\,\Omega$. The reading range is also very important in RFID. When the power absorbed by antenna is larger than its threshold power P_{th}, the antenna will work. The maximum read range is given by

$$R_{\max} = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t G_r \tau}{P_{th}}} \tag{2}$$

where λ is the wavelength, P_t is the power transmitted by the reader, G_t and G_r are the gains of transmitting antenna and the receiving tag antenna, respectively, P_{th} is the minumum threshold power necessary to power up the RFID chip, and τ is the power transmission coefficient given by $1 - \Gamma$. Typically, P_t, G_t, and P_{th} are all given before the tag antenna is designed. Therefore, G_r and τ are dominant factors which determine the reading range.

Table 1: Optimized dimensions for the proposed antenna (unit: mm).

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
W	20	W1	1.0	W2	0.7	W3	0.7	W4	0.5
L	50	L1	10.9	L2	3.05	L3	13	L4	3.05
H	1.6	H1	10.9	H2	2.4	Gap	1.1		

3. RESULTS

The simulation and optimization of the antenna were carried out by Ansoft HFSS 13. The ultimate optimized value of each parameter is given in Table 1. Figure 2 shows the simulated impedance of the proposed antenna. It can be seen that the antenna impedance is equal to $0.17+j149\,\Omega$ at the central frequency of 915 MHz, which satisfactorily matches the chip. As the frequency varies, the reactance increases from $70\,\Omega$ to $200\,\Omega$ slowly and smoothly. It indicates that the impedance bandwidth of the tag antenna is bound to be very wide in the case when the reactance of RFID chip decreases slightly with the rising frequency.

The simulated result of the return loss of the compact antenna is shown in Figure 3(a). It can be seen that this antenna's impedance bandwidth at -10 dB is 835 MHz (510 MHz–1345 MHz) which entirely covers the global range 100 MHz. Furthermore, the large impedance bandwidth ensures that the antenna can be applied to other systems whose working frequency is in the range.

The simulated x-z and y-z plane patterns at 915 MHz are plotted in Figure 4(a). It can be seen that the radiation pattern in the y-z plane is nearly omnidirectional and the beam angle in the x-z plane is 120°.

The above results present a perfect performance when the tag antenna is attached to the non-metallic object. Then the antenna's quality of anti-mental will be explored in the following. To abate the influence of the metal, the foam will be added between the tag antenna and the metal surface directly and this is a very convenient way with a low cost.

Figure 3(b) shows the S_{11} features with the change of the thickness. It is observed that the resonant frequency shifts down as the thickness increases. Though the impedance bandwidths narrow down, the range entirely covers the RFID bandwidth. The simulated radiation patterns are shown in Figure 4(b). It can be seen that the gains are almost constant at the central frequency.

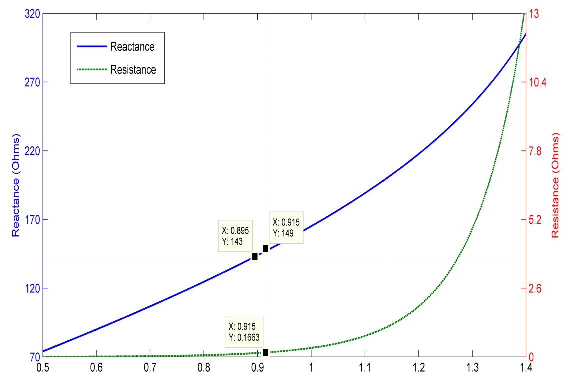
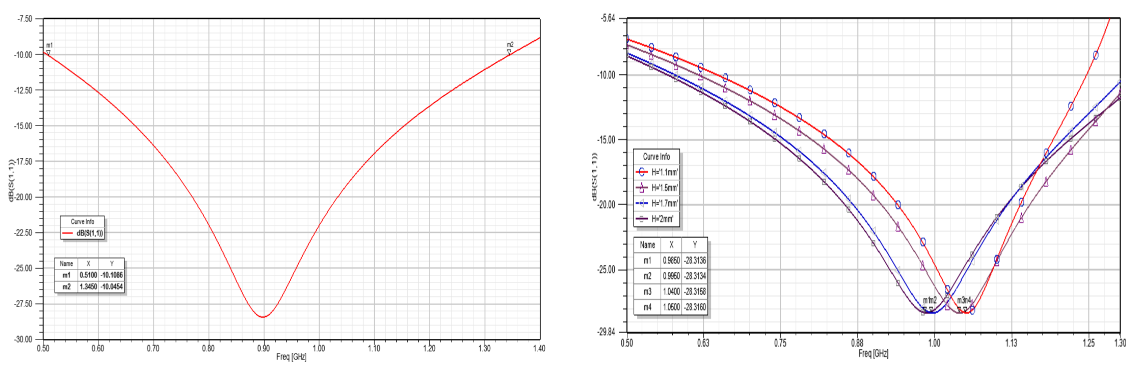
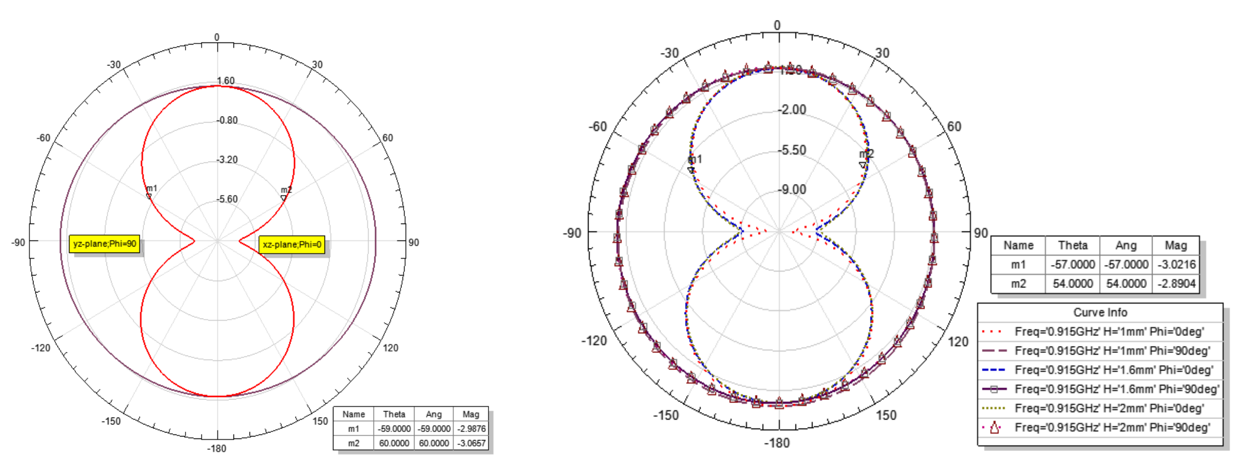


Figure 2: Simulated impedance of the proposed antenna as the frequency increases.



(a) (b)

Figure 3: (a) Simulated return loss of the proposed tag antenna. (b) Simulated power reflection coefficient against frequency of the proposed antenna with different thicknesses of the foam.



(a) (b)

Figure 4: (a) Simulated radiation patterns of the prototype antenna at 915 MHz. (b) Simulated radiation patterns at 915 MHz with different distances to the metallic surface.

4. CONCLUSION

A compact and low-profile antenna for RFID which operates well in the worldwide UHF RFID frequency bands (860–960 MHz) is proposed in this research. The T-matching network is used to easily match the RFID chip impedance. The two loading and meandering parts are added to augment the gain. The simulated bandwidths of the tag antenna are 835 MHz and 635 MHz or more, respectively. Moreover, the tag antenna is easy for massive production due to its simple structure. In the future, measurement for the antenna will be carried out.

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