A Broadband UHF RFID Tag Antenna with a Novel T-matching Network

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Abstract— In this paper, an-ultra-high frequency (UHF) passive broadband radio frequency identification (RFID) Tag Antenna with a novel T-matching network is presented. By slightly tuned the arm lengths of the T-matching network, the impedance matching between the antenna and the chip and a broad impedance bandwidth is obtained. Thanks to the bent radiating element, the size reduction of the proposed antenna is realized. The bandwidth ($S_{11} < -20$ dB) and the corresponding 3 dB PRC bandwidth of the proposed antenna are 133 MHz (835–968 MHz) and 88 MHz (882–970 MHz) respectively, which means that both bandwidths are wide enough to cover the whole global UHF RFID frequency band. In the simulated results, a smooth and stable gain curve between 0.04 dBi to 1.86 dBi is found throughout the entire operating frequency band, and a gain of 1.38 dBi is obtained at the desired operating frequency point (915 MHz). In conclusion, the designed antenna owns the advantages of low-profile, compact size ($56 \times 56\,\text{mm}^2$), low cost and stable gain. Based on the simple structure, the designed tag antenna can be easily manufacture and widely used in practical applications.

1. INTRODUCTION

Radio frequency identification (RFID) technology is a wireless communication technology which use radio frequency signal to read and write the data with no touching the target. RFID system consists of reader, tags and application software systems. The tags are divided into passive tags, semi-active tags and active tags according to whether there is an internal power supply. The tag is the device that carries data on the RFID systems. The tag consists of an electronic chip and an antenna. The performance of the tag mainly depends on antenna. In RFID system, the read distance of the tags is a most important index.

Nowadays, the application field of radio frequency identification (RFID) is quite extensive, such as supply chain managements, health care, manufacturing, transportation, animal identification, asset management, logistics,identifying books in library and so on [1]. RFID systems are operated at widely differing frequencies, such as LF (135 KHz), HF (13.56 MHz), UHF (840–960 MHz), and microwave Frequency (2.45 GHz and 5.8 GHz). However, according to the different standards of the globe, the ultra-high frequency (UHF) is divided into different frequency range. For instance UHF RFID applications is 840–845 MHz and 920–925 MHz in China, 865–869 MHz in Europe, 902–928 MHz in South America and North America, 908–914 MHz in Korea, 918–926 MHz in Australia, and 950–956 MHz in Japan. In order to realize cover the entire UHF RFID frequency band, a broadband folded loop tag antenna with T-matching network is presented in [2]. Its bandwidth is 220 MHz (800 MHz–1.02 GHz) covering the whole UHF RFID bandwidth and the gain of the tag antenna is -0.65 dB at 915 MHz. A Two closely spaced bent dipole tag antenna with double-T matching network is presented [3], where it presents an impedance bandwidth of 78 MHz (848–926 MHz) that not including entire UHF RFID bandwidth. Based on reference [3], amodified UHF RFID tag antenna using a double-U patch and a double-T matching network is designed [4]. Although the bandwidth ofthe modified tag antenna can reach 102 MHz (875–977 MHz), it can't also meet the requirement of covering the whole UHF RFID frequency band. It also has found the same problem of narrow bandwidth in [5]. The design of [5] realizes conjugate impedance matching between a dipole and three loading bars, and its bandwidth is about 6 MHz far from coving the whole global UHF RFID bandwidth.

A compact bent line UHF RFID tag antenna with novel T-matching network is proposed in the paper. The novel T-matching network is applied to improve broad impedance bandwidth. The complex impedance matching could be easily attained by slightly tuned the arm lengths of the T-matching network. Thanks to the bent radiating element, the size reduction of the proposed antenna is realized. The simulated bandwidth ($S_{11} < -20$ dB) of the proposed antenna is 133 MHz whichcovers the whole global UHF RFID bands. The gain of the operating frequency 915 MHz is

1.38 dBi. Based on the simple structure and the results, the tag antenna is designed as a practical application in the whole UHF RFID systems.

2. ANTENNA STRUCTURE AND DESIGN

The geometry of proposed tag antennais shown in Fig. 1. The UHF RFID tag antenna consists of radiating meander line, a novel T-matching network and an FR-4 layer ($\varepsilon_r = 4.6$, loss tangent $= 0.02$, thickness $= 1.6$). The tag antenna (yellow part) is carved on the cheap FR-4 layer (gray part). To get the small size, the radiating part of antenna uses folded micro-strip line. The overall size of the tag antenna is $0.17\lambda \times 0.17\lambda$. In the paper, the UHF RFID tag antenna is designed for a tag microchip with the impedance of (11-j143) at 915 MHz. The conjugated impedance matching of the microchip and the tag antenna is easy to implement by adjusting the parameter Lx of the novel T-matching network.

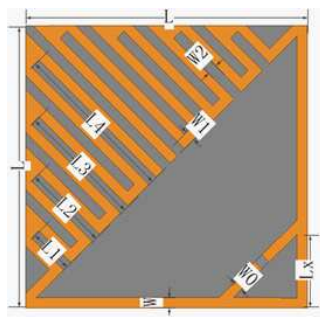


Figure 1: Structure and parameter of the proposed tag antenna.

3. ANTENNA ANALYSIS AND RESULT

In the example, the Ansoft HFSS is utilized to simulate the designed UHF RFID tag antenna. Simulated input reactance values of the tag antenna are shown in Fig. 2 with different parameter Lx. From Fig. 2, we can see that the reactance of the tag antenna increases by extending the parameter Lx at 915 MHz. The parameter Lx is adjusted to 14.6 mm to get the reactance of the proposed tag antenna equal to 143 Ω at 915 MHz.

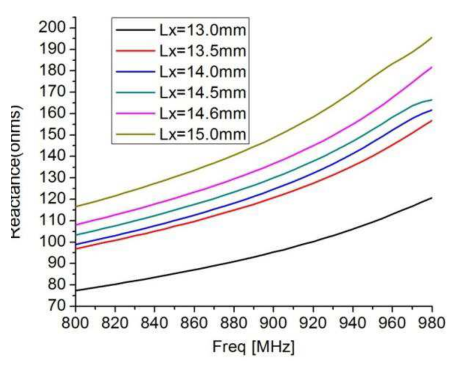


Figure 2: Reactance of antenna with each Lx.

Table 1 exhibits the final optimized design parameters of the tag antenna. The size of the antenna is only 65 mm × 65 mm etched on a FR-4 substrate with size of 65 mm × 65 mm × 1.6 mm. H and H_{copper} show thickness of the FR-4 substrate and the copper, respectively.

Simulated return loss of the designed UHF RFID tag antenna is presented in Fig. 3. The simulated bandwidth is 133 MHz (835–968 MHz) under the condition of $S_{11} < -20$, which cover the whole global passive UHF RFID frequency band and Fig. 4 shows the power reflection coefficient (PRC) $\Gamma < -3$ dB [6] with bandwidth 88 MHz (882–970 MHz).

The simulated normalized radiation patterns of the proposed tag antenna at operating frequency of 915 MHz are shown in Fig. 5. Fig. 5(a) shows E-plane normalized radiation pattern. H-plane normalized radiation pattern is plotted in Fig. 5(b). The gain of the presented tag antenna is

Table 1: Optimized design parameters of the proposed tag antenna.

L	H	H_{copper}	ε_r	μ_r	$L1$	$L2$
56 mm	1.6 mm	0.035 mm	4.6	1	9 mm	17 mm
$L3$	$L4$	Lx	W	$W0$	$W1$	$W2$
25 mm	33 mm	14.6 mm	2 mm	2 mm	2 mm	2 mm

drawn in Fig. 6 from 800 MHz to 980 MHz. A stable gain curve between 0.04 dBi to 1.86 dBi is found throughout the entire operating frequency band (840–960 MHz), and a gain of 1.38 dBi is obtained at the desired operating frequency point (915 MHz), which obtains a good read distance for the proposed UHF RFID tag antenna. The performance of a stable reading range is very helpful in practice.

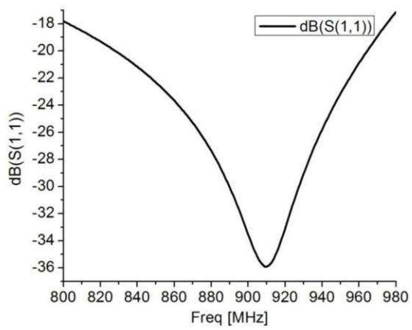


Figure 3: Return loss of the tag antenna.

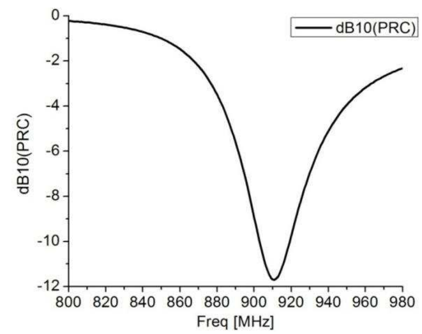
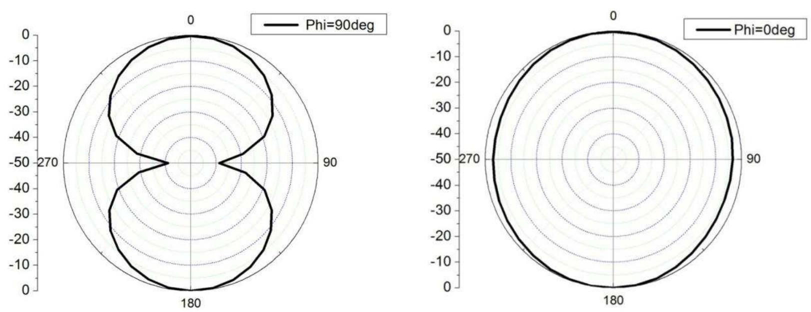


Figure 4: Power reflection coefficient of the tag antenna.



(a) E-plane (b) H-plane

Figure 5: E-plane and H-plane of simulated normalized radiation patterns.

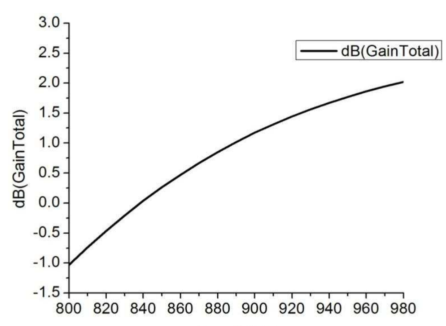


Figure 6: Gain curve of the tag antenna.

4. CONCLUSIONS

A broadband meander line UHF RFID tag antenna with a novel T-matching network is presented. Results demonstrate that the impedance bandwidth ($S_{11} < -20$) of the designed UHF RFID tag antenna is 133 MHz from 835 MHz to 968 MHz. Its bandwidth covers the whole UHF RFID frequency bands. At the same time, the tag antenna owns a good power reflection coefficient bandwidth 88 MHz (882–970 MHz) and a good gain 1.38 dBi at 915 MHz. Based on the simple structure and good performance, the designed tag antenna can be easily manufacture and widely used in practical applications. The UHF RFID tag antenna also has advantages of low cost, low profile, small size and high gain.

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