A Novel UHF RFID Dual-Band Tag Antenna with Inductively Coupled Feed Structure

Yejun He and Bing Zhao
Shenzhen Key Lab of Advanced Communications and Information Processing
College of Information Engineering, Shenzhen University, 518060, China
Email: heyejun@126.com, zhaobing0322@yahoo.cn, http://cie.szu.edu.cn/heyejun

***Abstract*—A dual-band tag antenna for UHF RFID systems is proposed. The tag antenna is composed of a zigzag main body and a zigzag loop, which is an inductively coupled feed structure antenna. The proposed structure is simple, which is not only easy to adjust the matching impedance but also to reduce the size of the antenna. Compared with the same type of antennas, this antenna structure is more compact and the length of antenna is reduced by at least 18%. Using the Alien's Higgs-3 tag chip, the proposed antenna operates at 860 MHz and 920 MHz, and the impedance match is achieved in a wide frequency band. We also measure the reading distances of the tag. Simulation and measurement results show that the proposed antenna has good performance and is very practical.**

I. Introduction

As a contactless automatic identification technology, Radio Frequency Identification (RFID) uses the RF signal to realize the transmission of information and object recognition by electromagnetic coupling [1]. RFID is a short range wireless communication system that consists of tag, reader, data transfer and processing subsystems. Compared to other identification technologies, RFID technology has a number of outstanding advantages, therefore it has achieved promotion and application in many areas such as industrial and commercial automation, transportation control management, access control, and it may have even more potential applications [2].

In a RFID system, tag antenna is a crucial part of RFID system, which acts as a media for the electromagnetic power transmission. The performance of tag antenna greatly impacts the whole RFID system. Therefore, the research of RFID tag antenna has been paid more and more attention in recent years. With the fast development of RFID technology and the wide use of RFID, the RFID system calls for a more rigid requirement of the tag design. The common requirements of the tag antenna are as follows: low-cost, small size, omnidirectional radiation, and perfect match to the RFID IC(Integrated Circuit) chip.

Due to its longer read range and higher data transfer rate compared to the low-frequency (LF) and high-frequency (HF) RFID systems, ultra-high frequency (UHF) RFID system has drawn more and more attention and has broader development prospects. However, due to the different worldwide regulations, each country has its own frequency allocation for UHF RFID. Thus, UHF RFID in Europe operates at 866-869 MHz, the UHF RFID in US at 902-928 MHz, UHF RFID in Japan at 950-956 MHz, and UHF RFID in China at both 840-845 MHz and 920-925 MHz [3]. Therefore, the design of tags able to cover at least two of the regulated UHF bands is also an important challenge.

In order to make the UHF RFID system can work at different bands, antenna should have sufficient bandwidth or multi-frequency characteristic. By increasing the parasitic branch, coupling resonance and the load reactance as well as other technologies, the antenna can operate in two frequency bands simultaneously. There have been some efforts to design broadband tags [4], but it is difficult to obtain large read range at two regulated frequency bands simultaneously.

A dual frequency tag antenna based on the coplanar inverted-F/L structure [5] is proposed, but the antenna structure is more complex and not easy to adjust the matching impedance. In [6], a slot-coupled dipole antenna for dual-band passive tag antenna is presented, however the input impedance of this antenna is designed to match the traditional feeder whose impedance is 50 Ω. The tag chip is usually directly connected to the tag antenna, and the impedance of commercial chip is generally complex, which has large capacitive reactance and small resistance and is not equal to 50 Ω. Therefore, the tag antenna impedance must be designed to conjugate matching with the input impedance of the chip so that maximum power can be transmitted to the tag chip [7]. Inductively coupled structures have been introduced in [8]-[10] to make the RFID tag antenna operate at two bands, but this antenna structure is still complex.

In this paper, we propose a simple and compact dual-band UHF RFID tag antenna structure by using inductively coupled feed. According to the Higgs-3 tag chip made by Alien Technology Co., the antenna operates at 860 MHz and 920 MHz. Compared with the same type of antennas, the proposed antenna structure is more compact and the length of antenna is reduced by at least 18%. The antenna also has a good performance. We use the Ansoft's HFSS software to simulate the proposed tag antenna and physically fabricate the tag to confirm design practicality.

The rest of this paper is organized as follows. Section II introduces the structure of the proposed antenna and analyzes the impedance of the antenna along with the parameters. Section III proposes the input impedance of tag chip and shows the simulation results. In Section IV, the measurement results

978-1-4673-5939-9/13/$31.00 ©2013 IEEE

are obtained. Conclusion is drawn in Section V.

II. Antenna design and analysis

The configuration of the proposed antenna is shown in Fig. 1. The antenna consists of a symmetrical zigzag main body and a zigzag feed loop. The zigzag structure can reduce the size of the antenna, but do not affect the antenna performance. Two terminals of the loop are directly connected to the chip. The coupling strength between the antenna radiator and loop is mainly affected by two factors: one is the distance between the loop and the radiator, and the other one is the size of the loop. The equivalent circuit of the inductively coupled feed structure is shown in Fig. 2, where R_r and R_{loop} are the individual resistances of the radiator (or the radiating body) and the feed loop, respectively. M is the mutual inductance between the radiating body and the feed loop. L_{loop} is the self-inductance of the feed loop. According to Fig. 2, when f=f_0, the resistance and reactance components of the antenna input impedance are given by

$$R_{in} = \frac{(2\pi f_0 M)^2}{R_{r,0}}, \tag{1}$$

and

$$X_{in} = 2\pi f_0 L_{loop}, \tag{2}$$

, respectively. Thus, at the resonant frequency f_0, equations (1) and (2) show that R_{in} is only dependent on M, while X_{in} only depends upon L_{loop}. Therefore R_{in} and X_{in} could be adjusted independently, and it is easy to make the antenna impedance to match to a chip impedance. In RFID tags the load is the RFID chip. A mismatch will result in RF energy being reflected back to the transmitter without powering up the RFID chip. Therefore, it is important to match the antenna impedance to the complex conjugate of the RFID chip impedance to achieve good power transfer from the antenna to the load.

We use the HFSS software to analyse the effect of the parameters of the proposed tag antenna. Figure 3 shows the antenna impedance against f with variation of the gap spacing d between the radiating body and the loop. Figure 3(a) shows that, as the gap distance increases, the resistance component of the antenna input impedance decreases. Figure 3(b) shows the reactance component changes little, but the

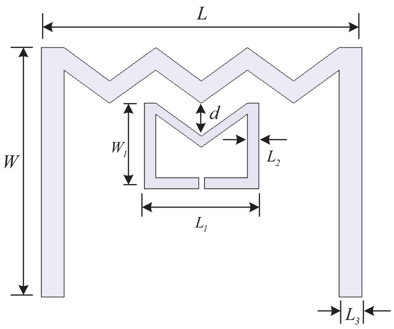


Fig. 1. Structure of the proposed RFID tag antenna.

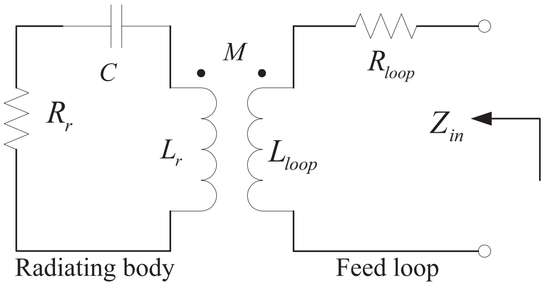


Fig. 2. Equivalent circuit.

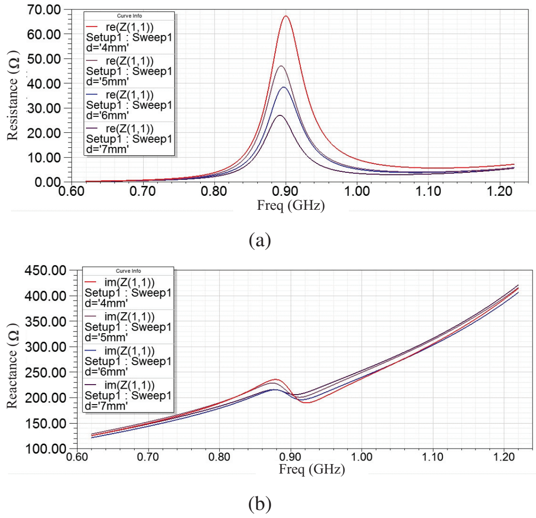
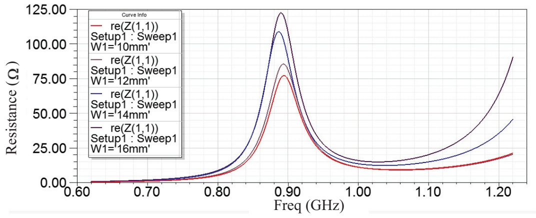


Fig. 3. Antenna input impedance against f for different values of the gap d. (a) Resistance component against f. (b) Reactance component against f.

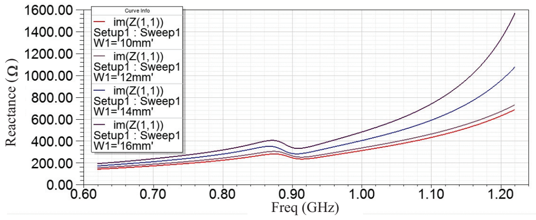
coupling between the radiating body and the loop gradually weakens. The antenna impedance against f is shown in Fig. 4 with variation of W_1. It is found that the larger the parameter W_1 is, the larger the resistance and reactance components of the antenna impedance are, and the stronger the coupling between the radiating body and the loop is. This is because the change of the loop size can also affect its inductance value and the coupling with the radiating body. This provides a simple and effective method for adjusting the impedance of the antenna: we firstly select the appropriate size loop to offset the imaginary part of the chip impedance, and then the gap between the radiating body and the loop is adjusted to obtain a suitable impedance real part. The tag antenna impedance can thus be adjusted to conjugate match with the arbitrary chip impedance.

III. Antenna simulation and analysis

Based on the above analysis, we select a Higgs-3 tag chip made by Alien Technology Co. to optimize the tag antenna. The parallel resistance and capacitance of the Higgs-3 tag chip are 1500 Ω and 0.85 pF, respectively. The chip input impedanc is calculated by ADS software. Figure 5(a) shows that the resistance components of the chip input impedance at 860

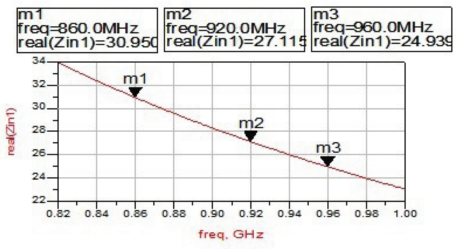


(a)

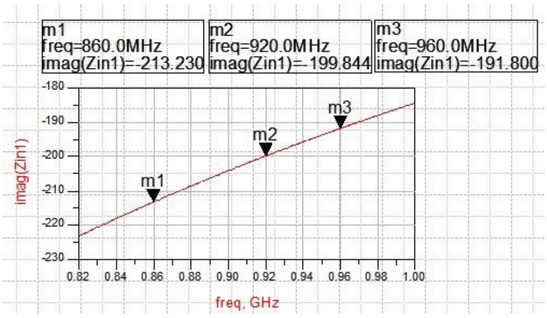


(b)

Fig. 4. Antenna input impedance against f for different values of W_1. (a) Resistance component against f. (b) Reactance component against f.



(a)



(b)

Fig. 5. The input impedance of the chip against f.(a) Resistance component against f . (b) Reactance component against f.

MHz, 920 MHz and 960 MHz are about 30.95 Ω, 27.155 Ω and 24.93 Ω, respectively. Figure 5(b) shows that the reactance components of the chip input impedance at 860 MHz, 920 MHz and 960 MHz are about -j213.23 Ω, -j199.844 Ω and -j191.8 Ω, respectively. Therefore our antenna was designed for the tag chip with (30.95+j213.23) Ω and (27.155+j199.844) Ω at 860 MHz and 920 MHz, respectively.

The main task of RFID tag antenna design is to achieve good matching between the chip and the antenna, which means small power reflection coefficient when the antenna transports the maximum power to the RFID tag. Power reflection coefficient s is given by [10]:

$$s = \frac{Z_c - Z_a^*}{Z_c + Z_a}, \tag{3}$$

where Z_c represents the impedance of the chip and Z_a represents the impedance of the chip with Z_a^* being its conjugate. Generally, we use return loss S_{11} to reflect the degree of impedance matching between the tag antenna impedance and the chip impedance. S_{11} is given by

$$S_{11} = 20 \times \lg |s| \tag{4}$$

The simulated antenna impedance and radiation pattern are numerically computed in HFSS by introducing an RLC boundary along with the port impedance that simulates the behavior of the chip (with its complex impedance feed). Based on the antenna impedance simulation results from HFSS, we use equation (4) to calculate the S_{11}.

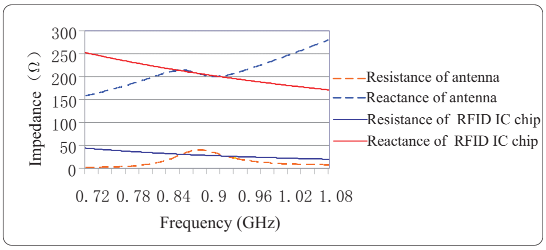
For the Higgs-3 tag chip, after simulation and the optimization analysis, the final antenna parameters are as follows: L=56 mm, W=47.5 mm, L_1=20 mm, W_1=15.8 mm, L_2=2 mm, L_3=4 mm, d=3 mm. Based on the above parameters, the simulation results are shown in Fig.6.

Figure 6(a) shows the impedance responses of the antenna and the tag chip. It is obvious that the reactance component of the antenna input impedance is relatively flat near the resonant frequency, so the tag antenna impedance can achieve a conjugate match with the chip impedance in a wide band. There are two resonant frequencies near 860 MHz and 920 MHz, as shown in Fig. 6(b), and the impedance bandwidth (S_{11}<-15dB) reaches almost 90 MHz. It is clearly seen that the antenna can match well near 860 MHz and 920 MHz. Figure 6(c) and Figure 6(d) show the antenna three-dimentional radiation pattern at 920 MHz and 860 MHz and two-dimentional radiation pattern for the phi=0^o and phi=90^o, respectively. The maximum gain are almost 2.0 dBi and both are omni-directional.

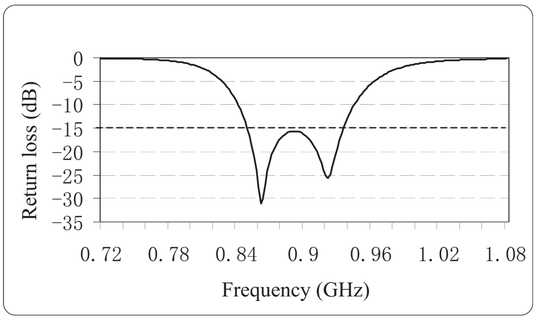
IV. Antenna measurement results

The tag antenna was fabricated using the cheapest FR4 substrate with relative permittivity of 4.6 and thickness of 1.6 mm. According to the proposed antenna parameters, we have manufactured an antenna as shown in Fig. 7.

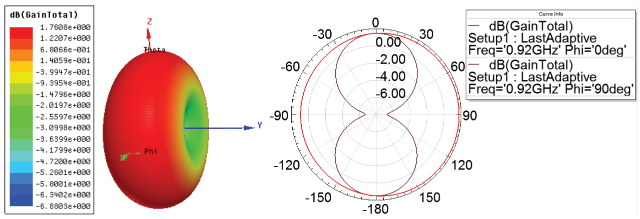
The geometry size of the proposed tag antenna is 65mm×52mm×1.6 mm, which meets the requirements of the general application. The antenna is measured by Agilent's E5071C network analyzer as shown in Fig. 8. The measured tag antenna impedance accords with the simulated results, as shown in Fig. 9. Due to the factors such as material processing, the simulated and measured return lossess have minor differences, as shown in Fig. 10. However, the performance is still good, and the measured result also satisfies the dual-band characteristics. The tag chip meets the ISO 18000 standard. We use 7527 handheld reader produced by Psion Teklogix Co. to measure the reading distances. The reading distance reaches



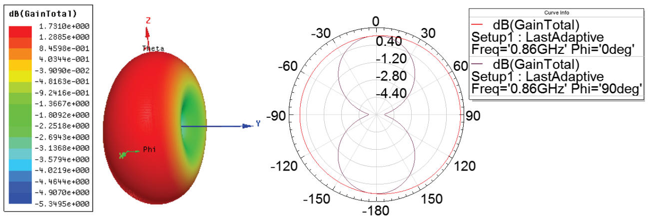
(a)



(b)



(c)



(d)

Fig. 6. Simulation results. (a) Input impedance of the antenna and the impedance of RFID IC chip. (b) Antenna return loss S_{11} against f. (c) Radiation pattern at 920 MHz. (d) Radiation pattern at 860 MHz.

2.5 m and 2.0 m when the center frequency is set to 860 MHz and 920 MHz respectively, which meets the requirements of the general application of the tag antenna.

V. Conclusion

A simple and compact dual-band UHF RFID tag antenna with inductively coupled feed structure has been designed and implemented. The antenna is composed of the zigzag radiating body and a zigzag feed loop. The insertion of the zigzag structure reduces the length of antenna. Compared with similar antennas, this antenna size is reduced by at least 18%, and the coupled structure presents a simple and convenience method to match the tag chip impedance. For the Higgs-3 tag chip, the proposed antenna can directly result in a conjugate match with the chip impedance at 860 MHz and 920 MHz. Simulated and measured impedance and S_{11} are presented. Results show that the proposed antenna can basically meet the requirements of UHF RFID tag.

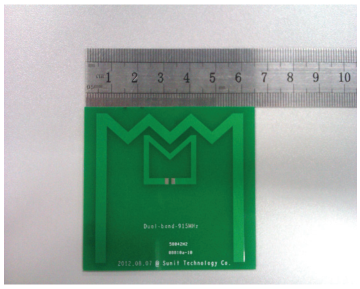


Fig. 7. Fabricated antenna.

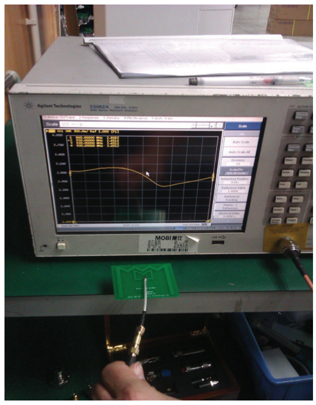


Fig. 8. Antenna measurement.

Acknowledgment

This work was supported in part by The National Natural Science Foundation of China (No. 60972037), The Fundamental Research Program of Shenzhen City (No. JC200903120101A and No. JC201005250067A) and International Cooperative Program of Shenzhen City (No. ZYA201106090040A).

References

[1] J. Landt, "The history of RFID," *IEEE Potentials,* vol. 24, no. 4, pp. 8-11, 2005.
[2] V. Chawla and D. S. Ha, "An overview of passive RFID," *IEEE Commun. Mag.,* vol. 45, no. 9, pp. 11-17, Sep. 2007.
[3] V. D. Hunt, A. Puglia, and M. Puglia, *RFID: A Guide to Radio Frequency Identification*. New York: Wiley, 2007.
[4] F. Paredes, G. Zamora, F. J. Herraiz-Martinez, F. Martin and J. Bonache, "Dual-Band UHF-RFID Tags Based on Meander-Line Antennas Loaded With Spiral Resonators ," *IEEE Antennas and Wireless Propagation Letters,* vol. 10, pp. 768-771, 2011.
[5] Jian Liu, "Dual-Band RFID Tag Antenna Using Coplanar Inverted-F/L Structure," *IEEE International conference on RFID,* pp.96-99. June 2010.
[6] S. Jeon, Y. Yu and J. Choi. , "Dual-band slot-coupled dipole antenna for 900 MHz and 2.45 GHz RFID tag application," *Electronics Letters,* vol. 42, no. 22, October 2006.

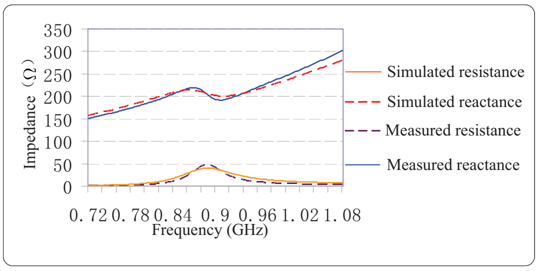


Fig. 9. Simulated and measured impedance of the proposed antenna vs frequency.

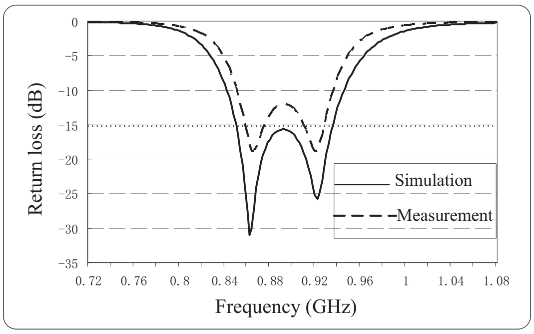


Fig. 10. Simulated and measured return loss of the proposed antenna vs frequency.

[7] P. V. Nikitin and K. V. S. Rao, "Antenna Design for UHF RFID Tags:A Review and a Practical Application," *IEEE Transactions on Antennas and Propagation,* vol. 53, no. 12, pp. 3870-3876, Dec. 2005.

[8] J. Wu, J. Li, X. Cui and L. Mao, "Circular Loop Antenna for UHF RFID Tags with Inductively Coupled Structure," *International Conference on Control, Automation and Systems Engineering,* pp. 1-4, Aug. 2011.

[9] C. Cho, H. Choo and I. Park, "Design of UHF small passive tag antennas," *2005 IEEE Antennas and Propagation Society International Symposium,* vol. 2B, pp. 349-352, July 2005.

[10] P. V. Nikitin, K. V. S. Rao and S. F. Lam, "Power reflection coefficient analysis for complex impedances in RFID tag design, " *IEEE Transactions on Microwave Theory and Techology* , vol 53, no. 9, pp. 2721-2725, 2005.