

# Analysis and Design of Tag Antenna Based UHF RFID for Libraries

Xue Jian-bin<sup>\*1,3</sup> He Fengjie<sup>1</sup>, Wang Dong<sup>2</sup>

<sup>1</sup>School of Computer and Communication, Lanzhou University of Technology, Lanzhou 730050, China

<sup>2</sup>Software Institute, Shanghai Jiao Tong University, Shanghai 200240, China

<sup>3</sup>National Mobile Communications Research Laboratory, Southeast University, Nanjing 210096, China

\*Corresponding author, email: 278596049@qq.com

## Abstract

A kind of UHF RFID tag antenna for library management is designed. The series of design requirements are proposed through rich analytics. Refer to the management model of intelligent library based on UHF RFID. For the antenna, the size is  $90\text{mm} \times 3\text{mm}$ , adopting T-shaped matching which good for adjusting of antenna impedance matching, the center frequency by simulations is 918 MHz under application environment, Return Loss is less than  $-10\text{dB}$  in the frequency band of 860MHz~960MHz, the minimum value of return loss is  $-24.4\text{dB}$ . Simulation results show that the tag antenna has a good performance under application environment for library.

**Keywords:** UHF RFID, library tag, antenna, library

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## 1. Introduction

At present, the management model of library has been transformed from manual mode to semi-intelligent management model which combined magnetic stripe and barcode. But there exist some problems, such as intelligent inspection, fast stock taking and so on. The advantages of management in library, based on ultra high frequency (UHF) radio-frequency identification (RFID) technology, are mostly embodied in such aspects as the self-check, intelligent inspection, raking, inventory check and safety system of book. So the application of UHF RFID in library can solve the above problems.

Based on the research situation and commercialization at home and abroad, the study of UHF RFID tag antenna mainly has the following aspects: near-field antenna, dipole antenna, circularly polarized antenna, dual-band antenna. Nor the RFID tag on sale in the market, the client need to consider tag and memory capacity in order to make the situation and application objects matching with tag. So antenna design in RFID tags is a problem urgently needed to be solved in concrete industry. Reference [5] shows that the major factors which influence the RFID tag antenna, designed a RFID tag antenna on papery substrate which is not sensitive to materials of the container. Reference [6] analyzes the effect of the distance between antenna and metal plates and size of metal planes on antenna parameters in detail, and a UHF RFID tag antenna used in container is proposed. Reference [7] use text as a meander line to design antennas, in the article the text can be used as a function element or manufacturer logos. In [8], a possible method of utilizing paraffin wax as a substrate material in developing a threshold heat sensing RFID tag is discussed, according to the sensitivity of paraffin wax to temperature it can be used as sensor or RFID tag. In [9], the author use standard metal paperclip bodies as antennas which can still be used for its primary purpose (mechanically holding together sheets of papers) while acting as an RFID tag storing data at the same time. The main effect for tag antenna caused by metal background is studied in [10], the author proposed an anti-metal tag antenna design scheme used in cigarette cases and design of bow-tie dipole antenna which was practicability of the proposal.

Most of the UHF RFID Inlay tags were universal tag, but for some particular applications, such as library, document, valuables, considering the particularity of size, shape, distance in tags, we should design the tags according to the application object and

environment. This paper analyzed the application environment effect on performance of tags and obtained the influence factors and design requirements of tags. And then design a UHF RFID tag antenna suitable for library. Where, used T-matching network which helpful to adjust the antenna impedance, the centre frequency is 918 MHz, the  $S_{11}$  (the characteristics of return loss) are less than -10dB in the range of 860MHz~960MHz, the minimization of it is -24.4dB.

## 2. Analysis of Application Environment

Application of UHF RFID tags in the field of Book Management can simplifies the process of library management can collect information rapidly and accuracy, reduce the labor intensity of workers and effectively improve the efficiency of library management, meanwhile, the tags is hidden in books is beneficial to the anti-theft of books.

### 2.1. Application Environment of Library

In present, a RFID tag applied to library is based on the original magnetic stripe. In order to make the magnetic stripe and UHF RFID tags which can apply to the library management system, we will keep the tags in the crack of books. Figure 1 shows the application environment and stick way in book tags.



Figure 1. Application environment of UHF RFID tag in library

### 2.2. Design Requirement

According to the application of library, we need to consider three aspects: distance, tag antenna (backings, size, types) and compatibility when we are designing the tags.

#### (1) The requirement of reading distance

In the aspect of distance, due to the books arranged in simple double row and closed to the range, we have small values for reading distance namely the small gain for antenna so that seldom the collision between reader and tags.

#### (2) The requirement of tag antenna

In the aspect of tag antenna, the tag antenna should slender and thin. When used, we can stick it on the spine or keep it in the crack of books that is easy to reach the function of RFID tag and that keeps the tag can be hidden very well. So the tag of books should be met to the following limits: slender and thin, a good performance of hiding. Then the tag antenna mainly considered the backings of antenna, the size of antenna, the types of antenna, in here, the backings of antenna used PEL, the type of antenna used dipole antenna.

#### (3) The requirement of compatibility

UHF RFID tag used far-field coupling, the magnetic stripe is metal and stick it on the spine of books. Conflict will produce between the UHF RFID system and magnetic stripe and the phenomenon of misreading will appear when each book be placed many magnetic stripes for security reasons in library, thus affecting the success rate of read in whole system, and the performance of UHF RFID book tag based free space will become unstable. So we should consider this problem in order to achieve a good compatibility between UHF RFID system and stripe. We need to think of that in terms of our simulation design, slightly adjusting the resonance point and optimizes the performance of tag in practice.

### 3. Antenna Design of Book

#### 3.1. Layout Design of Antenna

In this article we use dipole antenna as tag antenna, and the polarization direction is liner polarized. Both are meet the requirements. Adopted T-type matching and PET (permittivity is  $3.5$ , loss angle tangent value is  $0.0012$ ) as the actualize manner of impedance matching and backings of antenna respectively. The impedance of chip is  $27 - j201\Omega$  in the frequency of  $915\text{ MHz}$ . The original size of tag antenna was set as  $100\text{ mm} \times 3\text{ mm}$ . The layout of antenna and the main structure parameters are shown in Table 1 and Figure 2.

Table 1. Original size of structure parameters of book tag antenna

主要结构参数	初始尺寸(mm)
L	100
W	3
w0	1
a1	24
b1	3
w1	0.5
a2	10
w2	0.5
a3	25

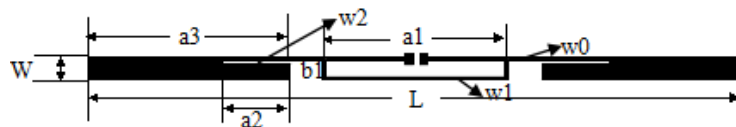


Figure 2. Layout of book antenna

#### 3.2. Simulation Analysis and Optimization

Model and simulate the antenna in free space and practical application respectively according to the original size of structure parameters in Table 1 and antenna structure in Figure 2. We should consider the backings of antenna, environment in practice. In here, the backings of antenna is PET and the magnetic stripes is located in the upper and lower of tag, its size is  $165\text{ mm} \times 2.5\text{ mm} \times 0.5\text{ mm}$ , the distance from the tag is  $6\text{ mm}$  (the thickness is about 40 pages).

The original structure parameters of antenna were simulated and the Figure 3 shown the return loss value of antenna, the minimum is about  $-37.7\text{ dB}$ . Simulation results show that the various characters of antenna will be affected when the antenna backings and environmental factors are added to the simulation. Center-frequency of antenna is  $0.908\text{ GHz}$  in simulation results of return loss. The center frequency shifted left  $0.11\text{ GHz}$ . And compared with free space, the bandwidth is decreased significantly under practical conditions. This illustrates that the antenna shows the characteristic of narrow-band at the interference of environment which containing magnetic stripe.

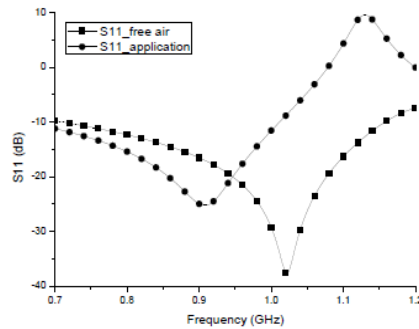


Figure 3. Return loss value of antenna

Figure 4 shows the simulation results of antenna impedance, including the real part and the imaginary part of impedance. The impedance is  $5.57 + j157.87\Omega$  and  $5.66 + j210.46\Omega$  in free space and the application environment respectively in the frequency of 915MHz. Been compared, the imaginary part of impedance change significantly. Figure 5 and Figure 6 is the gain pattern in free space and application environment respectively. The antenna gain is reduced seriously compared to the former.

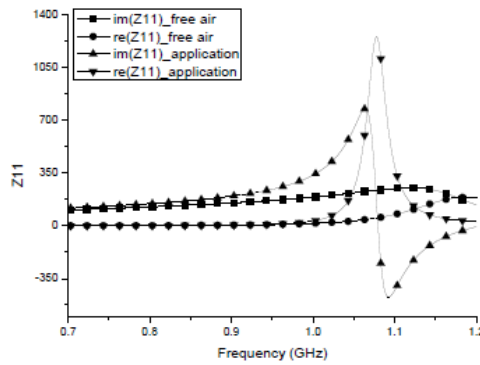


Figure 4. Simulation analysis of impedance

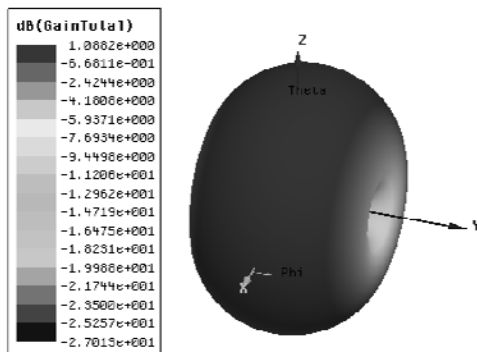


Figure 5. Gain pattern in free space

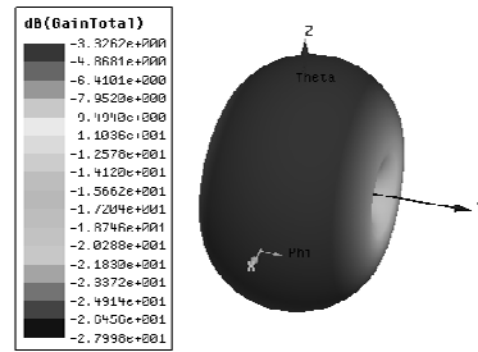


Figure 6. Gain pattern in application environment

Therefore, the performance of antenna will change much when we consider the application condition and antenna backings. This is the same analysis results that the library impact of antenna. The reason for this is the application condition and antenna backings cause the resonant frequency shift. The following are scanning analysis on the main parameters of antenna in application, the parameters is antenna length  $L$  and center loop length  $a^1$ .

Change the length  $L$  of antenna, the range is  $80\text{ mm} \sim 120\text{ mm}$  with step of  $5\text{ mm}$ . Figure 7 is the results of return loss. The results showed that with the change of  $L$ , the value of return loss slightly reduced and the center frequency shifted left and changed significantly. Thus the changes of the antenna length mainly affect the resonant frequency of antenna.

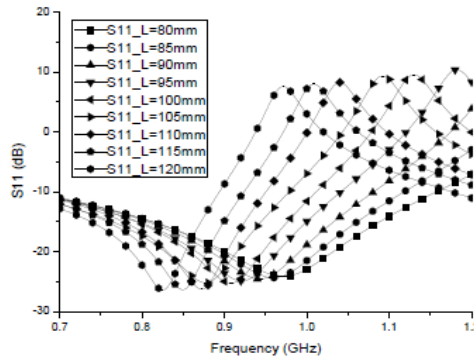


Figure 7. Influence of antenna length on return loss

Figure 8 and Figure 9 shows the real part and the imaginary part of antenna impedance. From the simulation results we can see that as antenna length changes the real and imaginary part of impedance increase obviously.

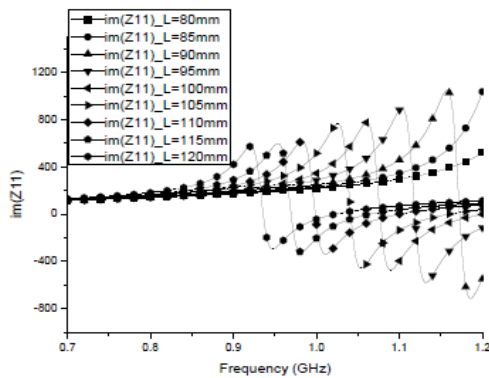


Figure 8. Influence of antenna length on the imaginary part of impedance

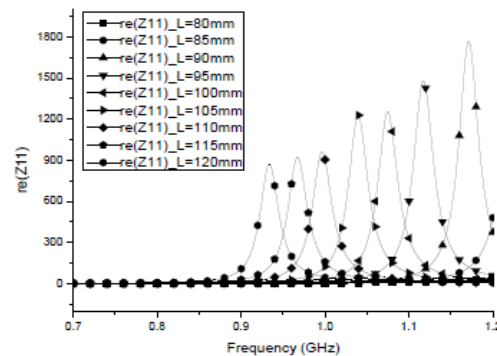


Figure 9. Influence of antenna length on the real part of impedance

Change the center loop length  $a_1$ , the range is  $22\text{ mm} \sim 26\text{ mm}$  with step of  $0.5\text{ mm}$ . The simulation results of return loss is presented in figure 10, from it we can see that with the change of  $a_1$  the center frequency shifted left and changed clearly, the return loss nearly unchanged.

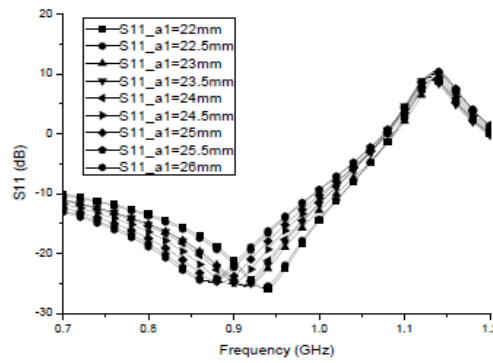


Figure 10. Influence of center loop length on the return loss

Figure 11 and Figure 12 shows that when we change the center loop of antenna from 22mm to 26mm, the real part of impedance almost no change and the imaginary part rose slightly.

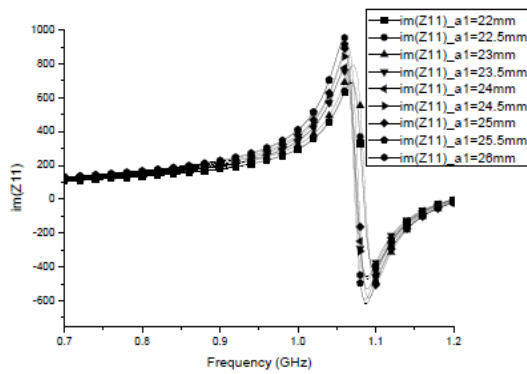


Figure 11. Influence of center loop length on the imaginary part of impedance

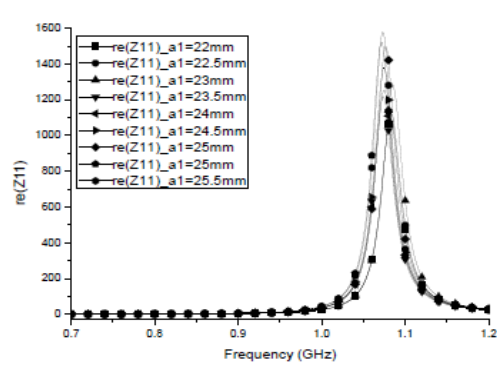


Figure 12. Influence of center loop length on the real part of impedance

As a result, the main structure parameters of the antenna are simulated in turn. Then optimize the antenna. The optimization is presented in Table 2.

Table 2. Size of book tag after optimization

主要结构参数	优化后尺寸(mm)
L	90
W	3
w0	1
a1	5
b1	3
w1	0.5
a2	9
w2	0.5
a3	27

Figure 13 is the return loss of antenna after optimization, from it we can see that the center-frequency of antenna is  $965\text{MHz}$  in free space, the minimum of return loss at about  $-26.7\text{dB}$ . But in practice, the center-frequency of antenna is  $918\text{MHz}$  and the minimum of return loss at about  $-24.4\text{dB}$ . We could see that the resonant frequency gains good result in practice, or the center-frequency shifted left and reached  $918\text{MHz}$ . The return loss increased slightly and the bandwidth change is not evident in free space compared with practical application. The results in Figure 14 show that the impedance of antenna in practice is increase and much closer to the conjugation of chip impedance compared with free space. That is, the performance of tag is better in practice.

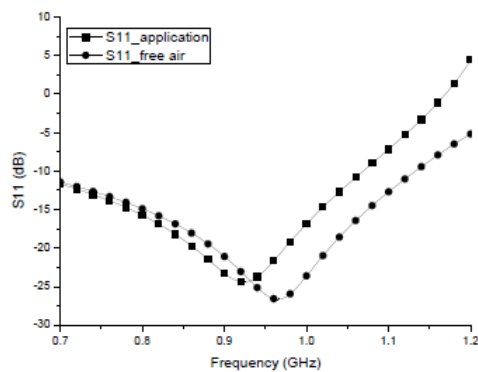


Figure 13. Return loss of antenna after optimization

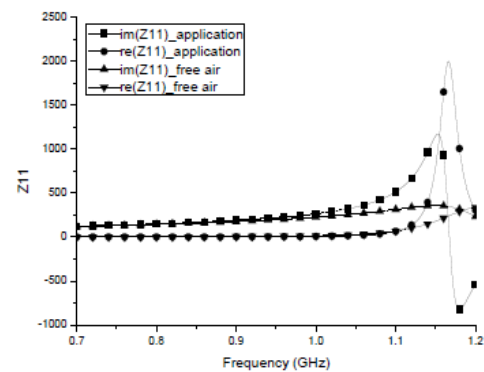


Figure 14. Impedance of antenna after optimization

#### 4. Test and Analysis

According to above simulation results, we adopted copper foil to manufacture the antenna sample and post it on a self-adhesive paper, then solder Alien Higgs-3 chip. The finished antenna sample is shown in Figure 15.

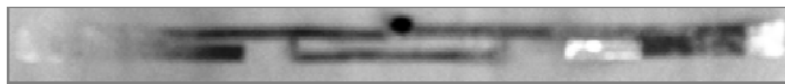


Figure 15. Antenna sample

We use performance testing instrument Voyantic Tagformance to test the tag at the testing frequency range from  $0.8\text{GHz}$  to  $1\text{GHz}$  within a radiation shielded environment. The testing result of read range is shown in Figure 16. Results show that the read range reduced evidently under the interference of magnetic stripe. The performance gap of tag will reduce when the frequency larger than  $925\text{MHz}$  in these different two cases, and the tag can achieving better performance at  $920\text{MHz} \sim 925\text{MHz}$ .

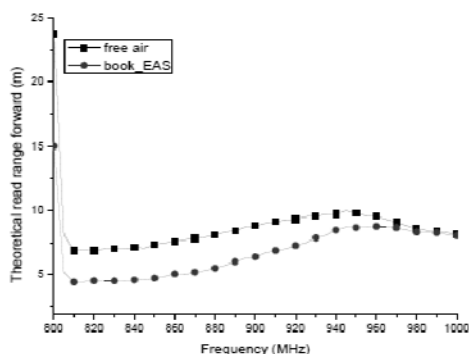


Figure 16. Read range

## 5. Conclusion

In this paper, the design requires of UHF RFID book tag has been proposed by analyzing the impact of tag performance in library. A UHF RFID tag antenna with the dimension of  $90\text{mm} \times 3\text{mm}$  which met library requirements is designed. Simulation results show that the resonant frequency is  $918\text{MHz}$ ,  $S_{11}$  are less than  $-10\text{dB}$  in the range of  $860\text{MHz} \sim 960\text{MHz}$ , the minimization of  $S_{11}$  is  $-24.4\text{dB}$ . Test results show that the tag has a better performance in library.

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