Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 174 (2017) 465 – 469

Procedia Engineering

www.elsevier.com/locate/procedia

13th Global Congress on Manufacturing and Management, GCMM 2016

A Novel Method to Evaluate the RFID System Reliability

Jiawen Xie[a,]*, Minli Wang[a], Jie Tan[a]

[a]Institute of Automation of, Chinese Academy of Sciences, Haiding District, Beijing, 100190， China

Abstract

The RFID system application environment may be different, this have huge influence to the RFID system reliability. This paper presents a data-driven model to evaluate the reliability of RFID systems by analyzing the factors that affect RFID system reliability. We construct free-space and semi-closed metal environment two scenarios by using the proposed model to determine the reliable reference parameter range in these scenarios. The experimental results show that the proposed model can evaluate the reliability of RFID system easily and quickly in different application scenarios.

Peer-review under responsibility of the organizing committee of the 13th Global Congress on Manufacturing and Management

Keywords: RFID system; data-driver; least squares; reliability;

1. Introduction

RFID as an automatic identification technology, has been widely used in security, asset tracking, supply chain management and other fields[1]. With the concept of the Internet of Things, Intelligent Manufacturing, Made in China 2025 proposed, RFID technology will be more widely used and development. RFID system consists of reader, tags, antenna and the application software. The application software sends a command to the reader to send the electromagnetic wave modulated with data information to the tag. Then the tag acquires the electromagnetic wave energy and is activated to write the corresponding data information, and returns the information required by the reader to in the form of electromagnetic wave. Such a system with high data density, fast reading, anti-pollution, anti-humidity and other functions. But the RFID system is also affected by many factors, such as RF power, the speed of tag, target size, shape, material, surface structure. Among many factors, many researchers have done a lot of research to eliminate the interference of these factors to improve the RFID system read rate. M. Periyasamy

* Corresponding author. Tel.: 13261522125.
E-mail address: xiejiawen2014@ia.ac.cn

Peer-review under responsibility of the organizing committee of the 13th Global Congress on Manufacturing and Management
doi:10.1016/j.proeng.2017.01.167

evaluated and analyzed the performance of the RFID system in metal and liquid environments and found that the material and orientation in the environment had a significant effect on the read rate of the RFID system[2]; Xianming Qing found that because of the near-field effect of the metal environment, the size and orientation of the metal plate has a large effect on the reading range[3].

Scholars in these studies have made great breakthroughs, and makes the read rate and read range of RFID system improve in a certain range. However, these studies are specific to the application scenarios, if the appropriate changes happen in these scenarios, the results will be very different. Moreover, with the large number of commercial reader applied, we need a method to test the reliability of a general-purpose RFID system. Joshua studied the four link budgets of the backscatter channel transmission mechanism and analyzed the method of maximizing the performance of the RFID system[4]. In order to solve the over-estimation problem of free-range read range, Antonio proposed a multi-path read range estimation method[5]. ZhuZhiyuan aiming at the problem that the distance between the RFID reader and the reader is often changed at different speeds, a dynamic RFID performance test system is proposed in his paper[6]. Xiaofeng Ning designed a new model for the influence of the conveyor system on the performance of the RFID system[7]. Test the device, and design the system according to the test results. From these studies, we found that most scholars from theory or experiment to evaluate the performance of RFID systems, rarely driven by data to evaluate the RFID system. In this paper, we will study the factors that affect the RFID system, and propose a novel data-driven RFID system reliability evaluation method.

The paper is organized as follows: The next section will mainly describe the electromagnetic propagation theory and electromagnetic wave propagation in all aspects of the factors. Section III describes the proposed evaluation method; Section IV uses the proposed evaluation method for different environments to evaluate RFID system performance; the final section V to make a summary.

2. Electromagnetic propagation theory and factors

UHF RFID system is through the UHF electromagnetic wave in the way of backscatter to carry out energy transmission and data transfer. The communication between the reader and the tag consists of two links, one is the Power-Up link to activate the passive radio-frequency tag, and the other is the backscatter link for tag-to-reader data exchange. According to the electromagnetic wave propagation theory, the Power-Up link can be described as follows:

$$P_t = \frac{P_T G_T G_t \lambda^2 X \tau}{(4\pi r)^2 \Theta B F} \tag{1}$$

Where P_t is the received power of the tag, P_T is the reader transmit power, G_T is the transmit antenna gain, G_t is the tag antenna gain, λ is the carrier wavelength, X is the plan match, τ is the power transfer parameter, and r is the tag to the reader Distance, Θ is the gain penalty of the tag antenna on the attachment, B is the path obstacle loss, and F is the unidirectional active power attenuation.

The backscatter link can be described as follows:

$$P_R = \frac{P_T G_{TR}^2 G_t^2 \lambda^4 X^2 M}{(4\pi r)^4 \Theta^2 B^2 F_2} \propto \frac{1}{r^4} \tag{2}$$

Where, P_R is the reader-side antenna reverse receive power, M is the modulation factor, G_{TR} is the receiver antenna gain, F_2 is the single-station attenuation.

From the formula, we can see that the power in the transmission process by a variety of factors, including antenna gain, carrier wavelength, polarization matching, attachments, and path obstacles. In particular, the final received power is inversely proportional to the r^4 in free space. The above equation is the received power of a single-station backscatter link. In a single-station mode, the reader-writer transmit and receive antennas share, The transmit and receive gains are the same, which is also used in most commercial readers. Since the commercial RFID reader system is evaluated in this paper, the commercial reader is used, so the received power model is applied as described in the formula.

3. Proposed method

Table 1.the parameters of RFID system

P_T	G_{TR}	G_t	λ
1W	8	1.6	0.33

In the previous section, we know that the energy in the transmission engineering will be affected by factors such as the antenna gain, carrier wavelength, plan matching, attachments and path obstacles. If data analysis is needed to effectively evaluate the performance of an RFID system, it is necessary to be able to quickly calculate the final received power for each factor to evaluate. However, in addition to RFID system inherent attributes, polarization matching will be with the tag of the paste, the placement of objects and other factors, and in the process of tag may be attached to the metal or non-metallic objects, path obstacles Will change due to different environments. This leads me to be unable to calculate by specific parameters. Considering this situation, we ignore the influence of these factors and provide compensation through a large number of experimental data, and get an evaluation model without detailed understanding of these parameters. The experimental parameters are shown in Table 1.

$$P_{RP} = \frac{P_T G_{TR}^2 G_t^2 \lambda^4 X^2 M}{(4\pi r)^4 \Theta^2 B^2 F_2} \approx \frac{P^T G_{TR}^2 G_t^2 \lambda^4}{(4\pi r)^4} = 7.62 \times 10^{-5}/r^4 \tag{3}$$

The above formula for the estimated received power, by ignoring the X, M, Θ, B, F parameters to simplify the calculation of the estimated received power, the formula only need to consider the reader to the tag distance r^4. There is expected to receive power, we need to compensate to achieve the results of compensation closer to the actual test results. The model is as follows:

$$P_{RP}(1-\alpha) + d\beta + \varepsilon\gamma = y \tag{4}$$

Where P_{RP} is the estimated received power, d is the distance from the reader antenna to the tag, ε is a random number between [0,1], y is the measured received power, α is the system reliability factor, β is the distance Compensation factor, γ for the impact of compensation factor.

When the model is adopted, the power radiation is not necessarily radiated by the circle in the actual RFID system. Therefore, the power compensation according to the distance, the actual influence factor of the open rate and the compensation of the influence are carried out, and finally the result is close to the measured result. Then in the evaluation of RFID systems, we only need to have multiple sets of experimental data containing distance and actual received power. Suppose

$$x_i = [-P_{RP_i}, d_i, \varepsilon_i],$$
$$y_i = \mathrm{y} - P_{RP},$$
$$\mathrm{X} = [x_1, \cdots, x_n]^T,$$
$$\mathrm{Y} = [y_1, \cdots, y_n]^T,$$
$$\mathrm{w} = [\alpha, \beta, \gamma]^T$$

then there are:

$$\mathrm{Xw} = \mathrm{Y} \tag{5}$$

Using the least squares can get w,

$$\mathrm{w} = (X^T X)^{-1} X^T Y \tag{6}$$

For different systems, the stability of the system can be determined by the value of α, β and γ. The larger the value of α, the greater the influence of the factors to the RFID system.

4. Experiments setup

The proposed method can be used to test the performance of a single tag in the system and to test the performance of a multi-tag RFID system. As a result, we designed two experiments for this situation.

- *Experiment 1***:** The tags put in the free space, change the distance between the tag and the antenna, measure receive power of the reader antenna. As shown in Fig. 1.
- *Experiment 2***:** The tags put in the semi-Closed metal environment, arrange a number of tags in different locations at the same time, measure the receive power of reader antenna for each tag. As shown in Fig. 2.

In Experiment 1, the tool was placed in free space, and the received power of the reader antenna was measured by changing the position of the tool one by one using a single tool, the same placement posture, and the position was recorded. In Experiment 2, the tool is placed in a drawer, creating a semi-closed metal environment, placing multiple tools in the drawer, measuring their position, and recording the reader's Received power.

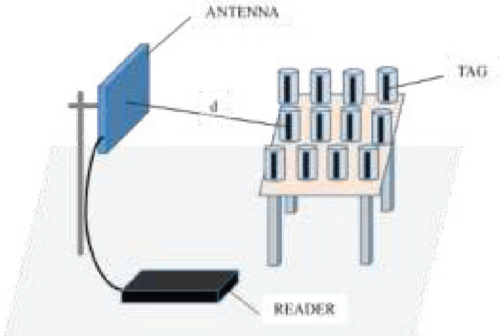

Fig. 1. free space experiment device

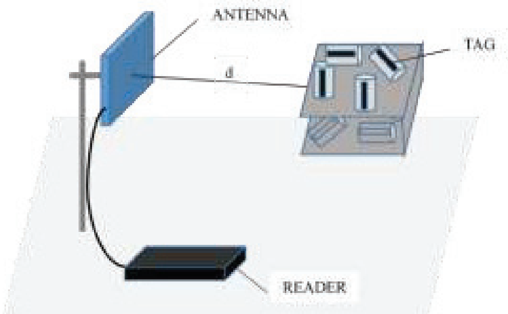

Fig. 2 semi-Closed metal environment experiment device

In the two experiments, we tested two different environments, in all the tags can be read, the test data will be applied to our model, calculated in both cases, And the range of values of α , β and γ is as follows:

Table 2. the range of variables α , β and γ

Environment	α	β	γ
Free space	0.08~0.25	0.1~0.25	0.05~0.15
Semi-Closed Metal	0.22~0.5	0.08~0.32	0.2~0.45

The test results show that in the free space, the range of α is closer to 0, which means that in the free space, the tag is less affected by other factors and has no great influence on the reading of the tag. In the semi-closed metal environment, the value of α becomes larger, the range of β does not change much, and the value of γ changes a lot, which means that in the metal environment, the reading of tag is influenced largely by other factors, because there is a significant increase in compensation due to other factors. After obtaining these three parameters, we can design the system by judging whether the three parameter values of the designed system are in the corresponding interval. If the system is not reliable, make the adjustment to the system so that the system can achieve to a reliable level.

5. Conclusion

This paper presents a method to evaluate the reliability of RFID systems, and constructs two different application environments to test. At the same time, for two different application environments, we give the reliability parameter range of the system through the experiment test, which makes the RFID system reliability test more convenient and understandable. These can provide the reference for the reliability of RFID system in large scale application. In future research, the test method can be extended to a wider range of environment, and the parameters of different environments range for different environments can provide more reliability reference.

Acknowledgements

The research is supported by National Science & Technology Support Plan of China under Grant 2014BAF07B04.

References

[1] Landt, J. "The history of RFID." IEEE Potentials 24.4(2005):8-11.

[2] Periyasamy, M., and R. Dhanasekaran. "Assessment and analysis of performance of 13.56 MHz passive RFID in metal and liquid environment." International Conference on Communications and Signal Processing IEEE, 2014.

[3] Qing, X., and Z. N. Chen. "Proximity Effects of Metallic Environments on High Frequency RFID Reader Antenna: Study and Applications." IEEE Transactions on Antennas & Propagation 55.11(2007):3105-3111.

[4] Griffin, Joshua D., and G. D. Durgin. "Complete Link Budgets for Backscatter-Radio and RFID Systems." IEEE Antennas & Propagation Magazine 51.2(2009):11-25.

[5] Lázaro, Antonio, D. Girbau, and D. Salinas. "Radio Link Budgets for UHF RFID on Multipath Environments." IEEE Transactions on Antennas & Propagation 57.4(2009):1241-1251.

[6] Zhu, Zhiyuan, et al. "A dynamic RFID performance test system." IEEE International Conference on Rfid-Technology and Applications IEEE, 2010:31-36.

[7] Ning, Xiaofeng, and H. Zhao. "A new testing device for RFID performance factors of Conveyor belt system." International Conference on Wireless Communications, NETWORKING and Mobile Computing IET, 2014:619-622.