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Analysis of RFID technology based on technology principles and construction of development model

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Abstract. Radio frequency identification (RFID) system uses radio frequency communication technology to realize the information transmission between reader and tag, and realize the identification, location, monitoring and tracking of target. In order to obtain a better performance of the passive UHF radio frequency identification system, a high-performance open test platform for RFID systems was developed in this paper; influences of factors such as reader, tag antenna polarization mismatch, mutual coupling effect of tag antenna and multipath effect on system performances were analyzed; with the development of test platform, influencing factors in the study were measured. The final experimental results show that: combined with the RFID system simulation application environment based on PLC and OPC technology, the testing platform can provide complete RFID system testing solutions including system performance and conformance testing, third party monitoring, and application testing, and provide better performances.

Key words. Video recognition, performance testing, research development.

1. Introduction

As one of the core technologies in the development of Internet of things, radio frequency identification technology has attracted more and more attention from governments, scientific research institutions and enterprises. Based on the RFID system, combined with the existing network technology, the database technology and middleware technology, it is composed of a large number of networked readers and numerous mobile labels. The Internet of things has become a trend in the development of RFID technology, which is more massive than the current Internet. In the architecture of Internet of things, RFID tags contain items of information that conform to uniform standards with the interoperability. Through wireless and

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wired network, it can collect relevant information to the central information system to realize the identification of objects. Through the open computer network, it can realize the information exchange and share, so as to realize the effective management of the goods. As the carrier of identification information, RFID tags have the advantages of data visibility, the character of real-time, security, environmental adaptability, and the potential of extending the lifecycle management of products. The research of RFID technology mainly includes two aspects: the industrialization key technology and the application key technology. The key technologies of RFID industrialization include tag chip design and manufacturing, antenna design and manufacturing, RFID tag packaging technology and equipment, RFID tag integration and reader design. The key technologies of RFID application include: RFID application architecture, RFID system integration and database management, RFID public service system and RFID testing technology and specifications.

2. State of the art

Foreign RFID related organizations, enterprises and research institutes have established their own RFID testing platforms to promote the development of RFID technology, as well as the industry and application. The Infineon Technologies Company founded the RFID solutions exhibition and evaluation center and system laboratory in Austria in 2004. The lab can provide solution information for the Infineon Technologies Company's RFID systems, including software and systems integration platforms, infrastructure, readers and tags, and other related equipment [1]. The RFID testing center, established by Sun Microsystems in Dallas, USA, focuses on the tag optimization and backend data integration issues. The terminal users of Sun Microsystems products can use the test center to ensure that the products they use can meet the application requirements and can test the RFID system before the actual deployment of the device [2]. At present, some institutions and research institutes in China have also made some progress in the construction of RFID test platform. With the support of the national high technology researches and development programs, in October 2004, Beijing Zhongjiaoguoke Logistics Technology Development Co. Ltd. and Chinese Academy of Sciences Institute of Automation Research Center RFID established the first national RFID test center in China. Through a number of reliability indexes of the key technology of the RFID test, the center put forward the reliability evaluation system to provide the basic data support and direction for further researches [3]. In 2004, the Auto-ID China Laboratory, affiliated to the State Key Laboratory of ASIC and systems, Fudan University, Shanghai was established. The platform can analyze and test the problems in practical applications, provide references for the relevant production enterprises, and provide the theoretical basis and technical supports for the establishment of independent RFID standards in China [4].

3. Methodology

Typically, a radio frequency identification system consists of an electronic tag, a reader, and a computer communication network, as shown in Fig. 1. For each part, the functions are as follows. Electronic tag: as a memory, it contains information about objects and is usually placed in objects. Each tag has a unique ID number UID; reader: as a recognition device, it exchanges information mainly through the RF technology and electronic tags, and it can be designed as hand held or fixed type. The signal power of the reader is much larger than the backscattered signal from the tag, and this has the same frequency as the received signal; computer network communication: it can complete communications, and it is used for data management. Some systems can also connect to the upper computer via a reader's RS232 or RS485 interface [5]. The working principle of the system is that when the reader is in working mode, the antenna will emit radio waves of sufficient powers, and when an object with an electronic tag is near the reader and in the radio frequency range of the reader, the RFID tag will be activated and sent information to the reader. The reader receives and demodulates the RF signals from the tag and sends them to the computer's main systems for processing. The main system makes corresponding processing and control according to the logical operation, and sends out the instruction signal [6].

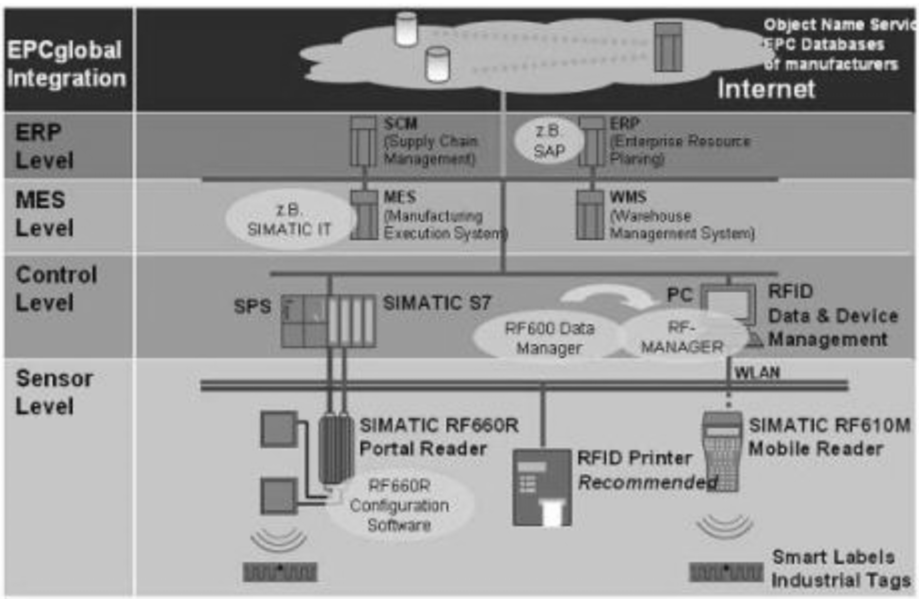

Fig. 1. Radio frequency identification system

RFID system test means testing related equipment through scientific testing methods, testing instruments and testing platforms, the readers, tags, antennas and middleware, and so on in the R & D design phase of RFID system or under the actual deployment environment set by terminal users [7]. Based on the related test contents, test results should be scientifically analyzed; according to different frequency bands and application field of RFID products, corresponding production standards and test specifications shall be established; the system of testing standards of the perfect RFID system should be established to improve the product performance and optimize the equipment deployment, and to promote the progress of RFID technology and the wide range of product promotions [8].

The application test of RFID system was aimed at the specific application environment. By changing the location of the tag, the location of the antenna, the tag, the material attached, and other environmental factors, system identification area, recognition rate, recognition rate, reliability and interoperability performance of RFID system under specific conditions were tested, and specific test contents are shown in Table 1.

Table 1. Application test of RFID system

Label location	Direction
	Angle
	Spacing
Antenna deployment	Direction
	Angle
	Position
Dielectric material	Frequency drift
	Dielectric constant
	Absorption reflex
Environmental factor	Multipath effect
	Electromagnetic interference
	Environmental temperature and humidity

The application test of RFID system faces specific application environment, so it has more practical reference values to terminal users [9]. The environmental factors involved in RFID application testing include: the change of parameters such as the direction, angle and relative position of labels caused by the tag position; the change of parameters such as the square, the angle and the height of the antenna caused by the deployment of the antenna; the change of frequency drift, dielectric constant and absorption reflection coefficient caused by dielectric materials; other changes in the application environment, such as multipath effects, electromagnetic interference, and environmental temperature and humidity parameters. Through the test, among the above parameters, in one or several hours, the identification area, recognition area, recognition rate, recognition rate, reliability and interoperability of RFID systems were changed; the internal relations between various environmental factors and system performance in application environment were analyzed; the influence degree of environmental factors on the system performances was graded; a visual system evaluation model was proposed; references were provided for the optimized and rapid deployment of equipment for terminal users [10].

According to the application requirements of the development of RFID testing technology, combined with the hardware and software design of test platform and four working modes, main functions of the RFID system test platform are shown in Fig. 2.

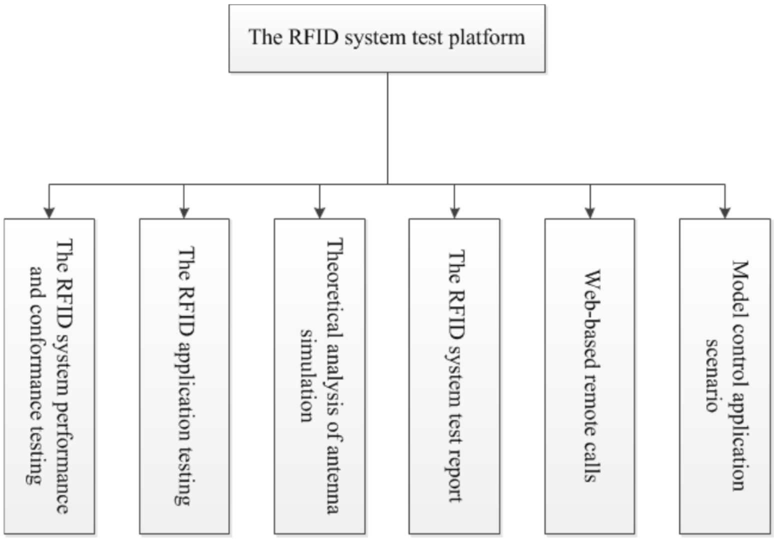

Fig. 2. Main functions of the RFID system test platform

The system performance and conformance testing of RFID mainly completes the conformance testing of air interface physical layer, protocol layer performance standards and other provisions of the standard RFID system under the environment of the system (such as anechoic chambers and open spaces, etc.), as well as the recognition, recognition rate, sensitivity, label RCS and system performance test [11]. RFID system conformance testing includes physical layer and protocol layer test. Physical layer tests include the time domain parameter tests, such as the power on the reader, the time, the pulse width, the duty cycle, the polling time and the state and storage time of the reader; frequency parameter tests such as frequency range, frequency offset, carrier stability, occupied bandwidth, intra band power, and adjacent channel power leakage ratio [1]; modulation domain parameter tests such as the modulation method, modulation index, modulation depth, envelope level value, envelope rising value, falling edge level and envelope value, envelope rising time, fall time, envelop overshoot and undershoot; and the joint time-frequency analysis of signal in time domain, frequency domain and modulation domain. The test protocol layer includes a data storage test; testing of state machines such as ready, arbitrate, answer, confirm, open, protect and inactivate; the test of instruction execution such as save, query, read and write; testing of data frames such as preamble, checksum, data rate, and delimiter length; and the collision test [12].

According to the relevant standards and testing standards, the consistency test of the air interface communication protocol used the developed test platform to complete the test of the reader, label performance and system communication process, as shown in Fig. 3.

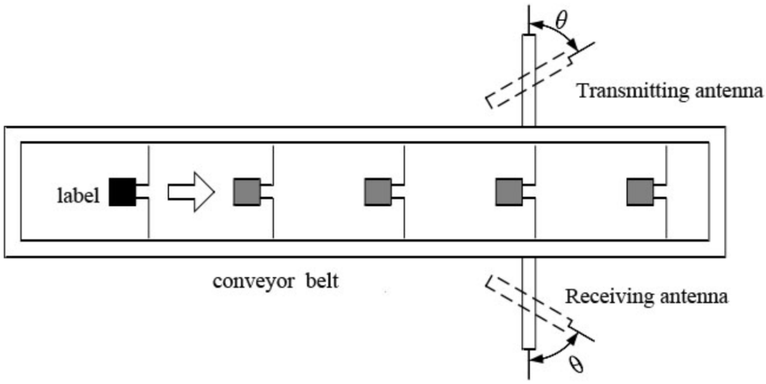

Fig. 3. Conformance testing of communication parameters of the tag's air interface

The test process is as follows: the first step: after the device deployment and initialization were completed, the PCI-5640R, PCI-5610 and PCI-5600 card aliases were selected, and the carrier mode was set to Burst. Second step: the carrier center frequency was set to 915 MHz; the transmit power was set to 27 dBm; the reference power was set to –10 dBm; the capture signal length was set to 10 ms. The third step: the firing command was selected as Inventory Sequence. According to the ISO/IEC 18000-6C standard, the relevant parameters of the instruction are set and the instructions were emitted. In the fourth step, the time domain and frequency domain characteristic parameters of instruction and response signal were analyzed and tested according to the captured instruction and the response signal waveform. By calculating, the differential radar scattering interface of the tag was obtained. The fifth step: according to the test result, the test report was given.

The real-time simulation system RFID reader test can identify the scope by using the developed test platform, system identification and test the reader and the tag antenna angle by rotating the reader antenna with the change of the angle between the reader and the tag antenna The test example of the ALN-9640 tag of Alien Company was given. A symmetrical half wave antenna was used to test the antenna.

Test process: Step 1: the ALN-9640 tag was attached to the conveyor belt, and the labels and readers were set parallel to the antenna. At this point, the azimuth of the transmit and receive antennas was assumed to be: $\theta = 0°$. The second step: the conveyor speed was set to 0.1 m/s; the transmitting power of the reader antenna was set to 27 dBm. The carousel was activated to record where the label was successfully identified. The third step: the angle of the transmitting and receiving antenna was set to 15 degrees, from 0 to 165 degrees. At different angles, the second step was repeated. The fourth step: the identification location of the tag was counted with the change of θ.

On the basis of the performance and conformance testing of the RFID system and the testing function of the RFID system application, the platform can also realize third party monitoring and data stream disk function. Based on the remote invocation function based on Web of the platform, the platform can provide users with data storage and open testing services, and further study and analyze the stored data.

3.1. Result analysis and discussion

The results of the system identification test are shown in Fig. 4.

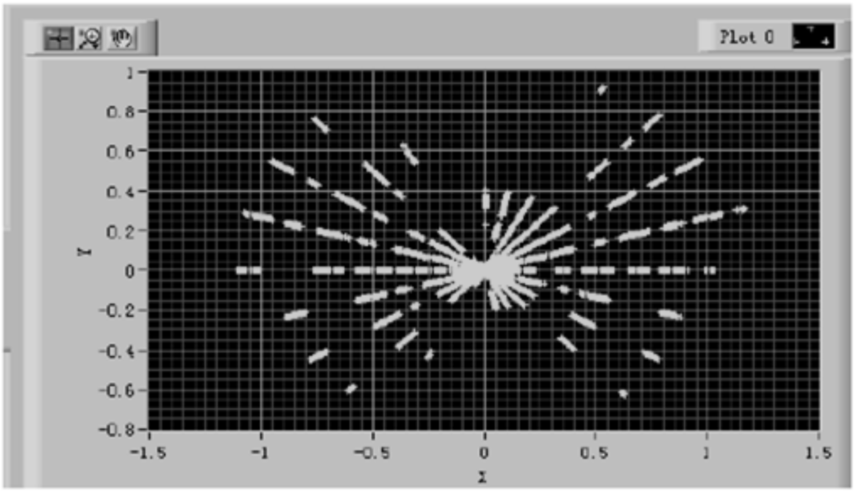

Fig. 4. The results of the system identification test

It can be seen that due to the effect of antenna, reader and tag reader and tag antenna main lobe direction angle, reader and tag antenna polarization mismatch labels and multipath effects and other factors, the recognition range was scrappy and uneven. In the maximum recognition range of the system, the tag had the location blind area which can't be identified, and it affected the recognition range and recognition rate and other system performance parameters.

The third party monitoring test can monitor the air interface of RFID system, and test the standard compliance of the system reader and tag equipment. The test platform supports the DSB-ASK, PR-ASK modulation, Miller encoding, NRZ-L encoding, PIE encoding, Manchester encoding and other encoding methods, and it can test the time domain waveform analysis, frequency domain analysis, and the baseband signal parameters of the whole communication process. It has the testing function of protocol layer parameters such as protocol state machine, data rate, and frame format, mandatory and user-defined command, so the sensitivity of monitoring test is relatively high, accompanied by simple testing methods. In the test, it is necessary to note that the tag response signal is weak, so in the case of limited antenna sensitivity, the monitoring antenna should be placed near the tag to obtain better listening effect. In order to further analyze, handle, and store the performance of the device to be tested, the test platform has realized the function of the signal flow disk. The acquired air interface signal can be entered into a microcomputer to carry out the advanced protocol analysis. The waveform data is in the standard format and it is compatible with software such as Matlab.

The test results of minimum transmit power of the reader antenna are shown in Table 2.

Table 2. Test results of minimum transmit power of the reader antenna

Tag number	1	2	3	4	5	6	7	8	9
$\bar{P}_{\text{seni}}$ (dBm)	23	33	34	17	16	17	21	20	21
$P_{\text{ni}-\min}$ (%)	–8.7	–9.1	–8.7	–5.9	–6.3	–5.9	–9.5	–10	–9.5
$P_{\text{ni}-\max}$ (%)	4.4	4.8	4.4	11.8	12.5	11.8	4.8	10	4.8
ΔP_{ni} (%)	13.1	13.9	13.1	17.7	18.8	17.7	14.3	20	14.3

When the tag spacing is less than 1.5 times the system operating frequency wavelength, the mutual coupling effect has great influences on the system performance; the effect of mutual coupling on the system performance is nonmonotonic, so it can be enhanced or reduced; for double label, the range of the minimum transmit power of the reader antenna is (–7 %, 11.6 %); increasing the transmit power of the reader antenna can reduce the influence of mutual coupling effect on the system performance; for the label double plane case, the range of the minimum transmit power of the reader antenna of target plane label is (–10 %, 12.5 %); the influence of the interference planar tag on the recognition rate of the target plane label system is similar to that of the metal plane.

4. Conclusion

In this paper, combined with the requirements of the project and the actual application requirements of RFID, the RFID system test platform based on software defined radio and virtual instrument technology was developed. By using the test platform and commercial RFID equipment, influences of polarization mismatch between reader and tag antenna, antenna inter-coupling effect and multipath effect on the performance of RFID system were analyzed and tested. Theoretical guidance and references were provided to the RFID technology research and the rapid deployment of equipment of terminal users. Through the research of this paper, some conclusions were obtained as follows.

Compared to existing RFID test equipment, the test platform developed in this paper has the characteristics of low cost, multi support protocol, user-defined test function and typical deployment scenarios, and it can provide complete solutions for the RFID system testing, such as the RFID system performance, the protocol conformance and application testing. When the tag spacing is less than 1.5 times the system operating frequency wavelength, the mutual coupling effect has great influences on the system performance; the effect of mutual coupling on the system performance is nonmonotonic, so it can be enhanced or reduced; increasing the transmit power of the reader antenna can reduce the influence of mutual coupling effect on the system performance; for double label and label biplane situations, the ranges of the minimum transmit power of the reader antenna of target plane label are (–7 %,11.6 %) and (–10 %, 12.5 %). Compared to free space, the degradation rate of system path loss in indoor multipath environment is faster; the propagation of the antenna from the reader to the tag electromagnetic wave is the first Fresnel region, and the additional loss is caused by the barrier so as to increase the loss rate of the system path loss; when Finel clearance is 1.5 times larger than the radius of the first Finel District, edge obstacles have less influence on the system path loss; compared with the traditional logarithm distance path loss model, the standard deviation of the t two-slope model proposed in this paper can be reduced by more than 10%. The reader antenna should be oriented to the geometric center of the target region; commercial reader antennas are mostly elliptical polarized; polarization mismatch is still an important factor that should not be neglected; compared to the single antenna case of a single reader, the multi reader antenna can effectively improve the target area recognition rate; multi antenna coherent multipath interference can produce new blind spots, but the improper use of it will reduce the identification rate of target areas; the system performance optimization method based on label set and phase switch can improve the target area recognition rate by 10 % and 7.6 %.

Because of the limitations of research level and condition, this research still has some problems: the expression of mutual impedance between tag antennas and the influence of mutual coupling effects on the performance of RFID system are only applicable to the condition where the antenna is in the far field of the antenna radiation, and the tags in practical applications may be in the near-field region of antenna induction; evaluation methods cannot reflect the density distribution of target region recognition rate; tag set optimization method increased system costs; when the target object is small, if the distance is less than 1.5 times the frequency of the label system wavelength, the mutual coupling effect between antennas may lower system performances; the phase switch optimization method increased the number of read times of readers, and reduced the recognition rate of the system.

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