The Method and Practice of Container Electronic Tag Performance Test

Shibo Xu¹, Shuquan Shi* , Jichun Li¹ and Shuhui Zhang¹

¹ China waterborne transport research institute, Beijing, 100088, China
*Corresponding author’s e-mail: winbul@126.com

Abstract. With the rapid development of container transportation, container transportation has become the main mode of transportation that promotes social development and accelerates the process of globalization. The container RFID electronic tag is expected to improve the transportation efficiency of the container. This article describes the testing methods of container electronic tags. At the same time, through the actual application test of container RFID tags, it summarizes and proposes how to optimize the reading efficiency of container electronic tags, so as to achieve the best performance of container RFID tag system.

1. Introduction

With the rapid development of container transportation, container transportation has become the main mode of transportation that promotes social development and accelerates the process of globalization. According to statistics, 90% of international cargo transportation uses container transportation. [1] The safety and efficiency of container transportation are getting more and more attention. At present, the commonly used container image number recognition technology uses image processing technology to extract a digital container number and collect it in a computer. The recognition accuracy of this technology is only about 90%, and it is greatly affected by the rainy and foggy weather and the destruction level of container. But even with such a low recognition rate, image recognition is still widely used in automatic identification of container number. In order to improve recognition accuracy, the RFID technology get widespread attention, which can not be affected by the weather and realize automatic identification at a longer distance. [2] Container electronic tags can record logistics information during container transportation. By installing readers at the transportation and operation nodes, you can quickly read the relevant information of the container, which helps to improve the efficiency of container customs clearance and makes container information exchange more convenient. However, in the actual practice of container electronic tags, there are many problems that cause the container electronic tags to be read incorrectly and successfully. The main reason may be the design problem of the container electronic tag itself, or it may be interfered by other environmental signals. It may also be other factors such as the location where the electronic tag is installed on the container, metal material, etc.

2. TESTING METHOD OF CONTAINER RFID TAG

In order to test the performance of container RFID Tag better, we will adopt a combination of laboratory testing and outdoor testing.

2.1. Laboratory test of container RFID tag

The frequency range commonly used for container RFID tag is 860-960MHz, which is according to the
protocol requirements of ISO 18000-6C[3-5]. Testing system we adopt is shown as figure 1, which contains a computer, Tagformance Pro device and testing antenna.

![Testing System](image)

**Figure 1. Testing system.**

2.1.1. Calibration of testing equipment
Before the formal equipment test starts, the equipment needs to be calibrated first, according to the standard performance curve of DUT( device under test), we find the testing result of this testing system is close to the standard performance curve, which is shown as figure 2.

![Calibration Graph](image)

**Figure 2. Calibration of testing equipment**

2.1.2. Performance resonance frequency
Through the test system, the resonant frequency of the electronic tag can be measured. It indicates the minimum power that the tag can be activated. The tag will be placed on air and metal, activation sensitivity curve of different medium is shown as figure 3. The red line indicates the tag is in the air, the blue line indicates the tag is on the metal plate.

![Activation Curve](image)

**Figure 3. Activation sensitivity curve of different medium**

We can find The best performance of the DUT tag in the air is at 940MHz, and the activation sensitivity is -19dBm. The activation sensitivity of 920MHz is -18dBm. The best performance of the tag on the metal plate is at 940MHz, and the activation sensitivity is -14.5dBm, the activation sensitivity is -13dBm at 920MHz. The difference between the forward activation sensitivity of the two is about 6dB.

2.1.3. Forward theoretical reading distance
According to theoretical read range forward, the equation is (1).

\[
R = \sqrt{\frac{P_{\text{max,ANT}}}{P_{\text{min}}}} \cdot \frac{c}{2\pi f T}
\]

(1)
Assuming the transmit power is 35dBm, the tag forward reading distance can be calculated as shown in figure 4.

We can find the performance of the tag in the air is better than the performance on the metal plate. The user tag can read 12m@920MHz in the air at the forward theoretical reading distance (+35dBm transmission power is calculated), but it can only be read on the metal plate about 6.5m@920MHz.

2.1.4. Reserve scattering power
Through the test system, the power on tag reverse is shown as figure 5. The red line indicates the tag is in the air, the blue line indicates the tag is on the metal plate.

2.1.5. Reverse theoretical reading distance
According to theoretical read range reverse, the equation is (2).

\[ R_{\text{max,RS}} = \sqrt{\frac{P_{\text{tag,RS}}}{P_{\text{EIRP,RS,im,0}}} \cdot \frac{c}{4\pi f}} \]  

The tag reverse reading distance can be calculated as shown in figure 6.

The reverse theoretical reading distance of the user tag in the air (calculated with -74dBm receiving sensitivity) is 22m@920MHz. The reverse theoretical reading distance on the metal plate is only...
6m@920MHz, which is less than 6.5m in the forward direction. The tag can be activated but the reader cannot demodulate.

2.2. Outdoor test of container RFID tag
We put the container RFID tag outdoor, and use the outdoor RF cable, the testing environment of outdoor is shown as figure 7.

![Figure 7. Outdoor testing environment](image)

We compare the tag sensitivity of tags in the laboratory and outdoors. The comparison chart is shown in Figure 8. The blue line indicates in the laboratory, and the yellow line indicates the tag outside.

![Figure 8. Tag sensitivity of tags in the laboratory and outdoors](image)

According to formula (1), the tag forward reading distance comparison in the laboratory and outdoors is shown in figure 9. The blue line indicates in the laboratory, and the yellow line indicates the tag outside.

![Figure 9. Theoretical read range forward in the laboratory and outdoors](image)

As can be seen from the test results in the above figure, in the indoor and outdoor tests, the RF cable used indoors is a 1.8m RF cable, and the RF cable used in the outdoor test is the RF cable in the user's field application system. In indoor and outdoor testing, the performance difference is 1.5dB at the 920MHz frequency point, and the deviation is within the normal range.

3. CONTAINER RFID TAG TEST AT ACTUAL APPLICATION SCENARIO
In addition to testing container electronic tags in the laboratory and outdoors, testing in actual application scenarios is also very important. The field application test uses the customer's field circular polarization test antenna and RF cable. Field application test is divided into two parts, test distance and relative test
angle. The relative test angle is divided into vertical direction, horizontal direction, 45 degrees left and 45 degrees right. The angle of the tag relative to the test antenna is as follows as Figure 10.

![Antenna test angle](image)

Figure 10. The angle of tag relative to the test antenna

The test distance is the horizontal distance between the tester and the field application antenna. The location diagram is as figure 11.

![Field test antenna](image)

Figure 11. Schematic diagram of test distance

The results of different test distances and relative test angles are as table 1.

### Table 1. Real field test data

| Testing location | vertical | horizontal | left 45 | right 45 |
|------------------|----------|------------|---------|----------|
| Directly below the test antenna | 3 M | 28.5 | 25.5 | 25.5 | 26.5 |
| | 4 M | Can’t read | 25.5 | 27 | 29 |
| | 5 M | 29 | 24.5 | 27 | 24.5 |
| | 6 M | 27.5 | Can’t read | 28 | 30.5 |
| | 7 M | 30 | 30.5 | 29 | Can’t read |
| | 8 M | Can’t read | 27.5 | 29.5 | 28.5 |
| | 9 M | 31 | Can’t read | Can’t read | 27.5 |
| | 10 M | Can’t read | 30.5 | Can’t read | Can’t read |
| | 11 M | Can’t read | 30.5 | Can’t read | 29.5 |
| | 12 M | Can’t read | Can’t read | 30.5 | Can’t read |
| Directly below the test antenna | 3 M | Can’t read | 24 | 28.5 | 25.5 |
| Left 1 M | 4 M | 29.5 | 25 | Can’t read | 23.5 |
| | 5 M | Can’t read | 26 | 28.5 | 26.5 |
| Directly below the test antenna | 3 M | 28.5 | 24 | 27.5 | 24.5 |
| Right 1 M | 4 M | Can’t read | 28 | 28.5 | 27 |
| | 5 M | Can’t read | 29 | Can’t read | 28.5 |

It can be seen from the test data in the above table that the user tag can be read normally most of the time when the horizontal distance is 8m, but it may not be read at some angles within 8m, which may be caused by the radiation range of the test antenna. However, due to ground reflection and other factors, the tag can still be read at 12m. The reverse signal strength of the tag received during the application test is between -57dBm~68dBm.
And the following problem can be found:
1. In the field application test, the horizontal test distance often fails to be read after 5m. When the range exceeds 5m, the tag can be read, mainly relying on reflection, and the performance margin is small.
2. The antenna used in the field is a circularly polarized antenna, but the minimum reading power of the test tag at different relative angles is different, and the maximum difference is 3~4dB.
3. The position of the tag 1m from the left and right of the antenna will have a better reading effect than the position facing the antenna.

4. CONCLUSION
According to the above test results, it can be seen that the tag can be read normally in most cases in the field application environment, but there are some problems exist. We should improve the reading efficiency of container RFID tags through the following experimental tests. Only by meeting the application requirements of containers can we better promote the combination of technology and industry and create economic benefits and social value.

1. Choice of container electronic tag
The test results show that the performance of DUT on metal plates is worse than that in air, and the container is made of metal, so the reading effect of the tag on the container will be far worse than other medium. In order to obtain better reading efficiency, actual tests should be carried out during tag design, so that the resonant frequency of the tag should be as close as possible to the frequency of the reader, so as to obtain better reading efficiency.

2. Choice of test antenna
According to the test results, it can be seen that the tag cannot be read at different relative angles. Therefore, in the actual application process, it is necessary to select a test antenna that satisfies the radiation range and can radiate stably at different relative angles. At the same time, the actual test should be carried out on the spot before the actual application, and the antenna angle should be adjusted to obtain the best reading effect.

3. Selection of reader equipment
In the process of field application test, the reverse signal strength of the read tag is between -57dBm~68dBm. If the receiving sensitivity of the reader is worse than -68dBm, it will appear that the tag can be activated, but the reader cannot demodulate the return signal of the tag, leading to read unsuccessfully. In order to ensure that the reader can receive the return signal of the tag normally and stably, the reader's receiving sensitivity needs to be higher than the actual test result by more than 3dB. Therefore, it is best to choose a reader with a receiving sensitivity below -71dBm in practical applications.

References:
[1] Jinhua Li, Jianhong Zhu, Haoan Xie. “Performance test and analysis of electronic tags applied to containers”, Information Technology and Standardization, 2011, 10, 59-62
[2] Shibo Xu, Munan Deng, Jichun Li, Jing Wang, “Test system design of container RFID tag based on virtual instrumentation” MEMCI 2021, Guangzhou, 2021, pp. 2068-2072.
[3] ISO/IEC18000-6 Information technology — Radio frequency identification for item management — Part 6: Parameters for air interface communications at 860 MHz to 960 MHz.
[4] ISO/IEC 18047-6 Information technology - Radio frequency identification device conformance test methods - Part 6: Test methods for air interface communications at 860 MHz to 960 MHz
[5] ISO/IEC 18046-3 Information technology - Radio frequency identification device performance test methods - Part 3: Test methods for tag performance