The sensitivity test of 2.45GHz RFID active tag

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ABSTRACT: RFID active tag sensitivity is an important indicator of the tag, and its sensitivity is related to the location and orientation of the tag. However, in the actual application of the tag, its optimal working position and direction cannot be determined directly. Analysed the existing test method of active tag sensitivity, the test result of the tag sensitivity in any direction is used as the tag sensitivity. For the limitations of existing test methods, this paper presents a new idea and method for sensitivity testing of a 2.45GHz RFID active tag. Setting up the test environment used the biconical antenna, based on the sensitivity test in the stepping at the same angle in different directions, and the analysis algorithm based on measured data. The test experiment shows that the test result based on this method is rigorous and effective, and can be widely used in 2.45GHz RFID active tag sensitivity test.

1. Introduction
RFID (Radio Frequency Identification) is a non-contact automatic identification technology and an important part of the Internet of Things (IOT) technology. Compared with traditional IC/ID cards, RFID has the advantages of non-contact, fast read speed, and the ability to operate multiple tags at the same time. Among them, the active tags’ reading and writing distance can be as far as 50 meters or more. These advantages of active tags make the 2.45GHz RFID have a wide application such as long distance reading and writing, high stability, and fast read speeds.

Active tags that are tags with internal power supply, can actively send data to the reader. The applications are mainly those where the transmission distance and data transmission quality are relatively high, such as personnel, asset management and positioning, vehicle management, and vehicle inspection. There are indisputable advantages in such application scenarios, among which the remote transmission distance and self-integrated sensors have advantages that passive tags do not possess.

In the requirements of RFID technology for tag, the tag antenna generally needs to be omnidirectional, or the radiation signal covers the directionality of the hemisphere. However, in an actual design, the omnidirectionality of the tag antenna is an ideal state. In general, the tag’s antenna still has obvious directionality, so it will have the best couple in the strong directional part and the coupling in the back part will be worse. Therefore, this article introduces the idea of measuring the sensitivity of tag in different directions.

According to the national standard, there is no clear standard for the sensitivity test method for 2.45GHz RFID active tags. However, this indicator is a critical performance parameter for designers and users. Designers can use the method to test and improve the design of the tag and also judge the merits of the tag based on the indicator.
2. Test environment setup and preparation

According to national independently developed standard of GJB7377.2 Air Interface for military Radio Frequency Identification Part 2: 2.45GHz Parameters\(^2\) and GJB7378.2 Conformance Test Method for Military Radio Frequency Identification Air Interface Part 2: 2.45GHz\(^3\), the performance should be tested in the anechoic chamber environment. The radiation method has been used to test the sensitivity of the active tag of 2.45GHz, and the test system works as the reference reader to transmit the modulated signal. All the equipment include: a reference reader (or protocol simulator), a transmit antenna, a receive antenna, a double-cone antenna, a spectrum analyzer, SMA RF cables, and RF connectors.

2.1. The gain of biconical antenna

In the test method, a biconical antenna with a known gain is used as an alternative antenna to replace the TUT (Tag under Test) to receive the signal from the transmitting antenna. So as to be observed on the spectrum analyzer in real time. Since the antenna under test is an omnidirectional antenna in the experiment. The evaluation of the measured tag at different angles is performed by using the respective gains of the eight points of 360° omnidirectional direction in 45° steps. And the sensitivity test referenced the test method of field strength in ETSI TS 103 052 V1.1.1\(^1\). So the gain of the eight points of the biconical antenna in a 360° omnidirectional direction at 45° steps need to be measured firstly. In this experiment, a biconical antenna after metering was used as an alternative antenna and its gain(dBi) at 3 meters was measured. The test results as follows:

| Frequency | Test angle | Gain (dBi) |
|-----------|------------|------------|
| 2.405GHz  | 0°         | 1.5        |
|           | 45°        | -5.2       |
|           | 90°        | -12.2      |
|           | 135°       | -0.2       |
|           | 180°       | 6.4        |
|           | 225°       | -1.8       |
|           | 270°       | -10.5      |
|           | 315°       | -9.2       |

2.2. Setting up the test environment of TUT

In the test, the reference reader/writer analyzer (or simulator) works in the control room, and the signal transmitting uses the RF cable (SMA-SMA) through wallboard interface connecting the transmitting antenna in the anechoic chamber. The receiving antenna is connected at the same side to receive the signal comes back from tag under test, and the receiving antenna is connected with the reference reader/writer in the control room through the wallboard interface with RF cable (SMA-SMA). The tag under test is placed on the turntable. The setup as follow:
2.3. **Biconical antenna alternative arrangement**

After the reply signal of the tag is tested in 360° omnidirectional direction in 45° steps. Remove the tag under test (TUT) on the turntable and replace with a biconical Antenna. Connecting the biconical antenna to the spectrum analyser with the RF cable (SMA-SMA) through the wallboard interface. The setup as follow:

![Diagram](image1)

**Fig. 1.** The Setting up of the Test environment

In the experiment, according to the RFID standard of 2.45 GHz, the maximum transmit power of reader should less than 30dbm. And the radiation emission signal transmission process is accompanied by the space loss. It is not necessary to add an attenuator when the spectrum analyser connected, that’s to say it is sufficient of direct connection. The original receiving antenna can be disconnected.

Respectively setting the power value of the transmitted signal of the reference reader/writer in each angle to the value of 8 points in 360° when the tag which measured with the setup of Fig.1 replies in 50% correct rate . The reference reader/writer sends ready command continuously and receives with the biconical antenna. The spectrum analyzer collects the received value in each point.

2.4. **Measuring the loss of RF cables**

Use the network analyzer E5063A or signal source and spectrum analyzer to measure the loss of the RF cables used in the experiment. Making effective identification on the tested cables. The loss of cables as follows:

- Reference reader/writer transmitter to anechoic chamber transmitting antenna port: \( L_{tx}=4.1 \) dbm.
- Anechoic chamber receive antenna to reference reader/writer receiver port: \( L_{rx}=3.9 \) dbm.
- Anechoic chamber biconical Antenna to spectrum analyser: \( L_{rx}=3.2 \) dbm.

Above test data will be used to the power loss in the result analysis.
3. Test Methods

3.1. TUT Test
1) Start the test software of the reference reader/writer and set the transmit parameters according to the standard requirement, such as the transmit frequency channel number, transmit power, and reference level. The transmit parameters should be supported by the tag, and the initial transmission power is the value which enables the tag respond correctly.
2) Arrange the test environment according to the setup in Fig.1. Send the sleep command, ready command, access start slot command, etc. to the tag with the reference reader/writer. When entering the tag collection state, send the random number command continuously to it. The tag will respond to the command.
3) Constantly adjust the transmit power of the reference reader/writer so that the reference reader/writer can receive the response signal of the TUT correctly with 50% probability. Record the transmit power of the reference reader/writer in this position.
4) Rotate the turntable in steps of 45°, and perform step 2) and 3) in each position.
5) When the reference reader/writer transmits with the minimum supported power and the tag still can correctly respond 100%. Add a 20db attenuator in the link.
6) Record the critical power value emitted by the reference reader/writer at each location. Taking the transmit frequency as 2405MHz, i.e., 0 channel as an example, the data recorded in this test is as follows:

| Frequency | Test angle | PTx (dbm) |
|-----------|------------|-----------|
| 2.405GHz  | 0°         | -49.5     |
|           | 45°        | -45.0     |
|           | 90°        | -44.8     |
|           | 135°       | -36.4     |
|           | 180°       | -42.5     |
|           | 225°       | -34.5     |
|           | 270°       | -45.0     |
|           | 315°       | -43.5     |

3.2. Biconical Antenna Replacement
Remove the tag (TUT) from the turntable and replace it with a biconical antenna after completing the test of 2.1. Connect the biconical antenna with the spectrum analyzer by the SMA-SMA RF cable which pass through the wallboard interface of anechoic chamber for the following test:
1) Set the test parameters of spectrum analyzer follow the section 2.1. The test bandwidth is 100MHz, the RBW is 100KHz, and the acquisition mode is Max Hold.
2) In the experiment, because the standard 2.45 GHz reader’s maximum transmit power is less than 30dbm, and the radiation emission signal transmission process is accompanied by space loss, it is not necessary to add an attenuator when connecting the spectrum analyzer. The original receiving antenna can be disconnected.
3) Rotary the turntable from 0° and the rotation direction is consistent with 2.1. Consider the noise floor of the spectrum analyzer and the higher sensitivity of the active tag itself. The reference reader/writer need to transmit signal uniformly with 0 dBm after replacing the tag under test with a biconical antenna. And the critical power have been recorded in 2.1 should be used during the analysis of results.
4) Record the maximum power value from the spectrum analyzer which received by the biconical antenna. Rotate the turntable at 45° steps. The reference reader/writer sends ready commands with 0dbm at each location. Record the signal power received by the spectrum analyzer. The data as follows:
Table 3. The signal power received by the spectrum analyzer

| Frequency | Test angle | P (Tx=0) | PRx(dbm) |
|-----------|------------|----------|----------|
| 2.405GHz  | 0°         | 0        | -54      |
| 45°       | 0          | -61.2    |
| 90°       | 0          | -72.46   |
| 135°      | 0          | -59.27   |
| 180°      | 0          | -54.05   |
| 225°      | 0          | -58.43   |
| 270°      | 0          | -77.28   |
| 315°      | 0          | -60.93   |

4. Analysis of test results
Set the power value of the transmitted signal of the reference reader/writer at each angle. They are the power values when the tag under test correctly reply in 50% probability at 8 points of 360°. Record the power received as \( P_r(i) \).

Biconical antenna gain per fixed step direction record as \( G(i) \).

The loss of receiver port record as \( P_{loss} \).

The sensitivity of the tag under test in each fixed stepping direction record as \( P_{TUT}(i) \).

Measured tag sensitivity RMS value record as \( P_{RMS} \).

Then,
\[
P_{TUT}(i) = P_r(i) + P_{loss} - G(i)
\]

\[
P_{RMS} = -\sqrt{\frac{1}{N} \sum_{i=1}^{N} P_{TUT}(i)^2}
\]

The following is the calculation process of the test:

Table 4. The calculation process and data in the test

| Frequency | Test angle | P (Tx=0) | PRx(dbm) | PTx(dbm) | (i)P ′r | G(i) | \( P_{loss} \) | \( P_{TUT} \) |
|-----------|------------|----------|----------|----------|---------|------|---------------|-------------|
| 2.405GHz  | 0°         | 0        | -54      | -49.5    | -103.5  | 1.5  | 3.2           | -101.8      |
| 45°       | 0          | -61.2    | -45.0    | -106.2   | -5.2    | 3.2  | -97.8         |
| 90°       | 0          | -72.46   | -44.8    | -117.26  | -12.2   | 3.2  | -101.86       |
| 135°      | 0          | -59.27   | -36.4    | -95.67   | -0.2    | 3.2  | -92.27        |
| 180°      | 0          | -54.05   | -42.5    | -96.55   | 6.4     | 3.2  | -99.75        |
| 225°      | 0          | -58.43   | -34.5    | -92.93   | -1.8    | 3.2  | -87.93        |
| 270°      | 0          | -77.28   | -45.0    | -122.28  | -10.5   | 3.2  | -108.58       |
| 315°      | 0          | -60.93   | -43.5    | -104.43  | -9.2    | 3.2  | -92.03        |

Then,
\[
P_{RMS} = -\sqrt{\frac{1}{8} \sum_{i=1}^{8} P_{TUT}(i)^2}
\]

\[=-97.95dBm
\]

Take the tested tag as an example, the sensitivity is -97.95dBm.

5. Summary
The sensitivity of RFID active tag is one of the most critical performance indicator. The sensitivity is not only determined by the tag chip but also related to the performance of the tag antenna. This article
proposes a new idea and method for the active tags’ sensitivity testing. Test the sensitivity of 2.45 GHz RFID active tag which stepping at the same angle in different directions. Finally, the RMS value which calculated for all direction as the tag's final sensitivity. This test method is more rigorous than using the theoretical space loss value directly as part of the sensitivity calculation. The test result is closer to the tag’s actual sensitivity through analyzing a large number of test data. The next step of this paper is to make further improvements based on this method. Reduce the complexity of the test as close to the true sensitivity of the tag as possible.

References
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