Performance Study of New Microwave Darkroom Shielding Effect

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Abstract: To study the transmission frequency range and transmission mode characteristics of wireless communication radio frequency equipment, the microwave darkroom was used to shield external electromagnetic interference. Absorbing materials were used to suppress interference from internal electromagnetic multipath reflections. The combination of the two resulted in a relatively silent electromagnetic measurement environment. The design, evaluation and verification methods for microwave darkrooms used for measurement of urban rail transit RF equipment were mainly studied. From the perspective of transmission mode and transmission frequency band, the measurement requirements of urban rail transit RF equipment were analysed. The main parameters required for microwave darkroom design were quantitatively calculated. The results showed that the measurement environment of the microwave darkroom met the performance requirements of the design process through the evaluation of multiple performance indexes of the microwave darkroom. Therefore, microwave darkroom measurement systems are available and reliable.

1. Introduction

At present, in the urban rail transit industry, the vehicle-to-ground communication system mainly includes the communication-based train control system (CBTC) and the passenger information system (PIS). Both use wireless LAN technology based on the 802.11b/g standard [1]. However, the 2.4 GHz and 5.8 GHz frequency bands used in the rail transit vehicle communication system are now in the range of ISM (Industrial Scientific Medical), which is in the same frequency range as WiFi. Most wireless routers on the market are in the ISM band. 802.11b/g is the standard product. This leads to wireless interference of various WiFi signals in the urban rail transit RF equipment test environment [2]. Especially in the 2.4GHz band, WiFi signals and RF devices transmit signals. At the same time, in the free wave test process, the complex terrain environment will lead to the emergence of multipath fading. The accuracy of the measurement results is affected. Nowadays, the rail transit vehicle communication system is gradually introducing LTE (1.8GHz band) radio equipment. However, wireless interference and multipath fading problems are unavoidable during the measurement process [3]. Therefore, for accurate analysis of equipment performance, the construction of microwave darkrooms for urban rail transit RF equipment is necessary.

The microwave darkroom uses shielding materials to shield external electromagnetic interference, and the absorbing material suppresses internal electromagnetic multipath reflection interference. The combination of the two results in a relatively silent electromagnetic measurement environment. It provides a low level and constant electromagnetic environment for improved measurement accuracy and reliability. To build a microwave darkroom suitable for urban rail transit RF equipment measurement, it is necessary to design the shielding material, absorbing material, structure size and measuring system of the microwave darkroom according to the requirements of the RF equipment in the transmission mode and transmission frequency band. For the design of the microwave darkroom, various parameter indicators need to be evaluated. The design of the microwave darkroom should meet the measurement requirements of urban rail transit RF equipment. Finally, the availability and reliability of the microwave darkroom measurement system are verified by measuring the commonly used RF equipment in urban rail transit.

2. State of the art

There are two commonly used measurement methods in microwave darkrooms: far field measurements and near field measurements [4]. The measurement directly taken in the far field of the antenna is called far field measurement. Far-field measurement is a common method used in microwave darkroom measurement because it is simple and easy to implement, and the test system is also relatively easy to set up. The measurement at three to ten wavelengths from the antenna aperture is called near field measurement [5]. Near-field measurement is limited by real-time factors, and the cost of the test system is high, so the practical application is not extensive. However, near-field measurements have low requirements on the site. It can adapt to the testing requirements of various types of antennas, and the accuracy of measurement results is also high. Therefore, the antenna near-field measurement technology has become the focus of research at home and abroad.

The antenna near-field measurement technology is a high-precision antenna measurement technology commonly used in the world. In foreign countries, from the 1950s, the antenna near-field measurement technology has entered the engineering application stage from the theoretical research stage [6]. It can be used not only to measure the radiation characteristics of an antenna, but also to diagnose the orbital field distribution of an antenna. This provides a reliable and accurate basis for the design and research of large planar array antennas. In China, the antenna near-field measurement technology started from the end of the last century. By the end of the 1980s, large-scale planar near-field measurement systems were developed. In recent years, some colleges and universities and research institutes have gradually introduced a near-field measurement system of a certain scale. For example, the near-field measurement system produced by Israel ORBIT and NSI in the United States represents the international level of the antenna planar near-field measurement equipment in the 1990s [7]. With the continuous advancement of technology, high-performance antennas have been widely used in various fields such as aviation, aerospace, shipbuilding, and transportation. The planar near-field measurement system based on the principle of Fourier transform emerged with the development of high-performance antennas. In the early days, this system had a small scanning range and low precision. Gradually, it has developed into a comprehensive optical, electromechanical and multidisciplinary system consisting of precision optical systems, precision mechanical systems, precision measuring instruments, precision servo drive systems and computers and various interface circuits [8].

3. Methodology

3.1 Microwave darkroom measurement requirements

The measurement of the microwave darkroom is divided into two types: near field measurement and far field measurement. The difference between the two is that the distance between the source antenna and the antenna under test is different, and the field of the antenna under test is different. There are three different types of field areas in the space immediately adjacent to the antenna radiation. According to the characteristics, it can be divided into the induction near-field area, the conditioned near field area and the far-field area. In the space immediately adjacent to the antenna, the induced near field region is centred on the field source and is in three wavelength ranges. The induced near field region is a non-radiative field. The electromagnetic field in this area has no work. The receiving antenna generates capacitive and inductive coupling in this area. Therefore, it cannot be used for antenna measurement. The induced near field region is outwardly a radiation field region. The region with 3-10 wavelengths from the field source is the radiation near-field region. The area above 10 wavelengths is the far field of radiation. Near-field measurements and far-field measurements of the antenna are performed in the radiated near-field region and the radiated far-field region, respectively.

At present, urban rail transit has three transmission modes: free wave, leaky cable, and leaky waveguide. The transmission devices used by the free waves are each a directional antenna. It is dominated by Yagi antenna. Figure 1 shows the Yagi antenna used in the field. For the

measurement of directional antennas, the main purpose is to obtain important electrical performance parameters of antenna gain, 3dB width and maximum sidelobe level, analyse antenna performance, and provide reference for the position of trackside antenna erection. These electrical performance parameters need to be obtained from the antenna pattern. The Yagi antenna is small. It is a high frequency antenna. The easiest and straightforward way to measure the antenna pattern is to measure the far field. Therefore, the microwave darkroom needs to build a far field measurement system for directional antenna measurement.
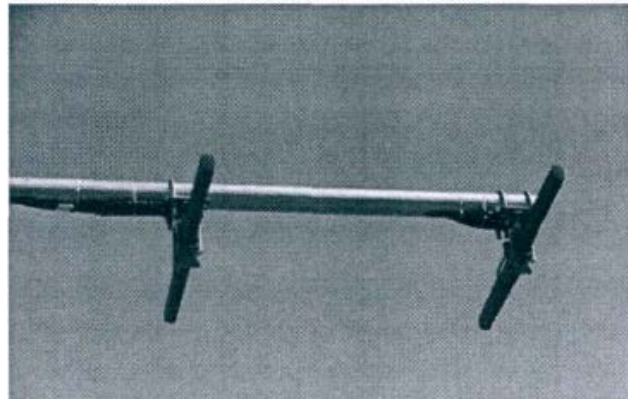

Figure. 1 Yagi antenna

3.2 Main parameter requirements for microwave darkroom

There are five main parameters of the microwave darkroom, including shielding effectiveness, static reflectance level, cross polarization, field amplitude uniformity and multipath loss. Shielding effectiveness reflects the shielding ability of microwave anechoic chamber to external signals. A good static air condition in the darkroom is guaranteed. In addition, it can simulate the free space test environment very well. The other four parameters reflect the performance of the quiet zone of the microwave darkroom to ensure the accuracy of the measurement results.

Shielding effectiveness is the total attenuation value that a radiated RF electromagnetic energy experiences when attempting to pass a barrier. As shown in Figure 2, electromagnetic waves are attenuated due to energy loss when passing through the shield. The energy loss is divided into two parts: reflection loss and absorption loss. When the electromagnetic wave passes through the first boundary of the shield, a part of the electromagnetic wave energy is reflected on the surface of the shield, which is called surface reflection loss. A part of the electromagnetic wave entering the inside of the shield is absorbed by the shield, which is called absorption loss. After the absorption loss, the remaining electromagnetic waves will also reflect during the process of passing through the second boundary. A part of the electromagnetic wave will be reflected between the two boundaries of the shield until it is absorbed by the shield.
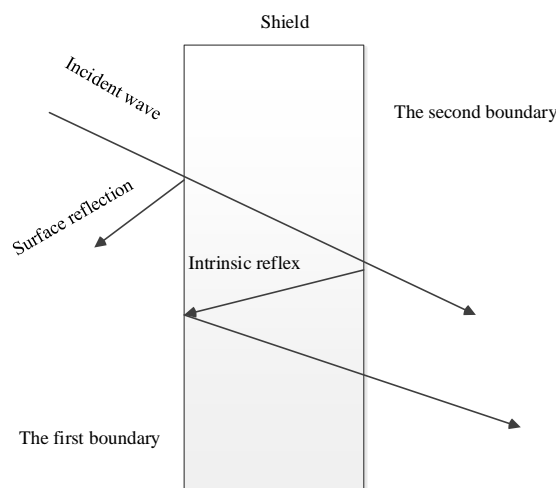

Figure. 2 Process of shielding loss

Electromagnetic waves will appear multiple reflections on the surface of the shield and inside the shield. Both reflection loss and absorption loss are expressed in decibel attenuation values. The shielding effectiveness of the microwave darkroom can be obtained by the formula (1):

$$SE = R + A + K \tag{1}$$

In the formula (1), R is the surface reflection loss of the shield. A is the absorption loss of the shield. K is the multiple reflection loss in the shield.

The reflection loss on the surface of the shield is caused by the impedance discontinuity at the surface of the shield, which can be calculated by equation (2):

$$R = 20\log_{10}\left[\frac{|Z_1|}{4|Z_2|}\right] \tag{2}$$

4. Results and discussion

4.1 Method and process for evaluating main parameters of microwave darkroom

The shielded housing of the microwave darkroom is not completely sealed. Various discontinuities in the shielding material are associated with holes, such as welds between shielding materials, louvers in darkrooms, shields, filters in darkrooms, and the like. The shielding effectiveness of the microwave darkroom is evaluated. One is to evaluate the shielding material's ability to shield the signal in and out, and the other is to measure whether the gap between the shielding materials and the shielding effectiveness at the hole meet the requirements of the microwave darkroom. The evaluation method of shielding effectiveness is shown in Figure 3:
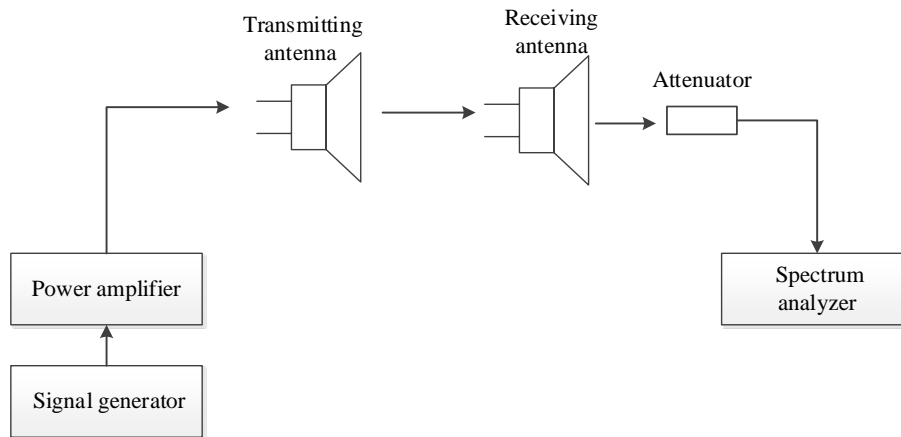

Figure. 3 Test method of shielding effectiveness

To evaluate the shielding effectiveness, the transmission loss when the electromagnetic wave is not shielded and the electromagnetic loss when there is shielding need to be obtained. Then, based on the difference between the two, the shielding effectiveness is calculated. The electrical signal generated by the signal generator is in the range of 0.5 GHz to 6 GHz. Starting from 0.5 GHz, every 0.5 GHz is measured as a sampling frequency point. The power amplifier amplifies the signal by 30dB. The transmitting antenna selects a standard horn antenna. The frequency of the selected antenna is determined by the measurement frequency. The receiving antenna uses the same waveguide probe as the transmitting antenna, and the distance between them is d=2m. When measuring the transmission loss with shielding, the receiving antenna and spectrum analyser are placed in the microwave darkroom. The electrical signal strength produced by the signal generator, the power amplifier, the selected antenna, and the distance between the antennas are unchanged. Measurement results of transmission loss before and after shielding are compared.

4.2 Cross polarization evaluation method and process

When the cross-polarization isolation is the same in the polarization direction of the two

antennas, the amplitude of the received signal is orthogonal to the polarization direction of the two antennas. It is represented by the difference in amplitude of the received signal. The purpose of evaluating the cross-polarization isolation is to ensure that the polarization isolation of the transmitting antenna is enough, so that the measurement results in both the horizontal polarization and the vertical polarization do not affect each other.

The calculation formula for cross polarization isolation is as follows:

$$CP = A - B \qquad\qquad (3)$$

In equation (3), CP is the cross-polarization isolation. A is the amplitude of the received signal when the transmit and receive antennas have the same polarization direction. B is the amplitude of the received signal when the polarization directions of the transmitting antenna and the receiving antenna are orthogonal. The evaluation of the cross-polarization isolation is to measure the amplitude of the received signal when the polarization directions of the transmitting antenna are the same and the polarization direction is orthogonal, and the difference between the two is calculated to obtain the cross-polarization isolation. The schematic diagram of the measurement of the cross-polarization isolation of the microwave darkroom is shown in Figure 4:
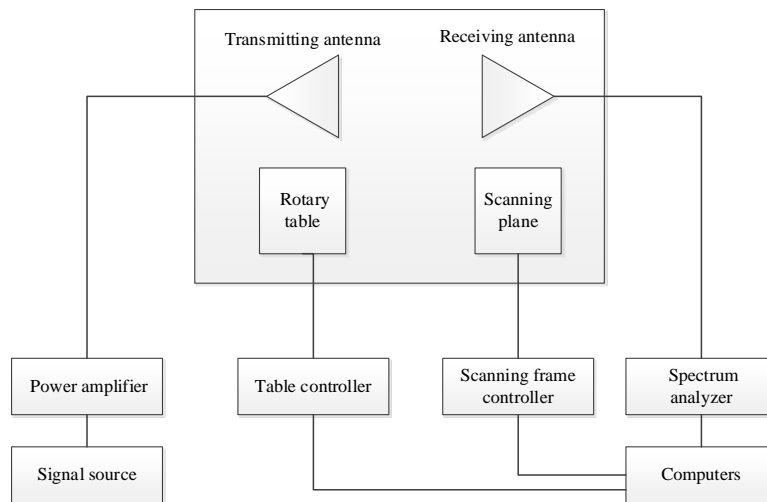

Figure. 4 Test method for cross polarization isolation

In Figure 4, the transmit antenna selects any standard horn antenna in the range of 0.5 GHz to 6 GHz. The receiving antenna selects a 1 GHz-18 GHz wideband horn antenna, and the distance between the two is the far field measurement distance. The signal source generates an electrical signal based on the frequency of the transmitting antenna and is amplified by the power amplifier to the transmitting antenna. The 360° rotating transmitting antenna is controlled by a computer, and the receiving antenna receives the electromagnetic signals of the transmitting antenna at all angles and transmits them to the spectrum analyser for reception.

5. Conclusion

The problem of wireless interference in the measurement of urban rail transit RF equipment was studied. Combined with the development status of microwave darkroom, a darkroom design requirement for urban rail transit RF equipment measurement is proposed. A design scheme of a comprehensive microwave darkroom including three kinds of measurement systems: antenna near field, antenna far field and leaky waveguide is given. Through the analysis of the transmission frequency band and transmission mode of urban rail transit RF equipment, the requirements of measurement frequency band and measurement system are proposed for the design of microwave darkroom. According to the requirements, the main parameters of the microwave darkroom are calculated. According to the requirements of the parameter indicators, the structure of the microwave darkroom and the position of the measuring system are designed. The shielding material and the absorbing material of the dark room are selected.

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