

Research on Vehicle Radiation Immunity Test Method Based on Actual Electromagnetic Environment

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Abstract—In order to assess the radiation immunity performance of the vehicles in the actual electromagnetic environment, the radiation immunity test method based on the actual electromagnetic environment is studied. The test methods are analyzed from the aspects of electromagnetic environment acquisition and playback, field strength calibration, vehicle state setting and performance evaluation methods. The vehicle adaptability tests to actual electromagnetic environment are also carried out in actual location and in the 10m semi-anechoic chamber. The test results show that the vehicle malfunctions in the actual location can be effectively reproduced when tested in the 10m semi-anechoic chamber and the feasibility of the actual electromagnetic environment radiation immunity test method is preliminarily verified, which is of great significance for the enterprises to comprehensively evaluate the electromagnetic compatibility performance of the vehicles.

Keywords—actual electromagnetic environment; radiation immunity; acquisition and playback; field strength calibration

1 INTRODUCTION

According to the intuitive classification method, the electromagnetic environment can be divided into two types, one is the laboratory electromagnetic environment constructed in the semi-anechoic chamber, and the other is the actual electromagnetic environment of the outside world.

With the electric, intelligent and connected development of the automotive industry, more and more electronic and electrical systems are installed in vehicles, making the electromagnetic environment inside the vehicle even more complicated. On the other hand, there are a lot of electromagnetic radiation sources such as substations, power plants, ETCs, mobile communication base stations etc. in the environment. The electromagnetic signals generated by the electromagnetic radiation sources are superimposed and coupled with each other, making the actual electromagnetic environment very complicated. At present, there have been many cases showing that vehicles have malfunctions due to the influence of the actual electromagnetic environment, such as radio noise, abnormal electric driven system, invalid electronic hand brake etc., which fully demonstrates that the complex actual electromagnetic environment not only affects the functions of vehicles, but also threatens the safety driving of the vehicles. Under such circumstances, it is of great significance to study the radiation immunity test method based on the actual electromagnetic environment to ensure the high

reliability of the vehicle electromagnetic compatibility performance^[1].

2 ANALYSIS OF EXISTING VEHICLE RADIATION IMMUNITY TEST METHODS

In view of the vehicle radiation immunity tests to the external environment, the corresponding test methods are specified in the international and domestic standards. The international standards mainly include ECE R10.05 and ISO 11451-2:2015 and the domestic standards mainly include GB 34660-2017 and GBT 33014.2-2016. The test parameters of each standard are shown in Table 1.

TABLE 1 Parameters of radiation immunity test standards

Standard	Test signal	Frequency band	Test level	Antenna polarization
ECE R10.05	AM、PM	20MHz~2000MHz	30V/m	Vertical
ISO 11451-2:2015	CW、AM、PM	0.01MHz~18GHz	Multiple recommended field strengths	Vertical and horizontal
GB 34660-2017	AM、PM	20MHz~2000MHz	30V/m	Vertical
GBT 33014.2-2016	CW、AM、PM	0.01MHz~18000MHz	Multiple recommended field strengths	Vertical and horizontal

It can be seen from Table 1 that the test signals in the existing test methods are CW signal, AM signal and PM signal, and the test level in the full frequency band is constant. However, the actual electromagnetic environment has the characteristics of complex modulation mode, field strength change with time, etc., which causes some vehicles to malfunction in the actual environment after tested in accordance with the standards in Table 1. In order to ensure the normal operation of the vehicle electronic and electrical systems, the vehicles should be performed radiation immunity tests in a real or simulated actual electromagnetic environment. The modulation and field strength of the actual electromagnetic environment should be regarded as the main research parameters.

At present, some enterprises have carried out vehicle adaptability tests to actual electromagnetic environment. The vehicles are transported to the test site for actual road test and the functions of the vehicles are evaluated. The above method is relatively simple but there are certain insufficient, as follows: 1) It is vulnerable to weather and environment, which influences the repeatability of the test. 2) High field strength

of some test sites may affect the health of testers. 3) It is not conducive to the confidentiality of research and development models. 4) The cost of vehicle transportation is relatively high when tested at multiple locations. Based on the above deficiencies, it is necessary to propose a vehicle radiation immunity test method to actual electromagnetic environment in the 10m semi-anechoic chamber, and verify the adaptability of the vehicle to the actual electromagnetic environment in a safe, controllable and efficient manner^[2].

3 VEHICLE RADIATION IMMUNITY TEST METHOD IN ACTUAL ELECTROMAGNETIC ENVIRONMENT

Based on the test frequency specified in ECE R10.05 and GB 34660-2017, the actual electromagnetic environment radiation immunity test method in 20MHz~2000MHz is studied, including the actual electromagnetic environment acquisition and playback, field strength calibration, vehicle test methods and performance evaluation methods.

3.1 Acquisition and playback of actual electromagnetic environment

The actual electromagnetic environment acquisition and playback system is set up, as shown in Fig.1. In the acquisition process, on the one hand, it is necessary to record the IQ data of the actual electromagnetic environment through the ADC sampling function of the spectrum analyzer. On the other hand, field strength monitoring equipments are required to record the field strength value of the actual electromagnetic environment. During the playback process, the IQ signal is called by the vector signal generator and restored to the actual electromagnetic environment signal. The signal passes through the power amplifier, the antenna, etc. and the actual electromagnetic environment is reproduced in the 10m semi-anechoic chamber^[1].

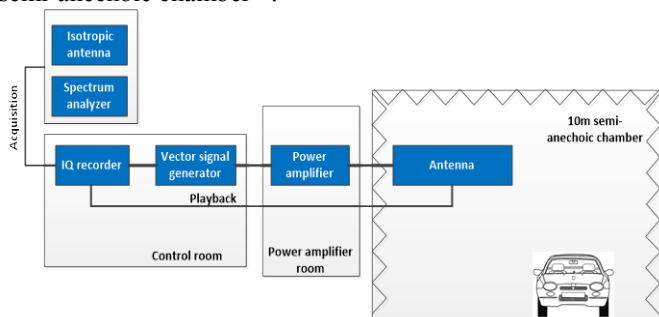


Fig.1 Actual electromagnetic environment acquisition and playback system

3.2 Field calibration method

As the actual electromagnetic environment signal has the characteristics of complex modulation mode and field strength change with time, the field strength calibration method of the actual electromagnetic signal will be quite different from the field strength calibration methods specified in the existing standards. At present, there is no reference at home and abroad. Thus, a field strength calibration method suitable for actual electromagnetic environment signal is proposed based on the accumulated research results.

In 20MHz~2000MHz, the calibration of the horizontal and vertical polarization fields should be performed according to the field strength of the actual electromagnetic environment. The four-probe method is used in the calibration process. The

average of the four field probe readings is used as the calibration value and the field probe is located on the vertical reference line. The specific definition refers to ECE R10.05.

3.2.1 Field strength calibration of CW signal

Before the field strength calibration of the actual electromagnetic environment signal in 20MHz~2000MHz, the field strength of the unmodulated sine wave CW signal should be calibrated. Taking the height of the vehicle not exceeding 3 meters as an example, the test setup is shown in Fig.2. The vector signal generator is set to output CW signal and the frequency of CW signal is the center frequency of the actual electromagnetic environment signal. Adjust the output power of CW signal and observe the field strength value on the field monitor. When the field strength reaches the field strength of actual electromagnetic environment, the output power of the vector signal generator and the polarization of the field generating device should be recorded. Adjust the polarization of the field generating device and record the corresponding output power of vector signal generator according to the above method.

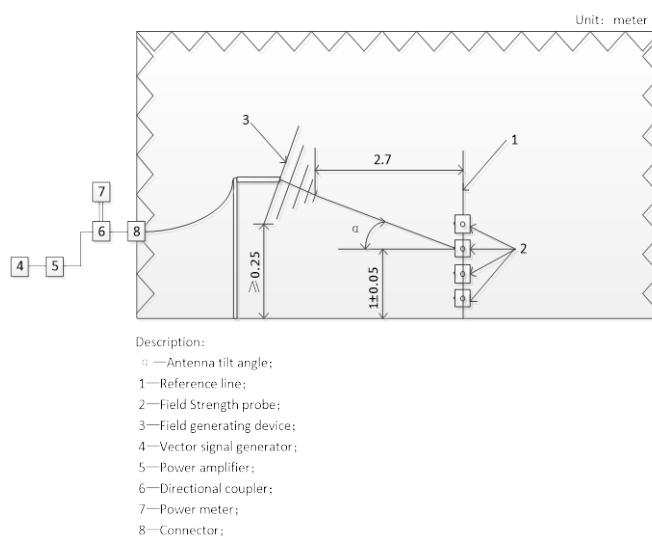


Fig.2 Test setup of CW signal field strength calibration

3.2.2 Field strength calibration of actual electromagnetic environment signal

After the field strength calibration of CW signal is completed, the field strength calibration of the actual electromagnetic environment signal can be performed. Keeping the position and height of the field generating device in Fig.2 unchanged, the field generating device should be adjusted to the direction of the field receiving device. The height and polarization direction of the field generating device and the field receiving device should be the same. There is no specific requirements for the distance between the field generating device and the field receiving device. However, it should remain unchanged during the calibration process, as shown in Fig.3. The vector signal generator should be set to output CW signal. The frequency and output power of CW signal are the corresponding values in section 3.2.1. Record the received power value measured by the receiver as A.

Then the vector signal generator is set to output the actual electromagnetic environment signal, and the output power of the vector signal generator is adjusted. When the measured channel power of the receiver in the band power mode is A,

the output power of the vector signal generator is recorded as B. The same method is used to record the output power of the vector signal generator in the other polarization direction of the field generating device and the field receiving device, which is recorded as C. After the field calibration, the actual electromagnetic environment can be reproduced in the 10m semi-anechoic chamber only by outputting the actual electromagnetic environment signal through the vector signal generator and adjusting the output power of the vector signal generator to value B or value C.

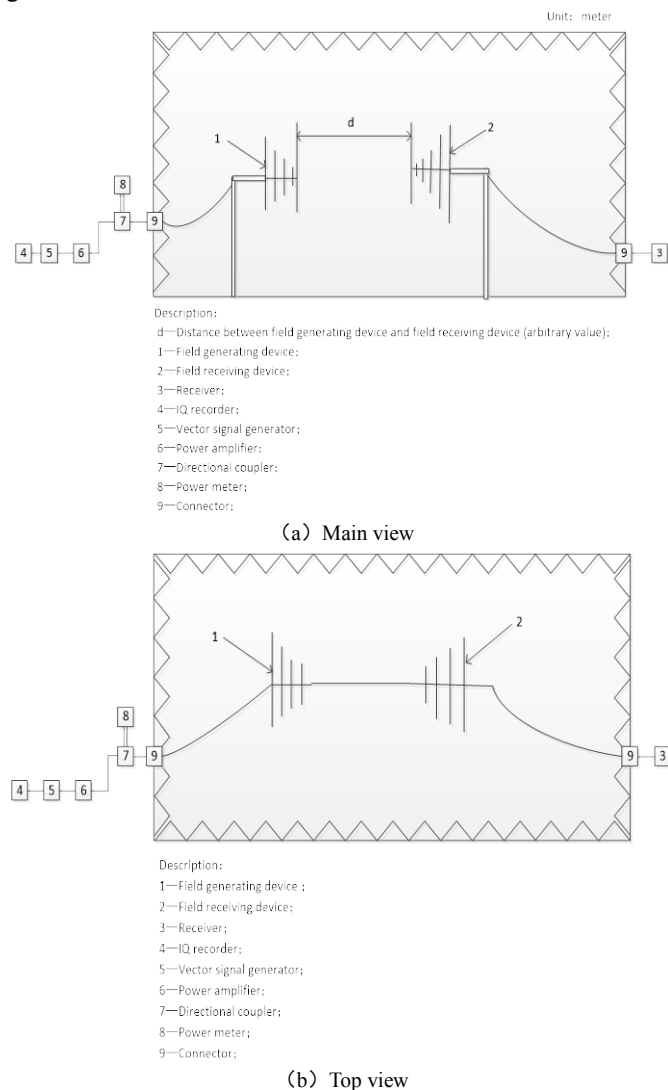


Fig.3 Test setup of actual electromagnetic environment signal field strength calibration

3.3 Vehicle test method

The vehicle is placed on the dynamometer after the field strength calibration is completed and the vehicle reference point should correspond to the calibration reference line. The position and height of the field generator are shown in Fig.2. The vehicle should operate as follows: speed 50km/h, dipped beam on, direction indicator on driver's side on, interior light off, front wiper maximum speed, alarm reset, airbag and safety control system operation, door lock, reversing image on (if applicable), speaker off, RKE function on, brake lever and suspension in normal position, the driver's seat and steering

wheel are in the middle position. The battery voltage of the vehicle 12V system should be kept above 12V, and the battery voltage of the 24V system should be kept above 24V.

The vehicles should be tested in actual electromagnetic environment with the antenna horizontal polarization and vertical polarization. The signal output power of the vector signal generator is the calibration value in section 3.2.2. During the test, the dynamometer should be rotated 360 degrees at a constant speed to analyze the effects of the applied test signal on all directions of the vehicle and all the malfunctions of the vehicles should be recorded.

3.4 Performance evaluation method

Vehicle performance failure criteria are defined in ECE R10.05. Corresponding to different vehicle states, the vehicle performance can be evaluated with reference to ECE R10.05. If the vehicle is subjected to the immunity test in the actual electromagnetic environment and the functional failure conditions in ECE R10.05 does not appear, the vehicle will be considered to meet the electromagnetic compatibility immunity requirements of the location corresponding to the actual electromagnetic environment^[3].

4 TEST METHOD VERIFICATION

In order to verify the effectiveness of the above test methods, the acquisition and playback of the actual electromagnetic environment in a downtown area is performed and the comparison test of the vehicle in the actual location and in the 10m semi-anechoic chamber is carried out, as shown in Fig.4 and Fig.5. Take the test frequency band with the center frequency of 950MHz and the bandwidth of 80MHz as an example, in order to prevent large electromagnetic signals from damaging the receiver, a 20dBm attenuator is connected to the input port of the receiver. The comparison diagram of the collected signal and the reproduced signal is shown in Fig.6. The blue curve is the collected signal and the red curve is the reproduced signal. The receiver compensates the noise level by 20dBm.

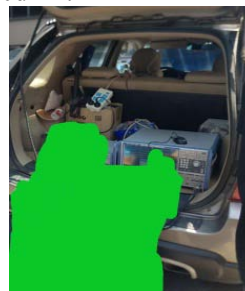


Fig.4 Acquisition of actual electromagnetic environment and vehicle test in the actual location



Fig.5 Playback of the actual electromagnetic environment and vehicle test in the 10m semi-anechoic chamber

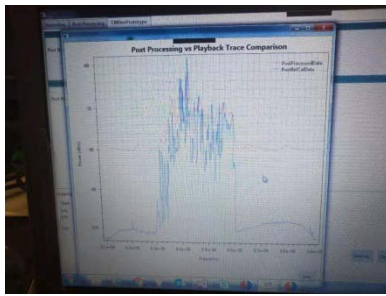


Fig.6 Comparison diagram of the collected signal and the reproduced signal

Due to the frequency characteristics, signal attenuation and other factors of the actual electromagnetic environment acquisition and playback system, the two signals in Fig.6 are not identical, but the signal amplitude and conversion trend are basically the same. On the other hand, the vehicle test results show that most of the vehicle malfunctions appear in the actual location can be effectively reproduced in the 10m semi-anechoic chamber, which also verifies the feasibility of the method.

5 CONCLUSION

According to the radiation immunity methods specified in the existing standards, the vehicle adaptability to the actual electromagnetic environment cannot be assessed. In such a condition, a radiation immunity test method to the actual electromagnetic environment is put forward and the effectiveness of the method is preliminarily verified, which plays an important role in helping enterprises comprehensively evaluate the electromagnetic compatibility of products and improve the electromagnetic compatibility quality of vehicles. In the next step, in-depth research will be carried out in the following aspects: 1) The influence of ground reflection on field strength calibration. 2) The compensation of signal parameters of the actual electromagnetic environment acquisition and playback system. 3) The consistency evaluation method of collected signal and reproduced signal.

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