Research on the Vehicle’s Susceptibility to Complex Electromagnetic Environment

CHUANQI WANG, LEI CHEN, XU ZHANG, YIFU DING and YUE ZHANG

ABSTRACT

With the electric and intelligent development of the automobile industry, the impact of electromagnetic environment on the vehicle becomes increasingly obvious and vehicle manufacturers received a lot of complaints about electromagnetic interference. Traditionally, vehicle manufacturers tried to go to the actual interference environment to investigate the malfunction and try to solve the problems, which is costly and inefficient. In consideration of the inconvenience of field test, a method of scene simulation test in the EMC chamber is proposed to research vehicle’s susceptibility in the complex electromagnetic environment, including the collection and recording of scene signal, the signal playback in the chamber and the vehicle electromagnetic interference test. In the vehicle tests, it is verified that the scene signal has more significant impact on the vehicle by comparing the traditional modulated method, like continuous wave or modulated continuous wave. Through the systematic research, technical support can be provided to the enterprise R&D engineer and technical reserves are prepared for the formulation or revision of related standards.

INTRODUCTION

According to the statistical data of International Organization of Motor Vehicle Manufacturers (OICA), the global automotive industry has shown a blowout growth in the past few years. Future global automotive market is expected to maintain steady growth with the further release of automotive demand in emerging market and the promotion of automobile manufacturing level brought by global intelligent manufacturing revolution.

In addition, it involves information platform such as communication, spectrum distribution, optical fiber, satellite, radar and database in electronic information field in the process of building modern city, digital city and smart city, which leads to the high density and high speed development of electronic products. Due to the limited space, time and spectrum resources, widely application of electronic systems and products makes the electromagnetic environment more complex. In many cases, even the electronic device or sub-system meets the electromagnetic compatibility requirements, the performance of the whole vehicle is still not guaranteed in a complex electromagnetic environment.

Chuanqi Wang, Lei Chen, Xu Zhang, Yifu Ding and Yue Zhang, China Automotive Technology & Research Center, Tianjin 300300, China
For the vehicle, it is equipped with a large number of internal electrical and
electronic systems, and the systems have high integration, complex functions and
diverse work patterns. In order to ensure the normal operation of the vehicle system, it
is necessary to carry out the research on the vehicle susceptibility in the complex
electromagnetic environment to improve the reliability of the vehicle.

**COLLECTION OF THE COMPLEX ELECTROMAGNETIC ENVIRONMENT**

To study the susceptibility of vehicle in the complex electromagnetic environment,
firstly, it is necessary to collect the field scene signal [1]. All the test conditions can be
controlled in this method, so it has the advantages of real, efficient, repeatable and low
cost.

**Composition of complex electromagnetic environment collection system**

Complex electromagnetic environment collection system includes antenna,
spectrum analyzer, IQR data recorder and computer, as shown in Fig. 1. Antenna is
used for signal reception, which frequency range is 30MHz ~ 3GHz. Spectrum
analyzer is used for frequency conversion of RF signal, power adjustment, sampling
and other functions. IQR data logger is used for broadband signal recording and
computer is used for analysis and data processing.

**Principle of complex electromagnetic environment collection system**

The electromagnetic signal in the environment is converted into an electrical
signal by the antenna and the signal is transmitted to the spectrum analyzer. Used as the
RF front end, the spectrum analyzer changes the signal to the intermediate frequency
[2].

The original signal is splitted into I digital data and Q digital data after ADC signal
quadrature sampling by the spectrum, and this two way digital signal will be recorded
by the IQR recorder, as shown in Fig. 2. The amplitude and phase relationship between
the RF signal and the I, Q signals are shown in Fig. 3 and Equation 1 and 2.
A = \sqrt{I^2 + Q^2} \quad (1)

\varphi = \arccot\left(\frac{1}{Q}\right) \quad (2)

**Frequency and location of complex electromagnetic environment**

The choice of acquisition frequency band in the complex electromagnetic environment is based on two considerations: 1) the frequency band related to the vehicle\(^\text{[3]}\); 2) the frequency band which is relatively high in the environment pre-scan. Several test bands of 76-108MHz, 300-330MHz, 420-450MHz, 800MHz, 900MHz, 2400MHz are determined through the analysis of the vehicle electronic and electrical system and the pre-scanning of the environment.

The collection sites include typical locations such as downtown areas, industrial areas, commercial areas, etc. and locations where the vehicles are known to have problems. Take the collection of Tianjin as an example, six collection sites are selected as shown in Fig. 4. The electromagnetic environment of each site is saved in the form of a scene signal.
Replay of Complex Electromagnetic Environment and Vehicle Susceptibility Test

After the scene signal collection, a complex electromagnetic environment playback system could be built in the EMC chamber, and vehicle test could be performed to assess the susceptibility of the vehicle's electromagnetic compatibility.

Composition of complex electromagnetic environment playback system

Complex electromagnetic environment playback system consists of semi-anechoic chamber, turntable, dynamometer, IQR data recorder, SMW200A vector signal generator, amplifier and antenna. The playback system is a combination of dynamic electromagnetic environment technology together with vehicle dynamics, as shown in Fig. 5.

When the electromagnetic environment signal is reproduced in the chamber, the data recorded in the IQR is transmitted to the SMW200A via the digital bus. The generator plays the recorded electromagnetic environment signal in real time and amplify the power of the signal through the power amplifier. The output of the amplifier is connected to the antenna to transmit the electromagnetic radiation.

As the antenna position is fixed, the turntable is set to rotate in the vehicle test to simulate the effect of the omni-directional electromagnetic environment. Meanwhile, the vehicle under test is running at a constant speed on the dynamometer in order to find any impact effects.
Vehicle susceptibility test

In order to comprehensively evaluate the susceptibility of the vehicle in the complex electromagnetic environment, it is necessary to carry out the vehicle immunity test in continuous wave, modulated continuous wave and scene signal and compare the test results[4]. The test conditions such as test frequency, polarization and field strength are shown in Table 1.

<table>
<thead>
<tr>
<th>Item</th>
<th>Continuous wave/MHz</th>
<th>Modulated continuous wave/MHz</th>
<th>Scene signal MHz</th>
<th>Polarization</th>
<th>Field strength V/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>92</td>
<td>92+FM</td>
<td>96</td>
<td>H,V</td>
<td>30,100</td>
</tr>
<tr>
<td>2</td>
<td>315</td>
<td>315+ASK</td>
<td>340</td>
<td>H,V</td>
<td>30,100</td>
</tr>
<tr>
<td>3</td>
<td>435</td>
<td>435+ASK</td>
<td>440</td>
<td>H,V</td>
<td>30,100</td>
</tr>
<tr>
<td>4</td>
<td>836.52</td>
<td>836.52+CDMA</td>
<td>870</td>
<td>H,V</td>
<td>30,100</td>
</tr>
<tr>
<td>5</td>
<td>902.4</td>
<td>902.4+GSM</td>
<td>928</td>
<td>H,V</td>
<td>30,100</td>
</tr>
<tr>
<td>6</td>
<td>2437</td>
<td>2437+WIFI</td>
<td>2442.5</td>
<td>H,V</td>
<td>30,100</td>
</tr>
</tbody>
</table>

The specific steps to carry out the vehicle adaptability test are:

1) Field strength calibration
   ① Calibrate the continuous wave, modulated continuous wave and the scene signal of different frequency bands, different polarization modes and different field strength, as shown in Fig. 6.

   The bandwidth of SMW200A is set to 80MHz in the field strength calibration and the center frequency of each interfering signal is shown in Table 1.

   Set the SMW200A outputs the corresponding interference signal when the continuous wave and modulated continuous wave is calibrated. Adjust the signal power until the field monitor displays the specified field strength and record the signal power value. Repeat the operation until all bands have been calibrated.

   When the scene signal field strength is calibrated, the maximum power hold and the integral function of the SMW200A are used to maintain the maximum power point in the band and realize the integral of the data in the whole frequency band. The integral value corresponds to the SMW200A output power. Adjust the baseband power of the SMW200A and record the baseband indication when the field strong monitor displays the calibrated field strength. Repeat this operation until all bands are calibrated.
② Vehicle test
To examine the impact of different interference signals, three representative models are selected to carry out the vehicle test, which are traditional car, hybrid car and pure electric car. Each car is required to perform the test in different frequency bands, different polarization and different field strength, as shown in Fig. 7. During the test, the vehicle is operated at a speed of 50km/h, and the headlights, double flash, wiper, fan and radio are turned on. The turntable is rotated at 2 degrees/s to simulate the influence of the space on the vehicle.

③ Test phenomenon record
Through the results of the vehicle test under different interference signals, it can be found that the scene signal has a greater influence on the electric car. The test phenomenon of partial frequency bands and field strength are recorded as shown in Table 2.

![Vehicle test](image)

Figure 7. Vehicle test.
<table>
<thead>
<tr>
<th>Frequency MHz</th>
<th>Traditional car</th>
<th>Hybrid car</th>
<th>Pure electric car</th>
</tr>
</thead>
<tbody>
<tr>
<td>92, 100V/m</td>
<td>no signal in radio</td>
<td>no signal in radio</td>
<td>small noise in radio</td>
</tr>
<tr>
<td>92+FM, 100V/m</td>
<td>no significant effect</td>
<td>no significant effect</td>
<td>small noise in radio</td>
</tr>
<tr>
<td>96, (scene signal), 100V/m</td>
<td>no significant effect</td>
<td>speed down, meter’s backlight flashes, need to restart the vehicle to open the cruise function</td>
<td>noise in radio, rear view image disappears and can be automatically restored</td>
</tr>
<tr>
<td>315, 100V/m</td>
<td>no significant effect</td>
<td>noise in radio</td>
<td>rear view image disappears and can be automatically restored, the meter’s backlight is on</td>
</tr>
<tr>
<td>315+ASK, 100V/m</td>
<td>no significant effect</td>
<td>no significant effect</td>
<td>The meter’s backlight flashes, rear view image disappears and can be automatically restored</td>
</tr>
<tr>
<td>340, (scene signal), 100V/m</td>
<td>noise in radio</td>
<td>noise in radio, steering wheel shake</td>
<td>meter interface switches, rear view image disappears and cannot be restored, related function recovery after disconnected and re-connected the low-voltage battery</td>
</tr>
<tr>
<td>435, 60V/m</td>
<td>no significant effect</td>
<td>noise in radio</td>
<td>noise in radio</td>
</tr>
<tr>
<td>435+ASK, 60V/m</td>
<td>no significant effect</td>
<td>noise in radio</td>
<td>noise in radio</td>
</tr>
<tr>
<td>440, (scene signal), 30V/m</td>
<td>noise in radio</td>
<td>noise in radio</td>
<td>Rear view image disappears and can be automatically restored</td>
</tr>
</tbody>
</table>

**Analysis of test results**

The results of the vehicle test show that the scene signal is more likely to affect the vehicle in the same field strength. In some frequency bands, even the field strength of the scene signal is much smaller the vehicle will still be affected comparing the intact performance in the traditional continuous wave or modulated continuous wave method. Therefore, the collection and playback of electromagnetic signals in the environment is of great importance for vehicle industry.

**CONCLUSION**

Comparing the traditional combustion engine powered vehicles, electric vehicles’ electric driving systems which have high power and large current and more susceptible to electromagnetic interference in the environment. It is found in the real vehicle test that the failure rate of electric vehicles in the complex electromagnetic environment is higher than the fuel vehicles. In the case of increasing popularity of electric vehicles, carrying out the complex electromagnetic environment test and research of the vehicle plays an important part in ensuring the reliability of the vehicle and improving the vehicle performance. With the expansion of collected real scene database, China Automotive Technology & Research Center will establish a more complete complex...
electromagnetic environment database to better meet the test requirements of vehicle manufacturer and promote the formulate and revision of relevant norms and standards.

REFERENCES


