EMC Reliability Evaluation of Networked Vehicle (V2X) In Laboratory

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Abstract. In this paper, a networked vehicle is taken as the research object. The system construction and test method of V2X EMC reliability evaluation in the laboratory are studied, and the experimental demonstration and analysis are carried out for the specific V2X scenes. The research results show that the V2X EMC reliability test system built in the laboratory can effectively verify the network connection performance, functional stability and reliability of the vehicle, making up for the shortcomings of the actual road test process, such as low efficiency, large impact of the external environment and the failure is not easy to reproduce. In general, the system verify the feasibility of the V2X EMC test and evaluation ideas built in the laboratory.

1. Introduction
The EMC reliability test of the Internet of vehicles (V2X) in the laboratory is an important evaluation method for the reliability, safety and efficiency of the vehicle related performance and function in the actual complex electromagnetic environment. It is a key point in the design and development process, and also an extremely critical bottom and transition period for the realization of the complete road performance and function verification of the vehicle. At present, researchers at home and abroad have done some research on the performance and functional reliability verification of V2X\textsuperscript{[1]}. Most of the research scenarios and locations are concentrated on the actual road and closed road test area. However, at present, there are few researches on the evaluation of V2X in the laboratory, so this paper mainly discusses the key technical points of the reliability of V2X electromagnetic compatibility in the laboratory level network connected vehicles, and studies the performance and function stability of V2X in different scenarios\textsuperscript{[2]}.

2. Construction of V2X test system in laboratory
In the future, the functions of networked vehicles are becoming more and more integrated and intelligent, and the communication environment around networked vehicles is becoming more and more complex\textsuperscript{[3]}. Building and simulating the network vehicle communication environment in the laboratory is conducive to eliminating the interference of the external environment, and can be analyzed and studied for a single signal. The V2X test system in the laboratory is shown in Figure 1. The whole test system consists of the navigation satellite signal simulator, integrated tester, EMC anti-interference test system, V2X communication terminal and automatic test software\textsuperscript{[4]}.

The test system has two sets of navigation satellite signal simulators, one is used to provide static or dynamic positioning information for the tested vehicle, and the other is used to provide static or dynamic positioning information for the V2X communication terminal; the V2X communication terminal is mainly used to simulate other vehicles in the actual road conditions, and carry out
information interaction with the tested vehicle, forming such as forward collision, intersection collision, emergency system Dynamic and other typical scenarios; the anti-interference test system is a traditional EMC darkroom measurement anti-interference performance system for networked vehicles, the system field strength can reach 200V/m, the frequency range covers 9KHz to 6GHz, fully meeting the requirements of GB 34660; the comprehensive tester simulates various wireless communication signals of networked vehicles, such as Bluetooth, WiFi, 2G \ 3G \ 4G, etc.

Under the normal working condition of the vehicle, the electromagnetic immunity signal is applied to monitor whether the vehicle operation is abnormal, and the reliability test of the vehicle Networking (V2X) electromagnetic compatibility is objectively evaluated[5].

3. Secondary development of software based on Vector Signal Generator

One of the key technologies of building V2X test system in the laboratory is to accurately simulate the driving position, speed, distance accuracy and scheduled driving trajectory of the vehicle in the actual road. Vector Signal Generator is a navigation device that can simulate GPS, BD, GLONASS and other global high-precision positioning systems, and can simulate the track route of vehicle running in real time[6]. At present, there are two methods for building V2X vehicle test scene, linear modeling method and iterative modeling method. In this paper, theoretical research is carried out for these two modeling methods[7].

3.1. Linear modeling

The principle of the linear modeling method is relatively simple. It needs to provide all the pre running longitude and latitude track coordinates of the vehicle. At the same time, it also needs to provide the running time t between adjacent coordinates, then the running speed \( V_n \) of the vehicle. In the same distance, when \( n \rightarrow \infty \), the vehicle running speed \( V_n \) is closer to the vehicle's current transient speed.

\[
\begin{align*}
(X_1, Y_1) & \quad (X_2, Y_2) & \quad (X_n, Y_n) \\
V_{nx} &= \frac{X_n-X_{n-1}}{t} \quad (2) \\
V_{ny} &= \frac{Y_n-Y_{n-1}}{t} \quad (3) \\
V_n &= \sqrt{V_{nx}^2 + V_{ny}^2} \quad (4)
\end{align*}
\]

3.2. Iterative modeling

For more complex scenes (multiple turns, multiple acceleration and deceleration, multiple vehicle dwell, etc.), iterative modeling method is more convenient than linear modeling method. On the whole, the
two algorithms have the same idea. Iterative modeling method also needs to plan the path, which is calculated and simulated in stages. Each of the two algorithms has its advantages and disadvantages and needs to be selected according to the situation.

**TABLE I. ITERATIVE MODELING INSTRUCTIONS**

| Instructions               | Meaning                                |
|----------------------------|----------------------------------------|
| REFERENCE: Lon, Lat, Alt   | Reference coordinates                  |
| START: E, N, U, Velocity   | Starting coordinate and speed          |
| ARC: E, N, Angle           | Turning coordinates and radians        |
| LINE: ΔE, ΔN, Acceleration | Straight distance and acceleration per unit time |
| STAY: Time                 | Dwell time of coordinate point         |

4. **V2X scene simulation**

V2V is a key and important part of V2X. The test scenarios mainly include forward collision warning, intersection collision warning, blind area warning, reverse overtaking warning, emergency braking warning, abnormal vehicle warning and other scenarios. The test scenarios discussed in this paper only give some typical examples, which play a role in drawing lessons from others.

In V2V test scenario, forward collision warning is the most easily triggered in vehicle traffic, as shown in the figure.

![Fig. 2. Forward collision - same lane](image)

The tested vehicle is HV and the auxiliary vehicle is RV. The initial longitude and latitude coordinates of the two scheduled tracks are given respectively by the satellite simulator. For example, the initial coordinates of the main vehicle are \((X_{H1}, Y_{H1})\), the end coordinates are \((X_{H2}, Y_{H2})\), which are substituted into equations (5) and (6).

\[
L = 2R \cdot \arcsin A
\]  \hspace{1cm} (5)  
\[
A = \sqrt{\sin^2 \left(\frac{x_1-x_2}{2}\right) + \cos(y_1) \cdot \cos(y_2) \cdot \sin^2 \left(\frac{y_1-y_2}{2}\right)}
\]  \hspace{1cm} (6)

In equations (5) and (6), \(L\) is the distance the vehicle travels; \(x_1\) is the longitude of the starting point; \(x_2\) is the latitude of the starting point; \(y_1\) is the longitude of the end point; \(y_2\) is the latitude of the end point; \(R\) is the radius of the earth.

To get the distance of the vehicle, we need to know the speed of the vehicle, which is determined by the longitude and latitude interval between any two points and the output frequency.

\[
\Delta \text{Lat} = \frac{x_1-x_2}{N}
\]  \hspace{1cm} (7)  
\[
\Delta \text{Lon} = \frac{y_1-y_2}{N}
\]  \hspace{1cm} (8)  
\[
\Delta L = \frac{L}{N}
\]  \hspace{1cm} (9)

In equations (7), (8) and (9), \(\Delta \text{Lat}\) is the longitude interval between two adjacent points; \(\Delta \text{Lon}\) is the latitude interval between two adjacent points; \(n\) is the total number of longitude and latitude coordinate points; \(\Delta L\) is the distance between two adjacent points. The output frequency value determines the vehicle speed by setting in the satellite navigation signal simulator.
The output frequency value determines the vehicle speed by setting in the satellite navigation signal simulator.

\[ t = \frac{\Delta L}{v} \]  

(10)

In equation (10), \( t \) is the output time interval of satellite simulator, \( v \) is the vehicle speed.

The vehicle speed of the main vehicle HV is derived from formula (5) - (10), and the complete track route of the main vehicle can be calculated according to the coordinates of the latitude and longitude coordinate interval and the starting and ending points, as shown in TABLE II.

| Starting longitude and latitude | Ending longitude and latitude | Real time longitude | Real time latitude |
|--------------------------------|------------------------------|---------------------|--------------------|
| Lat1, Lon1                    | Lat2, Lon2                   | Lat1 + ΔLat         | Lon1 + Δlon        |
| ...                            | ...                          | ...                 | ...                |
| Lat1, Lon1                    | Lat2, Lon2                   | Lat2                | Lon2               |

From the above analysis, we can get the speed and driving track of the main vehicle, and so on. We can also get the speed and driving track of the slave vehicle in the same way. When two vehicles are in the same lane, the distance between them is 100m, the speed of the main vehicle is 40km/h, and the speed of the slave vehicle is 20km/h, the forward collision warning conditions can be met, so as to verify the reliability and stability under the electromagnetic immunity conditions of the scene, mainly judging from the following judgment conditions, and the occurrence of any of the following conditions represents that the vehicle is not up to the standard:

- when two vehicles reach the warning distance, the main vehicle does not alarm;
- when two vehicles are separated from the warning distance, the main vehicle remains in the alarm state;
- in the process of main vehicle alarm, there is interruption and other abnormal alarm.

5. Analysis of experimental results

V2X experimental scene mainly includes three scenes: forward collision warning (the same lane), forward collision warning (adjacent lanes), and intersection warning. For the example of forward collision warning (the same lane), the electromagnetic immunity values are 30 V/m, 60 V/m and 100 V/m.

In the simulation scenario, the RV (simulation vehicle) is set to drive at a speed of 10km/h; the HV (tested vehicle) and the RV (simulation vehicle) are in the same lane, driving at a speed of 30 km/h. As shown in Figure 7, it is a forward collision (same lane) scene test monitoring platform. Under the electromagnetic interference environment, verify whether the forward collision early warning function has trigger failure problem:

A. whether the main vehicle triggers the alarm when the two vehicles reach the warning distance;
B. if the two vehicles are separated from the warning distance, whether the main vehicle still keeps the alarm status;
C. whether there is any interruption or other abnormal alarm during the main vehicle alarm.
The test results are shown in Table 3. Under the condition of low electromagnetic immunity level, the vehicle is in normal working state. When the field strength level is increased to 100V/m, the main vehicle fails to trigger in time when two vehicles reach the range of warning distance.

**TABLE III. FORWARD COLLISION TEST RESULTS (IN THE SAME LANE)**

| Field strength | Status class | Test result | Problem phenomenon |
|----------------|--------------|-------------|--------------------|
| 30V/m          | A            | ✓           | ———               |
| 30V/m          | B            | ✓           | ———               |
| 30 V/m         | C            | ✓           | ———               |
| 60V/m          | A            | ✓           | ———               |
| 60V/m          | B            | ✓           | ———               |
| 60 V/m         | C            | ✓           | ———               |
| 100V/m         | A            | ✓           | Wrong triggering of HV |
| 100 V/m        | B            | ×           | Wrong triggering of HV |
| 100 V/m        | C            | ✓           | ———               |

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