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Safety Assessment of Railway Vehicle Antenna Communication Management

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Abstract

In order to verify that multiple vehicle-mounted antennas do not appear electromagnetic interference due to integration on the same railway vehicle,an evaluation method suitable for electromagnetic compatibility of vehicle-mounted antennas is proposed. Based on the analysis of the forming factors of antenna interference and the changes of electromagnetic environment before and after loading,the combination of antennas that may produce electromagnetic interference is chosen.Then,the isolation between selected antennas is measured to supplement the evaluation data.Finally,the electromagnetic compatibility between antennas is evaluated by calculating the energy matching of transceiver antennas.The method has been applied to the development of railway vehicles.

Keywords:Railway vehicles;Evaluation method;Electromagnetic interference;Isolation

1. Overview

In recent years, the rapid development of railway transit vehicle has made great social and economic benefits, in which urban rail vehicles play an important role.With the continuous progress of technology, railway vehicle adopts a lot of wireless systems [1-2].At the same time,the harm and risk of electromagnetic interference between systems

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are increasingly prominent [3].For the railway vehicle, multiple antennas are arranged on the platform with relatively limited space, which is more likely to cause common address interference between antennas.With the emergence of electromagnetic interference problems, vehicle electromagnetic compatibility(EMC) is highly concerned by operators, signal system suppliers, communication system suppliers and vehicle suppliers and other stakeholders. Evaluation of vehicle electromagnetic compatibility has become an important aspect of the development and application of rail transit vehicles.At present, the conformity of vehicle electromagnetic compatibility is mainly evaluated based on the electromagnetic compatibility test results, and the test is mainly conducted according to EN 50121 "electromagnetic compatibility of rail transit" [4].This standard covers the cable port and chassis port, but does not cover the antenna port. Therefore, the test group designed according to this standard cannot directly evaluate the electromagnetic compatibility between antennas after each wireless device is loaded.

In this paper, taking a railway vehicle project of a city as the engineering background, aiming at the limitation that the vehicle-mounted antenna cannot directly evaluate the electromagnetic compatibility compliance only by test, an EMC evaluation method of combination actual measurement and calculation analysis is introduced.

2. Common Address Interference Principle

Antenna is used for wireless equipment to send and receive useful signal electromagnetic waves, so mutual compatibility between antennas is an important aspect of electromagnetic compatibility system.Antenna mutual interference need to meet three basement elements, namely, there are at least one antenna as the interference sources (hereinafter referred to as the source antenna), there are at least one antenna as sensitive body, there are at least one the electromagnetic wave propagation path allows the electromagnetic disturbance from interference sources antenna output port to sensitive antenna input ports.Above three elements, the source antenna needs to emit electromagnetic disturbance with strong enough energy, so that electromagnetic disturbance can enter the receiving device, and cause the receiving device to fail work, at this time, the phenomenon of antenna interference will occur.Since the intentional transmitting power in the transmitting antenna band is higher than the stray transmitting power, and the sensitivity threshold in the receiving antenna band is also lower than the sensitivity threshold outside the band, if the interference path of multiple antennas has been formed after loading, three kinds of antenna interference may occur: the source antenna and the sensitive antenna work at the same frequency band, that is, the same frequency interference;The level of source antenna out-of-band emission and stray emission [5] exceeds the sensitivity threshold within the sensitive antenna band;Or the transmission in the source antenna band exceeds the sensitivity threshold outside the sensitive antenna band.After compared with two kinds of interference, same frequency interference are more likely to be found, are more common in the field of urban rail transit, such as defined by the American association of electrical and electronics engineers 802.11 series of wireless local area network (IEEE802.11) technology standard of communication based train control (CBTC) system and passenger information system (PIS) is likely to happen between the same frequency interference, optional solutions including frequency planning [6] [7], frequency modulation, spread spectrum technology and the construction of special communication network, etc.

3. Analysis of Vehicle-Mounted Antenna

As the evaluation object, vehicle-mounted antenna is mainly used for vehicle-mounted equipment of train control system, vehicle-mounted equipment of wireless communication dispatching system, vehicle-mounted part of PIS system and linkage system of shielding door.Signal system can be divided into CBTC system and traditional signal system.The train control system of urban rail transit has cbtc-rf system based on radio frequency technology. The working frequency band of the onboard antenna of this system is around 2.4Ghz.There is a ring with cross sensing cable (Inductive Loop) and two-way communication vehicle antenna by electromagnetic induction coupling of CBTC - IL systems, with S40.For example, the working frequency of the system the on-board antenna in 36 kHz and 56 kHz.The traditional signal system generally adopts Track Circuit, axle counter and other train detection equipment as well as point-type transponder, all of which are installed under the bottom of the vehicle. The working frequency of the on-board antenna of the domestic mainstream Track Circuit generally falls within the frequency range of 1.7kHz-20.7kHz [8].Axle counter does not need onboard antenna.Take the transponder transmission module (BTM) of ctcs-2, a Chinese train control system, as an example, the working frequency of its onboard antenna is 27.095MHz and 4.234MHz.Urban rail transit wireless communication dispatching system widely adopts land cluster radio (Tetra) communication system, and the working frequency range of the onboard antenna of this system is 806 -866 MHz.WLAN technology is also commonly used in the PIS system of urban rail transit, and Screen Door linkage system may also use WLAN technology. The working frequency range of the vehicular antenna is also around 2.4Ghz.For convenience of analysis, the above vehicle-mounted antenna information is arranged and listed in table 1.

Table 1 vehicle-mounted antenna information

System	Frequency/MHz	Location	Remark
CBTC-RF	2 400-2 483.5	Vehicle roof	WLAN
Screen Door linkage	2 400-2 483.5	Vehicle roof	WLAN
Tetra	806-866	Vehicle bottom	WLAN
SelTrac S40	0.036, 0.056	Vehicle bottom	CBTC-IL
BTM	27.095, 4.234	Vehicle bottom	CTCS

4. Evaluation Methods

4.1 Spectrum planning management

Electromagnetic compatibility of on-board antennas of urban rail transit vehicles not only requires technical means, but also relies on management means. Spectrum planning is an important part of electromagnetic compatibility work at the beginning of system design, so the evaluation work also starts from spectrum planning inspection.First, collect the spectrum occupied by each wireless system, the installation position of vehicle-mounted antenna, the interface between the systems and their working principles, etc. Information collection should be as rich and comprehensive as possible to cover all wireless devices, so as to ensure the integrity of the evaluation content and the accuracy of the evaluation results.The key information collected is then tabulated and the antennas working in the same frequency band are screened and grouped together.Then, we need check whether there are anti-interference measures in the design document. If there are anti-interference measures, the applicability of the anti-interference measures will be analyzed . If no anti-interference measures are taken or the measures are not applicable, the compatibility of this set of antennas will be listed as the risk item for evaluation.Finally, in the internal interference test of vehicles, the effectiveness of anti-same-frequency interference measures of wireless equipment is checked by means of working simultaneously with pairs of antennas and monitoring the functional performance of wireless equipment of the test subjects, and the antenna listed as a risk is focused on.

4.2 Energy matching assessment

The purpose of energy matching evaluation is to compare the electromagnetic disturbance level from the source antenna output port to the sensitive antenna input port with the sensitive limit of the antenna port. If the disturbance level is lower than the sensitive limit of the antenna port, the source antenna is considered to be compatible with the sensitive antenna.The disturbance level is jointly determined by the transmitting power of the source antenna and the disturbance path characteristics, among which the disturbance path characteristics can be represented by the spatial isolation degree, and the relationship among the three is as follows:

$$C(f) = 10 \lg \left(P_t(f) / P_r(f)\right) \tag{1}$$

Where: $C(f)$ -- spatial isolation between two antennas, dB;
$Pt(f)$ -- input power of transmitting antenna input terminal, mW;
$Pr(f)$ -- output power of receiving antenna output terminal, mW.

Antenna transmission power and sensitivity limits are relatively easy to obtain, which are generally provided by equipment suppliers or subway operators. The disturbance path characteristics are affected by multiple complex factors such as loading position, vehicle structure and space environment of the transceiver antenna. Compared with theoretical calculation and simulation methods, field measurement is more appropriate. By substituting the transmitted power of the antenna and the measured spatial isolation into equation (1), the disturbance level of the sensitive antenna can be calculated, so as to evaluate the compatibility between the sending and receiving antenna ports by comparing the disturbance level with the sensitivity limit of the antenna port.

5. Engineering Application Cases

Taking a subway project as the engineering background, this paper introduces the application of electromagnetic compatibility evaluation of vehicle antenna by selecting 4 vehicle-mounted antennas as typical representatives.Respectively chosen vehicle antenna for wireless communication scheduling system cluster (Tetra) antenna, the entertainment system (Infotainment) (chime feel) antenna, Door control system and the WIFI antenna, the antenna of cluster and WIFI antenna installation at the top of the cab, entertainment system antenna and antenna installed on the driver Door control console and intersection area under the windshield edge position, the relative positions of the antenna and the test equipment in the car before the visual signal, as shown in figure 1.In the figure, 2 rectangles respectively represent the electromagnetic interference receiver of signal generator, 6 lines represent 6 cables, and pairwise pairs of solid, dotted and dotted lines respectively represent the connection of 1 pair of antennas when measuring the isolation degree.

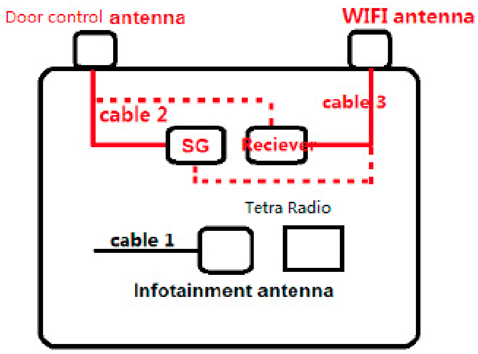

Fig. 1 Location diagram of the antennas

The key information of the vehicle-mounted antenna is shown in table 2. It can be seen that among the four antennas evaluated, WIFI antenna and gate control system antenna work in the same frequency band. After the spectrum planning inspection program, it is confirmed that these two antennas can work normally at the same time, and there is no electromagnetic interference between them.

Table 2 Evaluated vehicle-mounted antenna information

Antenna	Frequency/ MHz	Location
Tetro Radio	851-863	Cab inner
Door control	2400-2483.5	Cab roof
WIFI	2400-2483.5	Cab roof
Infotainment	5150-5350	Cab inner

The energy matching evaluation will be checked.Firstly, the in-band and in-band transmitting power and the in-band and out-band sensitive limits of each antenna are listed (table 3).Then, one by one for measuring the space between antenna isolation degree, has been considered in the process of testing cable the live-fire cable and cable loss difference, two collocation space isolation degree of test coverage, is a kind of transmitting antenna out-of-band emission falls within the receiving antenna belt, test results are shown in table 4, the other is a transmitting antenna in-band launch falls outside the receiving antenna belt, test results are shown in table 5 (table 4 ~ 5 when the antenna ACTS as the transmitting antenna in the table according to the line arrangement, as listed in the table according to the arrangement when receiving antenna, below the same as in table 6 ~ 7).Because the working frequency interval between the cluster antenna and the entertainment antenna is far from each other, the former is installed on the roof of the car while the latter is installed in the driver's room. There are better frequency domain and space isolation conditions between the two, and the two have passed the spectrum planning inspection project. Therefore, this time, it is no longer necessary to evaluate the in-band and out-band energy matching of the two.

Table 3 The in-band and out-band transmission levels and sensitive limits

Antenna	In-band transmission levels	Out-band transmission levels	In-band sensitive limits	Out-band sensitive limits
Tetro Radio	+35	-65	-100	-25
Door control	+24	-60	-100	-15
WIFI	+24	-50	-100	-15
Infotainment	+14	-70	-100	-2

Table 4 Measured results of spatial isolation between external transmission of source antenna band and internal reception of sensitive antenna band

Antenna	Spatial isolation/dB			
	Tetro Radio	Door control	WIFI	Infotainment
Tetro Radio	-	67.98	36.92	-
Door control	73.72	-	66.04	41.39
WIFI	58.03	62.81	-	61.06
Infotainment	-	52.42	75.89	-

Table 5 Measured results of spatial isolation between in-band transmission of source antenna and out-band reception of sensitive antenna

Antenna	Spatial isolation/dB			
	Tetro Radio	Door control	WIFI	Infotainment
Tetro Radio	-	68.95	57.74	-
Door control	51.14	-	63.95	55.46
WIFI	40.03	61.54	-	75.92
Infotainment	-	40.68	64.17	-

By substituting the data in table 2~5 into equation (1), the disturbance level from the interference antenna to the sensitive antenna can be obtained. Then, the sensitivity limit value minus the disturbance level can be used to obtain the calculated margin value (table 6~7).

Table 6 Calculation values of disturbance level and sensitivity limit between transmitting outside source antenna and receiving inside sensitive antenna

Antenna	margin calculation value/dB			
	Tetro Radio	Door control	WIFI	Infotainment
Tetro Radio	-	17.98	6.92	-
Door control	38.72	-	41.04	1.39
WIFI	23.03	12.81	-	21.06
Infotainment	-	2.42	45.89	-

Table 7 The calculated values of disturbance level and sensitivity limit between in-band transmission source and out-band reception of sensitive antenna

Antenna	margin calculation value/dB			
	Tetro Radio	Door control	WIFI	Infotainment
Tetro Radio	-	19.95	18.74	-
Door control	1.14	-	33.95	16.46
WIFI	3.03	11.54	-	49.92
Infotainment	-	1.68	35.17	-

Table 6 and table 7 show that there is a margin between the harassment level and the sensitive limit, so the electromagnetic compatibility of the rated antenna is satisfied.

6. Conclusion

Urban rail transit vehicle antennas are divided into two groups based on the vehicle body floor as the dividing line. The working frequency band of antennas installed on the vehicle body floor is below 30MHz, and the working frequency band of antennas installed on the vehicle body floor is above 30MHz. The probability of interference between the two groups of antennas is very small.

Taking a subway vehicle as an engineering example, an electromagnetic compatibility evaluation method of vehicle-mounted antenna is introduced.The evaluation method introduced in this paper makes up for the shortage of directly evaluating vehicle electromagnetic compatibility based on EN 50121 standard test method without covering antenna port, and has been successfully applied to multi-type urban rail transit vehicles.All the evaluated vehicles passed the EMC type test successfully, which ensured the electromagnetic compatibility level of delivered vehicles.

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