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Cable Height Dependence in Radiated Immunity Evaluation of Automotive Ethernet 100BASE-T1

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Abstract

Experimental study of height dependence of wire harnesses on the disturbance radiated in reverberation chambers, which is one of the immunity evaluation methods for in-vehicle equipment. The results of 10-mm and 50-mm wire harness heights showed that 10-mm heights had a higher incidence of errors in the frequency band above 1 GHz. Since the lower height of the cable also has better common-mode transmission characteristics, it is assumed that the disturbance induced in the cable is more easily reached by the communication equipment.

1 Introduction

Power electronics devices are increasingly being introduced into automobiles. These devices generate high-frequency disturbances during switching. Therefore, it is becoming increasingly important to evaluate the immunity of in-vehicle communication devices placed in the vicinity of these power electronics devices. As an in-vehicle communication standard, 100BASE-T1, a type of Ethernet, is being introduced in commercial vehicles. Since it also has the advantage of reducing the weight of the wiring harness, it is expected that a faster 1000BASE-T1 standard will be introduced in the future.

There is a test method defined in the ISO 11452[1] series of immunity standards for in-vehicle equipment. For example, the ALSE (Absorber-lined Shielded Enclosures) method described in ISO 11452-2ISO11452-2 and/or reverberation chamber method in ISO 11452-11ISO11452-11 can evaluate the immunity to radiated disturbance of in-vehicle equipment connected to a wire harness of a defined length. The height of the wiring harness must be 50 mm as specified in the regulation. However, for example, the 100BASE-T1 link segment evaluation method discussed in OPEN ALLIANCE specifies a height of 10 metersopen. In the actual in-vehicle environment, the wire harness height is not constant.

In this report, the immunity evaluation of automotive Ethernet 100BASE-T1 is performed in a reverberation chamber. The incidence rate of malfunction is evaluated by comparing the case with a harness height of 50 mm indicated in ISO 11452-11 and the case with a harness height of 10 mm discussed in the OPEN Alliance.

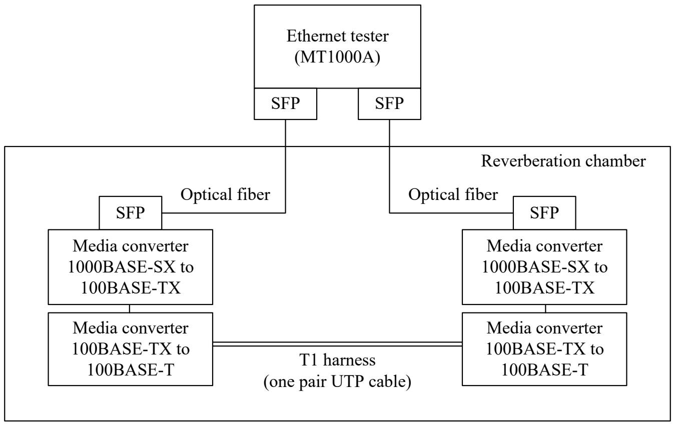


Figure 1. Communication module of automotive Ethernet (100BASE-T) in reverberation chamber.

2 Test Setup

2.1 Communication module

This section describes the configuration of the communication module for immunity evaluation. The module consists of media converters for 100BASE-TX and 100BASE-T1[5], and an optical media converter for 1000BASE-LX and 100BASE-TX, as shown in Fig. 1. An STP cable connects the two media converters.

To evaluate radiated immunity to the communication system, these media converters were installed in an aluminum enclosure. The power supply to the media converters is provided by a battery located in the enclosure.

2.2 Measurement setup in reverberation chamber

The two modules are placed on a reference ground in the reverberation chamber and connected by a T1 harness. The reference ground is a copper plate placed at a height of 900 mm from the floor metal. The module enclosures are connected to the reference ground by copper tape.

Communication quality is evaluated by an Ethernet tester placed outside the reverberation chamber. In order to focus on disturbance to the T1 harness, optical fibers are used for

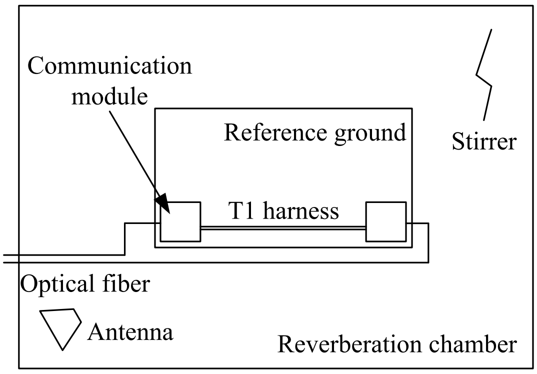


Figure 2. Placement of communication modules on reference ground plane in reverberation chamber.

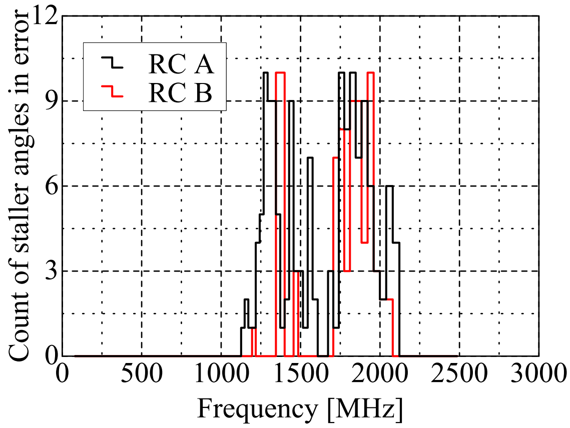


Figure 3. Comparison of experimental results in two reverberation chambers.

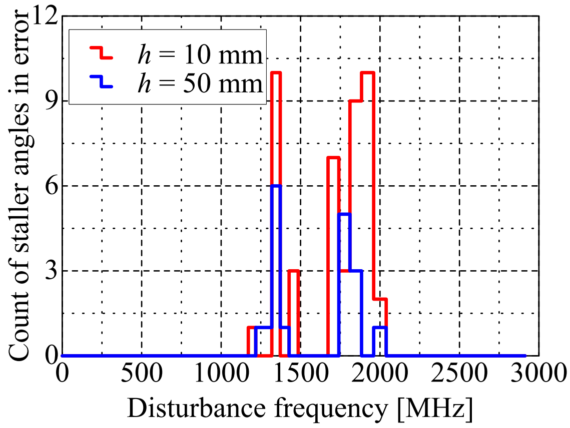


Figure 4. Comparison of experimental results in two height(10 mm and 50 mm) measured in reverberation chamber B.

the connection to Ethernet tester. The Ethernet tester has two communication ports, and full-duplex communication is performed between these ports.

Two reverberation chambers were used for the evaluation. The characteristics of each reverberation chamber are shown in Table 1. The reverberation chamber A (RC A) has a minimum frequency of 200 MHz, but the field strength can be 100 V/m in all frequency bands. On the other hand, the reverberation chamber B (RC B) has a minimum frequency of 80 MHz, but the maximum field strength is limited to 50 V/m in the frequency band above 1 GHz. In both reverberation chambers, the wire harness length is set to 2 m. For comparison, the wire harness heights in RC B are 10 mm and 50 mm.

In each reverberation chamber, the angle of the stars is changed every 30 degrees and the electromagnetic waves are exposed. In other words, 12 conditions for each frequency are checked for communication errors. The disturbance is a sine wave. The frequency is increased by 2% increments from the reference frequency. Communication errors are measured by checking the link status and frame error rate of the Ethernet tester placed outside the reverberation chamber.

3 Measurement Results

The results of the measurements in each reverberation chamber are shown in Fig. 3. The horizontal axis is the frequency of the disturbance. After counting the errors at a certain stirrer angle in the reverberation chamber, the cumulative error angle for each frequency is shown on the vertical axis.

Table 1. Measurement setup of radiated immunity in reverbration chamber.

RC	Frequency	Intensity of E field	Height	Length
A	200 MHz~600 MHz 600 MHz~1 GHz 1 GHz~3 GHz	100 V/m	10 mm	2 m
B	80 MHz~200 MHz 200 MHz~1 GHz 1 GHz~3 GHz	100 V/m 100 V/m 50 V/m	10 mm / 50 mm	2 m

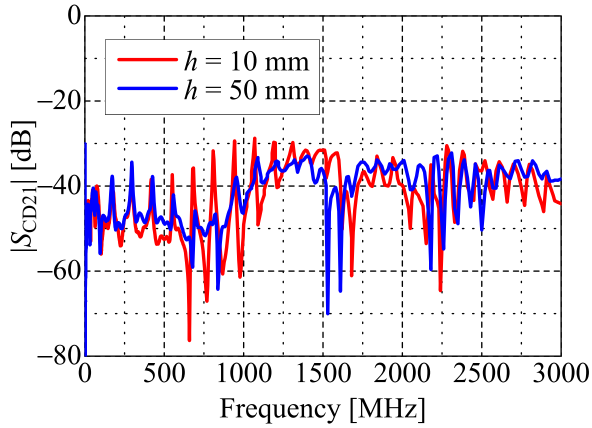
As a result, no errors occurred in the lower frequency bands. All errors were concentrated in the case of applied disturbances above 1 GHz. The frequency of errors was particularly high for 1.4 GHz and 1.7 GHz disturbances. It should be noted that in these frequency bands, the field strength is 50 V/m in RC B. Although each reverberation chamber differs in size and antenna location, similar results can be obtained for immunity evaluation.

Next, we experimented with RC B to determine the frequency of errors at different harness heights. The results are shown in Fig. 4. Many more errors are observed in the 10 mm height results, shown in red, than in the 50 mm height results, shown in blue. If the system consisting of the cable and reference ground is considered as a loop antenna, the result with a height of 50 mm, which has a larger antenna aperture area, is presumed to have higher reception sensitivity. However, the results show that the 10 mm height with a smaller aperture area is more sensitive.

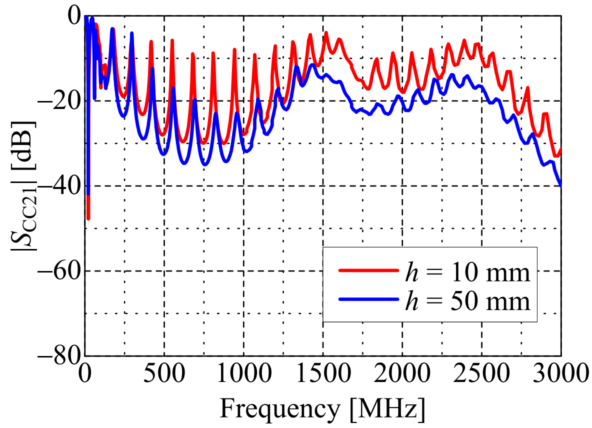
4 Discussion

The reasons why lower harness height increases sensitivity and degrades immunity are discussed in terms of the transmission characteristics of wire harnesses. Since the T1 harness is an unshielded twisted pair wire, it can be treated as a 4-port circuit with respect to the reference ground. Therefore, 1-m T1 harness is routed on the reference ground at a height h, and the S-parameters are measured by a 4-port vector network analyzer. To evaluate in differential mode, which is the signal component, and in common mode, which tends to couple with external electromagnetic fields, the S-parameters obtained by the measurement are converted to mixed-mode S-parameters[6].

The calculation results of the mixed-mode S-parameters are shown in Fig. 5. Here we discuss the common mode to differential mode mode conversion characteristic S_{CD21} and the common mode transmission characteristic S_{CC21}. In the frequency range of about 1 GHz, it can be observed that the mode conversion increases as the height of the harness is lowered. This can be assumed to be due to the asymmetry of the cable becoming more noticeable as the reference ground gets closer. Lowering the harness height also resulted in a larger common mode transmission characteristic. As mentioned above, if the wiring harness is considered as a loop antenna, the lower the harness height, the smaller the aperture area. However, the transmission characteristics of the common-mode current induced in the harness by the radiated disturbance will be improved, resulting in an increase in the disturbance reaching the communication equipment.



(a) S_{DC21}.



(b) S_{CC21}.

Figure 5. Mixed mode S parameters of 1-m T1 harness.

5 Conclusion

In this report, a disturbance application test was conducted on a 100BASE-T1 communication module, an in-vehicle communication device, using the reverberation chamber described in ISO 11452-11. A comparison was made between the case where the wire harness height was 50 mm as specified in ISO11452-11 and the case where it was 10 mm, which is used in the OPEN Alliance for evaluating link segments. As a result, errors occurred when the frequency of the disturbance was above 1 GHz. The incidence of errors was higher in the case of 10 mm height than in the case of 50 mm height. To investigate the reason for this phenomenon, the transmission characteristics of wire harnesses were measured. The common-mode transmission characteristics of the wire harnesses are better at a height of 10 mm. This indicates that more common-mode currents induced in the cable by radiated disturbance at 10 mm height can reach the telecommunication equipment.

References

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