Propagation Characteristics of 700MHz Band V2X Wireless Communication*

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In recent years, vehicle to vehicle and vehicle to infrastructure wireless communication has been developed for automotive use. DENSO has conducted field tests around the world to develop high performance and reliable radio system. In this paper, we introduce the study results about propagation characteristics of the radio wave under actual vehicle running condition and antenna requirements.

Key words :
V2X communication, 700MHz band, Antenna, Propagation characteristics

1. INTRODUCTION

In recent years, cooperative systems using V2X wireless communication have been developed for automotive safety. **Fig. 1** shows samples of cooperative safety applications. One informs about forward obstacles by vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) wireless communication[1]. Another one provides driving assistance information around the intersection such as the car behind the truck and/or pedestrian using V2V and/or V2I wireless communication. Today these V2V and V2I communications are together called V2X communication.

Cooperative safety applications using V2X wireless communication have been expected to assist safety driving, especially by informing real-time traffic situation in non line of sight (NLOS) area. Also, this V2X wireless communication is considered to be utilized for energy saving. So the V2X wireless communication became important technology for ITS and has been developed globally.

In Japan, 700MHz frequency band has been assigned for this V2X communication. This frequency is suitable for the NLOS communication required for most of safety applications since diffraction effect can be expected compared to gigahertz band. We, DENSO, have worked on the development of radio unit, antenna and application, in order to deploy the reliable and cost effective product using this 700MHz V2X communication. Through the development work, we realized that it is very important to validate propagation characteristics of the 700MHz band radio wave in the various environments for safety applications.

Propagation characteristics in urban areas are already introduced[2]. We think that it is also important to understand the characteristics of the highway for safety

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applications.

The example environments are a long distance tunnel and blocking by heavy truck. It is thought that these environments are severe for wireless communication on highway. In the long distance tunnel, significant multipath exists. Also obstruction by heavy trucks occurs frequently on the highway, and this may lead to deteriorated signal strength at the receiver.

Therefore, we think that it is important to understand propagation characteristics of both cases because we think that they both have impacts for communication performance.

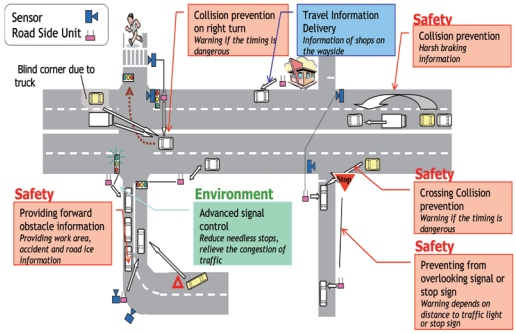

Fig. 1 V2X Applications

2. PROPAGATION CHARACTERISTICS ON THE HIGHWAY

2.1 MEASUMENT SYSTEM

We carried out the propagation characteristics measurement of 700MHz radio wave under the condition of long-distance tunnel and blocking by heavy truck on the actual highway.

The outline of the method for measurement is shown in **Fig. 2**. The three measured driving conditions are

(1) Line of sight without a heavy truck

The receiving vehicle runs at 80km/h towards a stationary transmitting vehicle with no objects in between.

(2) Heavy truck blocking

The receiving vehicle runs at 80km/h towards a stationary transmitting vehicle. The receiving vehicle follows a heavy truck at a distance of about 40m.

(3) Long-distance tunnel

The receiving vehicle runs at 80km/h in long-distance tunnel towards a transmitting vehicle that is stationary at the outside of the tunnel exit.

In each driving condition, the Received Signal Strength Indication (RSSI) on the receiving vehicle is recorded. Other measurement conditions are shown in **Table 1**. The radio unit is shown in **Fig. 3**.

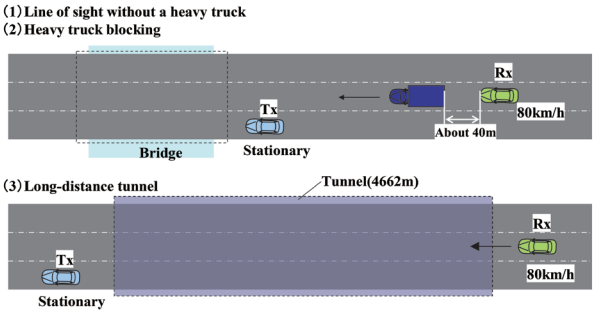

Fig. 2 Outline of the method for measurement

Table 1 Measurement condition

Test vehicle		Sedan type
Antenna	Gain	2dBi monopole antenna
	Mounting position	Roof center of each vehicle
Frequency	Center frequency	792.5MHz
	Band width	10MHz
TX parameter	TX power	19dBm
	Rate	6Mbps
	Packet length	100bytes
Cable loss		5.4dB
Radio unit		Manufactured by DENSO

Fig. 3 Radio unit

2.2 MEASUMENT RESULT

The measurement results are shown in **Fig. 4**. In the case of line of sight without a heavy truck, as the receiving vehicle approaches, RSSI grows stronger. On

the other hand, there is a spot that RSSI attenuates in both cases of heavy truck blocking and long-distance tunnel.

Under the heavy truck blocking condition, RSSI is the almost same as line-of-sight except at 50m range. At about 50m range, a big attenuation (about 20dB) of RSSI was observed. We think the reason of this result is interference between diffracted waves. It is important to receive diffracted waves in non-line-of-sight condition. In 700MHz in particular, the effect by the diffraction waves is expected, more so than at higher frequencies. However, it is thought that RSSI attenuates by a destructive canceling at 50m range.

In the long-distance tunnel environment, the average RSSI is higher, and RSSI sharply changes as compared with line of sight condition. Concerning average RSSI, we guess the reason is that the radio wave propagates without radiation to the outside of the tunnel. Also since a large number of multipaths exist in the tunnel, RSSI is higher when the phase of the strongest multipaths are the same. On the other hand, RSSI is lower when the phase of the strongest multipaths are out of phase.

We think that communication stability is necessary for future advanced safety applications under environments such as long-distance-tunnel and heavy truck blocking.

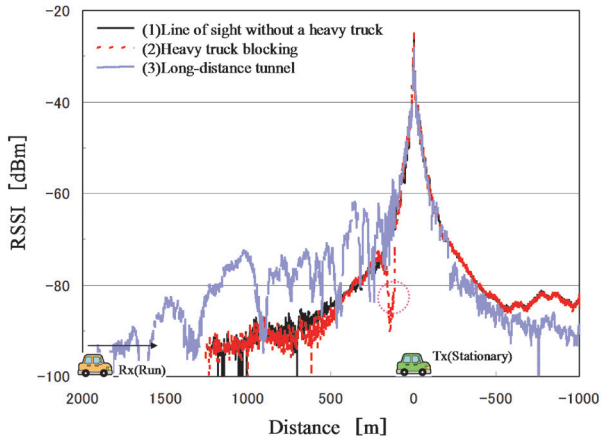

Fig. 4 Measurement result of propagation characteristic

3. EFFECTIVE OF DIVERSITY RECEPTION

3.1 MEASUREMENT SYSTEM

We think that stable reception is necessary under multipath environments for safety applications. Diversity reception that captures radio signals using multiple antennas is expected to be an effective method reducing the influence of sharp attenuation of the RSSI[3]. Therefore diversity reception is expected to be effective for interference between multipath and diffracted waves in both cases of the long-distance tunnel and heavy truck.

We validated the effect of diversity reception in the long-distance tunnel and heavy truck blocking. The diversity reception method we tested is Maximal Ratio Combining (MRC). Two receive antennas are mounted on the rear portion of the vehicle's roof in this test. The distance between two antennas is λ /2. A view of the antenna mounting is shown in **Fig. 5**. Other conditions are shown in **Table 1**. Our performance index is packet arrival rate (PAR).

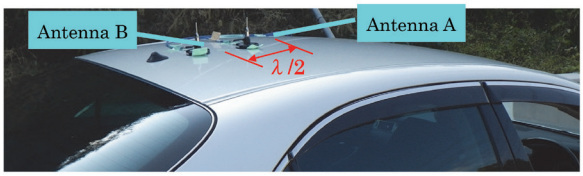

Fig. 5 Antenna mounting position

3.2 MEASUREMENT RESULT

3.2.1 HEAVY TRUCK BLOCKING

The measurement result for heavy truck blocking is shown in **Fig. 6** and **Fig. 7**. Measurement conditions are the same as for the measurement of propagation characteristics.

In the case of a single antenna, PAR decreases at -130m range from sudden RSSI attenuation.

On the other hand, in the case of diversity, PAR is improved at -130m range. Also PAR is improved at

-700m. The reason for the improvement is regarded as both diversity effect of antenna selection combining and MRC.

Therefore, we think that diversity reception is an effective method for an environment such as heavy truck blocking where RSSI can be attenuated.

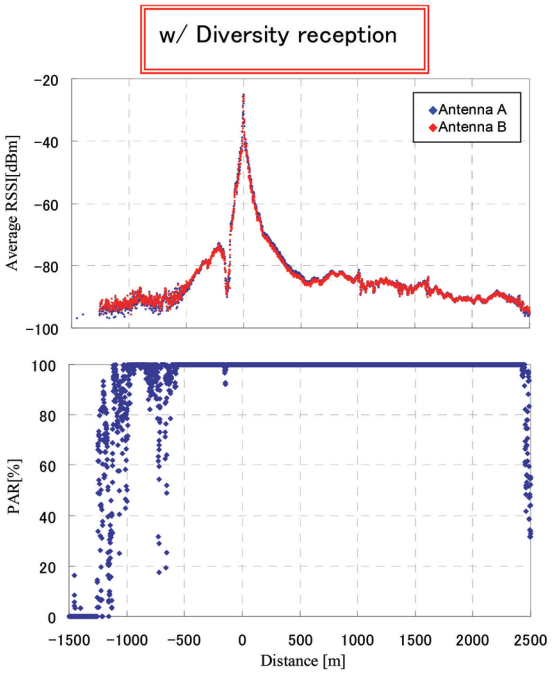

Fig. 6 Measurement result of heavy truck blocking with diversity reception

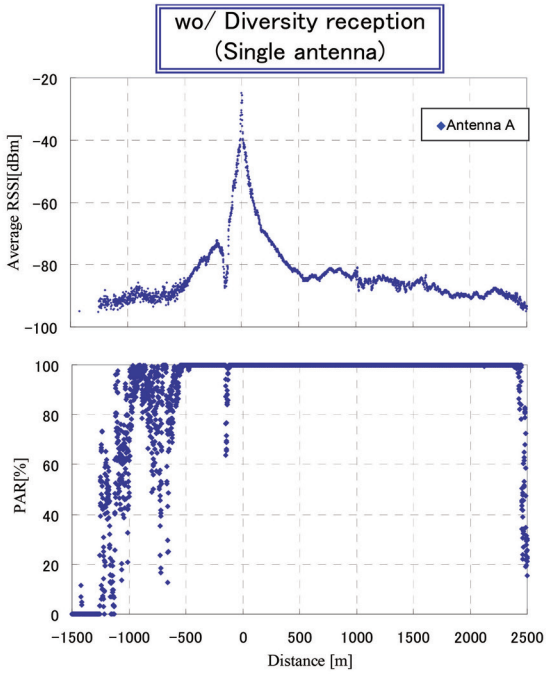

Fig. 7 Measurement result of heavy truck blocking without diversity reception

3.2.2 Long distance tunnel

The measurement result from the long distance tunnel is shown in **Fig. 8** and **Fig. 9**. The measurement condition is the same as the propagation characteristics. In the case of the single antenna, PAR decreased at the -450m and -900m ranges where RSSI attenuates. The reason for this is because RSSI is less than the receive sensitivity of radio unit.

On the other hand, PAR is improved at these ranges by diversity reception. The reason is that one of two antennas has enough RSSI for decoding packets. Especially, the RSSI of antenna B is about 5dB higher than that of antenna A at -450m,The radio unit demodulates using the received signal of antenna B. As a result, PAR is improved at this range by using diversity reception.

Therefore, we think that diversity reception is an effective method for environments such as the tunnel where RSSI can attenuate due the destructive interference of strong multipath.

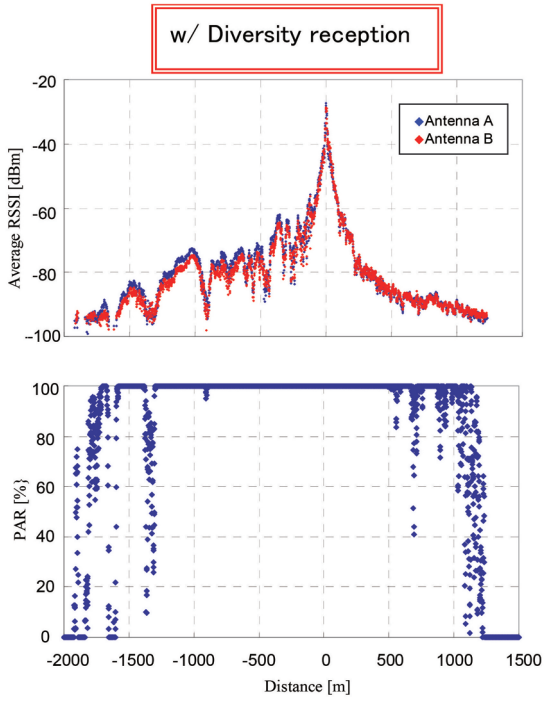

Fig. 8 Measurement result of long distance tunnel with diversity reception

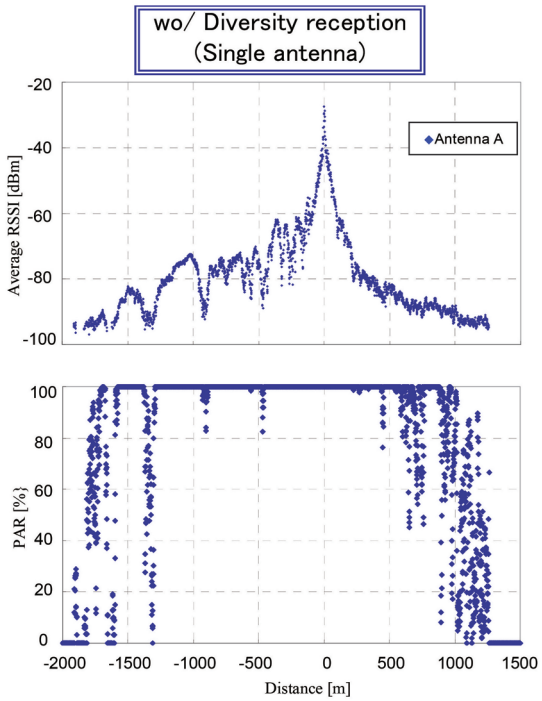

Fig. 9 Measurement result of long distance tunnel without diversity reception

4. SUMMARY

We introduced study results that measured propagation characteristics of the 700MHz radio wave under long-distance tunnel and heavy truck blocking on the highway. In addition, we showed the effectiveness of diversity reception in the environments such as the tunnel which has rapid changes in RSSI and heavy truck blocking. We think that this result is one of the methods of achieving stable V2V communications for safety applications.

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