2D4-4

Propagation Path Losses as a Function of Distance for Inter-Vehicle Communications in the 60GHz band

Atsushi Yamamoto, Koichi Ogawa, Tetsuo Horimatsu*, Akihito Kato**, and Masayuki Fujise**
Matsushita Electric Industrial Co., Ltd. Communication Devices Development Center
1006, Kadoma, Osaka, 571-8501 Japan, Tel : +81-6-6900-9613
yamamoto.on@jp.panasonic.com
*Fujitsu Ltd. **Communications Research Laboratory

1. INTRODUCTION

In recent years, study of the propagation characteristics of inter-vehicle communications (IVC) in the 60 GHz band has increased enormously [1]-[3], motivated mainly by some exciting new applications, which include multimedia communication between vehicles and automatic control of vehicles such as Advanced Cruise-Assist Highway Systems (AHS). In the line-of-sight (LOS) case, the 2-wave model [1], comprising a direct wave and a wave reflected from the surface of the road, has been shown to be effective in predicting the received power. In the non line-of-sight (NLOS) case, where an intermediate vehicle causes an obstruction, the 8-wave model using the uniform theory of diffraction (UTD) [3] is capable of providing accurate propagation characteristics. These models, in which a deterministic approach is employed, can provide the signal strength at a specific point in the radio cell. In practice, however, in designing a cell for mobile communications, the most important factor is to be able to predict a reliable value for the path loss for the point of interest.

This paper presents the propagation path loss for IVCs in the 60 GHz band. The path loss is derived from a cumulative distribution of the propagation loss by statistically processing a number of data obtained by changing the heights of the antennas. The path loss prediction formula is conducted by best fitting a line using the median path losses calculated from the 2-wave and 8-wave models. Finally, propagation tests between vehicles in motion were conducted. From this, the success of the path loss prediction formula in estimating the propagation loss was confirmed by the measurements.

2. EXPERIMENTAL SETUP

Figure 1 shows the configuration of the propagation test. A vertically polarized wave of 10 dBm at 59.1 GHz was radiated. Standard pyramidal horn antennas with a peak gain of 23 dBi were used for both receiving and transmitting antennas. A vehicle was located at the center between the transmitting and receiving antennas in the NLOS case. Figure 2 illustrates the structural parameters of this intermediate vehicle. Five types of commercial vehicle were selected for this, the dimensions of which are listed in Table 1.

3. PROPAGATION PATH LOSS

Figure 3 shows the measured received power in the LOS case as a function of the height of the receiving antenna between vehicles communicating at a fixed position. The height of the transmitting antenna (ht) was set to be 1.03 m. The height of the receiving antenna (hr) was varied from 0.39 m to 1.87 m. The distance between the transmitting and receiving antennas (D) was set to be 120 m. The results calculated using the 2-wave model [1] are also plotted in Fig. 3. The calculated results are in good agreement with the measured data. Figure 4 shows cumulative distributions of the propagation path loss, which are obtained from the received power shown in Fig. 3. The propagation path loss is defined by the following equation.

$$L = \frac{Gr \cdot Gt \cdot Pt}{Pr} \quad (1)$$

where Pt and Pr are the transmitted and received power, respectively and Gt and Gr are the gains of the transmitting and receiving antennas, respectively. In this paper, the propagation path loss is defined as the median of propagation losses obtained by varying ht and hr. The ranges of ht and hr are set to be from 0.4 m to 1.4 m since the antennas are considered to be mounted on the body of

ISBN: 4-88552-206-4 C3055©IEICE

the vehicle. In the calculation, ht and hr are incremented by intervals of 2 mm, which corresponds to 0.39 of the wavelength. Thus there are 500 data points for both ht and hr. Consequently, the amount of data needed for calculating the median of the propagation losses is 250,000. In addition, the propagation losses at 90 % and 10 % are obtained from cumulative distributions in order to examine the range of propagation loss, which may be used in the radio link calculation for a system with different outage.

Figures 5(a) and (b) show the propagation losses as a function of distance at 50 %, 90 % and 10 % in the LOS and NLOS cases calculated using the 2-wave and 8-wave models. The propagation losses in the NLOS case are average values calculated from the propagation losses of all the intermediate vehicles. It is found from Fig. 5 that the difference between the propagation losses at 90% and 10% in the NLOS case is smaller than that for the LOS case since only a major wave can arrive at the receiving antenna as a result of the obstruction of the direct wave by an intermediate vehicle. Furthermore, the results calculated using the path loss formula are plotted in Figure 5. The path loss formula for the propagation loss is defined as follows:

$$L = A \cdot 10 \cdot \log_{10} D + C + 16 \cdot D / 1000 \qquad (2)$$

where D is the distance between the antennas in meters and the third term on the right hand side is atmospheric attenuation of 16 dB/km at 60 GHz. A and C are obtained by a best fit to eq.(2) using the least mean square method and these are listed in Table 2.

4. PROPAGATION PATH LOSS BETWEEN THE COMMUNICATING VEHICLES IN MOTION

Figures 6(a) and (b) show a photograph of the communicating vehicles and the top view of the test course. The transmitter and receiver are mounted on the back of the leading vehicle and the front of the following vehicle shown in Fig. 6(a). ht and hr are set to be 0.49 m and 0.43 m. The received power measured along the 750 m straight part of the course is evaluated. Figures 7 shows the propagation characteristics at a value of D of 80m when the vehicles are moving at 40 km/hour. In the NLOS case, the minivan is used as the intermediate vehicle. The results calculated using the 2-wave and 8-wave models, with D measured instantaneously and constant values of ht and hr, are in substantially good agreement with the measured ones. Figure 8 shows the propagation path losses obtained from the experimental data when the communicating vehicles are moving. The data calculated from eq. (2) are also shown in the figure. Figure 8 indicates that the results from the experimental data are in good agreement with those calculated by eq. (2). As a result, it can be stated that the path loss formulas successfully estimate the propagation losses for communications between the moving vehicles.

5. CONCLUSION

We have derived a formula to estimate the propagation losses for the IVC in the 60 GHz band. This was obtained from the cumulative distributions in the LOS and NLOS cases. From the propagation experiments between vehicles communicating whilst in motion, it was concluded that the formula successfully estimates the propagation loss, and thus is suitable for the cell design of the IVC.

The authors wish to express their appreciation to Professor Dr. Hiroshi Shirai of Chuo University and Assistant Professor Dr. Jun-ichi Takada of Tokyo Institute of Technology, for their very useful advice. This study was made as a part of the Joint-research, by the Millimeter Wave Propagation Study Group, a subsection of the Inter-vehicle Communication Joint-research Group, which is also a section of ITS Joint-research Group at YRP.

REFERENCES

[1] Y. Karasawa, “Multipath Fading due to Road Surface Reflection and Fading Reduction by means of Space Diversity in ITS Vehicle-to-Vehicle Communications at 60GHz”, IEICE Trans. Commun., vol. J83-B, no.4, pp.518-524, Apr. 2000.

[2] A. Kato, K. Sato, and M. Fujise, “Propagation Characteristics at 60GHz on the Road for ITS Inter-Vehicle Communications”, IEICE Technical Report, ITS-99-101, Feb. 2000.

[3] A. Yamamoto, K. Ogawa, T. Horimatsu, A. Kato and M. Fujise, “An Accurate Propagation Path Model Obstructed by a Blocking Vehicle for Inter-Vehicle Communications at 60GHz,” ISAP i-02, Nov. 2002.

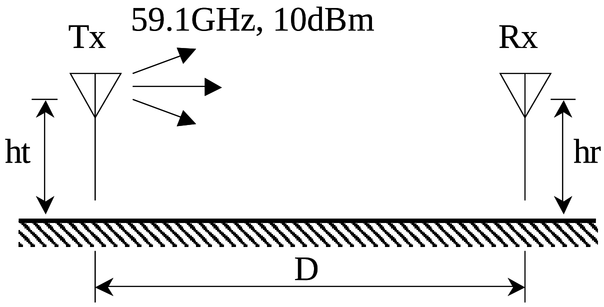


Fig. 1 Configuration of the propagation test.

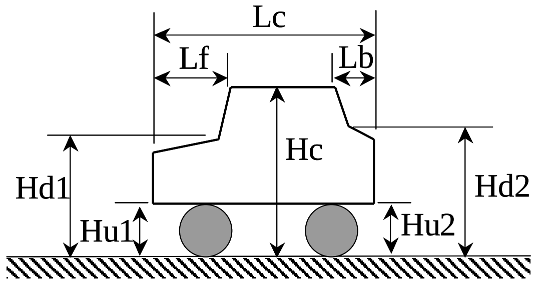


Fig. 2 Structural parameters of an intermediate vehicle.

Table 1 Dimensions of intermediate vehicles in m.

	Lc	Hc	Lf	Lb	Hu1	Hu2	Hd1	Hd2
Light motor vehicle	3.36	1.62	1.34	0.20	0.22	0.27	0.98	0.99
Truck	6.00	3.00	1.57	0.00	0.29	0.33	1.40	0.80
Wagon	4.54	1.45	2.00	0.50	0.23	0.36	0.90	1.00
Sedan	4.40	1.42	1.80	1.20	0.20	0.33	0.89	1.07
Mini-van	4.60	1.55	1.85	0.00	0.20	0.32	1.29	1.30

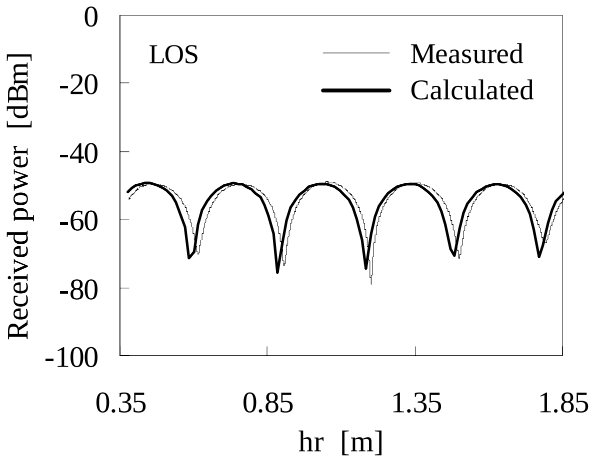


Fig. 3 Received power as a function of the height of the antenna.

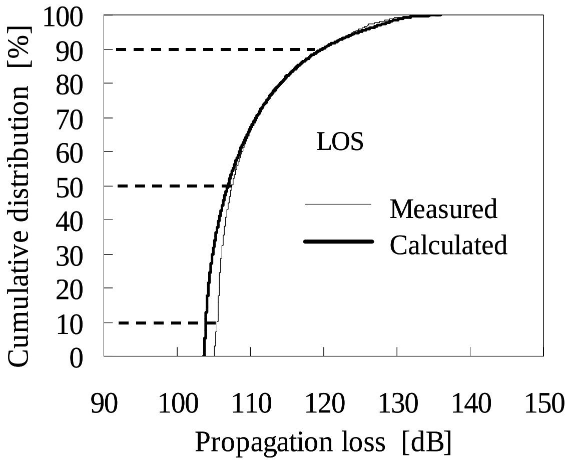


Fig. 4 Cumulative distribution of the propagation loss.

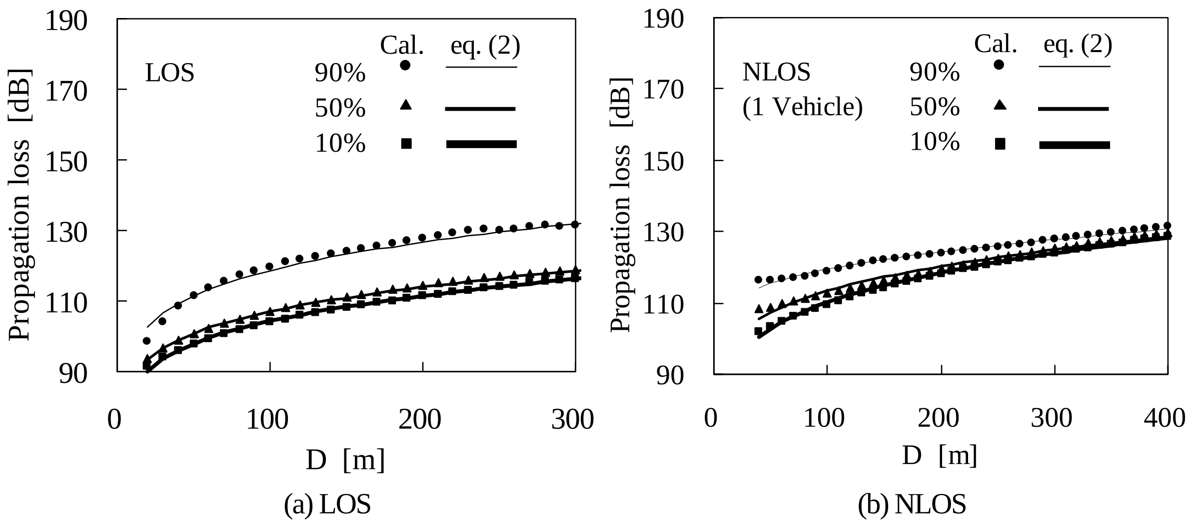
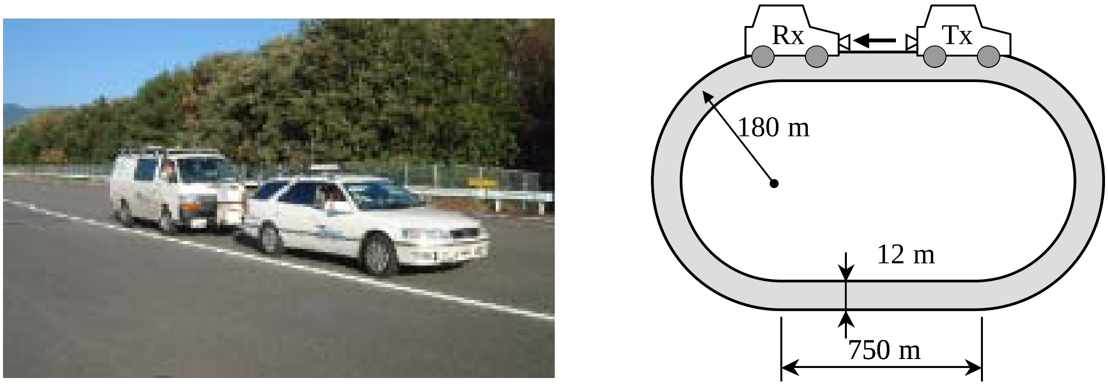


Fig. 5 Distance characteristics of the propagation losses at 50 %, 90 % and 10 %.

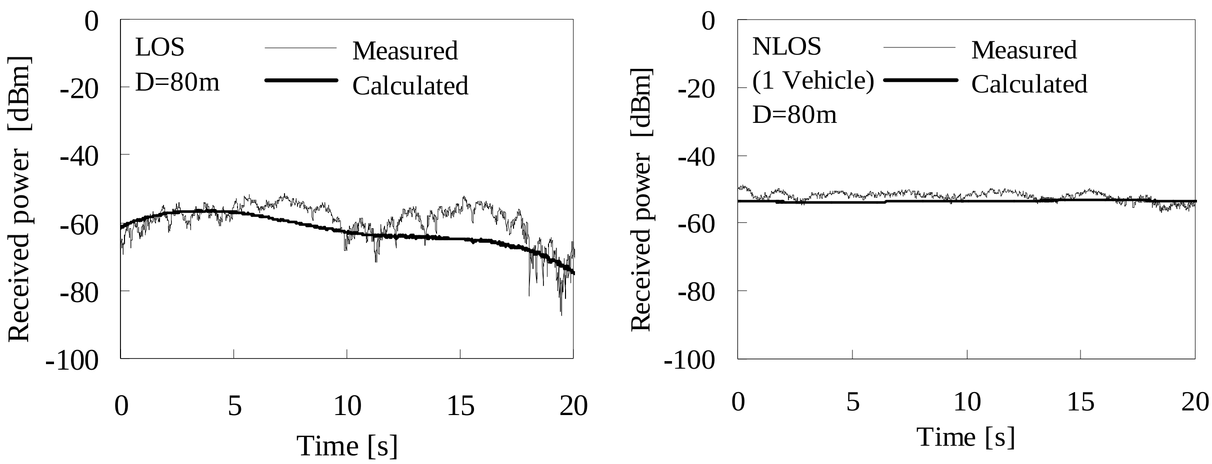
Table 2 A and C of a path loss formula when the ranges of ht and hr are set to be from 0.4 m to 1.4 m.

	A			C [dB]		
	0.50	0.99	0.01	0.50	0.99	0.01
LOS	1.83E+00	3.73E+00	1.88E+00	6.90E+01	5.33E+01	6.46E+01
NLOS	1.74E+00	6.92E-01	2.24E+00	7.70E+01	1.08E+02	6.30E+01



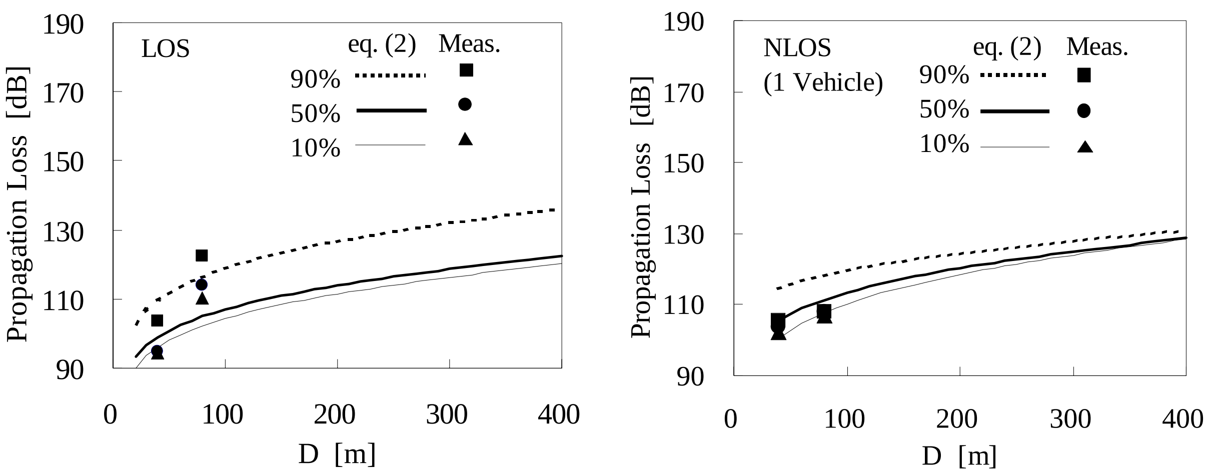
(a) Communicating vehicles (b) Top view of the test course

Fig. 6 Communicating vehicles and top view of the test course.



(a) LOS (b) NLOS

Fig. 7 Received power in the LOS and NLOS cases when the communicating vehicles are in motion.



(a) LOS (b) NLOS

Fig. 8 Propagation path losses calculated by the experimental data between the vehicles in motion.