Delay Profile Model in 700MHz Band for Road to Vehicle and Vehicle to Vehicle Communications

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1. Introduction

Research and development on ITS (Intelligent Transport System) has been advanced for recent years. As the radio spectrum of the ITS wireless systems, the 5.8GHz band has mainly been used up to now in Japan. On the other hand, it was recently decided that 700MHz is to be allocated for ITS along with the re-arrangement of the UHF spectrum due to the digitalization of the analogue television broadcasting services [1]. One of the reason why the lower frequency is preferred in ITS is the smaller diffraction loss. It is effective to enhance the service coverage particularly where the two communication vehicles are in non line-of-sight situation such as over-the-intersection.

The development of a new ITS system in the new frequency band is now being advanced in Japan [2]. In the development and the standardization, it is necessary to show the system achieves sufficient communication performance in the environment where it is actually used. In general, the performance is evaluated by computer simulations. To realize precise evaluation, propagation models, by which the actual propagation path of the wireless system is appropriately characterized, are indispensable. For link level simulations, a delay profile model is particularly important.

In the standardization of the wireless system for ITS of the 700MHz band, propagation measurement was firstly carried out. In this paper, the delay profile model for ITS in the 700MHz band based on the measured data is presented.

Numerous measurements were carried out in the campaign by changing various parameters. In addition to the delay characteristics, the propagation loss is also measured in the experiment. Among them, we focus on the delay model and some concrete examples of the established models are shown [3]. A detailed analysis of the statistical propagation characteristics such as the dependence on the environments, etc. is a remaining subject for the future study.

2. Propagation Measurement Campaign

The measurements are conducted considering two applications in the 700MHz band, road to vehicle communications (RVC) and vehicle to vehicle communications (VVC). In RVC, LOS (Line-Of-Sight) situation is mainly assumed, while NLOS (Non LOS) over intersections is in VVC. In order to measure propagation characteristics in various types of environments, the following three areas in Tokyo metropolitan area are selected.

- High-rise environment : Kyobashi area
- Residential environment : Tsukishima area
- Suburban environment : Tokyo Teleport area

The multipath delay characteristics are measured while the Rx. vehicle is moving in a short section as 5m. The measurement configurations are schematically shown in Fig. 1. The widths of the roads of the measured areas are summarized in Table 1.

Table 2 shows the specifications of the measurement system. The multipath delay is measured using a PN sounding signal of 24Mchip/s (RF bandwidth: 48MHz). The RF received signal is converted to the IQ complex baseband signal and it is A/D-converted and recorded. By the measurement system, data for 0.5sec can be recorded continuously. The delay profile is defined as “power profile of impulse responses averaged over sufficiently large area where WSSUS (Wide-Sense Stationary Uncorrelated Scattering) assumption is valid”. In this measurement, the area where the WSSUS assumption is valid is assumed around 5m travelling of Rx. and the measurement within 5m is realized by travelling at 5m/0.5sec=36km/h as constant as possible.

3. Data Processing and Analysis for Channel Modelling

In the standardization of the ITS wireless system for the 700MHz band, ITS FORUM RC-006 [2], a technical specification defining a guideline for experiments of the 700MHz ITS wireless system, is the basis of the system. Considering the situation, the technical parameters of RC-006 are considered in the propagation modelling. The RC-006 specifications include OFDM (Orthogonal Frequency Division Multiplex) transmission and the sample period of the FFT is 100nsec. Therefore, we adopt the same interval of the paths of the delay profile as the OFDM sample period in order to make the software simulations simpler.

The IQ baseband signal of the PN sequence at 24Mchip/s is continuously recorded with 4 times oversampling. The signal is firstly de-spread to obtain the impulse response of the transmission path. Figure 2 shows examples of the measured impulse responses in the high-rise environment for LOS and NLOS.

The method to obtain the delay profile model from the impulse response is presented here. Firstly, we separate the received signals and the noise. Based on the received power, we find the delay time range where the significant signal is not received and assume it is the noise. As the result of the data analysis, 8-20μsec range is selected for the noise area. The average signal power over the range, which corresponds to the average noise power, is calculated, and the maximum noise power among the all impulse responses at one measurement is identified. Here, we use a value which is T_n [dB] higher than the maximum noise power as the threshold for the noise discrimination and the received signals less than the threshold are discarded. The value of T_n is the relative signal strength where the instantaneous signal level is less than T_n at p [%] probability in the Rayleigh distribution whose average power is 0dB. In other words, it means a criterion that the probability where the signal exceeds the threshold is 100-p [%] when the distribution is assumed Rayleigh. In this paper, assuming p=99.9%, T_n =8.39dB is adopted.

The recorded data is sampled every 1/(96Msample/s)=10.4nsec and is converted into 100nsec interval. The average power of the delay profile model is calculated over the data at the same delay time of the all impulse responses. If more than 90% of the data at the same delay is missing, the path corresponding to the delay time is deleted from the final delay profile model.

Here we consider the distribution of the temporal variation of the signal level of each path. In general, it is often modelled by the Rayleigh distribution. It is because the distribution is the worst case and severer assumptions are usually adopted in system design. However, the fluctuation of the signal level particularly at the maximum peak of the impulse response is clearly different from Rayleigh as shown in Fig. 2. To consider the characteristics, in addition to the average power of each path, we present the Rice factor of each path, assuming the distribution of the signal level fluctuation follows the Nakagami-Rice distribution. Note that we don't show the fluctuation of the signal level in ITS environments follows the Nakagami-Rice. We just utilize the distribution to characterize the magnitude of the fluctuation of each path.

4. Established Model

The delay profile models of the three areas for LOS and NLOS are shown in Fig. 3(a)-(f). In each model, the values of the average power and the Rice factor are presented in the tables. The values of the Rice factors are ranging from 3dB to more than 20dB. Figure 4 shows the Nakagami-Rice distribution for different Rice factors. The distribution approaches to the Rayleigh when the factor falls below 5dB, and when it is over 10dB it becomes a distribution obviously different from the Rayleigh. For instance in Fig. 3(c), the Rice factor of the maximum path is large such as 20dB. So if the distribution is modelled by the Rayleigh, it results in overestimation of the effect of the propagation. However, in order to clarify whether all of the paths must be expressed by the Rician fading or not, further detailed study is required. For instance, in cases where the maximum path is not so great in comparison to the other paths, or where the number of the paths is great and the signal level fluctuation of the total received signal nearly follows the Rayleigh distribution, modelling of each path by the Rayleigh may realize sufficiently accurate evaluation. Detailed analysis and computer simulations are required to clarify the issue.

5. Conclusion

In the paper, the delay profile model constructed aiming to contribute to the standardization of the ITS RVC and VVC are presented. The method to establish the model is described and some concrete examples of the developed models are shown.

In the measurement, the characteristics at 5.8GHz band are also measured in addition to 700MHz. It is also important to study the propagation model in which the frequency characteristics are considered.

Acknowledgments: The paper is based on the result of the sponsored research from ITS Info-communications Forum. The propagation measurement was conducted as a commissioned project from Ministry of Internal Affairs and Communications of Japan. In addition, we obtained valuable advices through the discussion on the propagation models at ITS Info-communications Forum. The authors wish to express their sincere appreciation to all of the related people.

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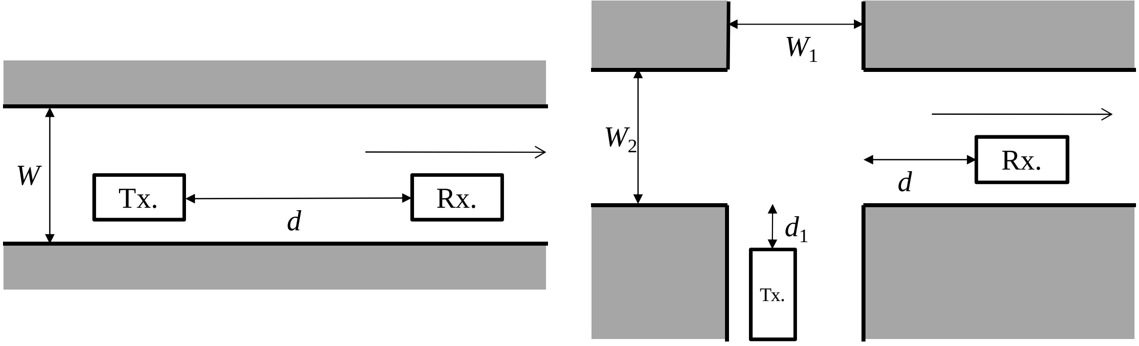


(a) LOS environment (b) NLOS environment

Fig.1 Configuration of measurement.

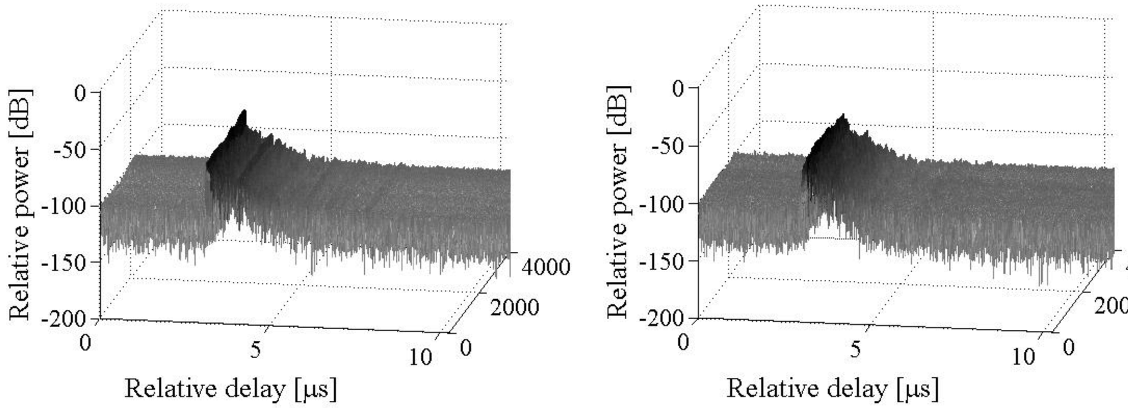
Table 1 Road parameters of measurement areas.

	$W(=W_2)$	W_1	d_1
High-rise	40m	15m	10m
Residential	11m	10m	10m
Suburban	*1		10m

*1: Since it is an open area, clear widths of the roads is not defined.

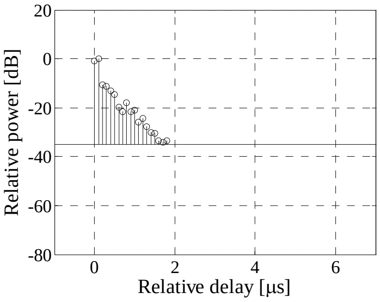
Table 2 Measurement specifications.

Transmission power	720mW (28.6dBm)
Carrier frequency	705.25MHz
Transmitted signal	9-stage M sequence (24Mchip/s)
Tx. and Rx. antenna gain	2dBi (Omni-directional)
Tx. antenna height	NLOS:1.85m and 3.5m, LOS:6.0m
Rx. antenna height	1.85m



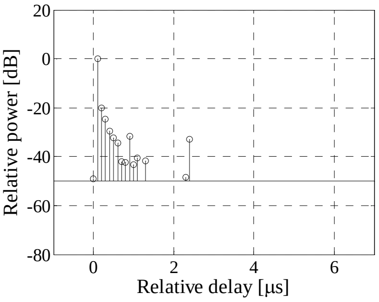
(a) LOS envrironment (d=200m) (b) NLOS environment (d=100m)

Fig. 2 Measured impulse response (high-rise environment)



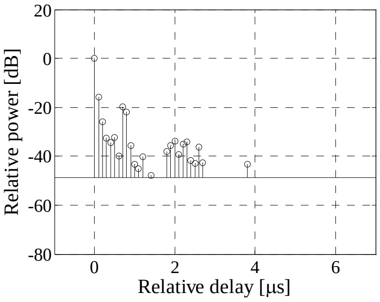
Delay (μs)	Power (dB)	Rice factor (dB)
0.0	-0.8	10.2
0.1	0.0	3.3
0.2	-10.8	4.5
0.3	-11.2	4.9
0.4	-13.2	6.2
0.5	-14.5	6.3
0.6	-19.8	5.2
0.7	-21.5	5.7
0.8	-18.1	5.5
0.9	-21.7	5.3
1.0	-21.1	7.4
1.1	-25.9	4.2
1.2	-24.5	3.1
1.3	-27.8	5.1
1.4	-30.0	5.2
1.5	-30.4	5.1
1.6	-33.5	4.4
1.7	-34.1	5.4
1.8	-33.6	4.6

(a) High-rise, LOS



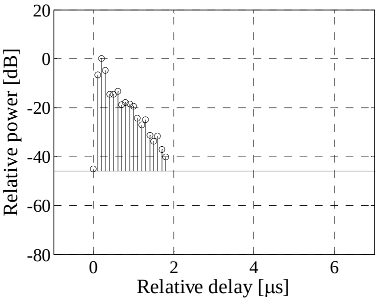
Delay (μs)	Power (dB)	Rice factor (dB)
0.0	-49.1	5.3
0.1	0.0	19.3
0.2	-20.0	6.9
0.3	-24.6	10.5
0.4	-29.4	7.4
0.5	-32.4	5.2
0.6	-34.5	4.5
0.7	-42.1	3.9
0.8	-42.3	4.7
0.9	-31.8	10.5
1.0	-43.2	6.6
1.1	-40.4	4.5
1.3	-41.8	6.0
2.3	-48.6	9.7
2.4	-32.9	16.5

(b) High-rise, NLOS



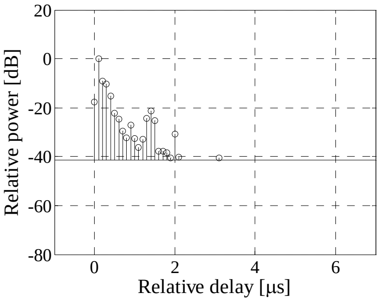
Delay (μs)	Power (dB)	Rice factor (dB)
0.0	0.0	21.5
0.1	-15.9	10.7
0.2	-25.7	9.2
0.3	-32.6	5.1
0.4	-34.4	5.7
0.5	-32.3	5.8
0.6	-40.0	5.0
0.7	-19.7	14.1
0.8	-22.0	10.3
0.9	-35.7	4.1
1.0	-43.2	5.4
1.1	-45.1	6.9
1.2	-40.1	8.8
1.4	-47.8	9.2
1.8	-37.9	6.6
1.9	-35.6	7.6
2.0	-33.8	7.1
2.1	-39.4	6.1
2.2	-35.1	4.6
2.3	-34.2	3.2
2.4	-41.7	5.0
2.5	-43.0	5.1
2.6	-36.4	6.7
2.7	-42.7	5.2
3.8	-43.3	5.5

(c) Residential, LOS



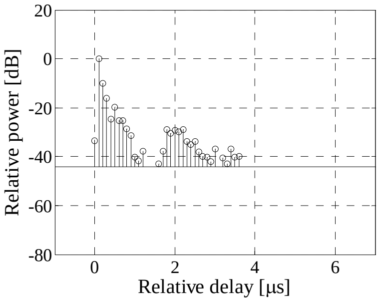
Delay (μs)	Power (dB)	Rice factor (dB)
0.0	-45.1	12.3
0.1	-6.8	9.4
0.2	0.0	11.1
0.3	-4.9	5.6
0.4	-14.7	4.2
0.5	-14.6	3.3
0.6	-13.4	5.4
0.7	-19.0	5.3
0.8	-18.1	2.5
0.9	-18.6	6.7
1.0	-19.6	5.3
1.1	-24.3	7.1
1.2	-27.2	5.6
1.3	-24.9	1.1
1.4	-31.4	3.9
1.5	-33.9	3.7
1.6	-31.6	3.4
1.7	-37.1	5.3
1.8	-40.3	6.4

(d) Residential, NLOS



Delay (μs)	Power (dB)	Rice factor (dB)
0.0	-17.7	10.9
0.1	0.0	6.5
0.2	-9.2	8.0
0.3	-10.3	4.2
0.4	-15.2	11.4
0.5	-22.1	5.5
0.6	-24.8	8.1
0.7	-29.5	4.5
0.8	-32.4	5.0
0.9	-27.2	2.1
1.0	-32.5	3.2
1.1	-36.1	5.7
1.2	-32.9	4.1
1.3	-24.4	5.4
1.4	-21.4	5.7
1.5	-25.2	8.7
1.6	-37.8	5.9
1.7	-37.8	6.6
1.8	-38.5	6.3
1.9	-40.4	8.6
2.0	-30.8	3.3
2.1	-40.1	8.0
3.1	-40.5	8.0

(e) Suburban, LOS



Delay (μs)	Power (dB)	Rice factor (dB)
0.0	-33.6	5.1
0.1	0.0	5.5
0.2	-9.9	6.0
0.3	-16.2	4.2
0.4	-24.5	5.7
0.5	-19.9	11.6
0.6	-25.2	4.6
0.7	-25.4	5.4
0.8	-28.8	7.2
0.9	-31.3	5.3
1.0	-40.4	5.2
1.1	-41.8	7.3
1.2	-37.7	4.8
1.6	-43.0	9.4
1.7	-37.8	5.0
1.8	-28.8	5.1
1.9	-30.5	5.1
2.0	-29.3	3.1
2.1	-29.8	5.2
2.2	-28.9	5.0
2.3	-33.8	5.2
2.4	-35.1	4.0
2.5	-33.8	5.3
2.6	-38.1	5.4
2.7	-39.9	5.6
2.8	-40.2	6.6
2.9	-41.9	6.4
3.0	-36.8	4.7
3.2	-40.4	7.6
3.3	-43.1	9.1
3.4	-36.8	6.7
3.5	-40.3	6.1
3.6	-39.8	6.4

(f) Suburban, LOS

Fig. 3 Delay profile models.

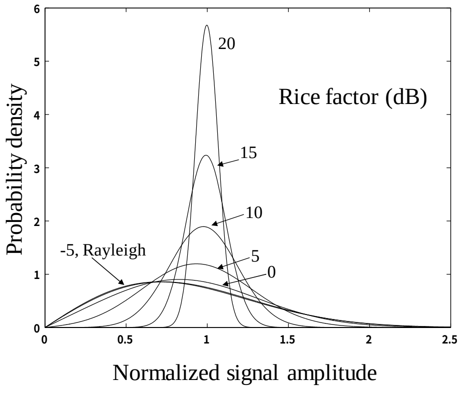


Fig.4 Nakagami-Rice distribution.