Delay Profile for ITS in 700 MHz Band and Evaluation of Influence to Symbol Synchronization

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Abstract

The propagation measurement in 700 MHz band for ITS inter-vehicle communications was conducted to evaluate delay profiles in actual environments. In this paper, some results of the measured characteristics are presented. The result of the influence of the delay characteristics to the symbol synchronization of the OFDM signal is also shown.

Keywords : ITS Delay profile Symbol synchronization

1. Introduction

Recently, research for ITS (Intelligent Transport Systems) has been advanced. The 5.8 GHz band has primarily been used for ITS around the world until now. Using the band, various ITS applications have been widely spread. For example in Japan, ETC (Electronic Toll Collection system) has become popular. On the other hand, new spectrum in 700 MHz band is now considered to be allocated to ITS in Japan. Inter-vehicle communication (IVC) to prevent traffic accidents is assumed to be a main application in the band. One of the reasons why the lower frequency is preferred is the smaller propagation loss in over-the-intersection environments owing to the smaller diffraction loss. It is desirable to construct wide and stable coverage in the IVC environments. In order to clarify the propagation characteristics in the band, propagation measurement campaign including delay profile measurement was carried out.

In the standardization of the wireless system for the new band, RC-006 [1] is assumed as a candidate system. RC-006 is a specification defining the guideline for experiment of 700 MHz ITS wireless systems. It is based on the IEEE802.11p standard and has OFDM (Orthogonal Frequency Division Multiplex) transmission. In general OFDM transmission systems, the acquisition of symbol synchronization is important to keep the required communication quality. The multipath waves possibly generate major impact on the performance of the symbol synchronization. Therefore in this paper, the influence of the delay characteristics to the symbol synchronization-timing is evaluated using the delay profiles measured in the actual environments.

We firstly present the measured results of the delay profiles and the evaluation results of the influence to the symbol synchronization timing are also shown.

2. Delay Profile Measurement

The measurements were conducted assuming two ITS candidate applications in the 700 MHz band, road-to-vehicle communication (RVC) and IVC. In RVC, LOS (Line-Of-Sight) situation was mainly assumed, while NLOS (Non LOS) over intersections is in IVC. Several areas were selected in Tokyo for the measurement, High-rise, Residential and Suburban environments.

Table 1 shows the specifications of the propagation measurement system. The transmission antenna height is varied as 1.85 m, 3.5 m, and 6 m and the receiving antenna height is 1.85 m. The multipath delay characteristics were measured while the Tx. vehicle was fixed and the Rx. vehicle was moving in a short section. In the delay measurement, the received RF signal is converted to the IQ complex baseband signal and it is A/D-converted and recorded in a hard disk drive. The IQ baseband signal of a PN sequence at 24 Mchip/s is continuously recorded with 4 times oversampling. The average powers of the paths are calculated from the recorded signal. In the RC-006 specifications, the sample interval of the FFT processing of OFDM is 0.1 μsec. Therefore, we adopt the same interval of the paths of the delay profile in order to simplify the computer simulation for the system evaluation. Next, we consider the fading statistics of each path. We observe the fluctuation of the signal level of the paths particularly near the maximum peak of the impulse response is clearly smaller than the Rayleigh distribution which is often used for the modelling of delayed paths of delay profiles. Based on the observation, the distribution of the fluctuation of the signal level of each path is modelled by the Nakagami-Rice distribution in this model. Using the above procedure, we calculate the average powers and the Rice factors to formulate a delay profile. Refer to [2] and [3] for the details of the data processing.

Figure 1 shows an example of the delay profiles obtained by the produce. We have 286 delay profiles for the different measured areas and the different experimental parameters such as Tx. antenna heights, Tx. positions, etc. Figure 2 shows the distribution of the delay spread over the measured 286 delay profiles. The values of the delay spread are distributed in the range from 7 ns to 0.7 μs and the average is 0.16 μs.

3. Evaluation of OFDM Symbol Synchronization

In usual OFDM transmission systems, the guard interval (GI) is inserted to prevent the degradation of the transmission quality due to the multipath delayed waves. The same signal waveform as the ending part of an OFDM symbol is inserted to the beginning of the symbol. In general, the correlativity of GI is used to acquire the symbol synchronization timing. Figure 3 shows the method of the symbol synchronization by detecting the correlation. We detect the timing of the correlation peak produced when the two time windows correspond to the beginning and the ending parts of the OFDM symbol. In this paper, we assume the synchronization method.

To express the success and the failure of the symbol synchronization, we define the following three cases. In Case 1, the timing of the correlation peak is detected at the start of the OFDM symbol. It indicates the correlation peak is detected at the timing of the first incoming wave. In this case, the synchronization is perfectly success. In Case 2, the timing of the correlation peak is detected within the period of GI. When the delay of the detected symbol timing is shorter than the GI length, we have the correct demodulated signal. So Case 2 indicates the synchronization is successful. In Case 3, the timing of the correlation peak is detected after the period of GI. In this case, the received signal is not correctly demodulated due to the inter-symbol interference and the transmission performance deteriorates. Therefore, Case 3 is classified as failure.

Case 1: The timing is detected at the beginning of the symbol. (Success)
Case 2: Success, the timing is detected in the period of GI.
Case 3: Failure, the timing is detected after the period of GI.

To evaluate quantitatively the influence of the multipath delay to the symbol synchronization, computer simulations are carried out. Table 2 shows the parameters of the simulation. We use a subset of RC-006 in the simulation. The delay profiles obtained from the measurements are implemented in the transmission path of the simulations. As the fading speed, we assume a quasi-static case in the processing period of the symbol synchronization and a 100 km/h travelling case. The processing period is assumed to be 5 OFDM symbols in this paper, which is the averaging period for the detection of the correlation.

4. Result of Computer Simulation

We evaluate the occurrence rates of the three cases over 286 profiles by the computer simulation. For one delay profile, by changing the level and phase of a delayed multipath to satisfy the given average powers and the Rice factors statistically, sufficiently large numbers of trials are made to calculate the rates precisely. CDFs (Cumulative Distribution Functions) of the occurrence rates are calculated over the results assuming various SNR (Signal to Noise Ratio). Figure 4 shows CDFs of the three occurrence rates in the quasi-static assumption. Where SNR is over 10 dB, very little change of CDF curves are observed. It is seen from the Fig. 4(a) that the occurrence rate of Case 1 decreases as SNR increases in some profiles. It is because the first incoming wave is not always the largest path. When SNR increases, the probability where the synchronization timing is at the largest peak increases. So the increase of SNR does not increase the Case 1 occurrence probability in some profiles. Figures 4(b) and 4(c) show that, when SNR is sufficiently large, synchronization is in most cases successful. It means the influence of the multipath delay to the symbol synchronization performance is little in actual environments, while the decrease of SNR significantly impacts to the performance. We also evaluate the performance of the 100 km/h travelling case, but it is almost the same as that of the quasi-static case. It means, in the RC-006 specifications, the influence of the fading to the symbol synchronization timing is not significant in the usual vehicular travelling speed.

5. Conclusions

The delay profiles in the 700 MHz ITS environments are presented based on the measured data. Using the obtained delay profiles, the influence to the symbol synchronization is evaluated. In the numerical analysis of the synchronization, the technical specifications of RC-006 are assumed. From the result, it is presented that the influence of delay waves to the symbol synchronization timing is little in almost all environments when the specifications are used.

References

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[3] H. Iwai and I. Sugae, "Delay profile model in 700MHz band for road to vehicle and vehicle to vehicle communications," Proc. of ISAP 2010, Nov. 2010

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Table 1 Measurement specification.

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

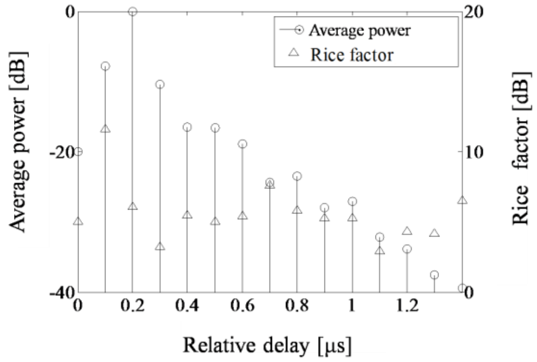


Fig. 1 An example of delay profile.

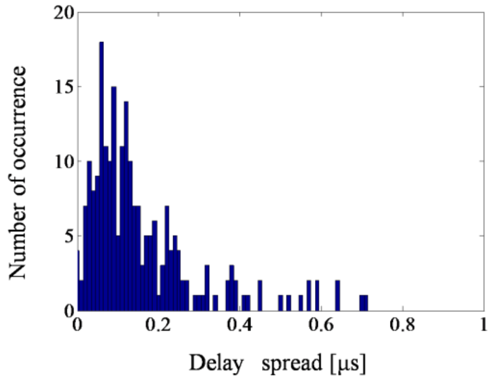


Fig. 2 Distribution of delay spread.

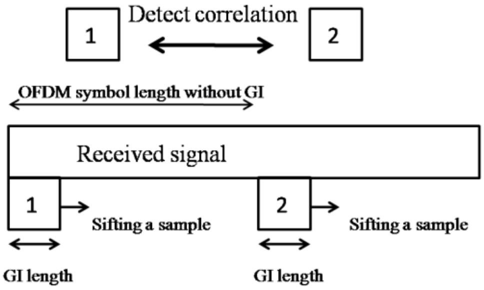
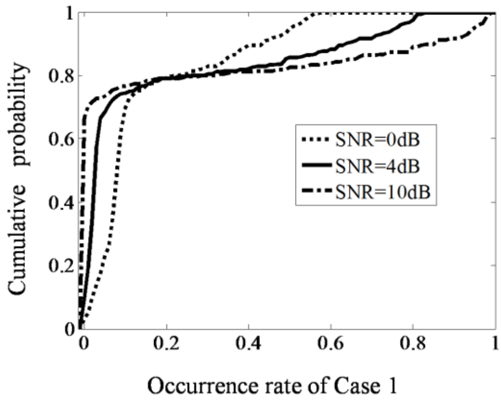


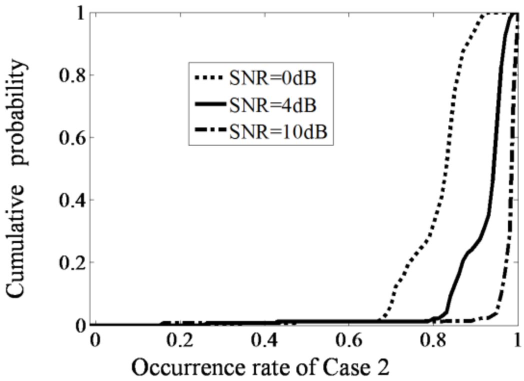
Fig. 3 Synchronization by detection of correlation.

Table 2 Parameters of computer simulation.

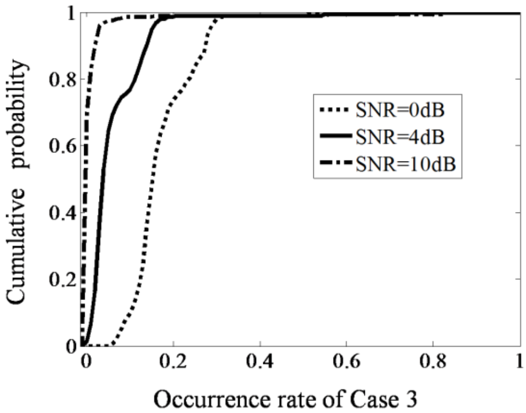
Modulation	OFDM (QPSK)
Number of FFT points	64
Number of subcarriers	48
OFDM symbol length	8.0 μs
GI length	1.6 μs
Averaging period for peak detection	5 OFDM symbols
Carrier frequency	700 MHz



(a) Case 1.



(b) Case 2.



(c) Case 3.

Fig. 4 Occurrence probabilities of Case 1, Case 2, and Case 3.