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Path Loss Characteristics for Vehicle-to-Infrastructure Channel in Urban and Suburban Scenarios at 5.9 GHz

Mi Yang[1], Bo Ai*[1], Ruisi He[1], Dongping Yao[1], Jianzhi Li[1], Bei Zhang[1], Qi Wang[1], Dan Fei[1] and Minming Ni[1]
(1) State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University, China
Email: boai@bjtu.edu.cn

Abstract

This paper investigates path loss characteristics for Vehicle-to-Infrastructure (V2I) communications in urban and suburban scenarios. We carried out measurements at 5.9 GHz. The transmitter antenna heights are 3.5 m and 1.5 m and the position of the receiver antenna is on the roof of the car. Then we analyzed the path loss characteristics by using the measured data. The results are helpful for the V2I communications system design.

1 Introduction

Recently, many countries are facing increasingly traffic problems, such as unbearable traffic congestion, high accident rate and low efficiency of the existing transportation infrastructure. Therefore, many companies are seeking to solve these problems through the implementation of intelligent transportation system (ITS) [1]- [6]. Intelligent transportation system requires high speed, high reliability, advanced communication system as the foundation, typical examples are vehicle to vehicle (V2V) and vehicle-to-infrastructure (V2I) communications.

The V2V communications have been widely investigated so far [7]- [14]. In addition to the V2V, V2I is also very important for ITS. V2I mainly aims at communications between vehicles and road infrastructure, such as traffic lights, traffic signs, etc. Through this kind of high efficient and reliable communications, traffic management can be more intelligent and more quality, it can effectively improve the road traffic environment. Hence the research for channel propagation characteristics of V2I communications is necessary and meritorious.

This paper analyzes path loss characteristics for V2I communications at 5.9 GHz based on measurements. Specifically, we measured in two scenarios (urban and suburban) and two transmitter antenna heights (3.5 m and 1.5 m), respectively. The results in this paper can be helpful for the researches of signal transmission range and antenna arrangement of V2I communications.

The remainder of the paper is organized as follows. Section 2 describes the measurement campaign. Section 3 presents the results of the measurements. Conclusions are drawn in Section 4.

2 Measurement campaign

In Section 2, we describe our measurement campaign with two parts: Section 2.1 introduces the measurement system, then the measurement environments are shown in Section 2.2.

2.1 Measurement System

The measurement system is based on National Instruments (NI) software radio equipment. The NI PXIe-5663E is a RF vector signal analyzer (VSA) with wide instantaneous bandwidth, which is used as the receiver. The NI PXIe-5673E is a wide-bandwidth RF vector signal generator (VS-G), which is used as the transmitter. In addition, there are some other necessary equipments, such as the power amplifier and clock modules. The amplifier is used to provide a 31 dBm maximum transmitted power. Then two clock modules locked with the GPS provide synchronization between the transmitter and the receiver.

2.2 Measurement Environment

A pair of omnidirectional microstrip antennas are used in the measurements. As shown in Figure 1 (a), the position of the transmitter antenna is fixed, set up in 3.5 meters and 1.5 meters, be used to simulate the higher and the lower road infrastructure respectively. The receiver antenna is placed on the roof of the car, about 1.5 meters.

The measurements are conducted on the urban and suburban scenarios in Beijing, China. Figure 1 (b) shows the urban scenario. There are dense buildings around, in addition many pedestrians and vehicles on the road. And as shown in Figure 1 (c), only a small amount of buildings in suburban scenario. The transmitting antenna is placed on the bracket, and the receiver and antenna move along the blue routes shown in Figure 1. Receiver and transmitter nearest distance is 5 m, and the farthest distance is 700 m. We try our best to avoid obstructions of large vehicle obstructions, to ensure the existence of the line-of-sight (LOS) in the measurements [15].

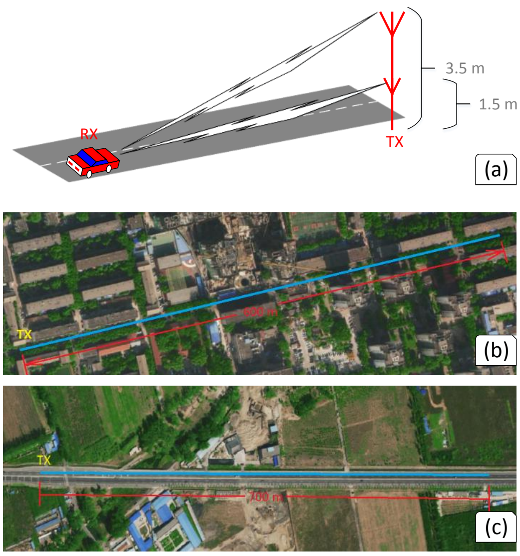

Figure 1. Figure.1 (a) is the schematic diagram of the measurements. Figure.1 (b) and Figure.1 (c) show the urban and suburban scenarios respectively.

3 Results

3.1 Power Delay Profile

The power delay profile (PDP) has been widely used to describe the distribution of multi-path components (MPCs) on delay domain in the measured environments [16, 17].

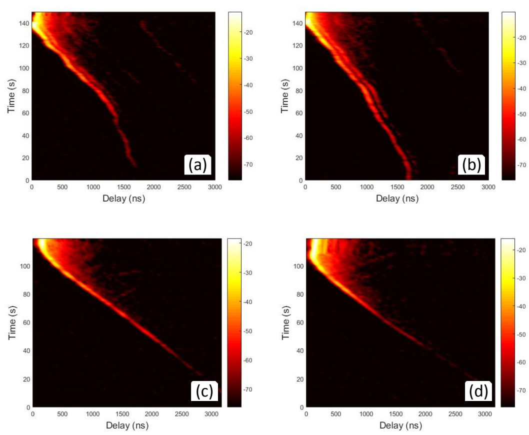

Figure 2. Power delay profile. (a) 3.5 m transmitting antenna in urban scenario, (b) 1.5 m transmitting antenna in urban scenario, (c) 3.5 m transmitting antenna in suburban scenario, (d) 1.5 m transmitting antenna in suburban scenario.

The instantaneous PDP is denoted as [18]

$$P(t,\tau) = \mid h(t,\tau) \mid^2 \tag{1}$$

Table 1. γ and $PL(d_0)$

	γ	$PL(d_0)$
Urban-3.5 meters	1.98	44.8
Urban-1.5 meters	1.92	45.5
Suburban-3.5 meters	1.12	66.3
Suburban-1.5 meters	1.41	60.1

where $h(t,\tau)$ is the measured channel impulse response at time t with delay τ. In order to get more accurate analysis results, we set a noise threshold, and only those signals larger than the noise threshold are considered. Then we obtain the average PDPs (APDPs) by using a sliding window with a length of 20 wavelengths.

Figure 2 (a) and (b) show the measured APDPs in urban scenario (3.5 m and 1.5 m transmitter antenna respectively). And the APDPs in suburban scenario are shown in Figure 2 (c) and (d). It can be seen in Figure 2, there is a clear MPC next to the main component in urban scenario, and this multi-path component is not obvious in suburban scenario. In addition, when the distance between receiver and transmitter is very small (minimum 5 meters), the urban receiving power is slightly larger than the suburban scenario, meanwhile, it is lower with longer distance between receiver and transmitter.

3.2 Path Loss

Path loss is a measure of the average RF attenuation to the a transmitted signal when it arrives at the receiver. Path loss model uses γ to show the relationship between the separation distance and the received power. It is modeled as follows [19]

$$PL(dB) = PL(d_0) + 10\gamma log(\frac{d}{d_0}) + X_\delta \tag{2}$$

where γ is the path loss exponent and $PL(d_0)$ is the intercept value of the path loss model at the reference distance d_0 [20]. X_δ is a zero-mean Gaussian distributed random variable describing the random shadowing [21].

Based on the measurements, the γ and $PL(d_0)$ are shown in TABLE.1. It is clear that antenna height has a small influence on the results of the γ and $PL(d_0)$ in urban scenario. As for suburban scenario, the results with higher antenna has a smaller γ.

We test the two-ray path loss model with the measurements [22]. Figure 3 and Figure 4 describe the scatter plot of path loss versus log-distance and the theoretical path loss two-ray model in urban and suburban scenarios, respectively. It is found that the path loss generally fits the two-ray path loss model, especially when the distance between transmitter and receiver within 50 meters to 300 meters. The reason is that the difference between the realistic environment and ideal environment is very huge, there are a large number of reflectors and obstacles. Especially when the distance is small, the surrounding reflection has a strong effect on the received signal power.

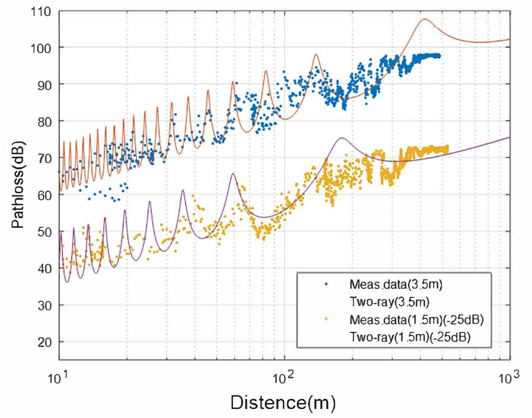

Figure 3. Scatter plots of path loss versus log-distance and the theoretical path loss two-ray model in urban scenario.

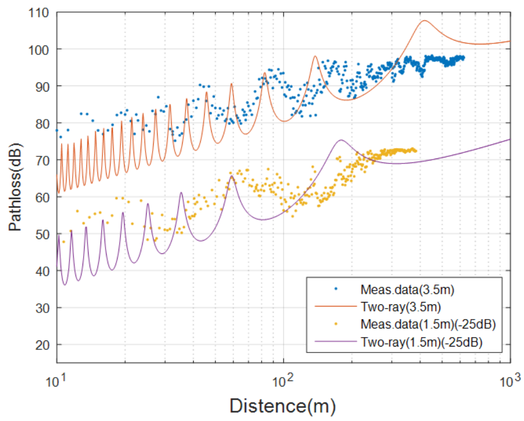

Figure 4. Scatter plots of path loss versus log-distance and the theoretical path loss two-ray model in suburban scenari-o.

4 Conclusion

In this paper, measurement-based V2I path loss characterizations are presented for urban and suburban scenarios with different antenna heights. The conclusion is that the two-ray model can be used to describe the path loss when the distance between transmitter and receiver within 50 meters to 300 meters. A higher antenna generally leads to a smaller path loss exponent γ for urban scenario, and the path loss exponents with different antenna heights are generally the same for suburban scenario. The work for signal transmission range and antenna arrangement of V2I communications will benefit from these results.

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