Investigation of the Path Loss Propagation for V2V Communications in the Opposite Direction

Lorenzo Rubio, Vicent M. Rodrigo-Peñarrocha and Juan Reig
iTEAM Research Institute
Universitat Politècnica de València
46022 Valencia, Spain
e-mails: {lrubio;vrodrigo;jreigp}@dcom.upv.es

Herman Fernández
Escuela de Ingeniería Electrónica
Universidad Pedagógica y Tecnológica de Colombia
152211 Sogamoso, Colombia
e-mail: herman.fernandez@uptc.edu.co

Abstract—**In this work, we investigate the path loss propagation of the vehicular-to-vehicular (V2V) channel when the vehicles are driving in the opposite direction. The investigation is based on narrowband channel measurements at 700 MHz and 5.9 GHz carried out in different environments under real road traffic conditions, i.e., rural, highway, suburban and urban environments. The results show that there is a path loss offset between the forward and reverse directions, which is related to the environment. Also, we provide mean values of the path loss propagation exponent showing that are higher than the values derived when the vehicles are driving in the same direction. These results should be considered for a proper simulation and design of the future V2V communications systems.**

I. Introduction

The characteristics of the vehicular-to-vehicular (V2V) propagation channel are influenced by the type of environment, vehicles speed, road traffic density, and the direction of motion of the transmitter (Tx) and receiver (Rx) vehicles (the same or in opposite directions). Several V2V studies of the path loss propagation based on measurement campaigns have been conducted over the past few years [1]–[6]. These measurement campaigns have been carried out at the 5.9-GHz dedicated short-range communications (DSRC) frequency band, or adjacent bands, e.g., at 5.3 and 5.8 GHz. Nevertheless, with the exception of Fernández [6], Sevlian [7], and Yoshida [8], there have not been published results at the opening 700-MHz frequency band, recently adopted by Japan for the development of intelligent transportation system (ITS) applications. In both frequency bands, the measurements are mainly focused on convoy situations, i.e., Tx and Rx vehicles driving in the same direction (convoy traffic). Nevertheless, since there can be differences in the propagation depending on the direction of Tx-Rx motion [3], [4], further investigations are necessary in order to improve the knowledge of the vehicular propagation channel.

In this contribution, we present a path loss investigation for V2V communications based on channel measurements when the vehicles are driving in the opposite direction (oncoming traffic). The measurements have been carried out at 700 MHz and 5.9 GHz simultaneously, facilitating comparisons between the two frequency bands, and under real driving conditions, road traffic densities, and vehicles speed. Four different and typically expected V2V environments have been considered in our investigation, i.e., rural (R), highway (H), suburban (SU), and urban (U) environments.

II. Channel Measurements

A. Measurement Setup

Two signal generators (SGs) were used at the Tx side (Tx vehicle) to transmit an unmodulated continuous wave at 700 MHz and 5.9 GHz. High power amplifiers (HPAs) were used to achieve an equivalent isotropically radiated power (EIRP) equal to +26.3 and +23.8 dBm at 700 MHz and 5.9 GHz, respectively. At the Rx side (Rx vehicle), we have used a spectrum analyzer (SA) to measure the received power level at 700 MHz, whereas a vector network analyzer (VNA) was used to measure the received power level at 5.9 GHz through the b_2 parameter. Short-term fading fluctuations were filtered averaging the power samples in each measured trace, resulting in a sampling interval of about 225 ms at 700 MHz and 245 ms at 5.9 GHz. We have used the same antenna at the Tx and Rx in each frequency band, which were omnidirectional monopoles: a half-wave monopole at 700 MHz and a quarter-wave monopole at 5.9 GHz. The antennas were roof-mounted in the center of the vehicle through a magnetic base, transmitting in vertical polarization. The height of the Tx and Rx antennas was 1.43 m and 1.41 m, respectively. The radiation pattern and the gain of the antennas were measured in an anechoic chamber in order to remove their effect in the measured path loss. In addition to the radio frequency equipment, the Tx and Rx vehicle were equipped with GPS receivers to provide information about the acquisition time of measurements, as well as the Tx-Rx distance. More details about the measurement setup and configuration of the SA and VNA, omitted here due to space restrictions to 2 pages, can be found in [5], [6].

B. Measurement Environment

The measurements were performed in four different environments under real road traffic conditions in and around of the city of Valencia, in Spain. In all cases, the Tx and Rx vehicles traveled in the opposite direction. Rural measurements were taken on a two-lane, with almost no traffic during the

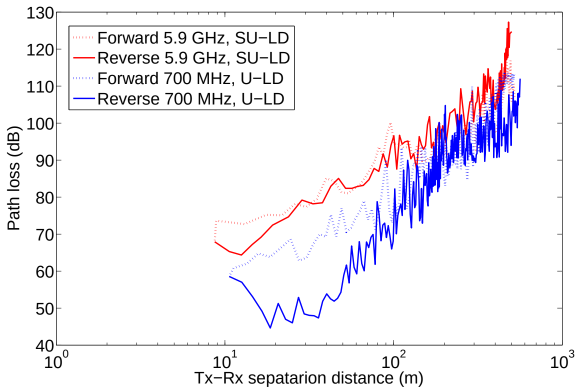

Fig. 1. Path loss versus Tx-Rx separation distance.

TABLE I
MEAN VALUES OF ΔPL, d_0 AND γ: RURAL (R), HIGHWAY (H), SUBURBAN WITH LOW DENSITY (SU-LD), SUBURBAN WITH HIGH DENSITY (SU-HD), URBAN WITH LOW DENSITY (U-LD), AND URBAN WITH HIGH DENSITY (U-HD) ENVIRONMENTS

	700 MHz			5.9 GHz		
Scenario	ΔPL (dB)	d_0 (m)	γ	ΔPL (dB)	d_0 (m)	γ
R	20.1	180	3.22	24.0	116	2.88
H	10.4	407	3.11	10.3	110	2.78
SU-LD	12.8	155	3.41	4.7	35	2.20
SU-HD	13.1	123	2.56	4.9	88	2.61
U-LD	14.4	83	3.36	8.6	35	3.07
U-HD	5.2	20	3.17	≈ 0	10	2.56

measurements. Highway measurements were taken on a two-lane, with the traveling directions separated by a low concrete wall, and in some sections by a metal fence (≈80 cm high). Suburban measurements were collected in two scenarios, one with low traffic density (LD), ≈12850 veh/24h and two-lane, and other with high traffic density (HD), ≈35300 veh/24h three-lane. Urban measurement were taken also under LD and HD conditions, ≈18900 veh/24h two-lane and ≈38350 veh/24h three-lane, respectively.

III. MEASUREMENT RESULTS

As an example, Fig. 1 shows the measured path loss in terms of the Tx-Rx distance when the vehicles move toward each other (forward direction), intersect, and then move away in the opposite direction (reverse direction). These results correspond to a record measured in U-LD and SU-LD environments at 700 MHz and 5.9 GHz, respectively. It can be seen a path loss offset (ΔPL) before and after the Tx and Rx vehicles meet each other. From the ensemble measurements, we have observed that the path loss is higher in the forward direction for the majority of cases. This behavior occurs in all the environments measured. An explanation of this offset is that the antennas gain in the forward and reverse directions can be different due to a finite inclination at the position of the roof-mounted antenna. This offset was also observed in [3] from measurements at 5.2 GHz. It is worth noting that ΔPL is lower at 5.9 GHz and is related to the number of scatterers, or interacting objects, between the two-way (trees, street lamps and road signs, among others in urban and suburban environments). Nevertheless, from a certain Tx-Rx distance, d_0, ΔPL is negligible and there are not significant differences between the path loss in the forward and reverse direction.

Table I summarizes the values of ΔPL and d_0 derived from each environment. Also, we have incorporated the path loss propagation exponent, γ, derived in a least-square (LS) sense adopting a classical log-distance path loss model for longer Tx-Rx distances than d_0. Note that the values of the path loss exponent are higher, in both frequency bands, than the reported for convoy traffic in the same environments [5], [6].

IV. CONCLUSION

In this contribution, we have presented path loss results for four different environments when the vehicles are driving in opposite directions. The results show that there is a path loss offset between the forward and reverse directions, which is lower at 5.9 GHz and is related to the propagation environment. The results show that it is necessary to take into account this offset for proper V2V system simulations under real propagation conditions. Otherwise, this offset could lead to a large variance of the path loss, especially when the vehicles are approaching.

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