Path Loss Characterization for Vehicular-to-Infrastructure Communications at 700 MHz and 5.9 GHz in Urban Environments

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***Abstract*—In this work, we perform a path loss characterization of the vehicular-to-infrastructure (V2I) channel in an urban environment based on a log-distance path loss propagation model. The model parameters have been derived from channel measurements at 700 MHz and 5.9 GHz. The correlation between the path loss exponent and the height of the antenna used in the infrastructure side is investigated. The measurements have been collected in an urban area of Valencia, Spain, under real road traffic conditions.**

I. Introduction

New applications related to safety and efficient traffic management have been and are being proposed under the concept of intelligent transportation system (ITS) [1]. These applications require to develop and implement new communications technologies, where one of the many challenges to be addressed is the characterization and modeling of the propagation channel. Early studies related to vehicular-to-vehicular (V2V) channel modeling began about 10 years ago. Several measurements campaigns have been conducted to investigated the propagation channel characteristics at the 5.9-GHz dedicated short-range communications (DSRC) band, or adjacent bands, in different environments [2]. In addition to the 5.9-GHz DSRC band, Japan has recently allocated 10 MHz at the 700-MHz band (from 755 to 765 MHz) for ITS applications. Nevertheless, with the exception of Sevlian [3], Yoshida [4], and Fernández [5], there have not been published measurement results at the opening 700-MHz frequency band. Although significant advances have been made within V2V channel characterization based on channel measurements, little attention has been devoted to vehicular-to-infrastructure (V2I) channel characterization. When V2I communications are considered, two communications technologies can be used: (i) conventional cellular infrastructure, i.e., mobile cellular communications, where the infrastructure access point is the base station of the cellular system; and (ii) own infrastructure for ITS connectivity following the IEEE 802.11p standard at the same frequencies that V2V communications. In this last case, the frequency bands operations make that the path loss in V2I systems differs from the traditional cellular or fixed-to-mobile (F2M) systems.

In this conference contribution, we present a path loss characterization of the V2I propagation channel based on channel measurements. 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. We have adopted the classical log-distance path loss model and we have studied the correlation between the path loss exponent and the height of the antenna used in the infrastructure side.

II. Channel Measurements

A. *Measurement Setup*

Two signal generators (SGs) were used at the infrastructure side (Transmitter, Tx) 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 receiver (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. At the Rx, the antennas were roof-mounted in the center of the vehicle through a magnetic base. The height of the Rx antenna was 1.43 m. At the Tx side, the antennas were placed in a mast, transmitting in vertical polarization. We have performed measurements for different Tx antenna heights, from 2 to 5.5 m, a typical height for access points of the infrastructure, and placing them in vertical and inverted positions. 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 Rx vehicle was equipped with a GPS receiver to provide information about the acquisition time of measurements, as well as the distance between the Tx and Rx. More details about the measurement setup and configuration

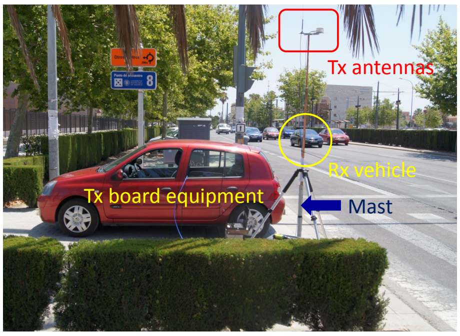

Fig. 1. View of the Tx antennas mounted on a mast and the Rx vehicle.

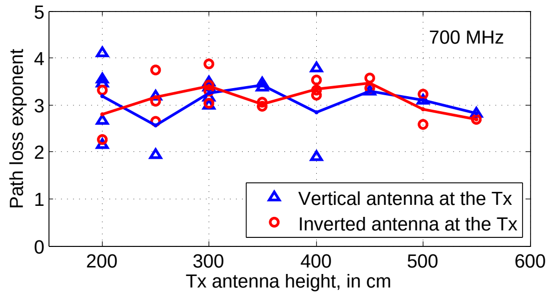

Fig. 2. Path loss exponent in terms of the Tx antenna height at 700 MHz.

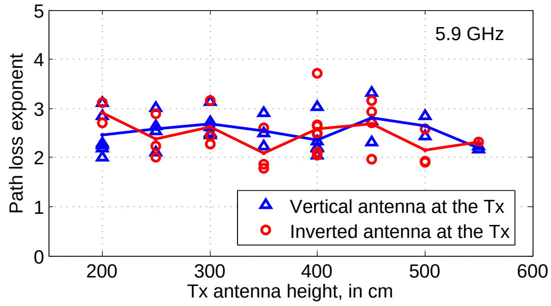

Fig. 3. Path loss exponent in terms of the Tx antenna height at 5.9 GHz.

of the SA and VNA, omitted here due to space restrictions to 2 pages, can be found in [5], [6]. Fig. 1 shows a view of the Tx antennas mounted on a mast and the Rx vehicle during the measurements campaign.

B. Measurement Environment

The measurements were collected in a 1.5 km long avenue with 67 m wide. The avenue has 4 lanes of road traffic for each direction, separated by a 2-tramway. During the measurements, the road traffic density was of about 2000 vehicles/h. There were cars parked at the curb on both sides of the avenue. Other characteristics of the environment are low rise buildings, between 20 and 30 m high, and many trees along the sidewalk.

III. Measurement Results

In our study we have adopted the classical log-distance path loss model [5], where there is a lineal relationship between the path loss and the Tx-Rx separation distance. The path loss exponent has been derived from the measured data using the least-squares (LS) method. The maximum Tx-Rx distance for the measurements was about 840 m. The value of the path loss exponent ranges from 1.90 to 4.12 at 700 MHz, whereas at 5.9 GHz the path loss exponent ranges from 2.01 to 3.33. These values have been derived considering the Tx antenna in vertical position. If the antenna is inverted, the path loss exponent ranges from 2.26 to 3.87 at 700 MHz, and from 1.79 to 3.71 at 5.9 GHz. Note that the differences between consider the Tx antenna in vertical and inverted positions are due to the impossibility of eliminating the full effect of the antennas radiation pattern. The relationship between the path loss exponent and the Tx antenna height is shown in Figs. 2 and 3, at 700 MHz and 5.9 GHz, respectively. The solid lines connect the mean values. Although a slight decrease of the path loss exponent is observed with the Tx antenna height, the results do not show a significant correlation degree. The tendency indicates that higher path loss exponents are given at 700 MHz, nevertheless the path loss offset is lower, resulting in less path loss compared to 5.9 GHz, as expected. The same trend was observed in V2V channel measurements in [5].

IV. Conclusion

In this conference contribution, an experimental characterization of the path loss for V2I communications has been performed based on a log-distance path loss model. Narrowband channel measurements at 700 MHz and 5.9 GHz have been collected in an urban area. For the Tx antenna heights considered, the results do not show a significant correlation degree between the path loss exponent and the Tx antenna height. The values of the path loss exponent reported here can be useful for the design and implementation of future vehicular networks.

Acknowledgement

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