A Fully Mobile, GPS Enabled, Vehicle-to-Vehicle Measurement Platform for Characterization of the 5.9 GHz DSRC Channel

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Introduction

The need for reducing accident fatalities and alleviating traffic congestion is widely recognized. The idea of exchanging information among moving vehicles and roadside infrastructures has attracted significant recent attention as a tool for achieving these goals [1]. The importance of having dedicated wireless communications between vehicles has been recognized by the FCC, resulting in the allocation of 75 MHz of spectrum at 5.9 GHz in 1999 for the purpose of Dedicated Short Range Communications (DSRC) in vehicular environments. There exists a need to gain a detailed understanding of DSRC technology over various vehicle-to-vehicle (V2V) propagation channels. While [2, 3, 4] presented work to establish theoretical channel models, propagation experiments are also needed to confirm system performance in real driving environments. Reported experiments include narrow-band measurements at 5.2 GHz presented in [5], joint Doppler-delay power profile measurements at 2.4 GHz presented in [6], and vehicle-to-vehicle channel measurements and modeling at 5.9 GHz presented in [7].

To understand the characteristics of vehicle-to-vehicle channels, in this paper, we describe a mobile channel measurement platform operating at the 5.9 GHz designated DSRC frequency band. Similar to the setup used in [6, 7], our system uses programmable instrumentation for both the transmitter and receiver, enabling the use of a wide range of waveforms. Our system permits the generation and analysis of arbitrary waveforms with instantaneous bandwidth up to 40 MHz. Our system also has several key features which distinguish it from other similar systems. First, in contrast to [2, 3, 4, 5, 6], our RF measurement system is operating in the 5.9 GHz frequency band designated for DSRC. Second, we have taken the additional step of incorporating *location*-based information via GPS receivers. The GPS receiver provides far richer statistics to characterize the channel, which allows us to better understand the relationship between this highly mobile V2V channel and location information.

Measurement System

The RF system architecture of the transmitter is depicted in Fig. 1. An Agilent E4433A Digital Signal Generator (DSG) is used for signal generation. It is capable of generating signals with carrier frequencies up to 4.0 GHz. To obtain a CW signal at 5.9 GHz, a 2.95 GHz signal from the generator is frequency doubled using a mixer and the signal from the coherent carrier output of the DSG. The coherent carrier output is a fixed power output at the same frequency as the carrier tone of the generated digital signal. This technique simply avoids the need for a second local oscillator. While this technique results in a total frequency drift double the inherent drift of the DSG, the drift is still quite low and is far better than the drift that would be added from an additional, inexpensive crystal oscillator. A band-pass filter (BPF) is used to ensure undesired mixer products are removed before transmission. Lastly two stages of amplification are used to reach signal levels comparable to expected DSRC transmit level specified in the IEEE 802.11p (DSRC) standard under development [8].

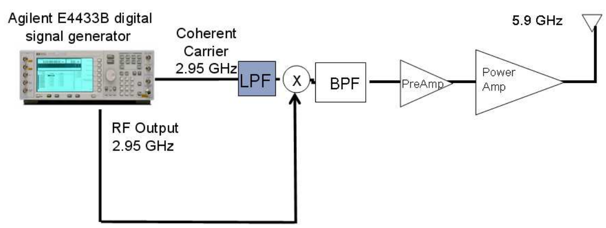

Figure 1: System setup diagram at transmitter side.

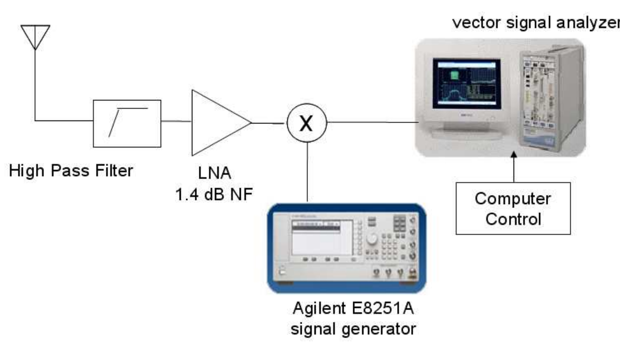

Figure 2: System setup diagram at receiver side.

Fig. 2 describes the RF system setup at the receiver side. A broadband, low noise amplifier with a noise figure of 1.4 dB is used to maximize the sensitivity of the receiver. To prevent a loss of gain due to out of band signals, a high-pass filter is used which provides a minimum of 40 dB of attenuation to all signals below 3.8 GHz and 1 dB of attenuation across the 5.9 GHz frequency band. A mixer is used to down-convert the received RF signal into the 0 to 40 MHz range that can be analyzed by the Agilent 89600 Vector Signal Analyzer (VSA). The VSA is set to measure a small range of frequencies around the CW tone to further improve the system dynamic range. Automation software is used to record a 200 ms data capture of the signal at 1-second intervals. We refer to each of these 200 ms captures as a

VSA measurement sweep. An Agilent 8251A precision RF signal generator is used to provide a LO signal to the mixer at the receive side.

Measurements of the the relative carrier drift between the transmitter and receiver systems was found to be about 3 Hz per minute at 5.9 GHz. This is less than one part per billion per minute and less than one part per million per day. Although small, we still take the drift into account and conduct a compensation procedure in the data post-processing.

In addition to the RF components, each vehicle is equipped with a CSI wireless Differential GPS (DGPS) receiver and a Linux laptop computer that logs GPS data. The accuracy of DGPS is on the order of 1 meter. During the measurements, the GPS units recorded the location, speed, and heading information of vehicles, at a rate of five times per second. Special care is taken to ensure that measurement data with invalid GPS information due to a GPS outage are eliminated. GPS information is synchronized with VSA measurements relying on their time stamps.

Measurement Results

The data from 800 sweeps using a CW signal obtained while driving in a suburban environment near the campus of Carnegie Mellon University are shown in Fig. 3. Also shown is a regression fit to a standard log-normal shadowing model

$$P(d) = P(d_0) + 10\gamma \log_{10}\left(\frac{d}{d_0}\right) + X_\sigma, \tag{1}$$

where $P(d)$ is the received signal strength at a distance d, $P(d_0)$ is the received signal strength at a reference distance, d_0, γ is the path loss exponent, and σ is the standard deviation of the zero-mean Gaussian variable X_σ. As shown in the figure, the data is reasonably approximated using a path loss exponent γ of 2.75, and a standard deviation σ of 5.5 dB.

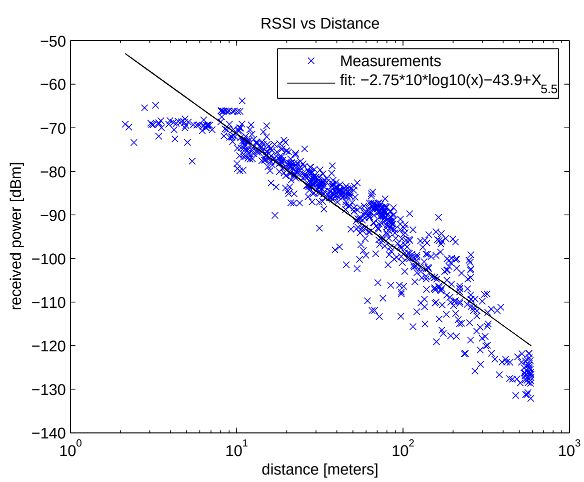

Figure 3: Pathloss measurements and the log-normal model fit.

Conclusion

We have described a measurement system to characterize V2V wireless communication channels. Our system features increased flexibility through the use of programmable signal generation and analysis to allow the use of arbitrary test signals up to 40 MHz in bandwidth. In addition, the system is capable of making channel measurements as a function of location while the vehicles are in motion by integrating GPS receivers into our system allowing for larger, more varied measurement cases. On-road experimental tests in a suburban area of Pittsburgh have shown the effectiveness of the proposed platform and made interesting observations regarding V2V channel characteristics.

References

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