

Study on the Doppler Shift and Channel Model for V2I, V2V in ITS

Sun-Kuk Noh¹, Byung-Rae Cha², Jae-Young Pyun³, DongYou Choi³

¹Dept. of Photoelectronics Information, Chosun College of Science & Technology, GwangJu, KOREA

²School of Information and Communication s, GIST, GwangJu, KOREA

³Dept. of Information and Communication Engineering, Chosun University, Gwangju, KOREA
nsh7078@hanmail.net, brcha@nm.gist.ac.kr, {jypyun & dychoi}@chosun.ac.kr

Abstract - The use of Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication will be an integral part on Intelligent Transportation System (ITS), and work on ITS has been growing substantially in recent years. A recent standard for V2V communication in the 5.2GHz band has been developed. Characterization of the channel in this frequency band in the ITS environment is of current interest to understand propagation behavior. More significantly for reliable communication is the presence of channel dispersion due to multipath propagation, also environment-dependent. It is important to note that the Doppler spectrum for vehicular environments is only valid for a short period of time. In this paper, to find effect of Doppler shift, we showed the simulation scenarios. And some channel models were simulated. As a results of, we confirmed an effect of Doppler shift in the ITS environments.

Index Terms - Doppler shift, Channel Model, ITS.

I. Introduction

The use of Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication will be an integral part on Intelligent Transportation System (ITS) [1], and work on ITS has been growing substantially in recent years. In particular, different applications will emerge enabled by the exchange of information between cars. The information flowing between vehicles will likely be multimedia: data, images, video, and voice. The main ones concern the enhancement of road safety and the reduction of the traffic impact on the environment. These networks are called Vehicular Ad-Hoc Networks (VANETs) [2]. In order to transmit information reliably on rapidly changing vehicular channels one has to rely on a robust physical layer. Finding an accurate channel model for VANETs is still a research issue. Indeed, it has been shown in several papers that vehicular wireless channels exhibits specific characteristics that makes them quite different from the very well characterized mobile telephony channels [3],[4],[5]. A recent standard for V2V communication in the 5.2GHz band has been developed [6]. Characterization of the channel in this frequency band in the V2V environment is of current interest to understand propagation behavior. The strength of the received signal can change significantly depending on the absorbing, diffracting, and scattering effects from the surrounding environment. More significantly for reliable communication is the presence of channel dispersion due to multipath propagation, also environment-dependent [7], [8]. A V2V system may require from 2-54Mbps for distance of 15 -1000m at maximum speeds of 200km/h. A 10MHz

bandwidth and higher order modulation can be used to achieve the required data rates.

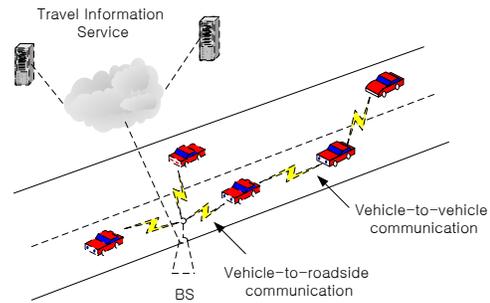


Fig.1 Intelligent Transportation system (ITS)

II. Wireless Channel Parameters

The simulation scenarios are Fig. 2 to find effect of Doppler shift.

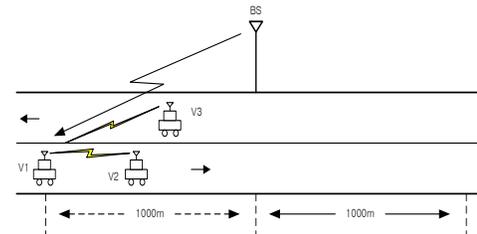


Fig.2. Simulation scenarios Two-way vehicle Environment (V2I, V2V)

TABLE 1 Simulation condition

Two-way road, Vehicle V1, V2, V3, Base station BS	
V1 ~V2 distance	1~1000m
V1~V3 distance	1~1000m
V1~BS distance	1000m
Carrier Frequency f_0	5.2GHz
Vehicle Velocity V	60~150Km/h (16.7 ~ 1.7m/s)
Direction of Arrival (DOA) α	$0 < \alpha < 180^\circ$

The Doppler frequency f_d depend on the relative velocity V between the Tx and Rx, the speed of light c_0 and the carrier frequency f_0

$$f_d = \frac{V}{c_0} \cdot f_0 \cdot \cos \alpha \quad (1)$$

In Eq. (1), α represents the angle between the direction of arrival of the examined propagation path and the Rx's movement. Maximum and minimum Doppler frequencies occur for $\alpha = 0$ and $\alpha = 180$, respectively, and determine the Doppler bandwidth $B_d = 2f_{d,max}$. The classical Jakes distribution depicted in Fig. 3.

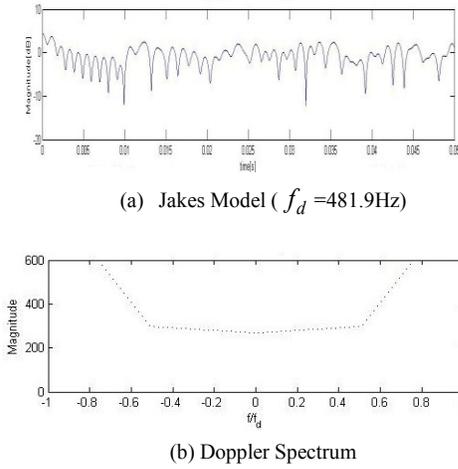


Fig.3. Distribution of Doppler frequencies for isotropic radiations (Jakes spectrum)

It is important to note that PDP and the Doppler spectrum for vehicular environments are only valid for a short period of time.

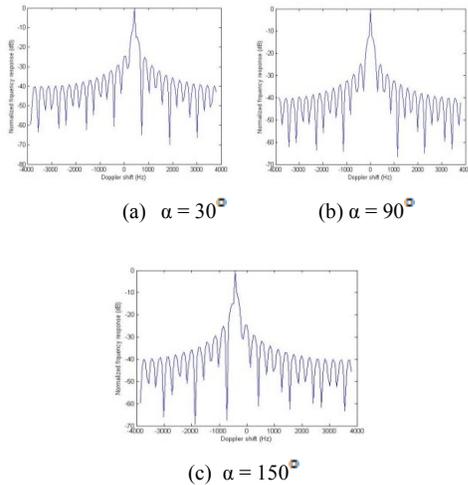


Fig.4. Doppler shift of α ($V_1=27.8$ m/s, V_{21})

In Fig. 4, we confirmed as follows. $0 < \alpha < 90^\circ$: the Doppler shift was more positive shift $\alpha = 90^\circ$: the Doppler shift was no shift $90^\circ < \alpha < 180^\circ$: the Doppler shift was more negative shift

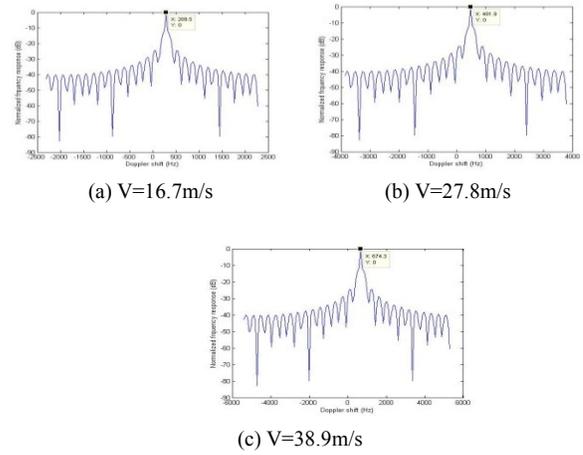


Fig.5. Doppler shift of velocity change of vehicle (V_{2I} , $V_1=V_2=V_3$)

In Fig. 5, we confirmed that the speed of the vehicle is more the fast, the Doppler shift was more shifted positive.

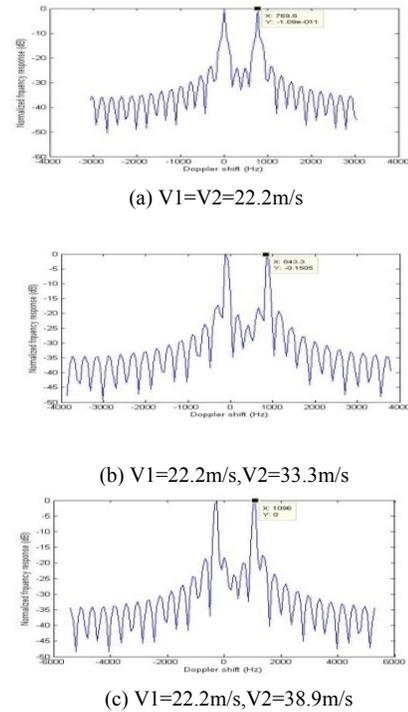


Fig.6. Doppler shift of velocity change of vehicle (V_{2V})

In Fig. 6, we confirmed that the higher the relative velocity between vehicles, the Doppler shift was more shifted positive. For single antenna systems, the influence of the channel can be described by the time-variant impulse response, $h(t, \tau)$, which is the superposition of the contributions of all the multipath components (attenuated, delayed and phase shifted echoes of the signal) that arrive at the receiver because of reflection, diffraction, wave-guiding or another propagation mechanism. This function is time-variant, it shows the response of the channel at a time t is due to an impulse input at a time $t - \tau$. Although the impulse response contains all the

information about the channel, there are condensed parameters which describe the channel in a more compact way, e.g. path loss, fading statistics, power delay profile, and Doppler spread.

IV. Channel Model Simulation

The Channel models have two groups. A group of V2V channel models is the stochastic channel models. These models provide statistics of the power with a certain delay, Doppler shift, etc. The second group of V2V channels are the geometry-based stochastic channel models (GSCM), which simulate the channel by using randomly placed scatterers in simulation environment, performing a simplified ray tracing and, summing up the total signal at the receiver [5],[7],[8].

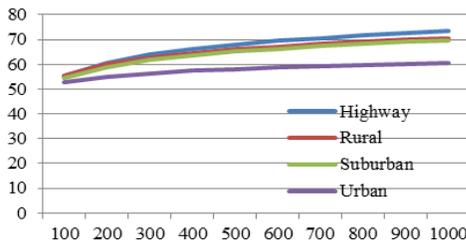
A. Path loss model

A path loss model is proposed for four different types of V2V environments: Highway, rural, suburban, and urban [5]. For network simulations, the interesting value is PL as a function of the position of the transmitter and the receiver, not of the time sample. Thus, using the recorded geographical location data, the authors model the distance-dependent path loss as.

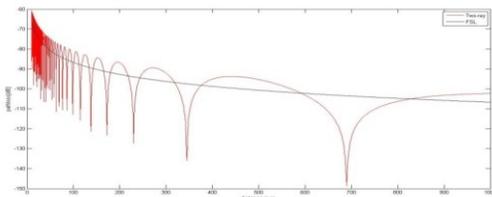
$$PL\left(\frac{d}{d_0}\right) = PL_0 + 10n \log_{10}\left(\frac{d}{d_0}\right) + X(d > 10m) \quad (2)$$

Where d is the transmitter-receiver distance, n is the path loss exponent, PL_0 is the path loss at a reference distance $d_0 = 10m$, and X is a zero-mean, normally distributed random variable with standard deviation σ_x . It should be noted that this model is valid only for $d > 10m$. This limitation came from the absence of valid measurement for transmitter-receiver separations smaller than 10m.

The parameters of the model, extracted from data for different environments can be found in Reference [5]. (Highway $PL_0 = 31.9$, $n=1.83$, X (dB) = 4.98)



(a) Path-loss model by configuration of the ground



(b) Two-ray model

Fig.7. Path-loss model

B. Tapped Delay-Line Model (TDL – COST 207)

Typically, channel models for mobile communication systems are almost always represented in the form of tapped delay lines. Both the channel and the transmitted signal must be represented in the discrete-time domain in order to carry out simulations. The Channel effects can be introduced in this discrete-time framework using Tapped-delay-line (TDL) model. The sampling rate, must account for the maximum Doppler, and take into account the signal bandwidth, B . Thus, the required sampling frequency $f_s \geq 2(B + f_D)$. The discrete time channel model assumed is a transversal or FIR filter with time-varying taps, $g_i(t)$, spaced $\Delta\tau = t_s$. In the COST207 model [3], this joint probability density function is given in the form

$$p(\tau, \nu) = p(\tau)p(\nu | \tau) \quad (3)$$

i.e, the channel is modeled in terms of the power-delay distribution, $p(\tau)$, and of the doppler distribution conditioned to each specific delay, $p(\nu | \tau)$.

Looking at Fig. 8, we can see two elements in each tap, R_i and W_i : the first is a normalized complex Rayleigh distribution with a given Doppler spectrum, and the second term is a weight indicating the power share for that specific tap. Combining these two terms into a single, time-varying coefficient, $g_i(t)$, the corresponding Rayleigh distribution parameter is given by $2\sigma_{g_i}^2 = \int_{t_s}^{(i+1)t_s} p(\tau) d\tau$ the tap spacing and the time sample spacing being $t_s = 1/f_s$. Parameter σ_{g_i} is the standard deviation for the two Gaussian random number generators in quadrature used for generating the complex samples of each tap $g_i(t)$.

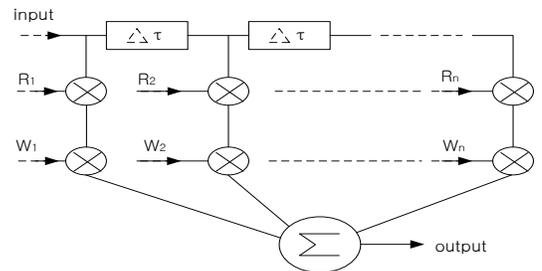


Fig. 8. TDL model representing a time-varying channel

C. FWGN model (Clarke/Gans Model)

The outdoor channel will be mostly characterized by Doppler spectrum that governs the time variation in the channel gain. Various types of Doppler spectrum can be realized by a filtered white Gaussian noise (FWGN) model. The FWGN model is one of the most popular outdoor channel models. The Clarke/Gans model is a baseline FWGN model that can be modified into various other types, depending on how a Doppler filter is implemented in the time domain or frequency domain. The Clarke/Gans model has been devised under the assumption that scattering components around

mobile station are uniformly distributed with an equal power for each component.

Fig. 9 shows the time-domain characteristics of the frequency-non-selective fading channel with a Doppler frequency of $f_d = 481.9$ Hz and a sampling period of $T_s = 50\mu s$. From these results, it is observed that the channel gain is time-varying with Rayleigh-distributed amplitude and uniformly-distributed phase.

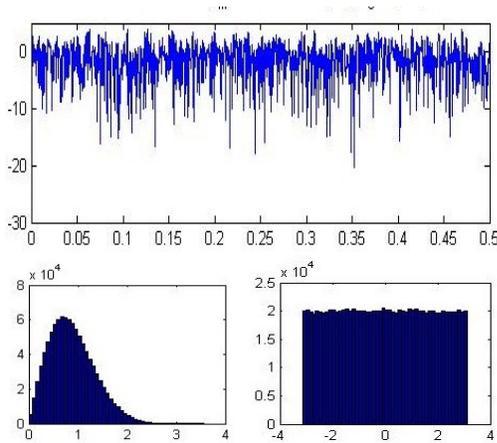


Fig. 9. FWGN model (Clarke/Gans Model)

V. Conclusion

The use of Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication will be an integral part on Intelligent Transportation System (ITS), and work on ITS has been growing substantially in recent years. Characterization of the channel in 5GHz frequency band in the ITS environment is of current interest to understand propagation behavior. More significantly for reliable communication is the presence of channel dispersion due to multipath propagation, also

environment-dependent. It is important to note that the Doppler spectrum for vehicular environments is only valid for a short period of time. In this study, to find effect of Doppler shift, we shown the simulation scenarios and some channel model for simulation. We have seen that multipath is a time-selective phenomenon and the movement of at least one of the terminals causes Doppler effects. In addition, we simulated some channel model in the V2V, V2I environment. As a result, we confirmed an effect of Doppler shift and multipath in the V2V, V2I environment. Hereafter, we will propose the channel model about V2V, V2I in ITS.

References

- [1] A Geometry-Based Stochastic MIMO Model for Vehicle-to-Vehicle Communications
- [2] "A survey of V2V channel modeling for VANET simulations, 2011 International Conference on Wireless On-Demand Network systems and Services
- [3] COST07, "Digital land mobile radio communications," Office for Official Publications in European Communities, Tech. Rep., 1989. final report, Luxembourg.
- [4] G. Acosta-Marum, M.A., "Six time-and frequency-selective empirical channel models for vehicular wireless LANs0", *IEEE Vehicular Technology Magazin*, Vol. 2, No. 4, pp. 4-11, Dec. 2007.
- [5] J. Karedal, F. Tufvesson, A. Paier, N. Czik, A.F. Molisch, "Four pathloss models for vehicle-to-vehicle communications", *IEEE Transactions on Vehicular Technology Magazin*, Vol. 2, No. 4, pp. 4-11, Dec. 2007.
- [6] I. Sen, David W. Matolak, "Vehicle-Vehicle Channel Models for the 5-GHz Band", *IEEE Transactions on Intelligent Transportation Systems*, Vol. 9, No. 2, pp. 235-245, June. 2007.
- [7] A.F. Molisch, Fredrik Tufvesson, Johan Karedal, "A Survey on Vehicle-To-Vehicle Propagation Channels", *IEEE Wireless Communications*, Vol. 2, No. 4, pp. 12-22, Dec. 2009.
- [8] Maria Kihl, Kaan B., Fredrik Tufvesson, Juan luis Aparicio Ojea, " Simulation Modelling and Analysis of a Realistic Radio Channel Model for V2V Communications", 2010 International Congress on Ultra Modern Telecommunications and Control systems and Workshops (ICUMT)