Applied Laser Technology

Vol. 28, No.2,April (2021), pp.01–06

Improving the Non-Geometric Stochastic Model of Inter-Vehicular Communications Beyond the WSSUS

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Abstract:

A novel non-geometrical stochastic model (NGSM) is created for V2V channels that do not depend on wide-sense stationarity and uncorrelated scattering (non-WSSUS). This model is based on a standard NGSM and employs a more exact approach to recreating the true features of V2V channels in order to successfully expand the current NGSM to include the line-of-sight (Loss) component. Several statistical aspects of the proposed model are simulated and compared to those of the present NGSM, including the Doppler power spectrum density (PSD), the power delay profile (PDP), and the tap correlation coefficient matrix. The simulation findings support our theoretical conclusions, which we have shown to be correct.

Keywords:

car-to-car, non-WSSUS channels, non-geometric stochastic model, Loss component, statistical characteristics.

Introduction

Increased productivity, decreased accident rates, and the potential for novel road uses are all made possible by V2V communication in intelligent transportation systems (ITS) [1]. While V2V communication has much promise, it has yet to be thoroughly studied and is currently unregulated. Researchers have put a lot of effort into channel modelling [2, 3] to help in the study and development of V2V communication systems. Both deterministic models, like the geometry-based deterministic model (GBDM) [6, 7], and stochastic models, such the non-geometrical stochastic model (NGSM) [7, 8], are explored in [4, 5]. (GBSM). While the deterministic nature of the V2V physical channel characteristics completely defines the GBDM, the computational cost of the GBDM increases with increasing accuracy requirements. Because they strike a more optimal balance between precision and complexity than GB DM, stochastic models are now widely used in V2V channel modeling. A number of GBSMs are proposed in [9–15]. These simulations modeled the propagation environment using a simplified ray-tracing method and the concept of an analogous scatterer.

While the GBSM requires more work than the NGSM, it is adaptable enough to be employed in many different contexts. The NGSM finds the V2V channel's physics without prior knowledge of the channel's shape. There are two commonly proposed wideband NGSMs in the literature that both make use of the tapped delay line (TDL) design [7], [8]. The wideband NGSM developed in [7] is a representative example of an IEEE 802. 11p-compliant channel model. In terms of losses,

included into the NGSM shown in [7], which features a broad range of Doppler spectra at different times. Because of the relatively short V2V communication (VTD) distance, the Loss component is more prevalent in the situation with low vehicle traffic density. To identify a Loss component, the model employs Rician fading. In addition, the NGSM [7] implies that there are several, indistinguishable sub pathways between each tap, and that the Doppler spectrum may take on different shapes depending on the delay, such as a flat shape, a round shape, the common 3 dB shape, or the classic 6 dB shape. While the NGSM [7] makes use of Rician fading, the assumption of wide sense stationary uncorrelated scattering (WSSUS) makes it impossible for the model to reliably reproduce the dramatic fading seen in V2V channels.

Modelling Non-WSSUS Vehicle-to-Vehicle Communications Channels

Here, we first go through the constriction phases of the NGSM in [8] and show that forcing a uniformly distributed tap phase is not acceptable. Next, a new, enhanced NGSM with a non-standard tap phase distribution is presented.

Old-School NGSM

consisting of a Regular Phase Distribution Present NGSM [8] has three elements that narrow it down: modelling without WSS, modelling outside the US, and modelling with extreme fading. In this part, we will quickly

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outline the model's constraint steps and show that imposing a uniform phase distribution on the NGSM is unrealistically restrictive.

Non-WSS

Modelling The quantity and intensity of multipath components fluctuate regularly because of factors including unexpected traffic and variations in the size, location, and velocity of scatterers. The NGSM in [8] uses the "birth and death" process with persistence process Zak (t) = 0, 1 in the V2V channel model to represent the non-WSS characteristic, where tap “off" signifies below the 25-dB threshold from the main tap.

In order to reduce the number of taps to just those with non-negligible energy [8, such thresholding approaches [19]-[21] are often utilised in the literature. Furthermore, first-order two-state Markov chains may characterise the on/off process's state transition process, and the transition (TS) matrix and the steady-state (SS) matrix [8] can be provided by

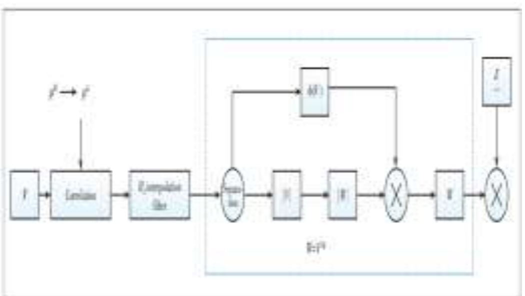
$$TS = \begin{bmatrix} P_{00} & P_{01} \\ P_{10} & P_{11} \end{bmatrix} \quad SS = \begin{bmatrix} P_0 \\ P_1 \end{bmatrix}.$$

where each element Pij in matrix TS is defined as the probability- ty of going from state I to state, and each SS element Py gives the “steady-state probability “associated with the jet state. Then, the channel impulse repulse (CIR) of the NGSM in [8] can be expressed as

$$h(t,\tau) = \sum_{k=1}^{N} z_k(t) c_k(t) \delta(\tau - \tau_k) \times \exp\left\{ j2\pi \left[f_{Dk}(t - \tau_k) - f_c \cdot \tau_k \right] \right\}.$$

Non-uniform phase distribution in an enhanced NGSM Here, based on the current NGSM [8], we present an enhanced version with non-uniformly distributed tap phase. Non-WSS modeling, non-US modeling, and severe fading modelling are the three components of the development procedure for the enhanced model. While the NGSM [8] is often used to depict V2V channel characteristics, the suggested model uses a more precise way by extending the bail it to include the Loss component. From what has been shown, it is clear that the Loss component is excluded from the NGSM [8]. Because the tap phase is uniformly distributed in the inter Val [-,], the Loss component disappears upon its separation from the Gaussian stop chiastic process. This necessitates a modification to the generally used tap phase. Since the amplitude and phase of complex stochastic variables are independent of one another, the Weibull stochastic process involves first transforming the amplitude and phase of complex Gaussian stochastic variables with complex exponentiation 2/, and then decomposing the resulting complex Gaussian stochastic variables into their amplitude and phase components. By virtue of the aforementioned transformation, the effects of on the amplitude and phase components are comparable. Weibull distribution is followed by the tap amplitude, whereas a non-uniform distribution is followed by the tap phase in cones. Figure 3 specifically displays the enhanced mode's constriction stages. As predicted, when is made larger, the resultant tap phase becomes more concentrated within a narrower phase range. So, an impulse at zero

is written as. When = 2, a unit also



▲ *Figure 2. The constriction steps of the NGSM [8] (V is an independent and identical complex Gaussian stochastic variable, and Z is a post-operation such as a persistence process).*

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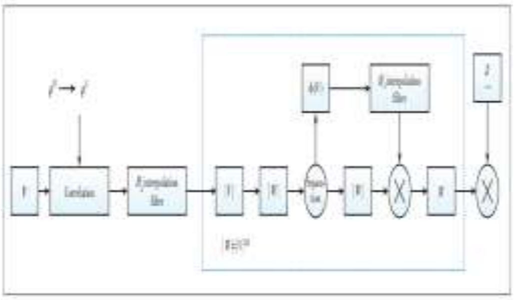


▲*Figure 3. The constriction steps of the improved model (V is an independent and identical complex Gaussian stochastic variable, and Z is a post-opera- action such as a persistence process)*

firmly distributed phase occurs, and the stochastic variables of the improved model can be expressed as

$$\tilde{W}'_k = \tilde{V}_k^{2/\beta_k} = (|\tilde{V}_k| \cdot e^{j\tilde{\phi}_k})^{2/\beta_k} = |\tilde{V}_k|^{2/\beta_k} e^{j\tilde{\phi}'_k},$$
$$\tilde{\phi}_k \in [-\pi, \pi], \tilde{\phi}'_k \in [-2\pi/\beta, 2\pi/\beta],$$

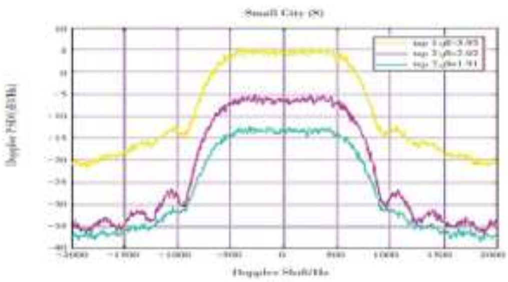
where the number of taps is assumed to be K and |Ṽ K |is the tap amplitude, which follows the Weibull distribution. ϕ̃ ' k is the tap phase of the improved model and follows the non-uniform distribution, which is a linear function of the uniformly diatribe- used phase. Specifically, the tap phase of the improved model can be given by

$$\tilde{\phi}'_k = \tilde{\phi}_k \cdot 2/\beta_k.$$

Similarly, the mean of the improved model can be calculated as

$$E(\tilde{W}'_k) = \frac{1}{2\pi} \int_{-2\pi/\beta_k}^{2\pi/\beta_k} |\tilde{V}_k|^{2/\beta_k} e^{j\tilde{\phi}'_k} d\tilde{\phi}'_k \Big|_{\beta>2} = \frac{|\tilde{V}_k|^{2/\beta_k}}{\pi} (1 - \cos\frac{4\pi}{\beta_k}) e^{j\frac{4\pi}{\beta_k}} \Big|_{\beta_k>2} \neq 0.$$

For V2V channels that don't rely on wide-sense stationarity and uncorrelated scattering (non-WSSUS), a new non-geometrical stochastic model (NGSM) is developed. This model effectively extends the existing NGSM to incorporate the line-of-sight (Loss) component; it is based on a regular NGSM and uses a more precise way to re-create the realistic properties of V2V channels. Doppler power spectrum density (PSD), power delay profile (PDP), and tap correlation coefficient matrix are only a few of the statistical properties of the proposed model that are simulated and compared with those of the current NGSM in a variety of situations. We have shown that our theoretical deductions are true, and the simulation results back up this claim.



(a)

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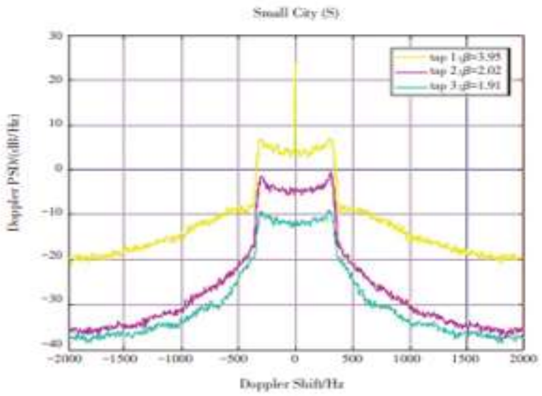

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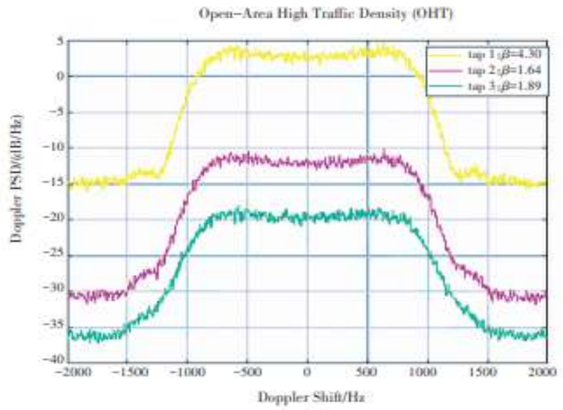

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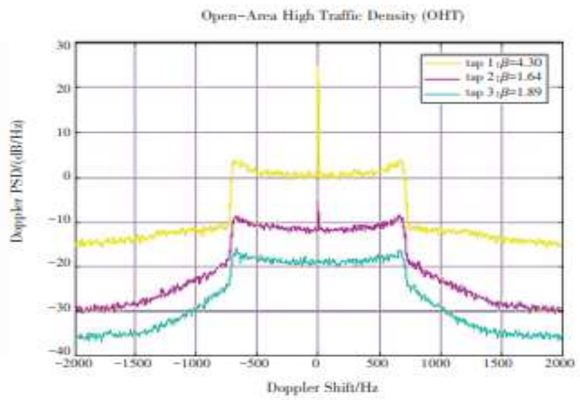

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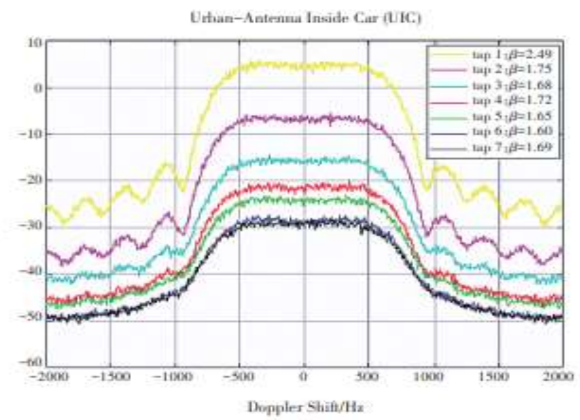

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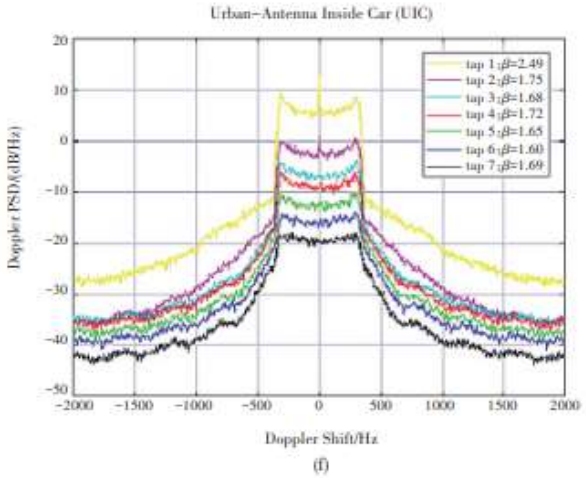

Figure 4. The Doppler PSD of different models for different scenarios. (a) Doppler PSD of the model in [8] for S scenario; (b) Doppler PSD of the mi- proved model for S scenario; (c) Doppler PSD of the model in [8] for OHT scenario; (d) Doppler PSD of the improved model for OHT scenario; (e) Dop- per PSD of the model in [8] for UIC scenario; (f) Doppler PSD of the improved model for UIC scenario;

Conclusions

Based on a traditional NGSM presented in [8], this work proposes a new NGSM for non-WSSUS V2V channels. In order to include the Loss component, the suggested NGSM uses a mechanism for generating phase that is not uniformly distributed in the Weibull distribution (NGSM [8]). The simulation results further show that the proposed model incorporates a dominating Loss component into the Doppler PSD, which directly identifies the existence of the Loss component, in contrast to the NGSM [8]. In addition, the suggested model's energy is more concentrated along the first route, as illustrated by the PDP comparison. As the suggested model more accurately describes the features of V2V channels, the simulation results confirm this.

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