Improving the Vehicle-to-Vehicle Channel Non-Geometric Stochastic Model Outside the WSSUS

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Abstract:

We construct a new non-geometrical stochastic model (NGSM) for V2V channels that do not rely on wide-sense stationarity and uncorrelated scattering (non-WSSUS). This model is based on a regular NGSM and employs a more accurate method to replicate the realistic features of V2V channels. It effectively expands the current NGSM to integrate the line-of-sight (Loss) component. The suggested model's statistical attributes, such as the tap correlation coefficient matrix, power delay profile (PDP), and Doppler power spectrum density (PSD), are only a few that are simulated and contrasted with those of the existing NGSM under various conditions. We have demonstrated the validity of our theoretical inferences, and the simulation results support this assertion.

Keywords:

automobile-to-automobile, non-WSSUS channels, non-geometric stochastic model, line-of-sight (Loss) component, statistical features.

Introduction

Vehicle-to-vehicle (V2V) communication is used by intelligent transportation systems (ITS) to boost output, lower accident rates, and create new opportunities for the road [1]. V2V communication is a new and promising kind of communication, although it is not well studied or standardized. Channel modeling has received a lot of attention from researchers to help with the analysis and development of V2V communication systems [2, 3]. Numerous V2V channel model types have been covered in [4, 5], including stochastic models like the non-geometrical stochastic model (NGSM) [7, 8] and deterministic models like the geometry-based deterministic model (GBDM) [6, 7]. (GBSM). The V2V physical channel characteristics completely deterministically characterize the GBDM, but as precision demands increase, so does its computational complexity.

Modelling Non-WSSUS Vehicle-to-Vehicle Communications Channels

Here, we first walk through the NGSM constriction stages in [8] and demonstrate that it is not appropriate to force a tap phase that is evenly distributed. After that, a brand-new, improved NGSM with an unconventional tap phase distribution is shown.

Old-School NGSM

With a Regular Phase Distribution as its component The three components of present NGSM [8] that make it more focused are modeling without WSS, modeling outside of the US, and modeling with extreme fading. Here, we will briefly review the constraint steps of the model and demonstrate why it is unnecessarily restrictive to impose a uniform phase distribution on the NGSM.

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Non-WSS

Creating Models Variations in the size, location, and velocity of scatterers as well as unforeseen traffic can generate frequent fluctuations in the number and intensity of multipath components. The non-WSS characteristic is represented by the NGSM in [8] using the "birth and death" process with persistence process Zak (t) = 0, 1 in the V2V channel model, where tap "off" denotes below the 25-dB threshold from the main tap.

Such thresholding procedures [19]–[21] are frequently used in the literature to narrow down the number of taps to only those with non-negligible energy [8]. Moreover, the state transition process of the on/off process may be characterized by first-order two-state Markov chains, and the steady-state (SS) matrix and the transition (TS) matrix [8] can be supplied 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

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

Improved NGSM with Non-Uniform Phase Distribution In this section, an improved NGSM with non-uniformly dis- tributed tap phase is proposed, which is based on the existing NGSM [8]. The process to develop the improved model also consists of three parts: non-WSS modelling, non-US modelling, and severe fading modelling. However, the proposed model me- ploys a more accurate method to represent the characteristics of V2V channels, which extends the NGSM [8] to have the bail- it to include the Loss component. As can be seen from the above analysis, Loss component can- not be included in the NGSM [8]. This is because the tap phase is directly gained from the separation from Gaussian stop- chiastic process and follows a uniform distribution in the inter- Val[- π,π], which causes the absence of the Loss component. Thus, the uniformly distributed tap phase must be changed. Specifically, in the Weibull stochastic process, the amplitude and the phase of complex Gaussian stochastic variables are both transformed with complex exponentiation 2/β, and then the complex Gaussian stochastic variables are separated into the amplitude part and the phase part since the amplitude and phase of the complex stochastic variables are independent on each other. As a result of the above transformation, β affects equivalently the amplitude part and the phase part. Cones- quaintly, the tap amplitude follows the Weibull distribution and the tap phase follows non-uniform distribution. Above all, the constriction steps of the improved mode are shown in Fig. 3. With β being increased, the resulting tap phase concentrates within a smaller phase range, as expected. Consequently, an impulse at zero occurs as β → ∞. Also, when β = 2, a unit-

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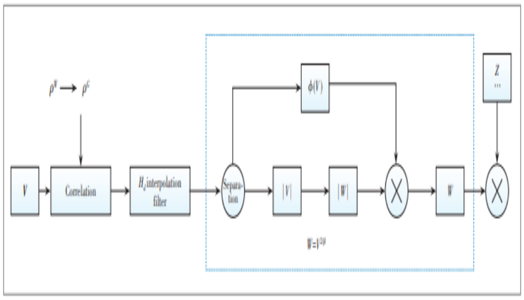
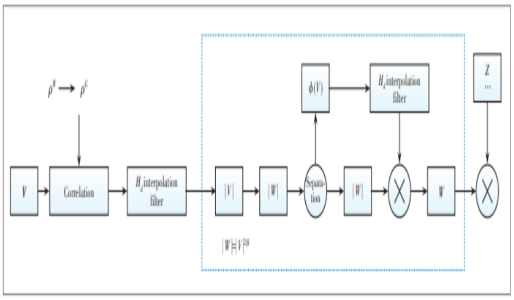


▲Figure 2. The constriction steps of the NGSM [8] (V is an independent and identical complex Gaussian stochastic variable, and Z is a post-operation such as a persistence process).



▲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

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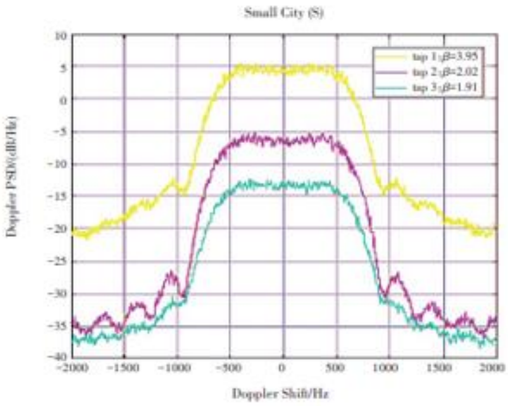
V2V channels. Doppler power spectrum density (PSD), power delay profile (PDP), and tap correlation coefficient matrix are only a few of the statistical properties of the proposed model that are simulated and compared with those of the current NGSM in a variety of tuations. We have shown that our theoretical deductions are true, and the simulation results back up this claim.



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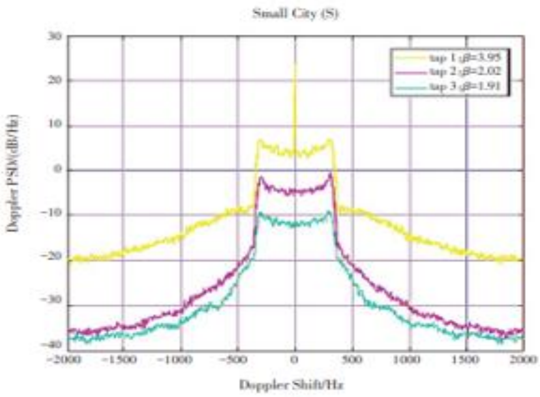

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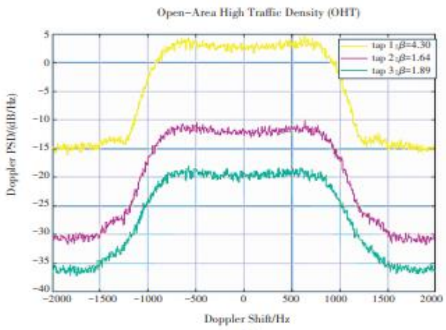

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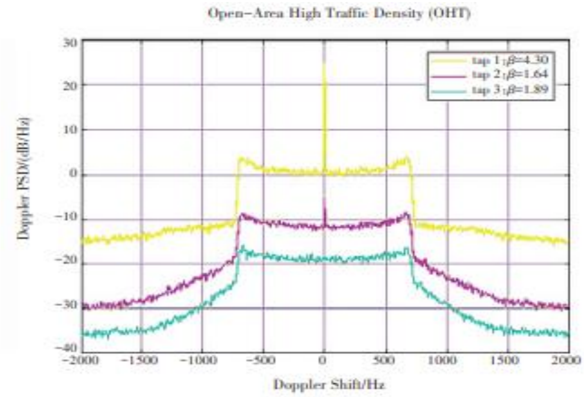

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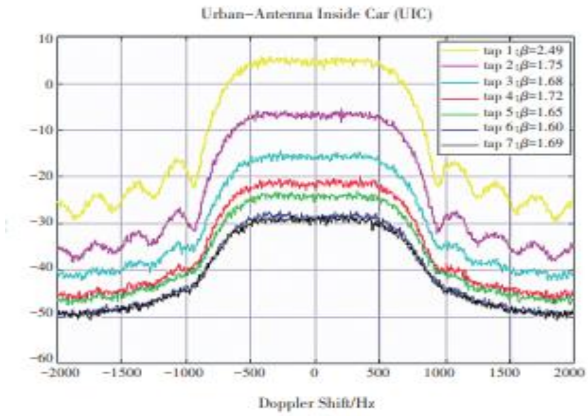

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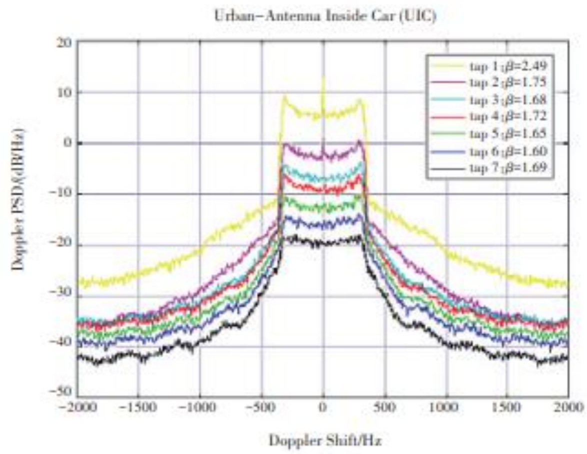

(f)

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

This work suggests a new NGSM for non-WSSUS V2V channels, which is based on a conventional NGSM that was published in [8]. The proposed NGSM employs a mechanism for producing phase that is not uniformly distributed in the Weibull distribution (NGSM [8]) in order to incorporate the Loss component. The simulation findings also demonstrate that, in

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contrast to the NGSM, the suggested model directly recognizes the presence of the Loss component by incorporating a dominating Loss component into the Doppler PSD [8]. Furthermore, the PDP comparison shows that the energy of the proposed model is concentrated greater along the first route. The simulation results validate that the proposed model better captures the characteristics of V2V channels.

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