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# Study of Path Loss Models in V2V mm-Wave Communication

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## Abstract

Recent research has focused on millimeter wave (mmWave) bands as a way to improve automated driving and meet the demanding data rate and latency requirements of developing automotive applications. Accurate channel models that can predict the uniqueness of vehicular propagation at these bands, particularly about Vehicle-to-Vehicle (V2V) communications, are required for the development of such systems to operate in bands over 6 GHz. In this paper, we have validated the proposed mmWave path loss models for the NR-V2X system with the help of link-level simulation. Here bit error rate (BER) performance of three path loss models has been compared by varying inter-vehicular distance (IVD). We also observe the effect of different modulation schemes on the BER curve for a fixed path loss model and proposed the best-suited modulation technique for the mm-wave V2X system.

## 1. Introduction

In recent days plenty of research is going on in the area of V2X communication in academia and industry to provide reliable data communication between Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), Vehicle to Network (V2N), and Vehicle to Pedestrian (V2P) to enable automated driving, increased road safety, vehicle platooning, reduce environmental impacts and provide traveler information service, etc. [1],[2]. In this regard, starting with the 3GPP Release-16 Study Item (SI) on NR-V2X, the 3rd Generation Partnership Project (3GPP) has recently developed some functionalities to provide enhancements to the conventional communication standards for both V2V and V2N communications [3]. This development includes NR-based sidelink design and V2X service in mm-wave bands. But mm-wave bands, above 52.6 GHz face more propagation and penetration loss than the conventional mm-wave band (below 52.6GHz) [4]. Therefore, a more accurate channel is required in this band to design a reliable communication link. [5],[6], and [7] several attempts have been made to design realistic channel models in mm-wave bands by real-time measurements. The 3rd Generation Partnership Project (3GPP) in [8] specified how to model channels for mm-wave frequencies, especially for V2V applications. Path loss models for vehicular and environmental blockages in highway and urban scenarios have been proposed. In [9] a system-level simulation study of 3GPP path loss models has been proposed. In this paper, we did a link-level simulation study for 3GPP path loss models and proposed a modulation scheme suitable for the mm-wave NR-V2X system.

## 2. Path Loss Models

According to [8] in V2V communication, the path loss model can be derived for the following states:

(a) LOS: Here two vehicles are on the same road and the LOS path is not blocked by other vehicles.
(b) NLOS$v$: In this case, the link between two vehicles is blocked by other vehicles and they are on the same street.
(c) NLOS: V2V link is blocked by environmental blockages, like buildings, trees, etc.

### 2.1 LOS Path Loss Models

The path loss model for the LOS condition is described in equations 1 & 2.

$$P_{LOS(H)} = 32.4 + 20log_{10}(d) + 20log_{10}(f_c) + \gamma_{SF} \quad (1)$$

$$P_{LOS(U)} = 38.77 + 16.7log_{10}(d) + 18.2log_{10}(f_c) + \gamma_{SF} \quad (2)$$

Here $P_{LOS(H)}$ and $P_{LOS(U)}$ are the respective path loss in highway and urban scenarios. Also, d denotes the Euclidean distance in meters, between two vehicles, $f_c$ is the center frequency in GHz and $\gamma_{SF}$ is the loss due to shadowing. The value of $\gamma_{SF}$ is 3.3dB and 5.2dB in highway and urban environments.

### 2.2 NLOS Path Loss Models

For NLOS$v$ condition, the additional vehicle blockage loss ($A_{NLOSv}$) can be modeled as a log-normal random variable with mean $\mu_A$ and standard deviation $\sigma_A$ and the blocker height is vehicle height randomly selected among three types of vehicles described in [10]. Depending on different vehicle types the $A_{NLOSv}$ can be evaluated as shown in table 1.

**Table 1.** Calculation of $A_{NLOSv}$ in three different environments.

| | | | |
|---|---|---|---|
| 1 | Minimum of Tx and Rx antenna height > Blocker height | $\mu_A = 0dB$ | $\sigma_A = 0dB$ |

| | | | |
|---|---|---|---|
| 2 | Maximum of Tx and Rx antenna height < Blocker height | $\mu_A = 9dB + Max(0,15log10(d) - 41)$ dB | $\sigma_A = 4.5dB$ |
| 3 | For all other conditions | $\mu_A = 5dB + Max(0,15log10(d) - 41)$ dB | $\sigma_A = 4dB$ |

Finally, the path loss can be derived for NLOS$v$ using equations 3 & 4.

$$P_{NLOSv(H)} = P_{LOS(H)} + A_{NLOSv} \quad (3)$$

$$P_{NLOSv(U)} = P_{LOS(U)} + A_{NLOSv} \quad (4)$$

The NLOS path loss model can be expressed by equation 5.

$$P_{NLOS} = 36.85 + 30log_{10}(d) + 18.9log_{10}(f_c) + \gamma_{SF} \quad (5)$$

## 3. Simulation Setup

In this paper, we have performed a link-level simulation of the V2V network in MATLAB. All the simulation parameters are mentioned in table 2. Here user data is convolutionally encoded and mapped to symbols using QPSK/16QAM/64QAM and converted to a time domain signal by OFDM modulation. Then the time domain signal has been passed through a Rayleigh fading channel. At the receiver, an additive white gaussian noise (AWGN) has been added. After demodulation and channel equalization, the bit error rate (BER) has been calculated for different inter-vehicular distances (IVD), carrier frequencies & modulation techniques.

**Table 2.** Simulation Parameters

| | |
|---|---|
| Carrier Frequency | 63GHz |
| Sub Carrier Spacing | 15KHz |
| FFT Size | 64 |
| Cyclic Prefix | 16 |
| Modulation | QPSK, 16 QAM, 64QAM |
| Channel | Rayleigh Fading Channel |
| Tx antenna height | 1.6 meter |
| Rx antenna height | 3 meters |
| Transmission Power | 21dBm |

## 4. Results

In Fig. 1 we have plotted IVD vs BER for three 3GPP mm wave path loss models. As foreseen, the BER increases very quickly in NLOS conditions compared to the other two models. Science in NLOS scenario the path loss is higher which directly affects BER.

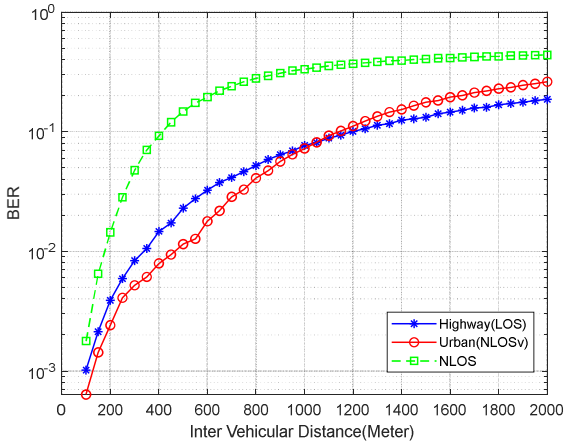


**Figure 1**. IVD vs BER plot for different path loss models. ($f_c$=63GHz, Modulation: QPSK & SNR=20dB)

The BER vs IVD is plotted for different modulation schemes and path loss scenarios in Fig. 2-4. In all three plots $f_c$=63GHz and SNR=20dB. From these plots, it is very clear that with increasing IVD, the path loss increases which in turn increases BER. From Fig. 2 & 3 we can observe that among the three modulation schemes, QPSK gives the best BER performance. Although at higher IVD, BER increases but compared to other modulation techniques QPSK shows better results. In the NLOS condition (Fig.4) again QPSK shows better results but when IVD increases, the BER increases very rapidly and became flat after 600 meters.

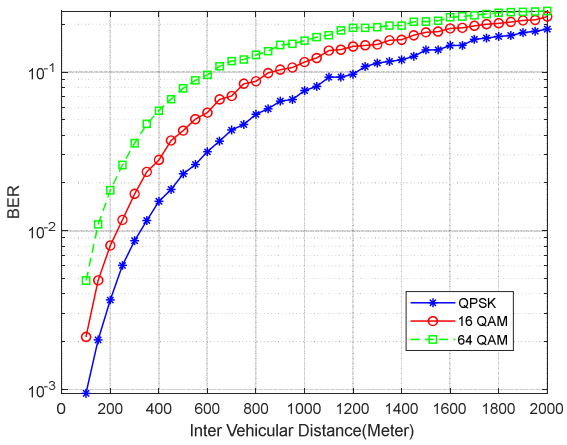


**Figure 2**. IVD vs BER plot in Highway (LOS) scenario. ($f_c$=63GHz & SNR=20dB)

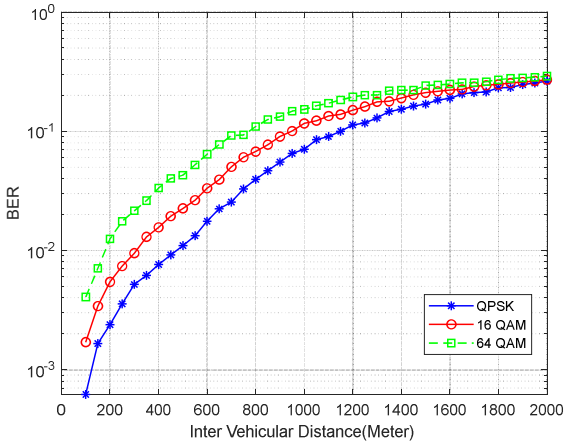


**Figure 3.** IVD vs BER plot in Urban (NLOS*v*) scenario. ($f_c$=63GHz & SNR=20dB)

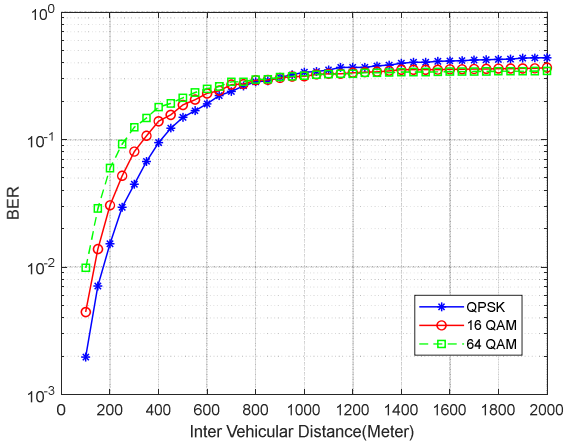


**Figure 4.** IVD vs BER plot in NLOS scenario. ($f_c$=63GHz & SNR=20dB)

## 5. Conclusions & Future Work

In this present study, simulation-based comparisons of 3GPP path loss models have been presented. The BER carves for all path loss models are plotted concerning inter-vehicular distance (IVD). From this plot, we can conclude that the NLOS path loss model shows poor BER performance compared to the other two path loss models. We also presented a comparative study among different modulation techniques for all three path loss scenarios. From this study, it is very much clear that QPSK performs well in all three 3GPP path loss models proposed for the millimeter wave NR-V2X system.

In our future work, we will try to predict the path loss models using real-time measured data and according to that, we will change our modulation schemes in the V2V communication system.

## 6. References

1. F. Boccardi, R. W. Heath, A. Lozano, T. L. Marzetta, and P. Popovski, “Five disruptive technology directions for 5G,” IEEE Communications Magazine, vol. 52, no. 2, pp. 74–80, February 2014.

2. V. Va, T. Shimizu, G. Bansal, and R. W. Heath, “Millimeter wave vehicular communications: A survey,” Foundations and Trends in Networking, vol. 10, no. 1, pp. 1–113, 2016.

3. 3GPP, “New SID on NR V2X (Release 16),” RP-181480, 2018.

4. “Study on NR beyond 52.6 GHz (Release 16),” RP-181435, 2018.

5. A. Kato, K. Sato, and M. Fujise, “ITS wireless transmission technology. Technologies of millimeter wave inter-vehicle communications: Propagation characteristics,” Journal of the Communications Research Laboratory, vol. 48, pp. 99–110, March 2001.

6. S. Takahashi, A. Kato, K. Sato, and M. Fujise, “Distance dependence of path loss for millimeter wave inter-vehicle communications,” in IEEE 58th Vehicular Technology Conference (VTC-Fall), Oct 2003.

7. A. Yamamoto, K. Ogawa, T. Horimatsu, A. Kato, and M. Fujise, “Pathloss prediction models for intervehicle communication at 60 GHz,” IEEE Trans. on Vehicular Technology, vol. 57, no. 1, pp. 65–78, Jan 2008.

8. 3GPP, “Study on channel model for frequencies from 0.5 to 100 GHz (Release 14),” TR 38.901, 2018.

9. M. Giordani, T. Shimizu, A. Zanella, T. Higuchi, O. Altintas and M. Zorzi, "Path Loss Models for V2V mmWave Communication: Performance Evaluation and Open Challenges," 2019 IEEE 2nd Connected and Automated Vehicles Symposium (CAVS), 2019, pp. 1-5, doi: 10.1109/CAVS.2019.8887792.

10.3GPP, “Study on evaluation methodology of new Vehicle-to-Everything V2X use cases for LTE and NR (Release 15),” TR 37.885, 2019.