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Channel Modeling and Analysis for Radio Wave Propagation in Vehicular Ad Hoc Network

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Abstract**—*VANET is the basic technology of Vehicle Infrastructure Integration (VII). Vehicular Ad Hoc Network (VANET) is the network that is connecting a vehicle to the infrastructure (V2I) and vehicle to vehicle (V2V) via wireless manner to convey the information between them. Therefore analyzing influence such channels on the VANET system performance is crucial. This paper is conducted to model and analyze the channel for radio wave propagation with considering free space, two ray ground reflection and single knife edge diffraction. The received power, path loss and effect state of the communication sides whether is in moving stable are discussed. The direction of moving of the vehicles and location of obstacles are also taken into account for calculating the received power and path loss.*

Keywords—Vehicle to Vehicle (V2V), Channel model, Radio propagation models, path loss, Doppler Effect.

I. INTRODUCTION

In the recent years, the number of vehicles is continuous increasing that is lead to increase the number of accidents. Therefore, the percentage of death due to an accident is increasing. The VANET technology has great attention to increasing safety road and plays a considerable role in decreasing number of the accidents, traffic jam and time traveling [1, 2]. Whenever the carrier's medium between connections sides in VANET is a wireless connection, therefore analyzing the channel mode is not direct. The transmitted signal is passing through the channel to reach the destination side. The channel may include many obstacles, such as buildings, trees, and cars that are affected by the power of transmitted signal. So, the transmit power suffers from attenuation and delay due to such factors (obstacles), which turn on the received power to be decreasing. The transmitter may send a signal by multipath: one's path is the direct that connect the transmitter and receiver is called a line of side path (LOS), other's path that may reflect from ground or wall and then reach to the destination is called (NLOS). The signal, also, may be scattering due to obstacles that found in the road between Tx and Rx and then reach the strong power to the receiver, so this path is NLOS. The receiver received signal with different amplitudes and times of arrival due to such multipath [3, 4]. Radio wave may be propagated in all direction through sky mode and can travel through long distance. Therefore, radio wave may be used in the AM radio due to the AM radio need long distance propagation [5].

Authors in [6] discussed the path loss and the received power for different vehicle's distributions. The presented radio wave propagation models are for free space, two-ray ground, single knife edge diffraction and multi knife edge diffraction. In [7] authors compared between free space, two-ray ground reflection and shadowing model to finding which of them have the significant impact on throughput and packet loss results.

In this paper, a model for radio wave propagation to free space, two-ray ground reflection and single knife edge diffraction is modeled and analyzed. The received power and path loss are discussed for multi-cases. Also, the state of the Tx and Rx are considered when Tx and Rx are moving and for fixed positions. The direction of moving is presented via Doppler Effect. The location of obstacles between Tx and Rx and reflection from the ground have affected the results of the received power and path loss with respect to the distance between Tx-Rx.

This paper is organized as follows. Section 2 radio wave propagation model is analyzed. In Section 3 the results of received power and path loss are given and discussed. Section 4 concludes this paper.

II. MODELING FOR RADIO WAVE PROPAGATION

This section presents radio wave propagation models for containing three: free space, two-ray ground, and single knife-edge diffraction model which is based on that presented in [6, 8].

A. Free space model

The distance between Tx and Rx sides is only affected on power of transmitted signal that travel on medium between connection sides. Whenever, the distance between connection sides increases, the received power decreases. The received power is given as:

$$p_r = P_t \frac{G_f \lambda^2}{(4\pi)^2 d^2} \quad (1)$$

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where, $P_t$is the transmitted power, G_f = G_t*G_r is the product of gains for the transmitter and receiver antennas, d is the Tx-Rx distance and λ is the wavelength of the signal(= c/f_c, where c is the light speed in vacuum), as shown in Fig. 1. The path loss is the attenuation occurs in the transmitted signal due to the distance between the connection sides, Tx and Rx. Therefore, the path loss can be found from:

$$PL|_{dB} = -20\log_{10}\frac{\sqrt{G_f}\lambda}{(4\pi)d} \quad (2)$$

B. Two-Ray Ground model

The transmitted signal may be reflection from ground; therefore, the receiver side receives two replicas of the signals: the signal that pass in direct path between the Tx-Rx and that is reflected from the ground and then reach to the receiver, as shown in Fig. 1. In this case the received power is given as:

$$P_r = P_t(\frac{\lambda}{4\pi})^2\left|\frac{\sqrt{G_l}}{d} + R\frac{\sqrt{G_r}e^{-j\phi_1}}{x_1+x_2}\right|^2 \quad (3)$$

where, G_r is the product of Tx and Rx gain in reflection path, d is the Tx-Rx distance in direct path, R is the ground reflection coefficient, x_1+x_2 is the length of reflection path and Φ_1 is the phase between direct and reflection path atthe receiver.

where,

$$\phi_1 = \frac{2\pi(x_1+x_2-d)}{\lambda} \quad (4)$$

$$R = \frac{\sin\theta - \sqrt{\beta - \cos^2\theta}}{\sin\theta + \sqrt{\beta - \cos^2\theta}} \quad (5)$$

β is the dielectric constant of ground and ϴ is the reflection's phase.Path loss of the two-ray ground is:

$$PL|_{dB} = -20\log_{10}(\frac{\lambda}{4\pi})\left|\frac{\sqrt{G_l}}{d} + R\frac{\sqrt{G_r}e^{-j\phi_1}}{x_1+x_2}\right| \quad (6)$$

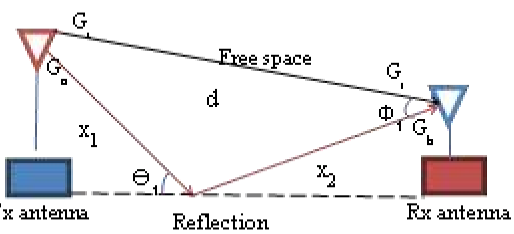

Fig. 1: Two-ray ground medium.

C. Single Knife-Edge Diffraction Model

Environment usually contains obstacle (such as tree, car, building, etc.), therefore the effect of obstacles that may be located in between the Tx-Rx must be taken into account of the received power. The Fresnel-Kirchhoff diffraction parameter F is:

$$F = h_o\sqrt{\frac{2}{\lambda}(\frac{1}{r_1}+\frac{1}{r_2})} \quad (7)$$

where, h_o is the height of obstacle, r_1 is the distance between Tx and the obstacle, and r_2 is the distance from obstacle to the Rx.

The receiver side may receive three replicas of the signals or even more: replica takes direct path Tx-Rx (LOS) path, one replica or more reflecteddue to the ground and one replica or more coming from scattering which due obstacle between the Tx-Rx. Reflection path and scattering path are called NLOS, as shown in Fig. 2.The received power from channel illustrated in Fig. 2 is given by:

$$P_r = P_t(\frac{\lambda}{4\pi})^2\left|\frac{\sqrt{G_l}}{d} + R\frac{\sqrt{G_r}e^{-j\phi_1}}{x_1+x_2} + F\frac{\sqrt{G_s}e^{-j\phi_2}}{r_1+r_2}\right|^2 \quad (8)$$

where, G_s = G_1*G_2 is the product of the Tx-Rx gain in upper NLOS path, Φ_1, R and F are defined in Eqs. (4),(5) and (7), respectively. Φ_2 is the different phase between the free space and scattering paths, denoted by:

$$\phi_2 = \frac{2\pi(r_1+r_2-d)}{\lambda} \quad (9)$$

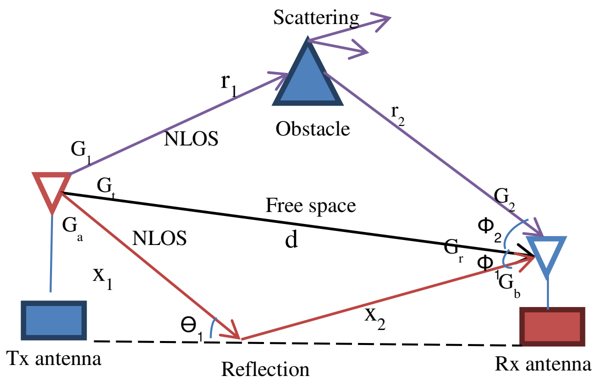

Fig. 2: Radio wave propagation.

The path loss is given by

$$PL|_{dB} = -20\log_{10}(\frac{\lambda}{4\pi})\left|\frac{\sqrt{G_l}}{d} + R\frac{\sqrt{G_r}e^{-j\phi_1}}{x_1+x_2} + F\frac{\sqrt{G_s}e^{-j\phi_2}}{r_1+r_2}\right| \quad (10)$$

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III. RESULTS AND DISCUSSION

Received power and path loss are analyzed for radio wave propagation models illustrated in Section 2. The values of the parameters that are used in this model are shown in Table 1. Four different important cases for the received power and path losses are illustrated as follows:

Case 1

When the separation between the Tx and Rx is fixed, without changing with considering the distance between the Tx-Rx is at fixed position. Let the obstacle is away from Tx antenna (r_1) in 70 m and the reflection from ground is occurring after 50 m from transmit antenna (x_1). And, the other used parameters are given in Table 1.

Table.1: The values of parameters

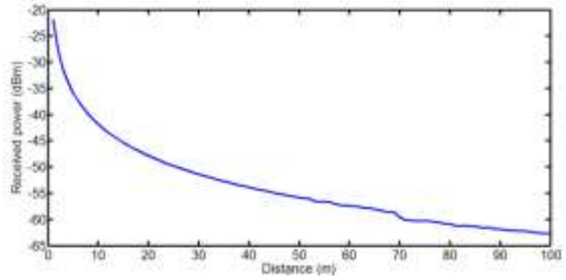
Parameter	Value
G_t, G_r	2
G_1, G_2, G_a and G_b	3
Transmit power P_t	20 dBm
Wavelength λ	0.051 m
Dielectric constant of the ground ε	1.02
Obstacle's height h_o	10 m

The received power and path loss are shown in Fig.3- a and b. It is obvious that when the distance between Tx-Rx is long the received power decreases while path loss increases. Increasing the distance between Tx-Rx is turn into increasing the scattering of the transmitted signal. Fig. 3 also shows that as the received power decreases, the path loss increases. The affected of attenuation due to obstacle is larger than influence of the reflectionthat is about distance ~ 70 m (d_1).

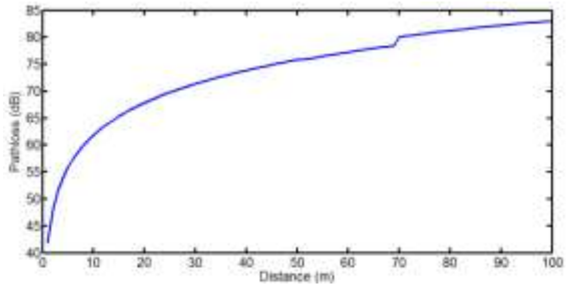
Case 2

This case analyzes when the receiver is moving away from the transmitter. Fig. 4- a and b shows the received power and path. Assuming the vehicle is moving with speed 60 Km/h.So the values of d, x_2 and r_2, in the model, are changed to $d + v \times t$, $x_2 + v \times t$ and $r_2 + v \times t$, respectively, where v is the vehicle's velocity (= 60 Km/h) and t is the time of travelling.

As the separation between the Tx-Rx increasesthe time of moving.The received power and path for 12 s and v = 16.67 m/s, therefore the total distance = $v \times t$ = 200 m. whenever the received vehicle away from the transmit antenna, decreases the power that it is received and increase the path loss due to increase the noise power that is affected on transmit power.

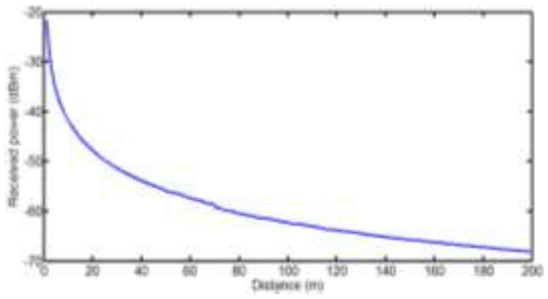


(a)

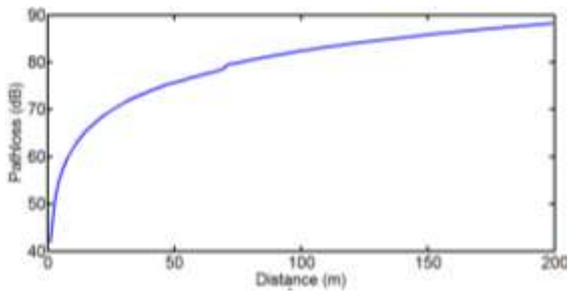


(b)

Fig. 3: Distance versus the received power and Path loss, for case 1



(a)



(b)

Fig. 4: Received power and path loss for case 2

Case 3

This case consider that the received vehicle is away from the transmitter in 190 m and is moving toward transmit antenna at 55 Km/h. In this case, the values of d, x_2 and r_2 of the model are changed to $d - v \times t$, $x_2 - v \times t$ and $r_2 - v \times t$, respectively. The received power and path loss for this case are shown in Fig. 5- a and b. When the vehicle is moving toward transmitter the distance between them is decreased. Therefore, the received power increases due to

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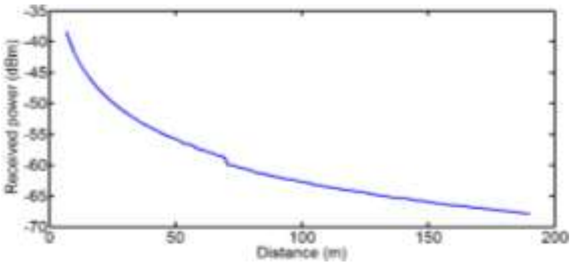
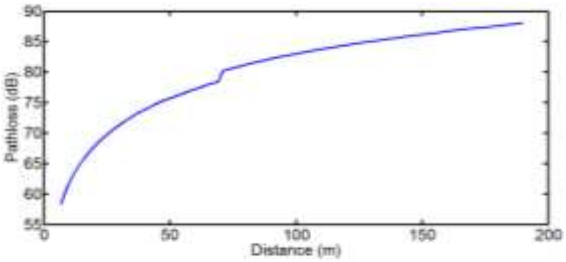
decreases the external factors that it causes attenuation in transmit power.



(a)



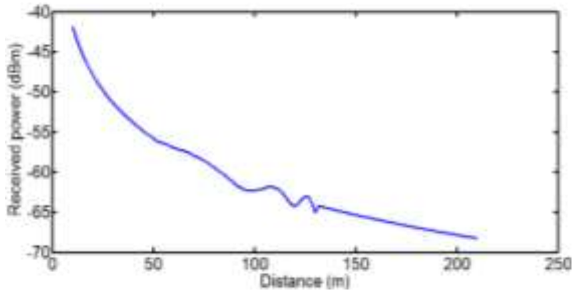
(b)

Fig. 5: Received power and Path loss with respect to distance.

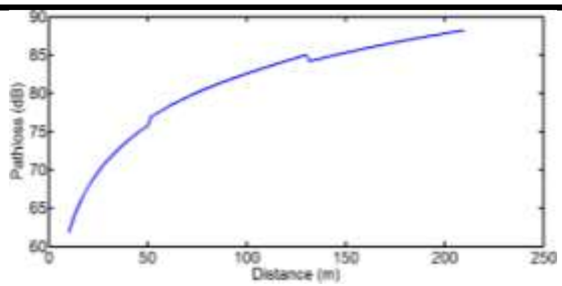
Case 4

When vehicle to vehicle (V2V) are connecting together and these vehicles are moving in the same direction and the distance between them is 10 m at the begging. The velocity of transmit and received vehicles are 30 Km/h and 90 Km/h, respectively. When the distance between Tx-Rx is longer than 50 m, the transmitted signal will suffer from reflection due to ground. The obstacle is away in 70 m from transmitter car. The received power and path loss are illustrated in Fig. 6 – a and b.

It is clear from this Figure, the values of the received power are changed after 50 m and 70 m distance due to affect of reflection and obstacle, respectively. The path loss increases after occuring the reflection in the transmitted signal from ground which turn on decrease this values after small distance from the obstacle's location.



(a)



(b)

Fig. 6: Received power and path loss between v2v.

IV. CONCLUSION

Due to distance, obstacles affected on the transmitted signal are caused reflection, diffraction and scattering on it. Therefore part from transmit signal reaching to the receiver side and the other part is lost in the medium. The power of received signal and path loss are function to the distance between the Tx-Rx. The distance between Tx-Rx is constant when the Tx and Rx is static (such as that between the base stations). Whenever the longer the distance the received power decreases while path loss increases. When the Rx is moving toward the base station, the distance between them decrease, therefore the received power is increase and path loss decreases and vice versa. When both the Tx and Rx are moving in the same direction, therefore the distance between Tx-Rx isn't constant. Then, the received power and path loss signals have more distribution due to distance, noise power and obstacle's location.

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