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Analysis of Position Angle of Arrival in Multipath Fading Channel using Correlated Double Ring Channel Model for VANET Communications

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Abstract — Correlated Double Ring channel modeling in the mobile to mobile communication system (M2M) and vehicular based communication system was pointed out. This modeling required the transmitter and receiver were randomly moving and surrounded by scatterers in a static ring. The scatterers' positions were placed randomly at the radius of the ring of transmitter and receiver. Received signals were measured based on complex envelope parameters. Two signals propagation scenarios were implemented, they were signals of Rayleigh and Rician distributed. In order to calculate the Rayleigh and Rician complex envelope values, there were some parameters involved which were Angle of Arrival (AoA) and velocity of transmitter and receiver that created Doppler effects. The effects of AoA parameter were investigated towards envelope complex values of Rayleigh and Rician according to predetermined various velocities and scatterers' positions were divided into four positions criteria. The simulation result shows that for scheme 2 at velocity 40 m/s, distribution magnitude for Rayleigh is 0,1 and Rician is 0,5. It concludes that Rician distribution always outperforms Rayleigh distribution for all predetermined velocities and this scheme give the largest magnitude over all. This is because of the closest distance between scatterers of transmitter and receiver. Also, certain velocities range over all scatterers' positions, the magnitude of Rayleigh and Rician complex envelope have similar graphic tendency.

Keywords – correlated double ring, Rician, Rayleigh, complex envelope, angle of arrival

I. INTRODUCTION

The communication system of the vehicle to vehicle has made a significant stride recently. Wireless Access for Vehicular (WAVE) technology has been used as a standard for the vehicle to vehicle communication. This technology is a change from IEEE 802.11. WAVE has been used over Intelligent Transport System (ITS) application in short length of distance. Vehicle to vehicle communication or vehicle to communication infrastructure uses frequency of 5,85 – 5,925 GHz [1]. This communication system is known as Vehicular Ad Hoc Network (VANET).

VANET based communication model has been developed as close as the real condition. The VANET modeling is divided into three models i.e. Mobility Modeling, Data Exchange Modeling, and Signal Propagation Modeling. The later model is divided into Deterministic Process and Stochastic Process [2].

One of modeling in Stochastic Process is Ring Model [3]. This modeling was applied to mobile to mobile communication with an assumption that scatterers were circling both structures. The structures were transmitter (TX) and receiver (RX). Scatterers coordinates were randomly positioned and were not moving (static), while TX and RX moved with slow velocity. Communication signals were sent by TX spread out, and hit scatterers around the ring of TX and RX before RX accepted them. This model is known as Correlated Double Ring [4].

The scatterers' randomness positions imposed the randomness of Angle of Arrival (AoA) parameter values. Validation of the model was tested with Auto

Correlation Function (ACF), Rayleigh Distribution and Rician by assigning different K values. The development of the model was based on Mobile to Mobile channel as explained previously [5]. Another modeling used similar conditions, but TX and RX were cars, moved in very high velocity that induced high Doppler effects. It was validated by using Rayleigh and Rician Distribution tested at low up to high velocities and gave a significant result. Measurement over the effects of some scattering on high velocity was another validation test for this model and yielded a significant result as well [6].

In the other paper, this modeling was validated by using second-order statistic parameters such as Average Fade Duration, Level Crossing Rate and Auto Correlation Function [7]. The results have shown that validation according to both parameters gave a valid result.

Those papers [5][6][7] worked on Correlated Double Ring modeling on VANET. However, none of them discussed the correlation between the scatterers' positions at TX and RX with the Complex Envelope values. In this paper, the effects of scatterers' positions on RX ring that created random Angle of Arrival towards received Complex Envelope values were accomplished.

In this research, scatterers position modeling has been added in quadrant circle division. This is to complement previous researches that merely used first order and second order statistic to validate correlated double ring channel. Scatterers' positions on both rings (TX and RX) were divided into 4 regions, their positions on TX ring were set to occupy 1 region only while on RX ring they were set into 4 quadrants of a circle.

Research that discussed the effect of AoA in VANET studied the estimation of AoA on the array antenna to rectify signal quality that received from Global Navigation Satellite System (GNSS) on V2V Communication [8]. The result was AoA values did not correlate with time when RX was dynamic. They used two non-stationary multipath channels models that were validated with autocorrelation function (ACF), time-dependent mean Doppler shift, time-dependent Doppler spread, and the Wigner-Ville spectrum [9]. Channel modeling that utilized AoA in an analysis was conducted with geometrically designed model and mapped diffuse component from scattering object to calculate Doppler Spectrum and AoA values [10].

The other research about AoA modeled the channel with 3D ellipsoidal on urban areas and canyon in M2M communication system. This study yielded a scatterers model that gave joint probability density function of AoA on azimuth and elevation from signals that came towards mobile station [11]. The research that used 2D geometry model regarding AoA on Mobile Communication was conducted by using ellipsoidal model. It studied the effects of scatterers distribution and segregation between AoA parameter and Time of Arrival based on multipath statistic data [12].

The other parts of this paper will discuss: Section II will discuss modeling system based on Correlated Double Ring, regions division schemes and VANET based on Correlated Double Ring concept in Rayleigh and Rician fading channel. Section III will show the result of research. Section IV will discuss about the results and section V in the form of conclusion.

II. RESEARCH METHODS

A. VANET Communications

Vehicular Ad hoc Networks (VANET) is a communication system used by vehicles to communicate amongst vehicles (V2V) or amongst vehicles and infrastructures (V2I). The mobile to mobile communication (M2M) is used in the case of communicating among vehicles. When it turns to communication among vehicles and infrastructures, the mobile to fix or fix to mobile communication is used. According to Doppler concept, vehicles that move fast induce Doppler effects which deteriorate communication system performance. The communication system of this modeling [14] is shown by Fig.1.

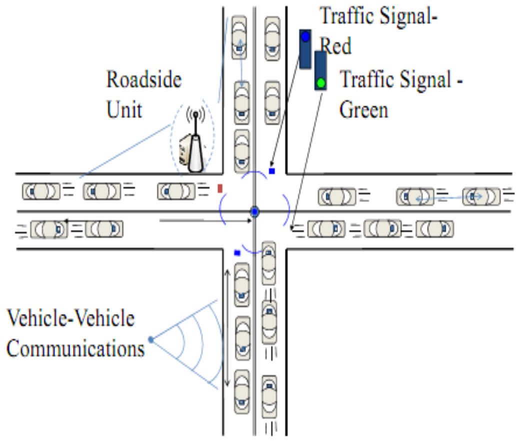


Fig. 1 Communication System VANET

The VANET technology was preceded by the communication system standard which is wireless access in vehicular environments (WAVE). This standard complemented the predecessor standard which is 802.11a that has been adopted and adapted for vehicular based communication system. WAVE uses Dedicated Short Range Communication (DSCR) standard for short length of distance communication. This standard uses IEEE 1609.2 standard for security system. On the physical layer, it uses 802.11p standard. Comprehensive layer division in WAVE technology [15] is described in Fig. 2.

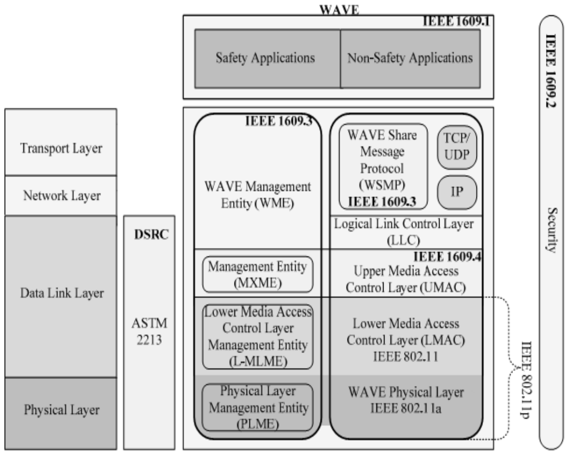
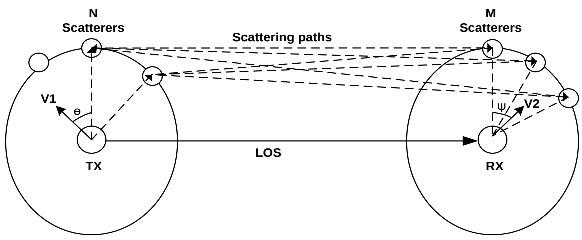
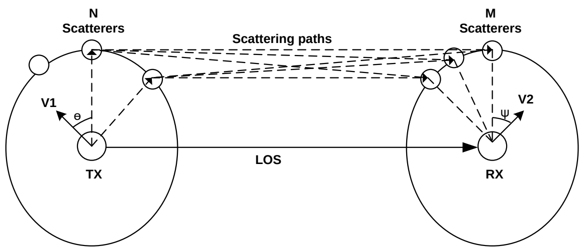


Fig.2. Layer Division in WAVE Technology

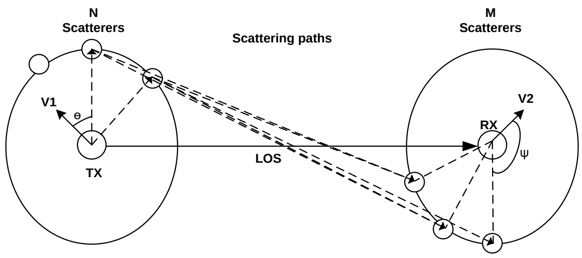
In this research, a VANET modeling system based on OFDM and Correlated Double Ring channel was used. This model was divided into 4 schemes related to scatterers' positions and AoA on the RX ring. The scatterers' positions on the TX ring were set to occupy 1 region only. Schemes division according to scatterers' positions on the RX ring is shown in Fig. 3.



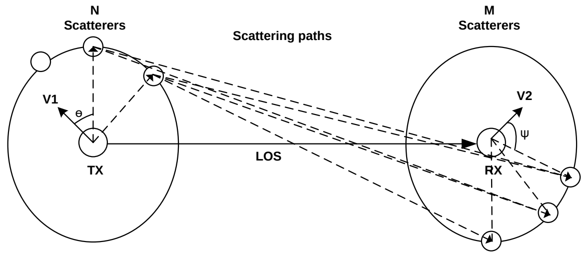
a) *Scheme 1*



b) *Scheme 2*



c) *Scheme 3*



d) *Scheme 4*

Fig.3. System model of position AoA in (a) Scheme 1, (b) Scheme 2, (c) Scheme 3, and (d) Scheme 4

Figure 3 shows that positions of scatterers on TX ring were fixed in the first quadrant as in circle quadrant systems, while the positions of scatterers on RX ring change according to the four proposed schemes. They are (a) scheme 1 with scatterers in the first quadrant, (b) scheme 2 with scatterers in the second quadrant, (c) scheme 3 with scatterers in the third quadrant, and (d) scheme 4 with scatterers in the fourth quadrant.

This figure shows that transmitter and receiver move with velocity V1 and V2 as well. There are N and M scatterers spread out around the ring of TX and RX. Parameter θ_n is angle between V1 and n^{th} scatterers trajectory, where n = 1, 2, 3, …, N, while ψ_m is angle of arrival between V2 and m^{th} scatterers trajectory, where m = 1, 2, 3, …, M. It is assumed that θ_n and ψ_m are random and uniformly distributed over $[-\pi,\pi)$. Therefore, this scattering mobile to mobile channel model was called as "correlated double ring" model.

Figure 4 shows the relative velocity from transmitter V3 when receiver velocity is set to 0. Parameter θ' is the angle between V3 and LOS component. The relative velocity V3 is derived by using geometry and trigonometric formulation as shown below [4]

$$V_3 = \sqrt{\left(V_1.\cos\left(\theta_{diff}\right) - V_2\right)^2 + \left(V_1.\sin\left(\theta_{diff}\right)\right)^2} \qquad (1)$$

$$\theta' = \theta_{send} + \theta_{31diff} \qquad (2)$$

$$\theta_{31diff} = \cos^{-1}\left(\frac{V_1^2 + V_3^2 - V_2^2}{2V_1.V_3}\right) \qquad (3)$$

where V1 and V2 are transmitter and receiver velocity in M2M communication. Parameter θ_{diff} is the angle between vector V1 and V2; θ_{send} is the angle between vector V1 and LOS component; θ_{31diff} is the angle between vector V3 and V1. Hence, LOS component can be formulated as below:

$$LOS = \sqrt{K}\,\exp\left(j\left(2\pi f_3 t\cos\left(\theta'\right) + \phi_0\right)\right) \qquad (4)$$

where K is comparison between specular and scattering power, while ϕ_0 is the initial phase distributed over [-π,π). This LOS component is formulated for highway. This research [13] had specifically observed the LOS parameter on the highway, urban areas and rural areas at day and night time.

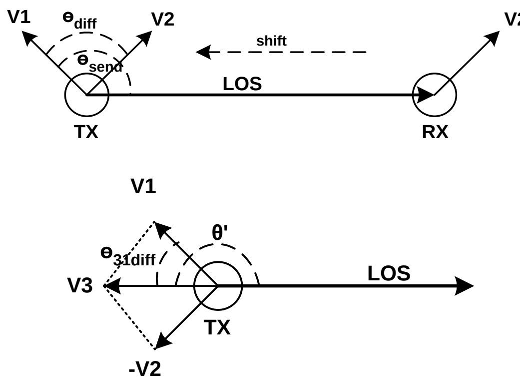


Fig.4. Definition of angle parameters

B. Rayleigh Fading Channel Model

Rayleigh fading channel used is formulated as follows [7]

$$Y(t)=\sqrt{\frac{1}{NM}}\left\{\sum_{n,m=1}^{N,M}\exp\left(j\left(2\pi f_1 t\cos\left(\alpha_n\right)+2\pi f_2 t\cos\left(\beta_m\right)+\phi_{nm}\right)\right)\right\} \tag{5}$$

where $f_1=\frac{v_1}{\lambda}$ and $f_2=\frac{v_2}{\lambda}$ are maximum Doppler frequencies yielded from the movements of TX and RX, N and M are number of scatterers around TX and RX, θ_{nm} is uniformly distributed random phase over [-π,π), with

$$\alpha_n=\frac{2n\pi-\pi+\theta_n}{4N} \tag{6}$$

and

$$\beta_m=\frac{2\left(2m\pi-\pi+\psi_m\right)}{4M} \tag{7}$$

C. Rician Fading Channel Model

Based on Rayleigh formula and LOS component, the Rician formula can be derived as follows

$$Z(t)=\frac{Y(t)+\sqrt{K}\exp\left(j\left(2\pi f_1 t\cos\left(\theta'\right)+\phi_0\right)\right)}{\sqrt{1+K}} \tag{8}$$

The complex envelope Z(t) has real and imaginary part as is represented below

$$Z(t)=x(t)+jy(t) \tag{9}$$

Real part is symbolized by x(t) and y(t) describes the imaginary part. The magnitude of complex envelope R(t) is calculated as follows

$$R(t)=|Z(t)|=\sqrt{x(t)^2+y(t)^2} \tag{10}$$

The angle between real and imaginary part is calculated as follows

$$\theta_t=tan^{-1}\left(\frac{y(t)}{x(t)}\right) \tag{11}$$

Hence, real and imaginary values become

$$x(t)=Re\{Z(t)\}=R(t)\,cos(\theta_t) \tag{12}$$
$$y(t)=Im\{Z(t)\}=R(t)\,sin(\theta_t) \tag{13}$$

Hence, the magnitude can be calculated by using formula

$$Z(t)=R(t).e^{j\theta_t} \tag{14}$$

III. RESULTS

Based on the simulation result, the magnitudes comparison between Rician and Rayleigh fading channel on 4 schemes were shown in Fig. 5 to Fig. 8. In the simulation, values of parameters were predetermined as follows

1. Carrier Frequency = 5,8 GHz
2. Initial Phase ϕ_0 = 30˚
3. Specular Power = 10 dBm
4. Scattering Power = 4 dBm
5. Angle of Departure V1 = 45˚
6. Angle of Arrival V2 = 45˚
7. Number of Scatters M and N = 10
8. Sampling Period = 5 ms
9. Velocity of Electromagnetic Wave (c) = 3 x 10^8 m/s

In all schemes, TX and RX were set to move with same velocity. The range of vehicle' velocities were managed carefully starting from low to high speed. They were 20 m/s for low speed and 100 m/s for high speed. The other values were set between low and high speed with 10 m/s step. Then magnitude for each of speed for Rayleigh and Rician distribution was calculated and plotted to show the communication system performance.

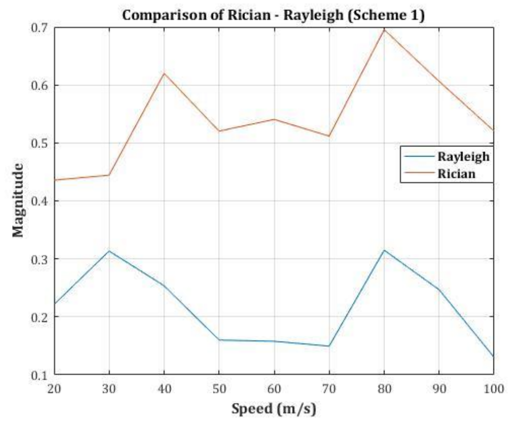


Fig.5. Magnitude Values Of Received Signal Of Rician And Rayleigh Fading In Scheme 1

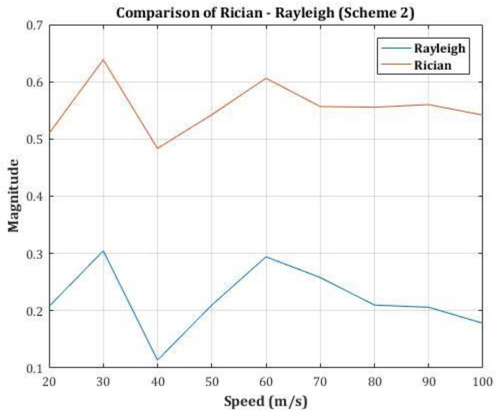


Fig.6. Magnitude Values Of Received Signal Of Rician And Rayleigh Fading In Scheme 2

Number of scatterers on the transmitter (M) had same amount on the receiver (N) but the scatterers' positions on the receiver were distributed into 4 different regions. The objective of the distribution was to give clear insight of the simulation result when velocities and scatterers' positions were set this way.

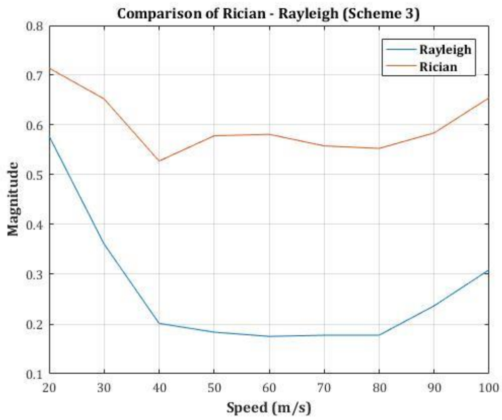


Fig. 7. Magnitude Values Of Received Signal Of Rician And Rayleigh Fading In Scheme 3

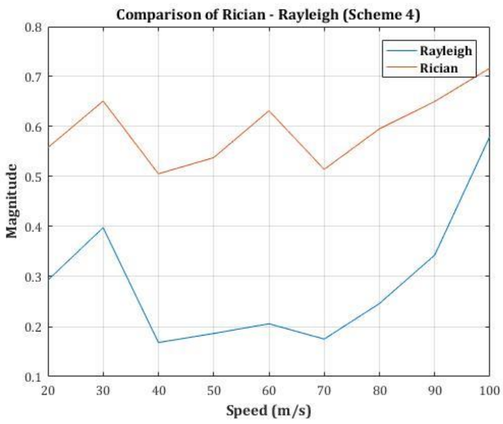


Fig. 8. Magnitude Values Of Received Signal Of Rician And Rayleigh Fading In Scheme 4

IV. DISCUSSION

In order to calculate magnitude value of complex envelope signal, formula (5), (8) – (14) were used. The magnitudes of Rayleigh fading channel had values lower than Rician fading channel. The LOS component in Rician fading channel over received signals damped the magnitudes. The equation (8) shows that Rician fading channel incorporates Rayleigh and LOS component.

The distance between scatterers on RX ring and scaterrers on TX ring can be used to justify the quality of propagated signal. Referring to Fig.3, scheme 2 had biggest average magnitude value compare to the other schemes. The order was scheme 2, scheme 3, scheme 1 and scheme 4. Farther distance yielded more damped average magnitude of propagated signal.

In the Fig.5, the comparison between Complex Envelope of Rician and Rayleigh asserted that in the velocity of 70 – 100 m/s, their multipath had similar trends when stepped up and stepped down. Overall, complex envelope values on Rician were higher than Rayleigh.

In the Fig.6, the result of scheme 2 was shown. Alike previous scheme, when TX and RX moved over velocity of 20 – 100 m/s the multipath had similar trends in the complex envelope form. When vehicles moved over velocity 60 – 100 m/s, magnitudes had decreased constantly. The magnitudes that went through Rician tend to have values higher than multipath that Rayleigh characterized.

Figure 7 was the simulation result for scheme 3. According to the result, for velocity of over 20 – 40 m/s the magnitudes had tendency to decrease then increased in the velocity of over 80 – 100 m/s. Meanwhile, Fig. 8 as the result of scheme 4 yielded similar trend of multipath for both of fading channel in the velocity range of 20 – 40 m/s. While in the velocity range of 70 – 100 m/s, the magnitudes increased constantly.

V. CONCLUSION

The conclusion of this research is magnitudes of complex enveloped of distributed Rician multipath always outperforms the distributed Rayleigh multipath in all proposed schemes. It proves that the largest magnitude happens in 2nd scheme because of the closest distance between scatterers of transmitter and receiver. This result offers another view point on how the analysis of performance of correlated double ring channel model for VANET communication can be conducted.

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