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Performance Comparison of Rayleigh and Rician Fading Channel Models: A Review

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Abstract—*A performance comparative analysis of Rayleigh and Rician fading channel models has been made by using MATLAB simulation in terms of different performance evaluating parameters. These parameters include source velocity and outage probability . In the multi path fading environment, source velocity and outage probability are the two important performance evaluating parameters for the design of digital communication system. On comparing the two channel models, Rayleigh model is observed to be the more accurate model that can be considered for developing multipath fading channel model.*

Keywords—*Channel models, fading channels, Rayleigh fading, Rician fading, outage probability,*

I. INTRODUCTION

A tremendous development has been made in the wireless industry by improving the infrastructure to meet the demands of the users and significant advancements for the implementation of wireless technology have been made. However, some unavoidable conditions attenuate the signal energy and made hindrances for obtaining the best desired outcomes from the system [1]. To transmit the information from source to destination, a communication channel or a radio link is used between the transmitter and receiver. This communication channel can be either a simple line-of-sight or the one in which the transmission or reception of data is severely hurdled by the obstacles like buildings, mountains etc and this results in multipath fading[2]. Because of the randomness of wireless channel they differ from the wired channels. Radio communications are more prone to fading and multipath effects. These effects were first seen in troposcatter systems in the 1950s and early 1960s. The behavior of a communication channels is defined by certain factors such as the relative motion of transmitter and receiver, weather conditions etc. There has been a significant research activity over the past few years to analyse such channels located at different places, this research led to the introduction of various models for both indoor and outdoor environment [3]. To determine the signal strength at the receiver, two traditional models are used, one is large scale model that gives the average value of signal strength at the receiver on the basis of the distance between transmitter and receiver. The other one is a small scale model that indicates the local variations of the average signal strengths [8-13]. In case of a lognormal model, the measured signals are normally distributed about the mean of a signal received and the large scale fading effects for the mobile channel model are suitably emulated by these levels. It is popularly accepted that the shadow channel is accurately represented by the log normal Rayleigh model while as for the unshadowed channel, Rician channel model is most appropriate[9].

The factors on which the error performance modeling of the wireless channels is inherently dependent are the radio propagation mode such as reflections, line-of-sight, diffractions and scattering resulted by an object having the dimensions of the order of wavelength [1]. There are a number of factors that are leading to the disturbance in wireless channels. One of the most prominent factor in the wireless environment that is the major obstacle to reliable communication is fading, which occurs when a number of signals along different paths arrive at the receiver at different times. This multipath component on reaching the receiver will be having different attenuations and delays and might get added at the receiver either constructively or destructively. A shift in frequency is also observed if the phase difference results due to the movement of the system. However in case of multipath propagation the movement of the transmitter or receiver or both and the bandwidth of the signal are the parameters that affect the fading in multipath delay nature of the channel, which is computed by the delay spread and coherence bandwidth. Also, Doppler spread and Coherence time are used to quantify the varying nature of the channel resulted by the movement [11]. The fading is usually modeled it by Rayleigh fading model. The focus on the throughput problem at vehicular space made the Rayleigh fading model very challenging. Rayleigh fading model involves the fading that results from multipath reception. These fading models assumes that according to a Rayleigh distribution the magnitude of a signal after passing through a transmission medium fades or varies randomly. On the other hand according to a Rician model the pharos sum of two or more dominant signals such as line of sight plus a ground reflection can result in another dominant signal. The combine dominant signals that results from the phasor sum of two other dominant signals are mostly considered as deterministic (fully predictable process). A satellite channels are modelled by using these well known supposition.

The rest of paper is organised as follows. Section II presents an overview of Rayleigh fading cahnnel model. Section III explores the Rician fading channel model. Section IV gives the performance comparison OF Rayleigh and Rician fading channel models and Section V concludes the work.

II. Rayleigh fading channel model

The term Rayleigh fading channel refers to a multiplicative distortion h(t) of the transmitter signals s(t), as in y(t) is equal h(t).s(t)+n(t), wire y(t) is the received waveform and n(t) is the noise[12] . In an environment where there is non-line-of-sight communication between a transmitter and receiver, the signal before arriving at the receiver undergoes a number of phenomenons like refraction, refraction and diffraction that are caused by the objects in the environment. This type of propagation environment is called as Rayleigh fading, and a specialized stochastic fading model for this type of fading environment is known as a Rayleigh distribution model. The factors that influence the channel fading includes the moving speed of the receiver or the transmitter or both[10]. Besides receiving the dominant signals over one line-of-sight path the mobile antenna receives a number of reflected and scattered signals due to the different path lengths.

The probability density function(PDF) of the received signal envelope *f*(r), can be shown to be relay given by;

$$f(r) = \frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}}$$

where σ^2 is the time-average power of the received signal before the envelope detection.

III. Rician fading channel model

Rician fading is also caused by multipath propagation . this fading occurs when one of the paths is wrongly line of sight. the strongest component goes into deeper fade compared to the multipath components. In Rician fading the amplitude gain is characterized by a Rician distribution.

Since Rayleigh fading is a specialized model for stochastic fading having no line-of-sight signal, it is sometimes considered as special case of Rician fading. However Rician fading is itself a case of two –wave with diffused forward (TWDP) fading. This kind of signal is approximated by Rician distribution [4,]. As the dominating component run into more fade the signal characteristic goes from Rician to Rayleigh distribution [16,19]. The probability density function of Rayleigh fading is,

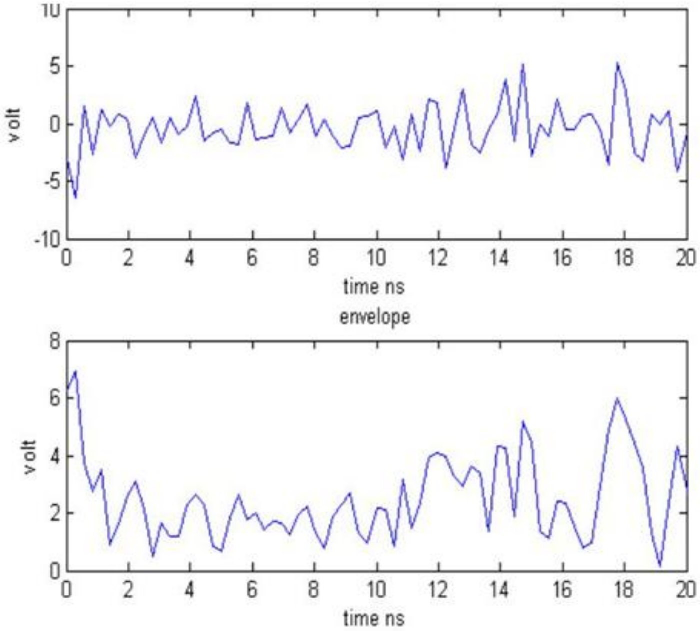
$$f(r) = \frac{r}{\sigma^2} e^{-\left(\frac{r^2+k_d^2}{2\sigma^2}\right)} I_0\left(\frac{rk}{\sigma^2}\right)$$

where I_0 (0) the 0^{th} order is modified Bessel function of the first kind.

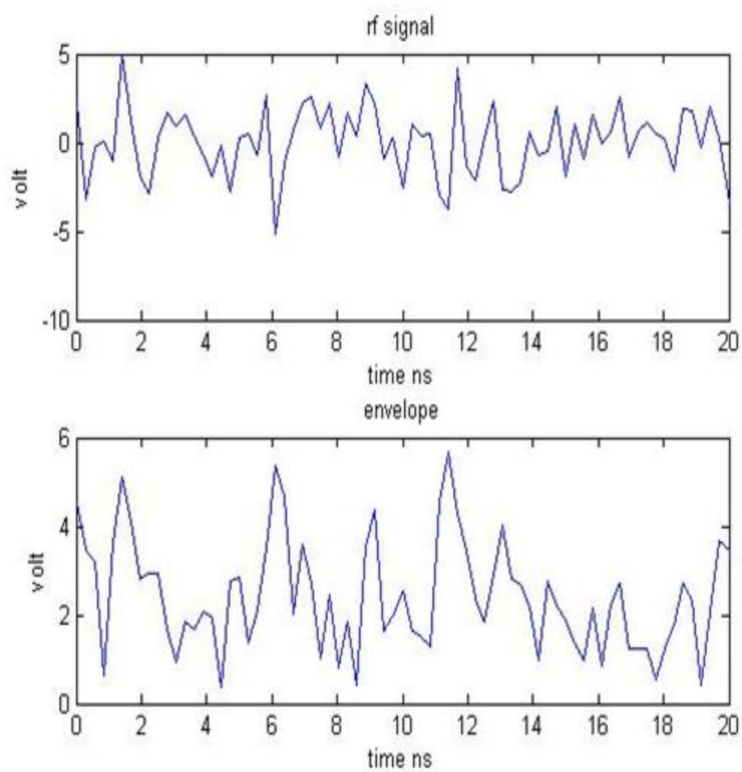
IV. Comparative study of Rayleigh and Rician fading channel model

A) Rayleigh fading channel model

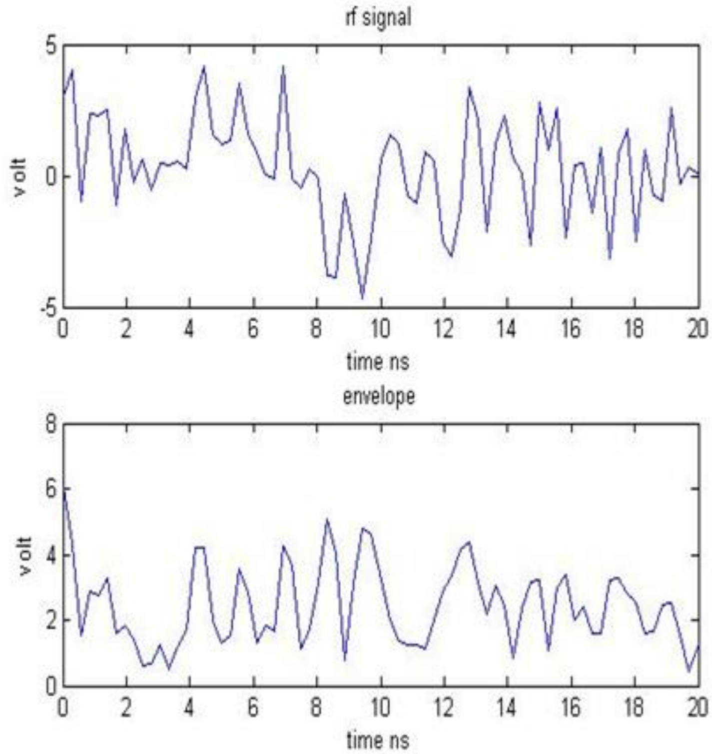
Outage probability is defined as the ratio of the number of samples of the signals are as follows:



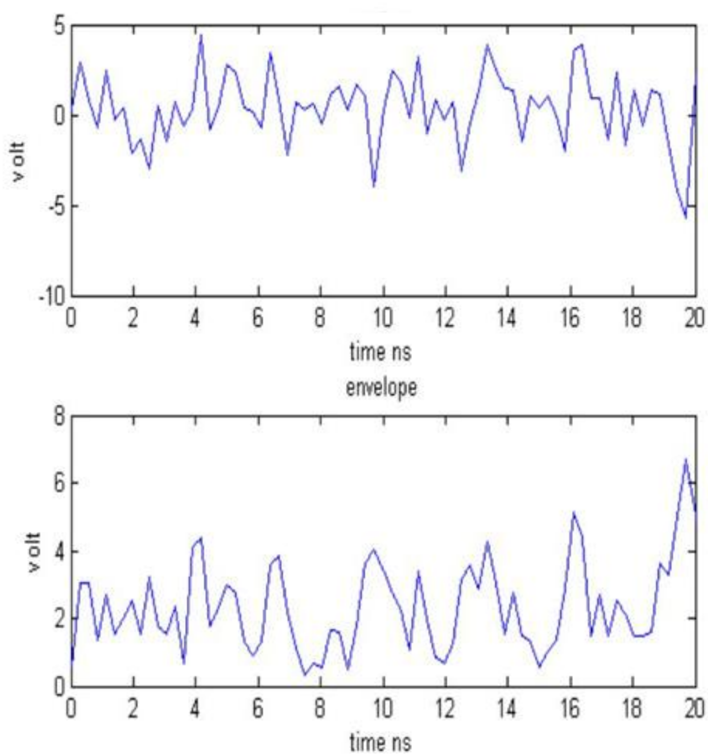
(a)



(b)



(c)



(d)

Fig. 1: Simulated radio frequency signal by using proposed algorithm for Rayleigh fading channel for (a) stationary source, (b) at source velocity 10 m/s, source velocity 25m/s, and (d) at source velocity 50m/s

when taking the source velocity in consideration as we go on increasing the speed of user from 0m/s to 5m/s, the amount of fading is increased in the signal envelope upto some threshold (2.3v). as the speed is increased, the more and more signal goes below the threshold hence the fading is the most disturbing factor in wireless communication.

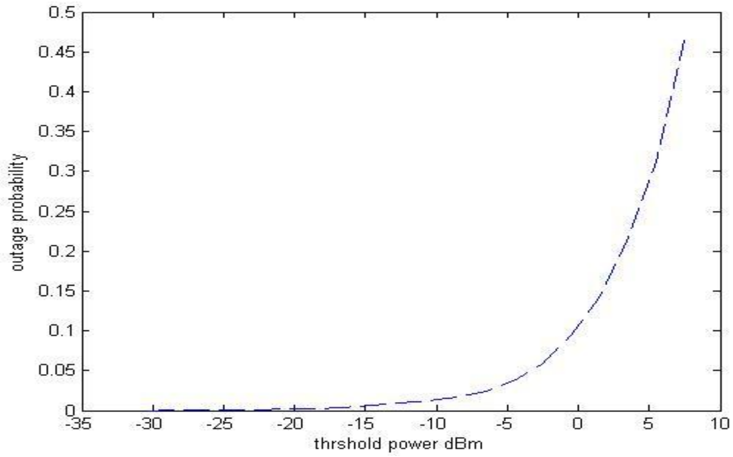
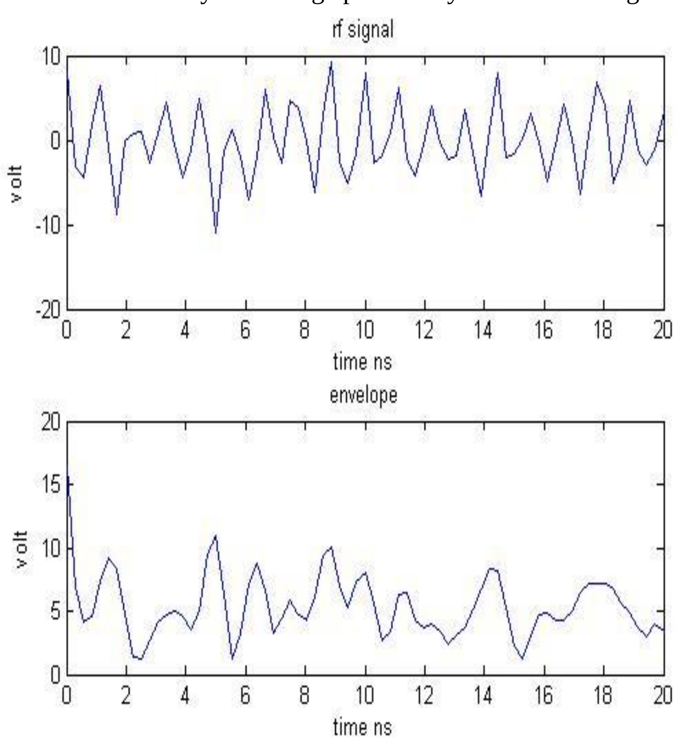


Fig. 2: Outage probabilities for the Rayleigh fading channel

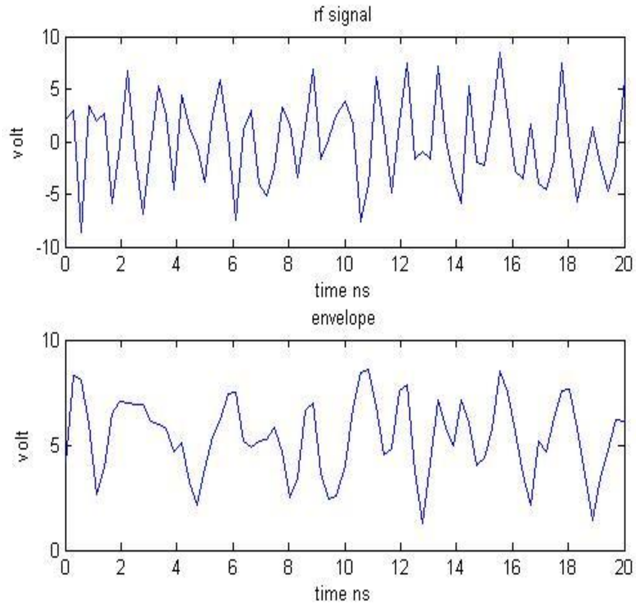
Fig.2 indicates that the outage probability is directly proportional to the threshold power i.e, as we increase the threshold power the outage probability is increased or we can say that the probability of detecting the signal in a better way is decreased.

B) Rician fading channel model

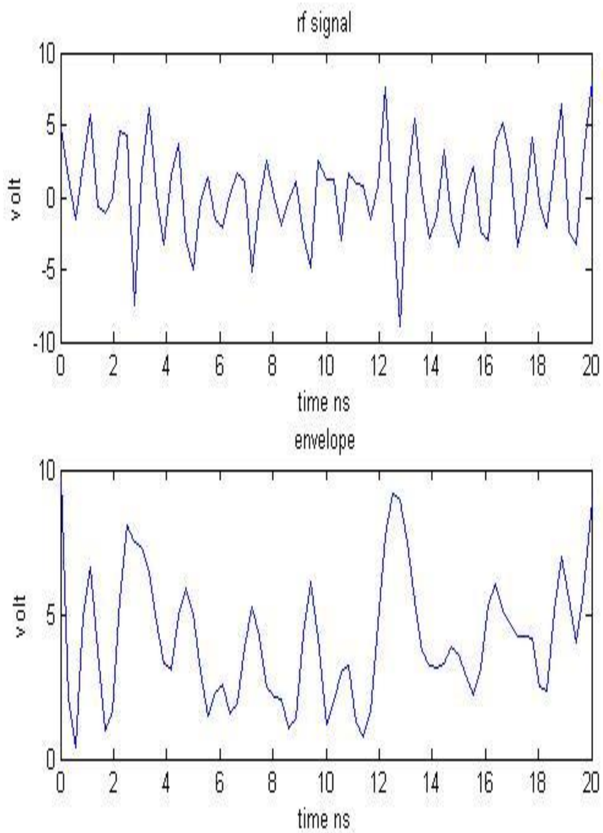
The graphs obtained for source velocity and outage probability for rician fading channel model are as follows:



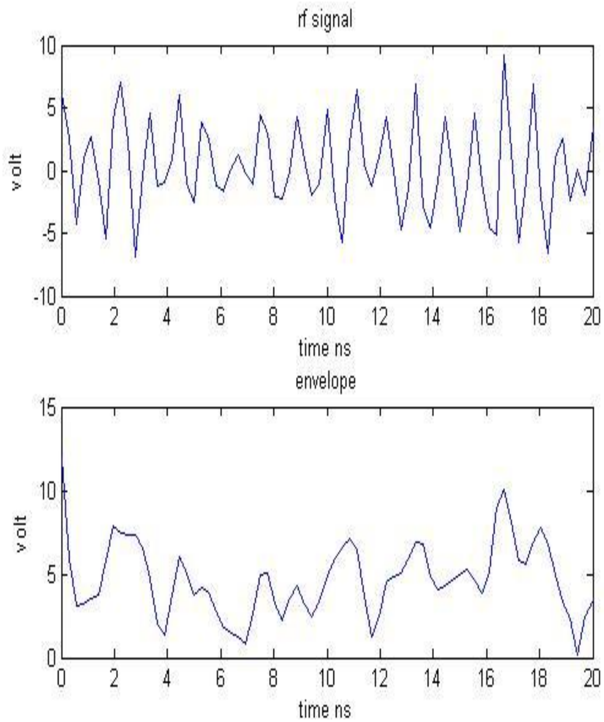
(a)


rf signal
volt
time ns
envelope
volt
time ns

(b)


rf signal
volt
time ns
envelope
volt
time ns

(c)



(d)

Fig. 1: Simulated radio frequency signal by using proposed algorithm for Rayleigh fading channel for
(a) stationary source, (b) at source velocity 10 m/s,
(c)source velocity 25m/s, and (d) at source velocity 50m/s

when taking the source velocity in consideration as we go on increasing the speed of user from 0m/s to 5m/s, the amount of fading is increased in the signal envelope upto some threshold (2.3v). as the speed is increased, the more and more signal goes below the threshold hence the fading is the most disturbing factor in wireless communication.

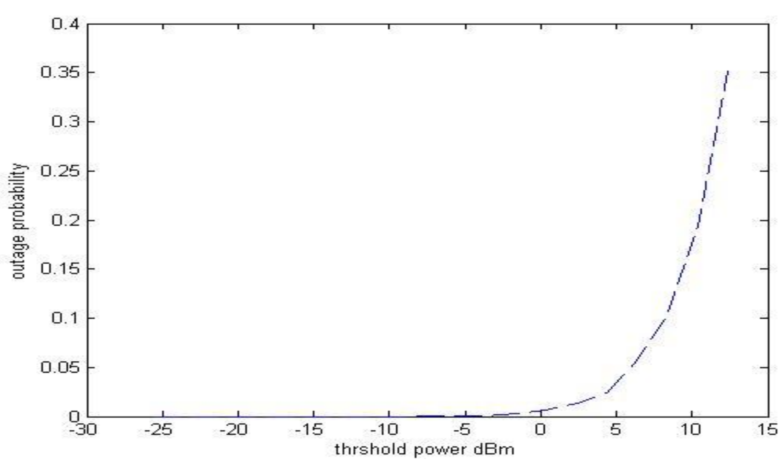


Fig. 4: Outage probabilities for the Rayleigh fading channel

Fig.4 indicates that the outage probability is directly proportional to the threshold power i.e. as we increase the threshold power the outage probability is increased or we can say that the probability of detecting the signal in a better way is decreased.

In the below table the Rayleigh and rician fading channel model have been compared in terms of their outage probabilities
Table1: performance comparison of Rayleigh and Rician fading channel in terms of the outage probability

Mobile velocity(m/s)	Outage probability(Rayleigh)	Outage probability(Rician)
0	0.19149	0.09311
2	0.19193	0.09312
4	0.19246	0.09314
6	0.19303	0.09346
8	0.19339	0.09350

V. Conclusion

In this paper, we have presented a comparative study of Rayleigh and Rician fading channel model in terms of the performance evaluating parameters-source velocity and outage probability. From the comparison we have concluded that as we increased the speed of user from 0m/s to 5m/s, the amount of fading is increased in the signal envelope upto some threshold (2.3v). as the speed is increased, the more and more signal goes below the threshold hence the fading is the most disturbing factor in wireless communication. We have also observed that outage probability in rician fading channel is lower then that of a Rayleigh fading channel. The increase in outage probability results from the line-of-sight path components in rician fading model.

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