International Journal of Scientific and Technical Advancements

ISSN: 2454-1532

Performance Comparison of Wireless Fading Techniques Using MATLAB Implementation

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***Abstract*—**An effort has been made to illustrate the performance comparison of the Rayleigh, Rician and Nakagami fading channel models by using MATLAB implementation in terms of source velocity and number of multiple paths. Algorithms for the Rayleigh, Rician and Nakagami-m fading channels have been developed, which computes the envelope and pdf. The parameters such as source velocity and pdf play a very important role in the performance analysis and design of the digital communication systems over the multipath fading environment.

I. Introduction

The development of the wireless technology has opened several new paths for its implementation, however some unavoidable circumstances attenuate the signal energy and make barriers to achieve the optimum results from the system [1]. The radio link between the transmitter and receiver varies from simple line-of-sight to one that is severely obstructed by the buildings, mountains, etc. and hence suffers from severe multipath fading [1-3]. However, the mobile channels are very different from the stationary as well as predictable wired channels, because of their randomness. There are several factors which determine the behaviour of a channel such as terrain features between the transmitter and receiver, the speed of transmitter and receiver, weather conditions etc. One of the most disturbing aspects in the wireless communication is fading, which is present when there are several multipath components and these components arrive at the receiver at slightly different times. If there is movement in the system then there is also phase difference between the received components, which leads to shift in the frequency [2]. However, in the multipath propagation, the movement of the transmitter/receiver or both and bandwidth of the signal are the factors that influence the fading and multipath delay nature of the channel, which is quantified by the delay spread and coherence bandwidth [4]. With the incorporation of computers, it has become much easier to demonstrate some of the concepts of this new and exciting field of wireless communication.

This paper developes an algorithm for the Rayleigh ,Rician and Nakagami-m fading in a vehicular environment.

The rest of the paper is organised as follows: Section II shows the block diagram of the system, section III discusses the performance of the Rayleigh fading and proposes algorithm. Section IV explores the Rician fading and developed an algorithm for it. Section V discusses the Nakagami Fading and offers an algorithm. Section VI draws a performance comparison between Rayleigh, Rician and Nakagami-m fading channel.

II. Block Diagram

The RF signal is generated using Weibull Distribution and Uniform distribution. The RF signal thus generated is modulated using 64-bit QAM [7]. This modulated signal is transmitted over the channel (either Rayleigh, rician or nakagami-m). The transmitted signal undergoes attenuation due to multipath components, Doppler shit, noise etc. The received signal is demodulated into in-phase and quadrature component. The envelope of the demodulated signal is detected using envelope detector.

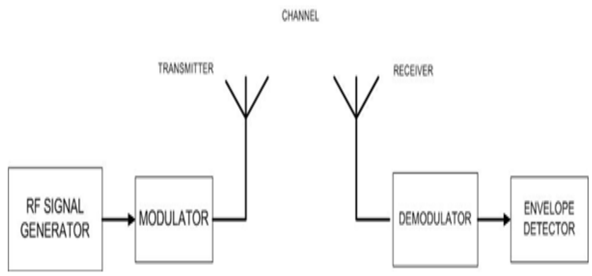

Fig. 1. Block diagam of the system.

Performance Analysis of Rayleigh Fading

In this section, the algorithm for Rayleigh fading has been proposed [1]. The proposed algorithm completes its functioning in various steps, where step-1 declares the various variables used in the proposed algorithm and step-2 is associated with the generation of random RF signal. In step-3, an envelope is detected for received Rayleigh signal using QAM-64 amplitude demodulation. Finally, the step-4 computes the probability density function using the theoretical and simulated methods [2].

Algorithm: Rayleigh Fading Channel

For the Rayleigh fading channel, all the variables such as input velocity (V), number of multiple paths (numpath), time array (t), carrier frequency(f_c), Sampling frequency (f_s),Radian frequency (ω_c), Sampling periods (T_s), pdf of Rayleigh(Fray), Rayleigh envelope (evn_ray), are declared. After the declaration, a random RF signal is generated using weibull

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and uniform distributions. Same RF signal is used for other fading techniques (Rician and Nakagami-m).

The received signal is demodulated into its in-phase and quadrature component. The envelope of the received signal is calculated using the formula:

$$r(t) = \sqrt{I^2(t) + Q^2(t)}$$

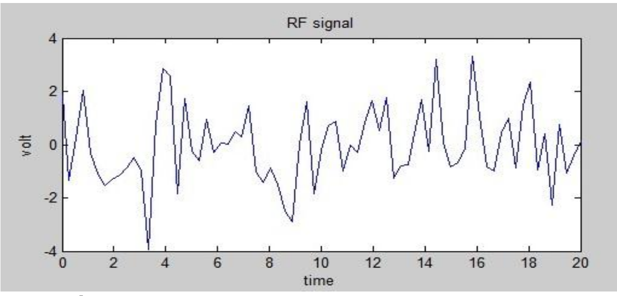
The probability density function (pdf) of the received signal amplitude (envelope), f(r) for Rayleigh distribution is:

$$f(r) = \frac{r}{\sigma^2} \exp\left\{-\frac{r^2}{2\sigma^2}\right\} \qquad r \geq 0$$

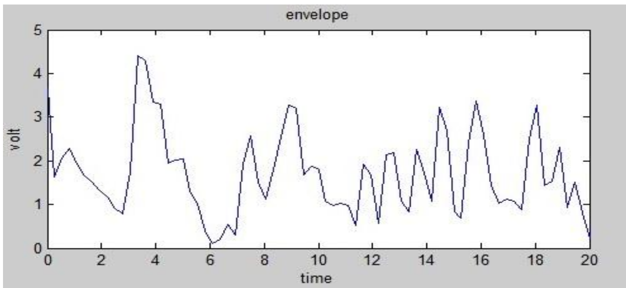
where r is the envelope and σ is the rms value of the received signal before envelope detection [4].

Simulation Results for Rayleigh Channel

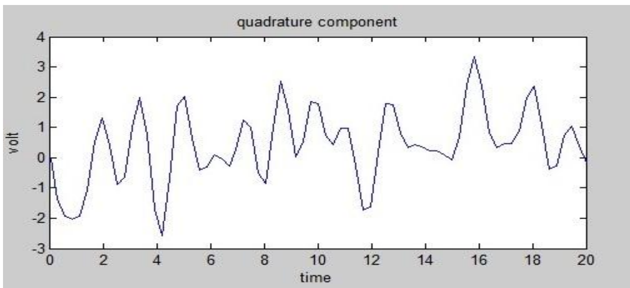
Figure 2, shows the RF signal and its envelop plot. As the speed of the user is increased from 0 m/s to 50 m/s, we can see that the amount of fading is increased in the signal envelop. In this simulation, we have set the threshold to 2.3 volt. As we increase the speed, more of the signal goes below the threshold. Hence the fading is one of the major problems in case of wireless communication.



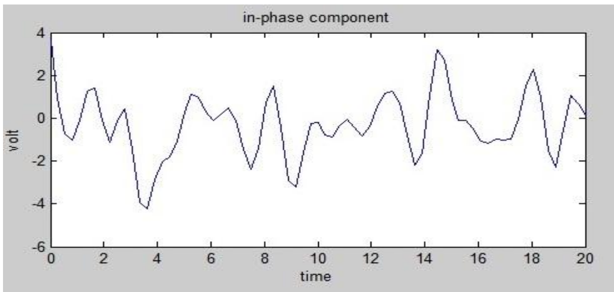
(a) RF signal.



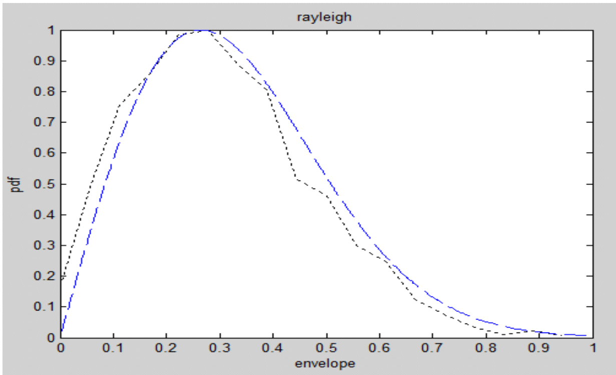
(b) Envelope.



(c) Quadrature component.



(d) In-phase Component.



(e) Probability density function.

Fig. 2. shows the RF signal and its envelop plot.

III. PERFORMANCE ANALYSIS OF RICIAN FADING

When there is a dominant stationary (nonfading) signal component present, such as a line-of-sight propagation path, the small-scale fading envelope distribution is Ricean. In such a situation, random multipath components arriving at different angles are superimposed on a stationary dominant signal. At the output of an envelope detector, this has the effect of adding a dc component to the random multipath. The effect of a dominant signal arriving with many weaker multipath signals gives rise to the Ricean distribution. As the dominant signal becomes weaker, the composite signal resembles a noise signal which has an envelope that is Rayleigh. Thus, the Ricean distribution degenerates to a Rayleigh distribution when the dominant component fades away.

In the presence of such a path, the transmitted signal can be represented as:

$$s(t) = \sum_{i=1}^{N-1} a_i \cos(\omega_c t + \omega_{di} t + \phi_i) + k_d \cos(\omega_c t + \omega_d t)$$

where the constant kd is the strength of the direct component, ω_d is the Doppler shift along the LOS path, and ω_{di} are the Doppler shifts along the indirect paths [5].

The derivation for the probability density function here is similar to that for the Rayleigh case. If N is sufficiently large, then by virtue of the central limit theorem, the inphase and quadrature components I(t) and Q(t) are independent Gaussian processes which can be characterized by their mean and autocorrelation function. In the Rician case, the mean values of I(t) and Q(t) will not be zero because of the presence of the direct component. The envelope r(t), of I(t) and Q(t) is

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obtained by demodulating the signal s(t) [2]. The envelope in this case has a Rician density function given by:

$$f(r) = \frac{r}{\sigma^2} exp\left\{-\frac{r^2 + k_d^2}{2\sigma^2}\right\} I_0\left(\frac{r k_d}{\sigma^2}\right) \qquad r \geq 0$$

where $I_0(\ )$ is the zeroth-order modified Bessel function of the first kind.

Proposed Algorithm for Riciam Fading

In this section, an algorithm for the Rician fading is developed [2]. The proposed algorithm completes its functioning in four different steps where ist three steps are similar as above, because same RF signal is used. Finally, the step-4 calculates the probability density function.

Simulation Results for Rician Fading

As the same signal is generated for this fading also ,so both the components and envelope as well as RF signal readings will be same as shown above in Rayleigh.

The probability density function plot for the Rician distribution will be like shown in the Fig. 3.

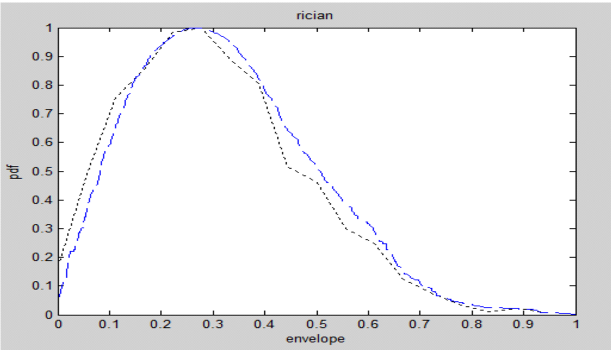

Fig. 3. Pdf of Rician distribution.

IV. Nakagami-m Distribution

It is possible to describe both Rayleigh and Rician fading with the help of a single model using the Nakagami-m distribution . Nakagami-m fading occurs, for instance, for multipath scattering with relatively large delay-time spreads, with different clusters of reflected waves. Within any one cluster, the phases of individual reflected waves are random, but the delay times are approximately equal for all waves. As a result, the envelope of each cumulated cluster signal is Rayleigh distributed [6]. The fading model for the received signal envelope, proposed by Nakagami-m, has the pdf given by:

$$f(r) = \frac{2m^m r^{2m-1}}{\Gamma(m)\Omega^m} exp\left\{-\frac{mr^2}{\Omega}\right\} \qquad r \geq 0$$

where $\Gamma(m)$ is the Gamma function, and m is the shape factor given by

$$m = \frac{E^2\{r^2\}}{E\{[r^2 - E(r^2)]^2\}}$$

The parameter Ω controls the spread of the distribution and is given by

$$\Omega = E\{r^2\}$$

Proposed Algorithm for Nakagami-m Fading

In this section, an algorithm for the Nakagami fading is developed [2]. The proposed algorithm completes its functioning in four different steps where 1st three steps are similar as above, because same RF signal is used. Finally, the step-4 calculates the probability density function.

Simulation Results for Nakagami-m Fading

As the same signal is generated for this fading also ,so both the components and envelope as well as RF signal readings will be same as shown above in Rayleigh.

The probability density function plot for the Nakagami-m distribution will be like shown in the Fig. 4.

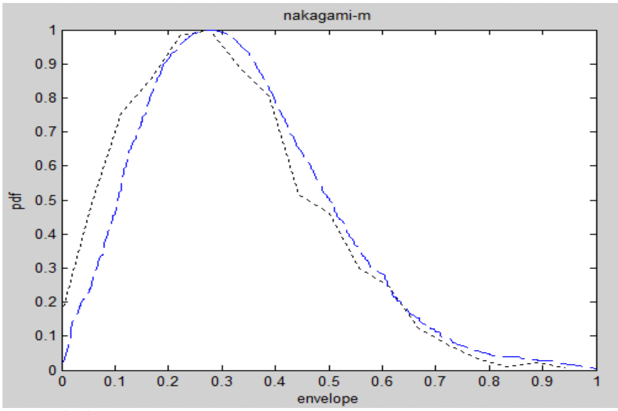

Fig. 4. Pdf of Nakagami distribution.

V. Performance Comparison

In this section, a graphical as well as mathematical comparison has been drawn. For the graphical comparison, the probability density functions of all the three distributions are displayed together as shown in Fig. 5.

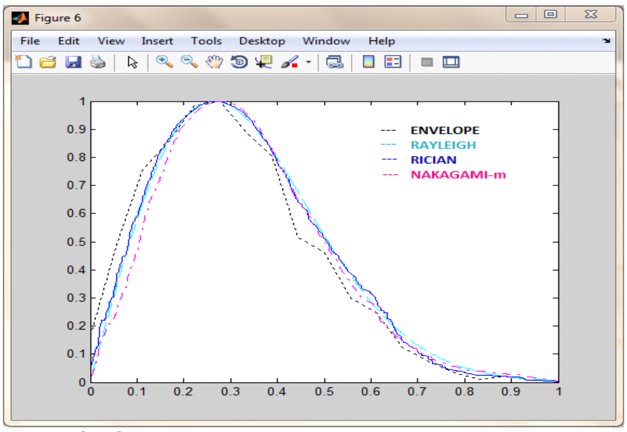

Fig. 5. Graphical comparison.

Since from the graphical comparison, it is difficult to conclude the performance of which fading channel is the best, mathematical comparison using CHI-SQUARE test has been drawn. The values of chi-square test are calculated for different velocities and same number of multipath components.

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Mobile Velocity (m/s)	Rayleigh Fading	Rician Fading	Nakagami-m
10	21.8637	23.71573	25.86377
20	12.90941	13.96939	16.98860
25	21.05159	14.09317	21.13052

The chi-square value for 20 degrees of freedom and 5% level of significance, is compared with the chi-square test value of Rayleigh, Rician and Nakagami fading channels and the error is calculated. The fading channel, whose chi-square test value lies more close to the predefined value has the best performance.

Considering velocity as 10 m/s, degrees of freedom as 20 and 5%level of significance the errors have been calculated as follows:

Fading Channel	Test Result	Predefined Value	Error
Rayleigh	21.8637	31.410	9.5463
Rician	23.71573	31.410	7.69427
Nakagami-m	25.86377	31.410	5.54623

VI. Conclusion

In this paper, simulation of Rayleigh, Rician and Nakagami-m Distribution fading channel models in vehicular environment for respective probability density functions and comparison between the respective probability density functions has been demonstrated. From the simulation results, it has been concluded that as the vehicle speed of user is increased, the amount of fading is increased in the signal envelope. Therefore, as the speed increases, more of the signal goes below the threshold and the amount of fading increases. Simulation of the Rayleigh, Rician and Nakagami-m fading channels in terms of the pdf by using MATLAB simulation for different received signals and comparison of these values to those calculated using chi-square test is done. Dynamically changed multipath and Doppler effects are the main causes behind the degradation of the channel capacity.

Even after the degradation in the channel capacity due to Doppler Effect, it has been concluded that some of the fading models are better than the others. By comparing these models, the better distribution can be further used to enhance the channel capacity. This can be done by using filters to reduce the interfering noise added to the received signal. Instead of using FIR filters, filters with higher order and better efficiency such as matched filters can be used. Along with using better filters, better modulation techniques can also be employed such as 128-QAM or 256-QAM. The distribution channels can be enhanced using these techniques to reduce the phenomenon of fading.

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