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Parametric Comparison of various Fading Channels using MATLAB Simulation

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Abstract— *Fading is caused by reflection, diffraction and scattering of transmitted signal so that multiple copies of the signal with varying delays can be received at the receiver with different phases.*

We have evaluated the performance of transmission modes by calculating the probability of Bit Error Rate (BER) versus the Signal Noise Ratio (SNR) under the various wireless channel models i.e. Gaussian, Rayleigh, Rician and Nakagami. We consider the data modulation and data rate to analyze the performance that is BER vs. SNR. We also consider multipath received signals. The simulation results had shown the performance of transmission modes under different fading channel models. Based on simulation results, we observed that some transmission modes are not efficient for digital communication.

Keywords – Fading, Gaussian, Rayleigh, Rician and Nakagami

I. INTRODUCTION

The performance of wireless communication devices needs to be evaluated by considering the transmission characteristics, wireless channel parameters and device structure. Also, performance of data transmission over wireless channels is well captured by observing their BER, which is a function of SNR at the receiver. Several models have been proposed and investigated to calculate SNR. All such models are function of the distance between the transmitter and the receiver, the path loss exponent and the channel gain. Several probability distributed functions are available to model a time-variant parameter i.e. channel gain. We have presented the four important and frequently used distributions in this paper. Those are Gaussian, Rayleigh and Rician and Nakagami models. The signal is detected and decoded by employing several replicas of the received signal. So, we consider multilink receiver structure.

As per IEEE 802.11 standard, each communication device should use a wireless transmission technique among Orthogonal Frequency Division Multiplexing (OFDM), Direct Sequence Spread Spectrum (DSSS), Frequency Hopping Spread Spectrum (FHSS).

1.1 WIRELESS CHANNEL MODELING

Wireless communication is one of the most active areas of technology development and has become an ever-more important part of our everyday life. Hence,simulation of wireless channels accurately is very important for the design and performance evaluation of wireless communication systems and components. Fading or loss of signals is a phenomenon that related to the Wireless Communications Field. This leads us to the fading models describing the fading patterns in different environments and conditions. As no model can perfectly describe an environment, they strive to obtain as much precision as possible. The better a model can describe a fading environment, the better can it be compensated with other signals. Hence, on the receiving end, the signal is error free or at least close to being error free. Our main object in the paper is to compare all the parameters as BER, Power delay profile, outage capacity and distortion. Important issue is in wireless application development is the selection of fading models.

1.2 FADING AND MULTIPATH

Fading refers to the distortion that a carrier-modulated telecommunication signal experiences over certain propagation media. In wireless systems, fading is due to multipath propagation and is sometimes referred to as multipath induced fading. To understand fading, it is essential to understand multipath. In wireless telecommunications, multipath is the propagation phenomenon that results in radio signals' reaching the receiving antenna by two or more paths. Various Causes of multipath include atmospheric ducting, reflection from terrestrial objects, such as mountains and buildings, ionosphere reflection and refraction. These propagation mechanisms are responsible for multipath propagation which includes constructive and destructive interference, and phase shifting of the signal. This distortion of signals caused by multipath is known as fading. In other words , multipath occurs when there is more than one path available for radio signal propagation. The phenomenon of reflection, diffraction and scattering all give rise to additional radio propagation paths beyond the direct LOS path between the radio transmitter and receiver.

1.2.1 FADING CHANNELS

A Fading Channel is known as communications channel which has to face different fading phenomenon during signal transmission. In real world environment, the radio propagation effects combine together and multipath is generated by these fading channels. Due to multiple signal propagation paths, multiple signals will be received by receiver and the actual received signal level is the vector sum of the all signals. These signals are impinging from any direction or angle of arrival. In multipath, some signals aid the direct path and some others subtract it.

1.2.2 CAUSES OF FADING

Fading is caused by many factors which are as follows::

A. Doppler Shift

When a mobile is moving at a constant velocity v along a path, v_s is the velocity of the source, f' is the observed frequency and f is the emitted frequency. All these terms will be related by the following equation:

$$f' = \left(\frac{v}{v \pm v_s}\right) f$$

(1)

From the above equation, the detected frequency increases for objects moving towards the observer and decreases when the source moves away. This phenomenon is known as the Doppler Effect [6].

B. Reflection

When a propagating electromagnetic wave impinges on object which has generated large dimensions wave length, when compared to wavelength of the propagating wave, then Reflection will occurred. Actually we know that if the plane wave is incident on a perfect dielectric, part of the energy is transmitted and part of the energy is reflected back into the medium. If the medium is a perfect conductor, all the energy is reflected back. Reflections occur from the surface of the earth and from buildings and walls. In practice, not only metallic materials cause reflections, but dielectrics also cause this phenomenon [5].

C. Diffraction

The sharp irregularities (edges) of a surface between transmitter and receiver and obstructs the radio path then diffraction will occurred. The bending waves around the obstacle, even when a Line of Sight does not exist between transmitter and receiver the secondary waves will be spread over the space. Diffraction looks like a reflection at high frequencies depends on the amplitude, phase and polarization of the incident wave and geometry of the object at the point of diffraction.

D. Scattering

The wave travels through the medium consists of smaller dimension objects compared to the wavelength and having larger volumes of obstacles per unit volume, then scattering will occurred. Due to rough surfaces, small objects and irregularities in the channel scattered waves are produced. In practice, in mobile communications, electrical poles and street signs etc. induces scattering [8] in communication.

1.2.3 TYPES OF FADING

According to the effect of multipath, there are two types of fading

a) **Large Scale Fading:** In this type of fading, the received signal power varies gradually due to signal attenuation determined by the geometry of the path profile.

b) **Small Scale Fading:** If the signal moves over a distance in the order of wavelength, in small scale fading leads to rapid fluctuation of the phase and amplitude of the signal.

There are two types of fading according to the effect of Doppler Spread.

a) **Slow fading:** When the coherence time of the channel is large relative to the delay constraint of the channel then slow fading will occurred. The amplitude and phase change imposed by the channel can be considered roughly constant over the period of use. The event such as shadowing, where a large obstruction as hill or large building obscures the main signal path between the transmitter and the receiver, causes the slow fading.

b) **Fast fading:** When the coherence time of the channel is small relative to the delay constraint of the channel causes the fast fading. The amplitude and phase change imposed by the channel varies considerably over the period of use.

1.2.4 TYPES OF SMALL SCALE FADING

There are many models that describe the phenomenon of small scale fading. Out of these models, Rayleigh fading, Ricean fading, AWGN and Nakagami fading models are most widely used.

a) **Rayleigh fading model:** The Rayleigh fading is primarily caused by multipath reception [8]. Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal. It is a reasonable model for troposphere and ionospheres‟ signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading [11] is most applicable when there is no line of sight between the transmitter and receiver.

b) **Ricean fading model:** The Ricean fading model [8] is similar to the Rayleigh fading model, except that in

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Ricean fading, a strong dominant component is present. This dominant component is a stationary signal and is commonly known as the LOS (Line of Sight Component).

c) **Additive White Gaussian Noise Model:** It is the simplest radio communication environment in which a wireless communications system or a local positioning system or proximity detector based on Time of- flight will have to operate is the Additive-White Gaussian Noise (AWGN) [6] environment. AWGN is the commonly used to transmit signal while signals travel from the channel and simulate background noise of channel. The mathematical expression in received signal is -

$$\mathbf{r(t) = s(t) + n(t)} \qquad (2)$$

that passed through the AWGN channel where s(t) is transmitted signal and n(t) is background noise.

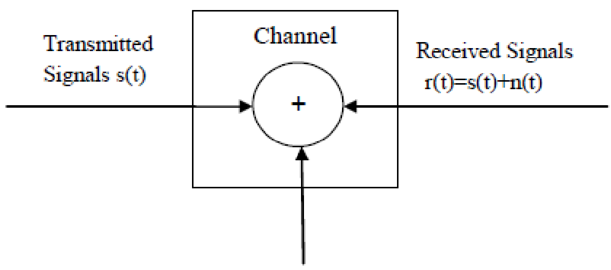

Fig. 1 Block Diagram of AWGN Channel

An AWGN channel adds white Gaussian noise to the signal that passes through it. It is the basic communication channel model and used as a standard channel model. The transmitted signal gets disturbed by a simple additive white Gaussian noise process.

d) Nakagami Channel: The Nakagami-m distribution has gained a lot of attention due to its ability to model a wider class of fading channel conditions and to fit well the empirical data. It has gained a lot of attention in the modeling of physical fading radio channels. Nakagami-m is more flexible and it can model fading condition from worst to moderate.

1.3 MODULATION

The easiest way to send the low frequency audio signal over long distance is to change a transmittable signal according to the information in the message signal. This alteration is called modulation, and it is the modulated signal that is transmitted. The receiver then recovers the original signal through a process called demodulation. Modulation techniques are expected to have three positive properties:

- ***Good Bit Error Rate Performance*:** Modulation schemes should achieve low bit error rate in the presence of fading, Doppler spread, interference and thermal noise.
- ***Spectral Efficiency*:** The modulated signals power spectral density should have a narrow main lobe and fast roll-off of side lobes. Spectral efficiency is measured in units of bit /sec/Hz.
- ***Power Efficiency*:** saving of Power is one of the critical design challenges in portable and mobile applications. Nonlinear amplifiers are usually used to increase power efficiency. However, nonlinearity may degrade the bit error rate performance of some modulation schemes. Constant envelope modulation techniques are used to prevent the re growth of spectral side lobes during nonlinear amplification

1.3.1 DIGITAL MODULATION

As compared to Analog modulation, Digital modulation schemes transform digital signals into waveform that are compatible with properties of the communications channel. One process uses a constant amplitude carrier and the other carries the information in phase or frequency variations (FSK, PSK). A major transition is from the simple amplitude modulation (AM) and frequency modulation (FM) to digital techniques such as Quadrature Phase Shift Keying (QPSK), Frequency Shift Keying (FSK), Minimum Shift Keying (MSK) and Quadrate Amplitude Modulation (QAM). In this paper, we have simulate the BER using various modulation technique.

A. Quadrature Amplitude Modulation:

Quadrature Amplitude Modulation (QAM) is a method for transmitting two separate channels of information using a single carrier.

QAM is both an analog and a digital modulation scheme. It conveys two analog message signals by modulating the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme.

64-QAM is same as 16-QAM except it is 64 possible signal combinations with each symbol represent six bits (26 =64). 64- QAM is a complex modulation technique but gives high efficiency. This digital frequency modulation technique is primarily used for sending data downstream over a coaxial cable network. It is very efficient, can support up to 28-mbps peak data transfer rates over a single 6-MHz channel. It's susceptibility to interfering signals makes it ill suited to noisy upstream transmissions.

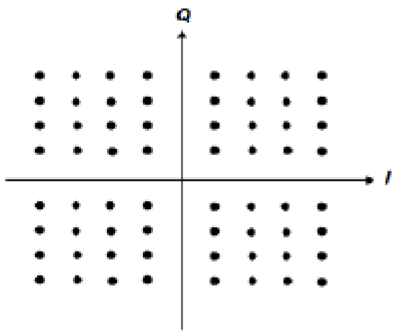

Fig. 2 Constellation Diagram for 64-QAM

1.3.2 BIT ERROR RATE (BER)

The BER, or quality of the digital link, is calculated from the number of bits received in error divided by the number of bits transmitted.

BER= (Bits in Error) / (Total bits received) (3)

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors. The BER is the number of bit errors divided by the total number of transferred bits during a particular time interval. BER is a unit less performance measure, often expressed as a percentage. We can sense the bit error rate (BER) of existing link and implement modulation to data rate and apply Forward Error Correction (FEC), which is used to set the BER as low error rate for data applications. BER measurement is the number of bit error or destroys within a second during transmitting from transmitter to receiver. Enviourment noise may affect the BER performance. Quantization errors also reduce BER performance, through incorrect or ambiguous reconstruction of the digital waveform. The accuracy of the modulation process and the effects of the filtering on signal and noise bandwidth also effect quantization errors. BER can also be defined in terms of the probability of error (POE) and represented in Eq. (4).

$$\text{POE} = \frac{1}{2}(1 - erf)\sqrt{Eb/No} \quad (4)$$

Where erf is the error function, E_b is the energy in one bit and N_0 is the noise power spectral density (noise power in a 1Hz bandwidth).

The error function is different for the each of the various modulation methods. The POE is a proportional to E_b/N_0, which is a form of signal-to-noise ratio. The energy per bit, E_b, can be determined by dividing the carrier power by the bit rate. As an energy measure, E_b has the unit of joules. N_0 is in power that is joules per second, so, E_b/N_0 is a dimensionless term, or is a numerical ratio.

1.3.3 SIGNAL TO NOISE RATIO (SNR)

SNR is the ratio of the received signal strength over the noise strength in the frequency range of the operation. It is an important parameter of the physical layer of Local Area Wireless Network (LAWN). Noise strength, in general, can include the noise in the environment and other unwanted signals (interference). BER is inversely related to SNR, that is high BER causes low SNR. High BER causes increases packet loss, increase in delay and decreases throughput. The exact relation between the SNR and the BER is not easy to determine in the multi channel environment. Signal to noise ratio (SNR) is an indicator commonly used to evaluate the quality of a communication link and measured in decibels and represented by Eq. (5).

SNR = 10 $\log_{10}$ (Signal Power / Noise Power) dB (5)

1.3.4 E_b/N_0

Energy per bit to Noise power spectral density ratio(Eb/N0) is an important parameter in digital communication or data transmission. It is a normalized signal to- noise ratio (SNR) measure, also known as the "SNR per bit". It is especially useful when comparing the bit error rate (BER) performance of different digital modulation schemes without taking bandwidth into account. Eb/N0 is equal to the SNR divided by the "gross" link spectral efficiency in (bit/s)/Hz, where the bits in this context are transmitted data bits, inclusive of error correction information and other protocol overhead. When forward error correction (FEC) is being discussed, Eb/N0 is routinely used to refer to the energy per information bit (i.e. the energy per bit net of FEC overhead bits); in this context, Es/N0 is generally used to relate actual transmitted power to noise.

II. SIMULATION RESULT

In this paper, we have simulated and analyzed the concept of fading by the approach available in MATLAB. The results obtained from the MATLAB simulations are discussed in this section.. It is necessary to explore what happens to the signal as it travels from the transmitter to the receiver. Then it is very easy to understand the concepts in wireless communications. As explained earlier, one of the important aspects of the path between the transmitter and receiver is the occurrence of fading. MATLAB provides a simple and easy way to demonstrate fading taking place in wireless systems.

The different fading models and MATLAB based simulation approaches will now be described.

TABLE 1 – Parameters used for Matlab simulation

S. NO.	Parameter	Values
1.	Modulation Scheme	B-PSK, BFSK, Q-PSK, 4-QAM, 8-PSK, & 16-PSK
2.	Nakagami parameter(m)	1, 2, 2.28, 3, 3.77, 4, 5 and 9
3.	Rayleigh	When k=0 in rician and m=1 in nakagami

TABLE 2 - BER in AWGN, Rayleigh and Rician fading channels in 64-QAM modulation scheme

E_b/N_o	BER in AWGN	BER in Rayleigh	BER in Rician
-5 : 0	0.0935	0.0905	0.1094
0: 5	0.0948	0.0935	0.0991
5: 10	0.0763	0.0769	0.0742
10: 15	0.0431	0.046	0.025728
15: 20	0.0168	0.02	0.000772
20 : 25	0.0056	0.0072	0.0000000263

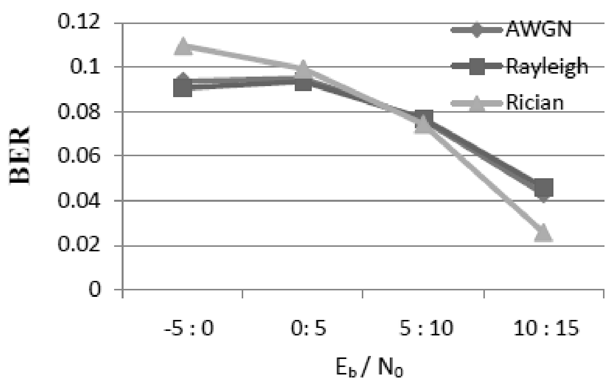

Fig. 3 Comparative Study of AWGN, Rayleigh and Rician in 64-QAM Modulation Scheme

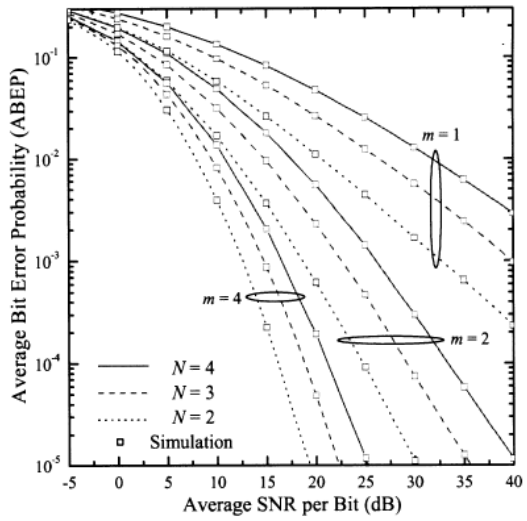

Fig. 4 Error performance of N-Nakagami channel using BPSK modulation technique

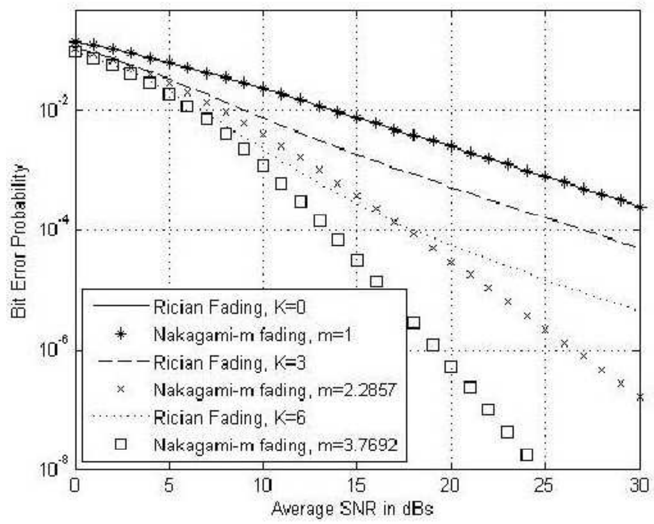

Fig. 5 Performance of Rayleigh and Rician ,Nakagami under BPSK Modulation Scheme

Figure 5 indicates the performance of Rayleigh and Rician ,Nakagami under BPSK Modulation Scheme.
Rayleigh fading channel corresponds to K=0 in Rician and m=1 in nakagami fading channel. It is represented by solid line in Fig. 5.
We know that , the relationship between the Rician fading factor 'K' and the Nakagami-m fading factor 'm' is given by-

$$k = \frac{\sqrt{m^2 - m}}{m - \sqrt{m^2 - m}}, m = \frac{k^2 + 2K + 1}{2K + 1} \quad \textbf{(6)}$$

It has been observed that performance of the system is better in case of Nakagami faing channel as compared to other fading channel under BPSK and in other modulation schemes .

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III. CONCLUSION

From the simulation results, the Bit Error Rate (BER) of a digital communication system is an important figure of merit which used to quantify the integrity of data transmitted through the communication system. By implementing the different modulation techniques, the criterion is comparison of the variation of BER for different SNR. It is observed that the BER is minimum for AWGN and maximum for Rayleigh and Rician fading channel. For Rician it is found that the BER is less than AWGN and Rayleigh for QAM. For higher values of Eb / N0, the BER is decreasing in all the fading channels for different modulation schemes. The decay in Average bit error probability with respect to average S/N ration per bit for different value of N statically independent random variables for BPSK modulation.

Furthermore, at higher M-PSK schemes, more carrier power is needed to modulate the signal in order to give low error performance; and in order to maintain the error performance of a scheme,the carrier power must be increased.

Here we can observe that Nakagami fading performance is better in comparison with other fading channels.

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