ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 1, Issue 6, August 2012

BER Performance of OFDM System over Nakagami-m Fading Channels with Different Modulation Schemes

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ABSTRACT
In this paper, we investigate the bit error rate (BER) performance of Orthogonal frequency division multiplexing (OFDM)-Binary phase shift keying (BPSK) OFDM-Quadrature phase shift keying (QPSK), OFDM-Quadrature amplitude shift keying (QAM) over different fading channels. The performance of transmission modes are evaluated by calculating the BER versus signal to noise ratio (SNR) under the Additive white Gaussian noise(AWGN), Rayleigh fading, Rician fading, Nakagami-m fading channel. In particular, the simulation of OFDM signals with different modulation schemes over different fading channels is carried out. Our simulation results are enough to understand the effect of fading channels with different modulation schemes and to verify the best suited fading channel in terms of BER Performance.

KEYWORDS
OFDM, AWGN non fading channel, Rayleigh, Rician, Nakagami-m fading channel, Modulations Schemes.

I. INTRODUCTION

It is important to evaluate the performance of wireless devices by considering the transmission characteristics, wireless channel parameters and device structure. The performance of data transmission over wireless channels is well captured by observing their BER, which is a function of SNR [1] at the receiver. In wireless channels, several models have been proposed and investigated to calculate SNR. All the models are a function of the distance between the sender 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 describe the three important and frequently used distributions. Those are AWGN, Rayleigh, Rician, Nakagami-m models. It is increasingly believed that OFDM results in an improved downlink multimedia services requires high data rates communications, but this condition is significantly limited by inter-symbol interference (ISI) due to the existence of the multiple paths. Multicarrier modulation techniques, including OFDM modulation are considered as the most promising technique to combat this problem [2] .OFDM technique is a multi-carrier transmission technique which is being recognized as an excellent method for high speed bi-directional wireless data communication. In OFDM system is capable of mitigating a frequency selective fading channel to a set of parallel flat fading channels, which need relatively simple processes for channel equalization. Rayleigh and Rician fading distributions in frequency selective fading channels have already been deployed and studied in depth for OFDM systems. Various channel estimation and diversity schemes have been proposed in literature to enhance the error performance under Rayleigh and Rician fading channel [3].Nakagami-m fading distribution is a useful and important model to characterize the fading channel [4].

II. OFDM

Orthogonal frequency division multiplexing (OFDM) is a communications technique that divides a communications channel into a number of equally spaced frequency bands. A subcarrier carrying a portion of the user information is transmitted in each band. Each subcarrier is orthogonal (independent of each other) with every other subcarrier; differentiating OFDM from the commonly used frequency division multiplexing (FDM).FDM is a technology that transmits multiple signals simultaneously over a single transmission path, Such as a cable or wireless system. Each signal travels within its own unique frequency range (carrier), which is modulated by the data (text, voice, video, etc.).Orthogonal FDM's (OFDM) spread spectrum technique distributes the data over a large number of carriers that are spaced apart at precise frequencies. This spacing provides the orthogonallity in this technique which prevents the demodulators from seeing frequencies other than their own.

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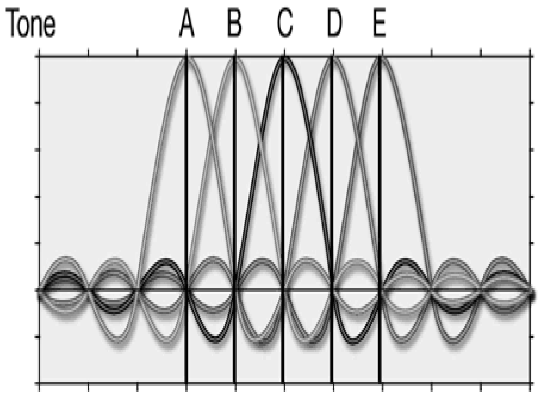

Figure 1 OFDM Tones shows Orthogonility

Let an OFDM system with N sub-carriers and X (k) is the kth OFDM data block to be transmitted with narrowband N subcarriers. These data are used to modulate N orthogonal sub carriers. Then IDFT is used to modulate the input signal. After modulation signal can be represented as

$$X(n) = 1/N \sum_{k=0}^{N-1} X(k) \exp\left(\frac{j2\pi kn}{N}\right) \quad n = 0,1 \ldots \ldots N-1 \ldots\ldots (1)$$

Cyclic prefix is inserted after IDFT modulation, which is removed before demodulation at the OFDM receiver. The received signal after removal of cyclic prefix can be demodulated using DFT. Output of DFT can be represented as

$$R(k) = \sum_{n=0}^{N-1} r(n) \exp\left(-\frac{j2\pi kn}{N}\right)$$

R (k) =X (k) H (k) +w_k k=0, 1…..N-1 ……………….. (2)

OFDM for Mobile Communication

OFDM represents a different system design approach. It can be thought of as a combination of modulation and multiple-access schemes that segments a communications channel in such a way that many users can share it. Whereas TDMA segments are according to time and CDMA segments are according to spreading codes, OFDM segments are according to frequency. It is a technique that divides the spectrum into a number of equally spaced tones and carries a portion of a user's information on each tone. A tone can be thought of as a frequency, much in the same way that each key on a piano represents a unique frequency. OFDM can be viewed as a form of frequency division multiplexing (FDM), however, OFDM has an important special property that each tone is orthogonal with every other tone. FDM typically requires there to be frequency guard bands between the frequencies so that they do not interfere with each other. OFDM allows the spectrum of each tone to overlap, and because they are orthogonal, they do not interfere with each other. By allowing the tones to overlap, the overall amount of spectrum required is reduced. The most basic form, a tone may be present or disabled to indicate a one or zero bit of information, however, either phase shift keying (PSK) or quadrature amplitude modulation (QAM) is typically employed. An OFDM system takes a data stream and splits it into *N* parallel data streams, each at a rate 1/*N* of the original rate. Each stream is then mapped to a tone at a unique frequency and combined together using the inverse fast Fourier transform (IFFT) to yield the time-domain waveform to be transmitted.

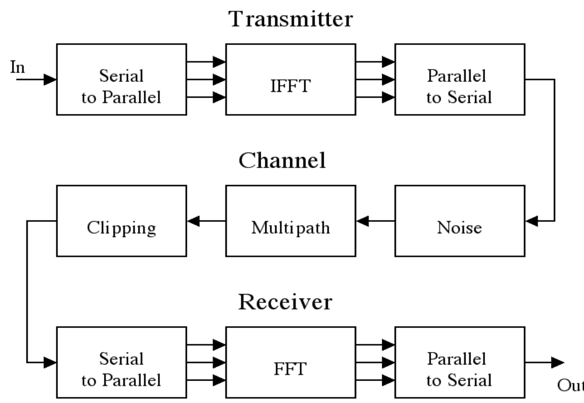

Figure 2 OFDM Simulation Flow Chart

III. AWGN channel

High data rate communication over additive white Gaussian noise channel (AWGN) is limited by noise .The received signal in the interval 0≤ t≤ T may be expressed as

$$r(t) = s_m(t) + n(t) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where n(t) denotes the sample function of additive white Gaussian noise (AWGN) process with power-spectral density.

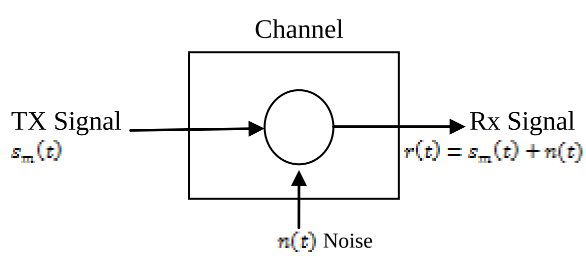

Figure 3 Model for received signal passed through AWGN channel

IV. FADING MODEL

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In this section we define the various types of fading models

A. Rayleigh Fading Distribution

It occurs when a signal takes more than one path between the transmitter and receiver .In this case the signal is not actually received on a line-of-sight path directly from the transmitting antenna [6]. Rather, it is reflected of various physical obstacles such as building, hills etc. and is received from several different indirect paths so the received signal strength is become very weak this type of fading is known as the Rayleigh fading.

It is commonly used to describe the statically time varying nature of the received envelop of a flat fading signal or the envelop of an individual multipath [7] component. It is well known that the envelop of the sum of two quadrature Gaussian noise signal obeys a Rayleigh distribution.

A Rayleigh pdf, expressed as

$$p(r) = r/\sigma^2 \exp -r^{2}/^{2\sigma^2} \quad \textit{For } r>=0 \qquad \ldots\ldots\ldots\ldots (4)$$

Where *r* is the envelope amplitude of the received signal, and is the rms value of the received voltage signal before envelop detection. And $2\sigma^2$ is the pre detection mean power of the multipath signal. The Rayleigh faded component is sometimes called the *random* or *scatter* or *diffuse* component.

B. Rician Fading distribution

When the received signal is made up of multiple reflective rays plus a significant line-of-sight (nonfaded) component, the envelope amplitude due to small-scale fading has a Rician pdf, and is referred to as *Rician fading* [8].

$$p(r) = r/\sigma^2 \exp -(r^2 + A^2)/2\sigma^2 \, I_0 \, (A_r/\sigma^2) \qquad \ldots\ldots\ldots\ldots\ldots (5)$$

Where A>=0, r>=0

Where A is the peak amplitude of dominant signal I_0(*) is the modified Bessel's function of the first kind or zero order

C. Nakagami-m Distribution

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 [9]. The reason behind taking this distribution is its good fit to empirical fading data. Due to free parameter it provides more flexibility. Nakagami –m fading distribution function is given by

$$p(r) = 2m^m r^{2m-1}/\Gamma(m)\Omega^m \exp\left(-\frac{mr^2}{n}\right) \quad r\geq 0 \qquad \ldots\ldots\ldots\ldots (6)$$

Where $\Gamma(.)$ is the gamma function Ω= mean of r^2 is the average power. M is the fading parameter and r is the Nakagami-m distribution envelope. Since, Nakagami-m distribution encompasses scattered, reflected and direct component of the original transmitted signal, it can be generated using the envelop of the both random signal processes are $r_{nlos}(t)$ for non line of sight envelop i.e. Rayleigh. And $r_{los}(t)$ for line of sight i.e. Rician as per the following expression.

$$r(t) = |r_{nlos}(t)\,|\exp(1-m) + |r_{los}(t)(1-e^{(1-m)})| \ldots\ldots\ldots\ldots (7)$$

So the value of r (t) is used as envelop Nakagami-m. System Description.

V. MODULATION

One way to communicate a message signal whose frequency spectrum does not fall within that fixed frequency range, or one that is unsuitable for the channel, 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.

Power Efficiency: Power limitation is one of the critical design challenges in portable and mobile applications. Nonlinear amplifiers are usually used to increase power efficiency. However, nonlinearity may be 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.

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.

A .digital modulation

Digital modulation schemes transform digital signals into waveform that are compatible with the nature of the communications channel. One category uses a constant amplitude carrier and the other carries the information in phase or frequency variations (FSK, PSK). A major transition 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).

A. Binary Phase Shift Keying (BPSK)

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Any digital modulation scheme uses a finite number of distinct signals to represent digital data. PSK uses a finite number of phases; each assigned a unique pattern of binary digits. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase. BPSK is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK. It does not particularly matter exactly where the constellation points are positioned, and in this figure they are shown on the real axis, at 0° and 180°.

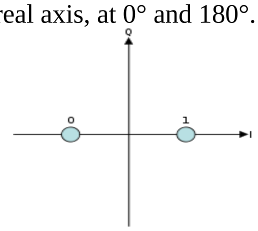

Figure 4 Constellations for BPSK

B. Quadrature Phase Shift Keying (QPSK)

Sometimes this is known as *quaternary PSK*, *quadriphase PSK*, 4-PSK, or 4-QAM. (Although the root concepts of QPSK and 4-QAM are different, the resulting modulated radio waves are exactly the same.) QPSK uses four points on the constellation diagram, equispaced around a circle. With four phases, QPSK can encode two bits per symbol, shown in the diagram with gray coding to minimize the bit error rate (BER) — sometimes misperceived as twice the BER of BPSK. The mathematical analysis shows that QPSK can be used either to double the data rate compared with a BPSK system while maintaining the *same* bandwidth of the signal, or to *maintain the data-rate of BPSK* but halving the bandwidth needed. In this latter case, the BER of QPSK is *exactly the same* as the BER of BPSK - and deciding differently is a common confusion when considering or describing QPSK.

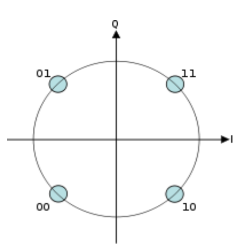

Figure 5 Constellations for BPSK

C. Quadrature amplitude modulation

QAM is the encoding of the information into a carrier wave by variation of the amplitude of both the carrier wave and a "quadrature" carrier that is 900 out of phase with the main carrier in accordance with two input signals. That is, the amplitude and the phase of the carrier wave are simultaneously changed according to the information you want to transmit. In 16-in 16-state Quadrature Amplitude Modulation (16-QAM), there are four I values and four Q values. This results in a total of 16 possible states for the signal. It can transition from any state to any other state at every symbol time. Since 16 = 24, four bits per symbol can be sent. This consists of two bits for I and two bits for Q. The symbol rate is one fourth of the bit rate. So this modulation format produces a more spectrally efficient transmission. It is more efficient than BPSK, QPSK or 8PSK [8].

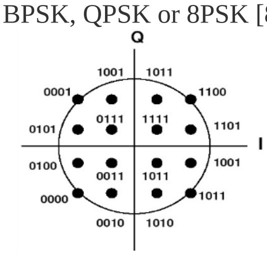

Figure 6 Constellations for BPSK

D. 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).

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. IEEE 802.11 standard has ability to sense the bit error rate (BER) of its link and implemented modulation to data rate and exchange to 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 source to destination. Noise affects the BER performance. Quantization errors also reduce BER performance, through incorrect or ambiguous reconstruction of the digital waveform. The accuracy of the analog modulation process and the effects of the filtering on Signal and noise bandwidth also effect quantization errors.

D. 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

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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. (8).

SNR = 10 log10 (Signal Power / Noise Power) dB ……..… (8)

V. RESULTS and ANALYSIS

We have to develop the structure for Simulating OFDM system. The performance evaluation has been carried out with the modulation technique of BPSK, QPSK and QAM Over fading channel. The system performance also checked over the non-faded AWGN channel, and faded channel Rayleigh and Rician with different modulation schemes. The results are shown

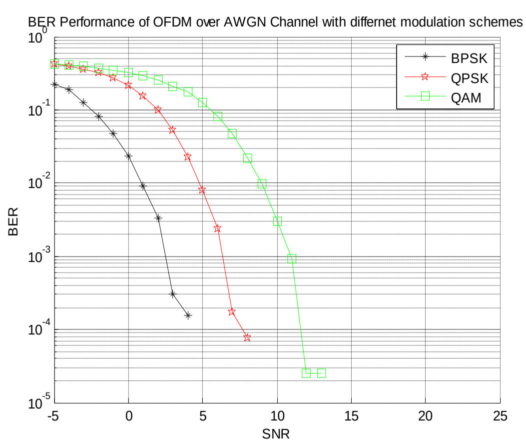

Figure 7 Shows the BER using different modulation schemes

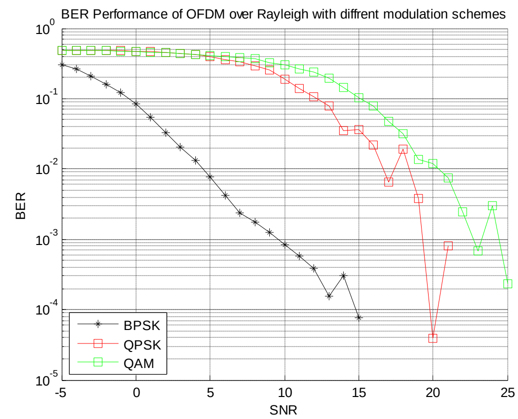

Figure 8 Shows the BER using different modulation schemes

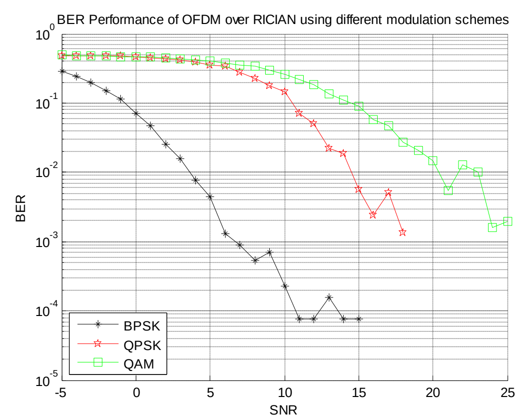

Figure 9 Shows the BER using different modulation schemes

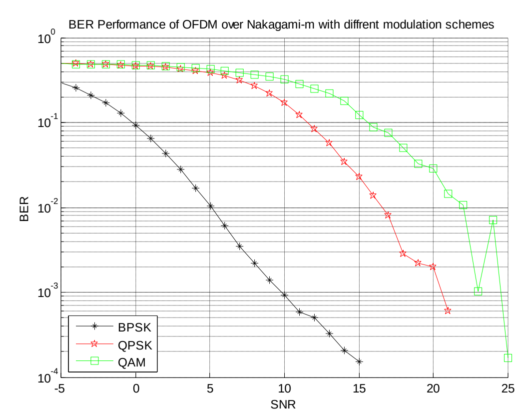

Figure 10 Shows the BER using different modulation schemes

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VI. CONCLUSION

From the simulation results, The Bit Error Ratio of a digital communication system is an important figure of merit used to quantify the integrity of data transmitted through the 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 non-faded AWGN and compare BER for Rayleigh, Rician and Nakagami-m. For Nakagami-m it is found that the BER is less than Rayleigh and Rician for the same SNR.

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