Evaluation of an Orthogonal Frequency Division Multiplexing System over general fading channels using BPSK & QAM

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Abstract – In last decade Ultra speed Wireless data communication techniques have increasingly been used in Orthogonal Frequency Division Multiplexing (OFDM). The principles of OFDM modulation have been in theory for a long time. But in recent years, this technology has crossed the limitations into the real world of modern communication systems to combat Inter-Symbol Interference (ISI) through multicarrier modulation. OFDM has proved to be very effective in mitigating adverse multipath effects of a broadband wireless channel. Especially the frequency selectivity of multipath channels by multiplexing information on different orthogonal carriers is the key to the OFDM success. In a wireless communication system, the spectral efficiency depends on Bit Error Rate (BER), coding rate and modulation technique. This study investigates BER performance evaluation of OFDM system over different fading channels with BPSK & QAM modulation techniques.

Index Terms – Bit Error Rate (BER), OFDM, Different fading channels, Different modulation techniques, SNR (Signal to Noise Ratio)

1. INTRODUCTION

The next generation wireless communications systems demand higher data rates transmission in order to meet the high quality services. Since there have been an increased demand for higher data rate transmission, the systems are using the Orthogonal Frequency Division Multiplexing (OFDM) transmission techniques. The main advantage of multicarrier transmission is its robustness in frequency selective fading channel. Therefore, OFDM is one of the efficient choices in wireless systems. OFDM has been adopted in many wireless standards such as worldwide interoperability for microwave access (WiMAX) and Long Term Evolution (LTE) [1-3]. From the last 3 decades, Wireless communications techniques have been growing very rapidly. More reliable wireless communication systems are required having higher spectral efficiency [4]. Also there is a great demand to provide high data rate in a wireless environment for the services like multimedia, internet, digital video broadcasting, wireless LANs (IEEE 802.11a, IEEE 802.11b IEEE 802.11g). Furthermore, The OFDM based multiple access technology OFDMA is also used in several 4G and pre-4G cellular networks and mobile broadband standards But the transmission of higher data rates makes a highly hostile radio channel. To combat the problem, the OFDM seems to be a solution. OFDM can be seen as either a modulation technique or a multiplexing technique. OFDM can save almost fifty percent of bandwidth by dividing the available spectrum into many overlapping carriers provided that the multicarriers should be in orthogonal. OFDM is a special case of multicarrier transmission, where a single data stream is transmitted over a number of low data rate subcarriers [1, 4]. This low symbol rate also decreases the effects of ISI. OFDM increases the robustness against frequency selective fading. In single carrier system a single fade or interferer can cause the entire link to fail, but in multicarrier only a small percentage of the subcarriers will be affected OFDM also provides high immunity against multipath dispersion [2,5]. This paper investigates the bit error rate evaluation of OFDM system over different fading channels for the modulation techniques of BPSK and QAM.

2. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

Orthogonal frequency-division multiplexing is the modulation technique for the standards such as the Digital Audio Broadcasting (DAB) and the Digital Video Broadcasting (DVB) systems. OFDM is a method of encoding digital data on multiple carrier frequencies. The data are sent over parallel sub-channels with each sub-channel modulated by a modulation scheme such as BPSK, QPSK, and 16 QAM etc. The prime advantage of OFDM is its ability to cope with severe channel conditions compared to a single carrier modulation scheme but still maintaining the data rates of a conventional scheme with the same bandwidth. As such it has received much attention and has been proposed for many other applications, including local area networks and personal communication systems. OFDM is a type of multichannel modulation (MCM) that divides a given channel into many parallel sub-channels or subcarriers so that multiple symbols are sent in parallel. Furthermore, channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal. Also, the low symbol rate naturally makes the use of guard interval between symbols reducing ISI. Orthogonal Frequency Division Multiplexing has become one of the mainstream physical layer techniques used in modern communication systems. The first OFDM schemes were presented by [6] and [7]. The actual use of OFDM was limited and the practicability of the concept was questioned the choice for OFDM as transmission technique could be justified by comparative studies with single carrier systems. OFDM is often motivated by two of its many attractive features: it is considered to be spectrally efficient and it offers an elegant way to deal with equalization of dispersive slowly fading channels.

A. OFDM Transmitter

OFDM transmitter is shown in Fig-1. Randomly generated data are encoded by forward error correcting code, in which Reed Solomon and convolutional coding are used.

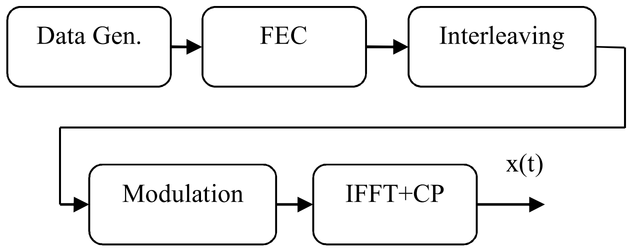

Figure 1 OFDM Transmitter Model

This coded data are interleaved and modulated. Different QAM techniques are used for modulation. The modulated output is transmitted simultaneously on *N* parallel subcarriers of bandwidth Δf. These parallel subcarriers are orthogonal to each other and can be generated by using Inverse Fast Fourier transform (IFFT). Now cyclic prefix is added as a guard interval to minimize the effect of Inter Carrier Interference (ICI). Finally parallel to serial converter (P/S) converts parallel data into serial data stream and transmit over channel. Let us denote *N* frequency domain subcarrier as S = [S0, S1, S2,…….., S_{N-1}]. In time domain operation s = [s0, s1, ………., s_{N-1}]. Thus the sampled transmitted sequence is given by

$$s[n] = \frac{1}{N}\sum_{k=0}^{N-1} S[k]e^{\frac{j2\pi kn}{N}} \quad ,0 \leq n \geq N \tag{1}$$

B. OFDM Receiver

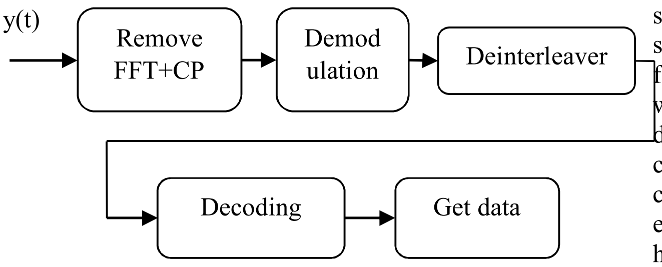

Figure 2 OFDM Receiver Model

Receiver model of OFDM is shown in Fig-2. From serial to parallel converter (S/P) received signal converts serial data into parallel. Cyclic prefix is removed from parallel converted data and then inverse IFFT is performed. These data are demodulated. The output of demodulator passes through the channel decoder to obtain the users data. The received signal is given by

$$r[n] = \frac{1}{N}\sum_{k=0}^{N-1} R[k]e^{\frac{j2\pi kn}{N}} \quad ,0 \leq n \geq N \tag{2}$$

Where *r[n]* is the sampled received signal and *R[k]* is the received complex modulation symbol of the *kth* subcarrier. The received symbol after multicarrier demodulation is

$$R[k] = H[k]S[k] + \eta \tag{3}$$

Where *H[k]* is the transfer function of the channel and η is additive noise of the channel. The spectral efficiency is presented in several ways in the literature. The spectral efficiency of a channel is a measure of the number of bits per second per Hz. We derived the spectral efficiency using the relation [5].

$$\eta_s = (1 - BER)^l kr \tag{4}$$

3. DIFFERENT FADING CHANNELS

The wireless environment is highly unstable and fading is due to multipath propagation. Multipath propagation leads to rapid fluctuations of the phase and amplitude of the signal. The presence of reflectors in the environment surrounding a transmitter and receiver create multiple paths that a transmitted signal can traverse. As a result, the receiver sees the superposition of multiple copies of the transmitted signal, each traversing a different path. Each signal copy will experience differences in attenuation, delay and phase shift while traveling from the source to the receiver.

This can result in either constructive or destructive interference, amplifying or attenuating the signal power seen at the receiver. Fading may be large scale fading or small scale fading [8]. Based on multipath time delay spread small scale fading is classified as flat fading and frequency selective fading. If bandwidth of the signal is smaller than bandwidth of the channel and delay spread is smaller than relative symbol period then flat fading occurs whereas if bandwidth of the signal is greater than bandwidth of the channel and delay spread is greater than relative symbol period then frequency selective fading occurs. Based on doppler spread small scale fading may be fast fading or slow fading. Slow fading occurs when the coherence time of the channel is larger relative to the delay constraint of the channel. The amplitude and phase change imposed by the channel can be considered roughly constant over the period of use. Slow fading can be caused by events such as shadowing, where a large obstruction such as a hill or large building comes in the main signal path between the transmitter and the receiver. Fast fading occurs when the coherence time of the channel is small relative to the delay constraint of the channel.

A. Nakagami Fading Channel

Nakagami fading model considers the 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. The average time delay is assumed to differ significantly between clusters. If the delay times also significantly exceed the bit time of a digital link, the different clusters produce serious intersymbol interference, so the multipath self-interference then approximates the case of cochannel interference by multiple incoherent rayleigh-fading signals [9].

B. Rayleigh Fading Channel

Rayleigh fading model considers the fading is caused by multipath reception. Rayleigh fading model assumes that the magnitude of a signal that has passed through transmission medium will vary randomly, or fade, according to a Rayleigh distribution. Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. Rayleigh fading is most applicable when there is no dominant line-of-sight propagation between the transmitter and receiver [10].

C. Rician Fading Channel

Rician model considers that the dominant wave can be a phasor sum of two or more dominant signals, e.g. the line-of-sight, plus a ground reflection. This combined signal is then mostly treated as a deterministic (fully predictable) process, and that the dominant wave can also be subject to shadow attenuation. This is a popular assumption in the modeling of satellite channels. Besides the dominant component, the mobile antenna receives a large number of reflected and scattered waves [11].

Fading Channel Structure

Fading channel models are often used to model the effects of electromagnetic transmission of information over the air in cellular networks and broadcast communication. Fading channel models are also used in underwater acoustic communications to model the distortion caused by the water. Fig.3 shows the basic block diagram of proposed multipath fading channel model.

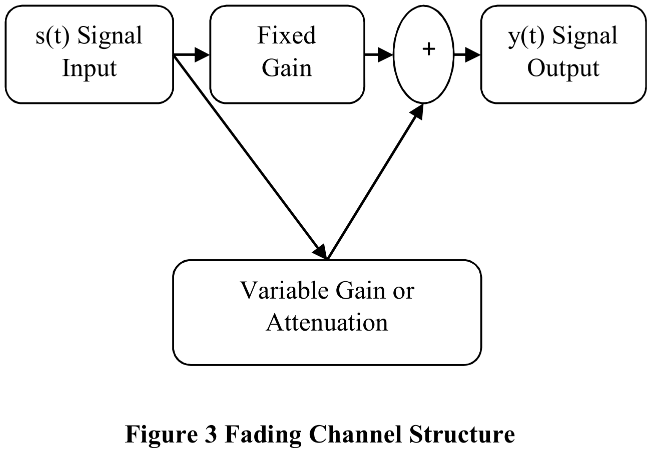

Figure 3 Fading Channel Structure

Table 1 Input parameters for the OFDM system

S.No.	Parameters	Value
1.	Transmitter	1,2,4
2.	Receiver	2,4
3.	Modulation	QAM-16
4.	Channel	Nakagami-m Fading Channel
5.	SNR	0-18dBm
6.	Equalizer	ML

4. DIFFERENT MODULATION TECHNIQUES

In the techniques of digital modulation, an analog signal is modulated with a binary code. The digital modulator device provides interface between the transmitter and the channel. The digital modulation can be classified mainly either on the basis of their bandwidth characteristics of compaction. The basic standards for the finest modulation method depends on Signal to Noise Ratio (SNR), , the efficiency of the power supply, Available Bandwidth, a better Quality of Service, Bit Error Rate (BER) and profitability [12]. The performance of every modulation method is calculated by the estimate of the probability of error with the assumption that system work with Additive White Gaussian Noise [13]. Modulation schemes which are proficient to transmit extra bits per symbol are extra error immune caused by the noise and interference induced in the channel [14]. The distortion of delay can be a significant measure as deciding of modulation method for digital radio [15]. There are different patterns of digital modulation methods which are used in the communications system. The fundamental types of digital modulation method are Phase Shift Keying (PSK), Binary Phase Shift Keying (BPSK), and Quadrature Amplitude Modulation (QAM) respectively [16-18]. The PSK, QAM and BPSK with pulse Nyquist pulse shaping on the baseband form the fundamental technical of digital modulation, while another methods are also probable by integrating two or more digital modulation techniques of database with or without inserting pulse shaping.

A. Binary Phase Shift Keying (BPSK)

The digital modulation technique BPSK is devoted to as the easiest form of PSK and in this method, the phase of the carrier represent only two states of phase. As any form of modulation by phase shift, there is the definition of the states or the points that are used for data bits of signaling. One of the main methods for PSK is BPSK. It is also called Phase Reversal Keying (PRK). A digital signal changing between +1 and -1 (or 1 and 0) will create phase reversals, that is to say the phase shifts to 180 degrees as the data shifts state. This operation is also called to two levels PSK as it uses two phases separated by 180º to represent binary digits. The principle equations that are used are as follows:

$S(t)=A\cos(2p\, f\, c\, t)$ for binary 1 (5)
$S(t)=A\cos(2pf\, c\, t + p)$ for 0 (6)
$S(t)=A\cos(2p\, fc\, t)$ for binary 1 (7)
$S(t)= -A\cos(2pf\, c\, t)$ for binary 0 (8)

This type of phase modulation is more efficient and robust in opposition to noise particularly in low data rate applications as it can modulate only 1 bit per symbol. A coherent BPSK modulation is categorized by having a one dimensional signal of the space with a constellation diagram composed of two points of message.

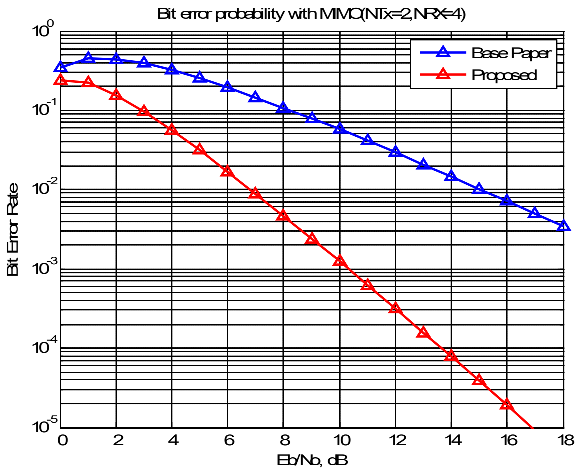

Figure 4 Variation of BER versus E_b/N_o for BPSK

B. Quadrature Amplitude Modulation (QAM)

The QAM is a modulation scheme where its amplitude is allowed to vary with the phase [19]. This technique can be viewed as a combination of install as well as PSK [20]. QAM is widely used in many applications of communication of digital data, where the rate of data beyond the 8-PSK are needed by a radio communication system and then diagram of

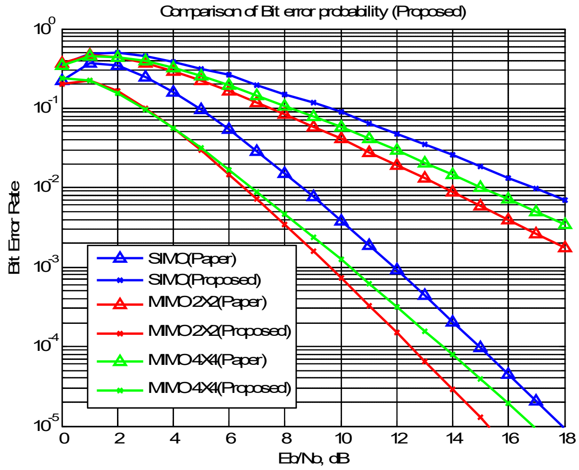

Figure 5 Variation of BER versus E_b/N_o for 16-QAM

QAM modulation is widely used because QAM allows you to achieve a greater distance between the adjacent points in the plan I-Q in distributing the points are more distinct and data errors are reduced. The QAM modulation is more useful and more effective than the other and is almost applicable for all modems progressive.
In the 16-QAM, the four levels of different magnitude are used. The joint stream would be of 4*4=16 states. In this method, each symbol represents 4 bits. It is identical to 16-QAM, except that it has 64 states where each symbol represents 6 bits. It is a complex modulation method but with superior efficiency. The mobile WiMax technology uses this technique of higher modulation when the Link status is high.

5. SEQUENCE GENERATOR

M sequence is commonly used pseudo-random sequence, which is the longest linear sequence shift register. Such sequence has good autocorrelation characteristics. Shift register sequence is a periodic sequence, its cycle not only relate to the degree of the shift register, but also relate to the linear feedback logic and shift register initial state. PN Sequence Generator generates a sequence of pseudorandom binary numbers by using shift register, as shown in Figure 6.

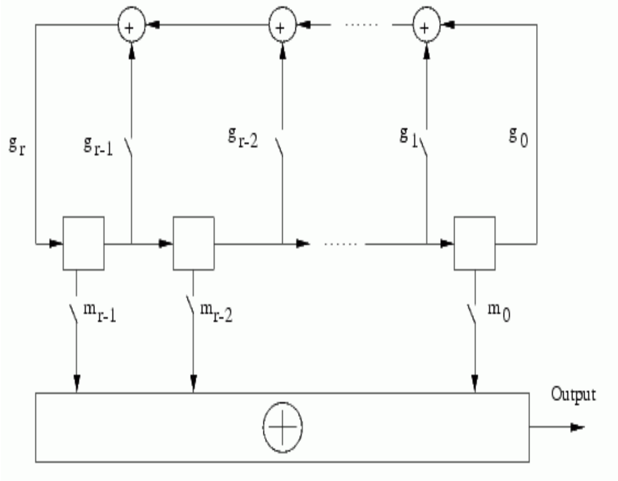

Figure 6 M-sequence Generator Structure

There are r registers in the generator which update their values at each time step depending on the value of the incoming arrow to the shift register. The shift register is described by the Generator Polynomial parameter, which is a primitive binary polynomial in z, grzr+gr-1zr-1+…………+g0. The coefficient gi is 1 if there is a connection from the ith register. The leading term gr and the constant term g0of the Generator Polynomial parameter must be 1. PN sequences are defined with the help of a polynomial of degree n:

$$P(x) = \sum_{i=0}^{n} a_i x^i \quad (9)$$

with ai € F2 and an = a0 = 1: The PN Sequence corresponding to this will satisfy the following recursion

$$Pn+k = \sum_{i=0}^{n-1} a_i Pk + i \quad (10)$$

6. CONCLUSION

The evaluation of OFDM System under some common fading channels has been presented for BPSK and QAM transmission modes in this paper depicts that selection of the technique of digital modulation and fading channel are entirely dependent on the type of specific application - accuracy in the receipt of data, power or bandwidth. The service quality supplied by the OFDM system can be significantly improved with the help of proper selection of modulation method and Fading Channel models. Therefore, the increase of the radio coverage and the reduction in BER can be found by the suitable selection of the digital modulation method and Fading Channel models. Some of the digital modulation method and Fading Channel models are also discussed for the Performance Analysis of OFDM System in this paper. For minimum BER some other hybrid techniques are needed which can give better Performance Analysis of OFDM System.

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