Bit Error Rate Performance in OFDM System Using MMSE & MLSE Equalizer Over Rayleigh Fading Channel Through The BPSK, QPSK,4 QAM & 16 QAM Modulation Technique

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Abstract

In this paper Bit Error Rate performance of OFDM - BPSK, QPSK, 4-QAM, 16-QAM System over Rayleigh fading channel is analyzed. OFDM is a orthogonal frequency division multiplexing to reduce inter-symbol interference problem. Two of the most equalization algorithms are minimum mean square error (MMSE) equalizer and maximum likelihood sequence estimation (MLSE) equalizer. Finally simulations of OFDM signals are carried with Rayleigh faded signals to understand the effect of channel fading and to obtain optimum value of Bit Error Rate (BER) and Signal to noise ratio (SNR).

Keywords:

OFDM, ISI, Rayleigh fading channel, minimum mean square error (MMSE) equalizer and maximum likelihood sequence estimation (MLSE) equalizer.

1. Introduction:

A general problem found in high speed communication is inter-symbol interference .ISI occurs when a transmission interferes with itself and the receiver cannot decode the transmission correctly.[1]

This paper will focus on Orthogonal Frequency Division Multiplexing (OFDM) Simulation and implementation and also compare the output result of BPSK and QPSK, QAM and 16 QAM modulation techniques with OFDM.

OFDM is especially suitable for high speed communication due to its resistance to ISI.As

communication systems increase their information transfer speed the time for each transmission.

The primary objective of our study is reducing the ISI problem in the wireless communication. One solution can be Orthogonal Frequency Division Multiplexing (OFDM).The idea of OFDM [3] is to distribute the high rate data stream into many low rate data streams that are transmitted in a parallel way over many sub channels. Thus, in a sub channel, the symbol duration is low as compared to the maximum delay of the channel and hence, ISI can be handled.

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique that has been recently recognized as an excellent method for high speed bi-directional wireless data communication [2].Its history dates back to the 1960s,but it has recently become popular because Economical integrated circuits that can perform the high speed digital operation necessary have become available .OFDM effectively squeezes multiple modulated carriers tightly together reducing the required bandwidth but keeping the modulated signals orthogonal so they do not interfere with each other .Today, the technology is used in such systems as asymmetric digital subscriber line(ADSL) as well as wireless systems such as IEEE 802.11 a\g (Wi-Fi*)and IEEE 802.16 (WiMAX*). It is also used for wireless digital audio and video broadcasting .It is based on Frequency Division Multiplexing (FDM), which is a technology that uses multiple frequencies to simultaneously transmit multiple signals in parallel .Each signal has its own frequency range (sub carrier), which is then modulated by data. Each subcarrier is separated by a guard band to ensure that they do not overlap. These sub-carrier are then demodulated at the receiver by using filters to separate the bands.

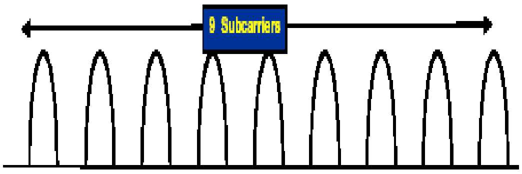

Figure 1: FDM

OFDM is similar to FDM but much more spectrally efficient by spacing the sub channel much more spectrally efficient by spacing much closer together. This is done by finding frequencies that are orthogonal, which means that are perpendicular in a mathematical sense, allowing the spectrum of each sub-channel to overlap another without Interfering with it. In the effect of this is seen as the required bandwidth is greatly reduced by removing guard bands and allowing signals to overlap .In order to demodulate the signal ,a discrete Fourier transform (DFT) is needed .Fast Fourier transform (FFT) chips are commercially available making this a relatively easy operation .

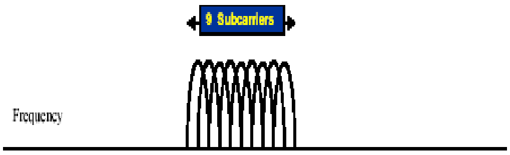

Figure 2: OFDM

2. System Model:

The base band discrete time complex valued model of OFDM system [4] considered in the paper is depicted in figure 3.The model consists of three subsections namely transmitter channel and receiver.

2.1 Transmitter

This subsection consists of following blocks

2.1.1 Random Data Generator:

Random data generator is used to generate a serial random binary data .This binary Data stream models the raw information that going to be transmitted. The serial binary data is then fed into OFDM transmitter.

2.1.2 S/P converter:

The input serial binary data stream is grouped into word size required for transmission in this each word. And word is converted into parallel stream.
Each stream is used to modulate one carrier out of group of orthogonal carrier.

2.1.3. Data to symbol Mapper:

This block does modulation like BPSK,QPSK ,QAM&16QAM .The data on each symbol is mapped to a particular phase based on the modulation method used .Each one the phase is assigned a unique pattern of binary bit .Usually each phase encodes an equal number of bits.

2.1.4. Zero-padding and IFFT:

The IFFT converts frequency domain data into the time domain signal. Prior to IFFT mapping zero-padding is performed to adjust the IFFT bit size of length. Zero padding is used because the number of subcarriers may be less then bit size.
Let Xp(k)is the input Vector to IFFT block and k varies from 0 to N-1 Where N=64.Out put of IFFT is given by

$$x_p(n) = \mathrm{IFFT}\left[X_p(k)\right] = \frac{1}{N}\sum_{k=0}^{N-1} X_p(k)e^{-j2\pi 2\pi kn}$$

2.1.5 Cyclic Prefix:

It is a cyclic extension of an OFDM symbol to eliminate ISI effect on original OFDM symbol .The length of cyclic prefix is chosen ¼ of the length of symbol .The cyclic prefix adds time over head decreasing the overall spectral efficiency of the system .After the cyclic prefix has been added [5]

2.2 Channel model:

Additive white Gaussian Noise (AWGN) is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts par hertz of bandwidth) and a Gaussian distribution of amplitude. The model does not account for fading, frequency, selectivity, interference, nonlinearity or dispersion. However, it produces simple and tractable mathematical models which are useful for gaining insight into the

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underlying behavior of a system before these other phenomena are considered.

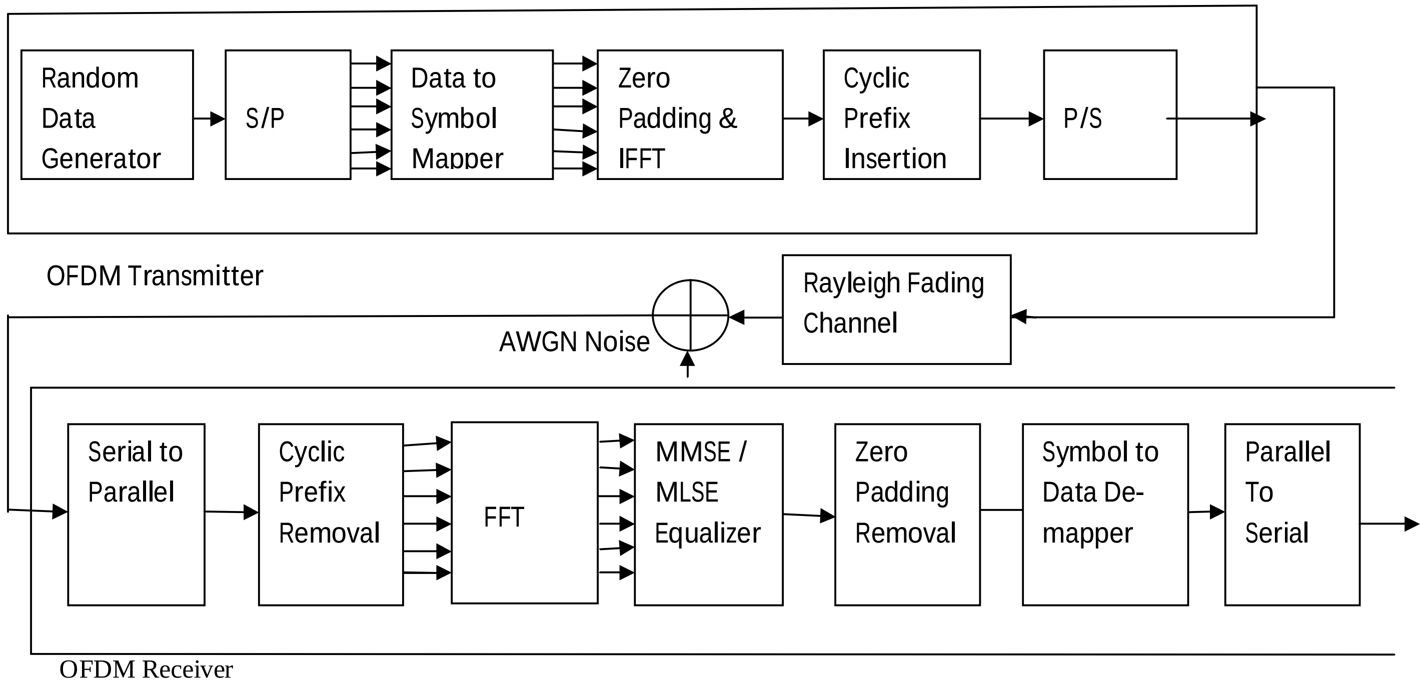

Figure 3: OFDM Simulation Model

Wideband Gaussian noise comes from many natural sources, such as the thermal vibrations of atoms in conductors (referred to as thermal noise or Johnson-Nyquist noise), shot noise, black body radiation from the earth and other warm objects and from celestial sources such as the sun[6]. AWGN does not work will thus the more specified model are used. Fading is deviation of the attenuation that a carried modulated telecommunication signal experiences over certain propagation media. A fading channel is communication Rayleigh fading is caused by multipath reception really fading is statistical model for the effect of propagation environment on a radio signal such as is used by wireless devices.

2.3 Receiver:

The receiver does the reverse in contrast to the transmitter. Firstly the serial output channel is a converted into parallel stream and then cyclic prefix bits are removed from it .Then FFT of Each symbol is performed .To remove these channel effect MMSE and MLSE is performed equalized output is converted back to data words by demodulator the data words are then multiplexed to get the original data .

3. Equalizer:

Equalizer [7] is a digital filter that provides an approximate inverse of channel frequency response. Equalization is to mitigate the effects of ISI to decrease the probability of error that occurs without suppression of ISI, but this reduction of ISI effects has to be balanced with prevention of noise power enhancement.

3.1 Adaptive equalization:

Adaptive equalizer is an equalizer that automatically adapts to time-varying properties of the communication channel. It is frequently used with coherent modulations such as phase shift keying, mitigating the effects of multipath propagation and Doppler spreading.

3.2 Blind equalization:

Equalizer minimizes the error between actual output and desired output by continuous Blind is a digital signal processing technique in which the transmitted signal is inferred from the received signal. While making use only of the transmitted signal statistics.

3.3 Minimum Mean Square Error Equalizer (MMSE):

Minimum Mean Square Error Equalizer consider error Y in terms of three other random variables as

$Y' = a_1X_1 + a_2X_2 + a_3X_3$

$€ = Y - Y'$

Min $E\{€^2\} = E((Y-Y')^2)$

$a_1 > a_2 > a_3$

$\partial \backslash \partial a_1 \{E\{(Y-a_1X_1-a_2X_2-a_3X_3)^2\}\}$

$= E\{\partial \backslash \partial a_1 (Y-a_1X_1-a_2X_2-a_3X_3)^2\}$

$= E\{2(Y-a_1X_1-a_2X_2-a_3X_3)(-X_1)\} = 0$

$(Y-a_1X_1-a_2X_2-a_3X_3) = €$

Similarly

$\partial \backslash \partial a_2$ and $\partial \backslash \partial a_3$ Yield: Collectivity

$E\{€ X_1\} = 0$

$E\{€ X_2\} = 0$

$E\{€ X_3\} = 0$

Error € is orthogonal to data $X_1 > X_2 > X_3$ are the data used to estimate Y

Ultimately, the normal equation

$$\begin{pmatrix} E(X_1 X_1) & E(X_1 X_2) & E(X_1 X_3) \\ E(X_2 X_1) & E(X_2 X_2) & E(X_2 X_3) \\ E(X_3 X_1) & E(X_3 X_2) & E(X_3 X_3) \end{pmatrix} \begin{vmatrix} a_1 \\ a_2 \\ a_3 \end{vmatrix} = \begin{pmatrix} E(Y X_1) \\ E(Y X_2) \\ E(Y X_3) \end{pmatrix}$$

$R_{xx}\, a = r_{yx}$ Wiener Hopf Equations

Where $R_{xx=}$ Auto correlation matrix of data

$r_{yx=}$ Cross –Correlation vector between quantity to be estimated and data

Again $X_1 > X_2 > X_3$ are the data used to estimate Y

3.4 Maximum-likelihood sequence Estimation (MLSE) :

The receiver uses a maximum-likelihood sequence estimation (MLSE) implemented by means of the Viterbi algorithm to compensate for the heavy selective distortions caused by multipath propagation. The performance of the receiver is evaluated through a channel simulator suitable for mobile communications. The results obtained show the good behavior characteristics for the receiver in different modes of operation. Easy implementation of the device using VLSI technology is expected For an optimized detector for digital signals the priority is not to reconstruct the transmitter signal, but it should do a best estimation of the transmitted data with the least possible number of errors. The receiver emulates the distorted channel. All possible transmitted data streams are fed into this distorted channel model. The receiver compares the time response with the actual received signal and determines the most likely signal. In cases that are most computationally straightforward, root mean square derivation can be used as the decision criterion for the lowest error probability.

Suppose that there is an underlying signal $\{x(t)\}$, of which an observed signal $\{r(t)\}$ is available. The observed signal r is related to x via a transformation that may be nonlinear and may involve attenuation, and would usually involve the incorporation of Random noise. The Stoical parameters of this transformation are assumed known. The problem to be solved is to use the observations $\{r(t)\}$ to create a good estimate of $\{x(t)\}$.

Maximum likelihood sequence estimation is formally the application of maximum likelihood to this problem. That is, the estimate of $\{x(t)\}$ is defined to be sequence of values which maximize the functional

$$L(x) = p(r \mid x),$$

Where $p(r|x)$ denotes the conditional joint probability density function of the observed series $\{r(t)\}$ given that the underlying series has the values $\{x(t)\}$.

4. Simulation and Results:

4.1 Simulation parameters: Simulation parameters chosen for the model of OFDM transceiver re listed in Table 1. Simulation is carried out Rayleigh channel using BPSK, QPSK, 4QAM, 16QAMModulation technique

Table1. Simulation parameters for OFDM transceiver

S .No.	Parameter	Value
1	Carrier modulation used	BPSK,QPSK,4QAM,16QAM
2	Number of data sub carriers	52
3	IFFT Size	64
4	Cyclic prefix length	16
5	Bandwidth	20Mhz
6	Channel type	Rayleigh channel
7	Sub carrier frequency spacing	20 MHz/64=0.3125Mhz
8	T_{FFT} :IFFT /FFT period	3.2 µsec
9	Symbol rate	Number of carrier/Symbol duration=52/3.2 µsec,16Mbps

4.2 Results:

Simulation Results are plotted for bit error rate performance of OFDM System simulation is performed Rayleigh channel using BPSK, QPSK, 4QAM, 16QAM Modulation technique condition considering absence and presence of MMSE and MLSE Equalizer.

4.2.1 Rayleigh Channel:

In this section bit error rate for BPSK QPSK, 4QAM, 16QAM using OFDM in a Rayleigh channel .OFDM technique along with cyclic prefix is used to reduce Inter symbol Interference (ISI) but still it cannot be eliminated completely in the case of MMSE and MLSE Equalizer. To reduce these effects equalization is performed on receiver side.

Bit Error rate performance in Rayleigh channel using BPSK, QPSK, 4QAM, and 16QAM modulation technique with and without equalizer it can be observed that bit error rate around 0.4 in BPSK QPSK, 4QAM, 16QAM when no equalization is performed. Bit error rate decreasing when MLSE equalization is performed but later on it maintains a constant value of 0.0015 in BPSK and 0.02 in QPSK, 0.12 in 16QAM, 0.0003 in 4QAM

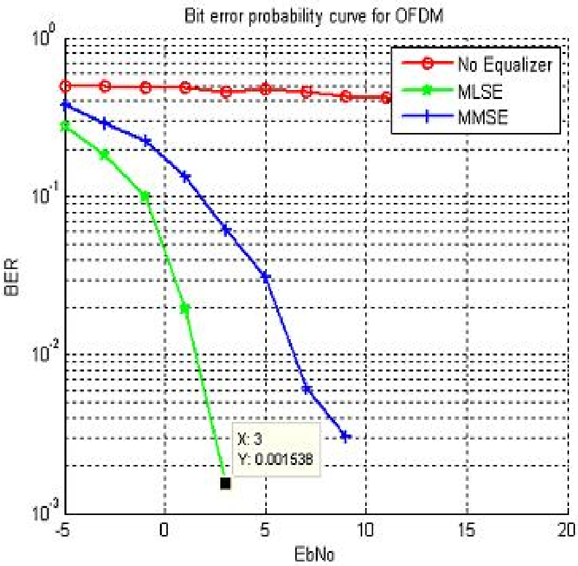

Figure 4: BER for BPSK using OFDM in Rayleigh channel

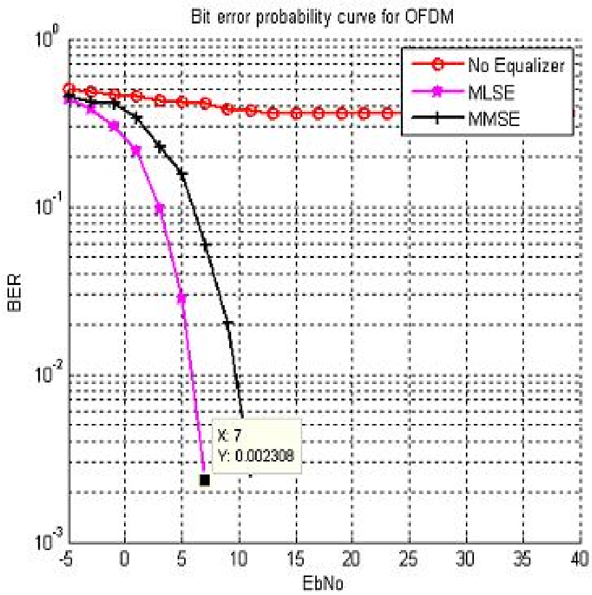

Figure 5: BER for QPSK using OFDM in Rayleigh channel

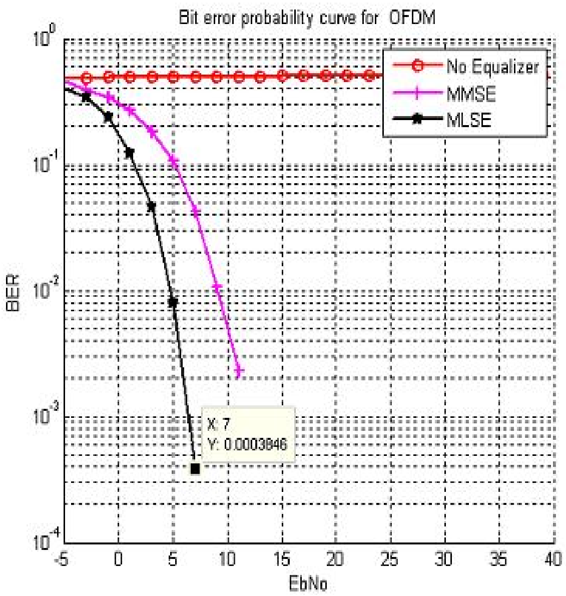

Figure 6: BER for 4 QAM using OFDM in Rayleigh channel

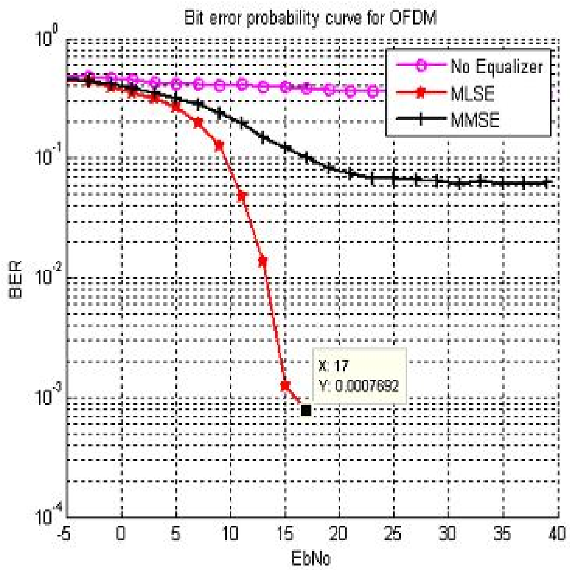

Figure 7: BER for 16 QAM using OFDM in Rayleigh channel

4.2.2 Rayleigh fading:

In Wireless communication, fading is deviation of the attenuation that a carrier modulated telecommunication signal experiences over certain propagation media. The fading may vary with time, geographical position and radio frequency and is often modeled as a random process. A fading channel is a communication channels that experiences fading. Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as That used by wireless devices. Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built up urban environments on radio signal.

5. Conclusion:

Rayleigh fading of signal which leads to inter symbol interference (ISI) maximum likelihood sequence estimation are used to improve the performance. The paper compares the performance of un equalized systems with the equalized system. The bit error performance is improved.

In this paper we have demonstrated the application of BPSK,QPSK,4QAM,16QAM,modulation technique in OFDM system with a view of reducing the inter symbol interference

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