International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 1 Issue 5 (June 2014) http://ijirae.com

A BER Performance Analysis of Shift Keying Technique with MMSE/MLSE estimation in Fading domain

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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).

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

I. INTRODUCTION

The physical layer of future wireless communications systems is expected to provide an even higher data rate when compared to current schemes. Multicarrier (MC) based systems have showed to be the best choice for this requirement because of its many advantages. The basic principle of MC to divide the frequency spectrum into many narrow subchannels is not new, but only in the last decade it could be observed a widespread use in practical systems. There are many classes of MC systems, but the CP-OFDM is certainly the most investigated one. It offers the advantage of efficient and simple implementation and the channel equalization becomes a trivial task. As a result of the insertion of redundancy (CP), only one tap per subchannel is necessary to compensate the frequency selectivity of the channel. The drawbacks of CPOFD M compared to other modulation schemes include a loss in spectral efficiency, as a consequence of the CP insertion, a higher level of out-of-band radiation, since the subcarriers have a sinc-like frequency behavior, and a higher sensitivity to narrowband interferers when the synchronization is not perfect, because the low attenuation of the sidelobes implies in an frequency undesired overlap of the subchannels. CP-OFDM is based on the general MC concept of modulated transmultiplexers (TMUX), which are composed of exponentially modulated analysis and synthesis filter banks, what we call FBMC systems. Maximally decimated filter banks are of particular interest. Instead of using a rectangular window for pulse shaping, a finite impulse response (FIR) prototype filter that has a longer impulse response than the symbol period, i. e. the number of filter coefficients is higher than the number of subchannels M, is modulated by complex exponentials to form each subchannel. Because of its longer length, the filters can be more concentrated in the frequency domain and the subchannels are shaped to overlap only with the contiguous ones. The prototype filter is also chosen to fulfill the Nyquist Intersymbol Interference (ISI) criterion, so that its impulse response has amplitude zero at the symbol period T. But it is known from filter bank [1] and communication theory [2] that, in a complex modulated and critically sampled TMUX, if the input signals are complex and in order to achieve the perfect reconstruction or ISI conditions, the real and imaginary parts of the input signals must be staggered by $T/2$, resulting in the so called Offset Quadrature Amplitude Modulation (OQAM).

The equalization problem in FBMC systems is still an active research topic. We focus here on solutions that depend only on the output signals of each subchannel. In this way per-subchannel equalizers work like single carrier (SC) equalizers for OQAM modulated symbols, but with the difference that Interchannel Interference (ICI) is present. Since noise cannot be considered white at the output of a filter with bandwidth smaller than the sampling frequency, this has to be considered in the equalizer design. Furthermore, in an FBMC system with OQAM input symbols the equalizer can be inserted in front of the de-staggering, leading to a fractionally spaced equalizer (FSE) working at a rate of $2/T$, where $1/T$ is the symbol rate.In the classical literature of receivers for frequency selective channels, the MLSE equalizer is referred as the optimal receiver [3]. In addition to completely mitigating the ISI, those receivers make use of the time diversity inserted by the multipath channel. The main drawback and an obstacle to practical use of the MLSE is its computational complexity. Some practical solutions for the problem of channel equalization already exist in the literature. In [4] the authors consider the equalizer optimization in the frequency domain, while in [5] a time domain optimization of the MMSE linear equalizer is presented. In [6] an MMSE decision feedback equalizer is derived. In this paper we evaluate the uncoded bit error rate (BER) of FBMC systems by considering a comparison

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between the MLSE receiver adapted to the OQAM modulation and the unbiased MMSE linear equalizer. Moreover, we compare the coded and the uncoded BER of CP-OFDM and FBMC systems when both have the same data\ rate.

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.

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 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.

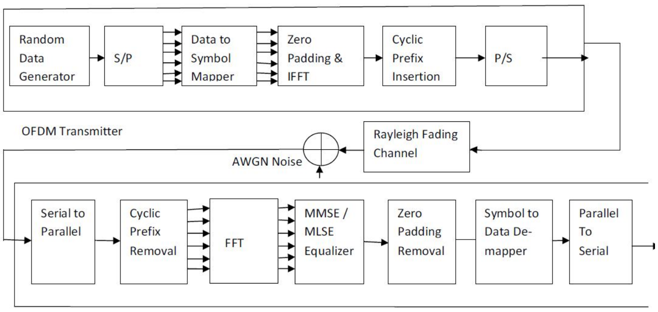

Figure 1: OFDM Simulation Model

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

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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'=a1X1+a2X2+a3X3

€=Y-Y'

Min E {€2} =E ((Y-Y') 2)

a1>a2>a3

Ə\ Əa1 {E {(Y-a1X1-a2X2-a3X3)2}}

=E {Ə\ Əa1 (Y-a1X1-a2X2-a3X3)2}

=E {2(Y-a1X1-a2X2-a3X3) (-X1)} =0

(Y-a1X1-a2X2-a3X3)= €

Similarly

Ə\ Əa2 and Ə\ Əa3 Yield: Collectivity

E {€ X1} =0

E {€ X2} =0

E {€ X3} =0

Error € is orthogonal to data X1>X2>X3 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 .Simulation is carried out Rayleigh channel using BPSK, QPSK, 4QAM, 16QAMModulation technique

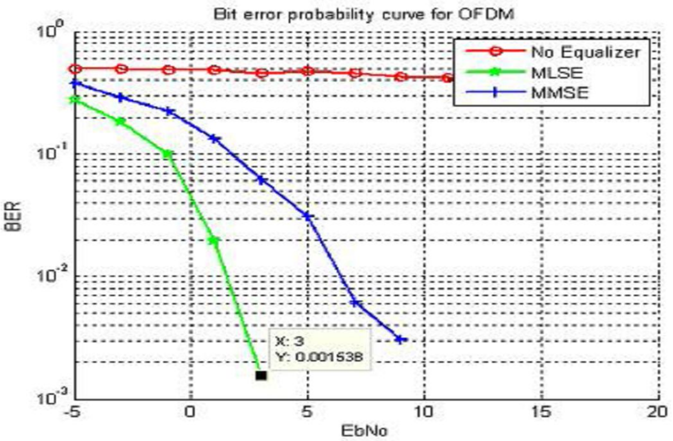

Fig.4.1.1 – System Model with Self cancellation

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

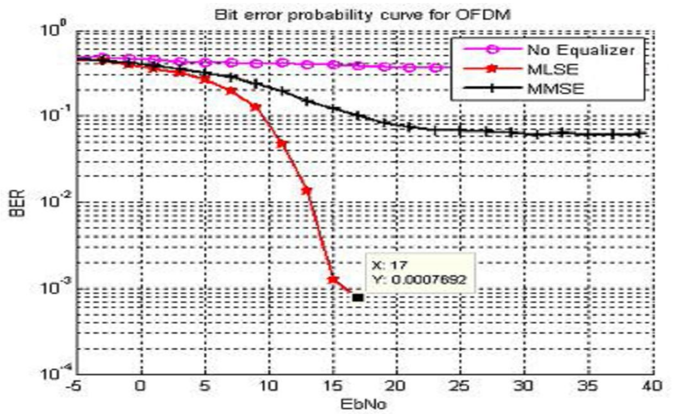

Fig.4.1.2 – System Model with Self Response

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. CONCLUSIONS

We presented in this work a comparison of the BER performance between the linear MMSE equalizer and the MLSE receiver for FBMC systems. The MMSE linear equalizer shows a performance very close to the MLSE for low values of $Eb/N0$ but at a much lower computational complexity. We also compared the uncoded and coded BER performance between FBMC and CP-OFDM in a wireless communications scenario. From the simulations results we can conclude that the FBMC system presents an advantage of 2.5 dB compared to a CP-OFDM system.

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