Bit Error Rate Performance Analysis for Various Modulation Techniques using SUI Channel in Multi-Carrier System

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Abstract— Orthogonal Frequency Division Multiplexing (OFDM) is one of the strong prospects as a future wireless communication system. Improved spectral efficiency has been found in OFDM based on DFT, has a good orthogonality but inter symbol interference (ISI) and inter carrier interference (ICI) degrade the performance. ISI and ICI can be improved by using cyclic prefix (CP). About 20% of bandwidth is consumed by CP. For preferable performance DWT based OFDM gives better outlook than DFT based OFDM. Three advantages of using DWT are desirable signal to noise ratio, desirable data rate and below per power requirement are given by wavelet based OFDM. Comparison of performances of BER using practical channel model known as Stanford University Interim (SUI) is given in this paper. Consideration to QPSK, 4QAM, 8QAM, 16-QAM, 32QAM, 64-QAM, 128QAM and 256 QAM has been given in modeling. Channel condition and modulation are the pre-curators given for the selection of particular performance.

Keywords— OFDM, MIMO, BER, Cyclic Prefix, DFT, DWT, SUI Channel.

I. INTRODUCTION

As a multicarrier modulation technique orthogonal frequency division multiplexing (OFDM) can be seen as a better prospect of future wireless communication, better quality audio, video and mobile integrated service are the requisites for data transmission at higher data rates in current and future mobile communication. Inter symbol interference (ISI) is caused due to extension of channel impulse response over a many symbol period and it results when data is send at high bit rates. Signal is send in parallel form and bandwidth is divided into narrow sub channel in Orthogonal frequency division multiplexing (OFDM) to do away with delay spread [1] [2].

Signal can be executed in joint time–frequency domains wavelet transform [3]. Orthogonality is improved using wavelet to support time and frequency domain. Orthogonal wavelets are capable to reduced the effect of inter symbol interference (ISI) and inter carrier interference (ICI) which are due to loss of orthogonality between the carriers as a result of multipath propagation over the wireless fading channels. Cyclic prefix (CP) is used in OFDM to overcome inter symbol interference (ISI) and inter channel interference (ICI). Cyclic prefix (CP) is not mandatory in wavelet based OFDM. CP may be 20% or more of symbol. Thus wavelets based OFDM gives about 19% - 21% of more bandwidth efficiency [4]. Wavelets based OFDM is less affected by Doppler shift. Time–frequency as well as orthogonality is support in wavelet based OFDM. Phase linearity as well as important out–of–band rejection is provided by wavelet.

Factors such as mult i–path, frequency offset, timing offset, and noise wireless environment is unforeseeable as wired medium. The received signal is thus suffer from amplitude and phase distortion as the signal passed through adverse channel conditions. Channel assessment gives the idea about channel response. The dynamic assessment of channel is important in of Orthogonal Frequency Division Multiplexing (OFDM) as radio channel is frequency selective and varying in time for wideband mobile communication systems [5]. Demodulated to binary data the channel assessment can be brought in used by as equalizer to improve the received constellation data.

Two types of channel models (i) Indoor channel models, and (ii) Outdoor channel models are the two main type of various channel models in the proposed wireless communication system [6] [7]. The Stanford University Interim (SUI) channel model has been discussed in this paper. SUI is an outdoor channel model. The SUI channel has some feature which are unique in a way, they are (a) Consideration of both co-channel and adjacent channel interference (b) Consideration of both macroscopic and microscopic fading effects, (c) having lower path loss as comparison to super cell architecture and (d) Doppler spread and greater multipath delay is also taken in consideration [8], and inclusion of many diversified properties such as speed of wind, range of traffic, specifications of antenna, terrain and bandwidth. K factor is one of the significant parameter of this channel model. The K factor rests on BTS and CPE heights, bandwidth, distance from the antenna, and surrounding conditions. SUI-1, SUI-2, SUI-3, SUI-4, SUI-5, and SUI-6 have all different K-factors [9].

The performance of wavelet based OFDM system against DFT based OFDM system for variety of modulation techniques using SUI Channel is analyzed. Daubechies2 and Haar wavelets have been used for system employing wavelets.

The paper is organized as first of all in section 2. DFT based OFDM system is discussed and section 3 contains wavelets based OFDM system. Section 4 contains Stanford University Interim (SUI) Channel and then the BER (Bit Error Rate) performance analysis and results from simulation in section 5. In section 6 summarized conclusions.
The conventional orthogonal frequency division multiplexing (OFDM) has a basis set which is orthogonal in nature which is formed by using the sinusoids of the discrete Fourier transform. Fast Fourier Transform (IFFT) is used for the implementation of the OFDM system because less number of computations required in FFT and IFFT. Multiple reflections of the signal are received at the receiver end because of the time dispersive nature of the channel, so frequency selective fading results and to reduce this interference guard interval is used, which is called cyclic prefix [10]. Cyclic prefix is copy of the same fraction of symbol end. As long as the channel delay spread remains within the limit of the cyclic prefix there would not be any loss in orthogonality. For LTE, in the downlink data of different users is multiplexed in frequency domain and access technique is called Orthogonal Frequency Division Multiple Access (OFDM A) [11]. In the up link of the LTE access technique used is Single Carrier- Frequency Division Multiple Access (SC-FDMA).

As shown in figure 1. Firstly, conventional encoding is done then data is converted to decimal form and modulation is done next. After modulation the IFFT converts time domain signal to the frequency domain and adds cyclic prefix which provides the orthogonality to the subcarriers. Cyclic prefix is removed after passing through the channel and after that pilot synchronization is done. FFT is then converted from frequency domain to time domain at the receiver end. Demodulated data is converted to binary and then decoded to obtain the original data transmitted.

![Fig 1: DFT based OFDM system design.](image)

### III. DISCRETE WAVELET TRANSFORM (DWT)

The DWT analyzes the signal at different frequency bands with different resolutions by decomposing the signal into an approximation containing coarse and detailed information. DWT employs two sets of functions, known as scaling and wavelet functions, which are associated with low pass and high pass filters. The decomposition of the signal into different frequency bands is simply obtained by successive high pass and low pass filtering of the time domain signal. The original signal $x[n]$ is first passed through a half-band high pass filter $g[n]$ and a half-band low pass filter $h[n]$. A half-band low pass filter removes all frequencies that are above half of the highest frequency, while a half-band high pass filter removes all frequencies that are below half of the highest frequency of the signal. The low pass filtering halves the resolution, but leaves the scale unchanged. The signal is then sub-sampled by two since half of the number of samples is redundant, according to the Nyquist’s rule. This decomposition can mathematically be expressed as follows:

$$y_{\text{high}}[k] = \sum_n x[n]g[2k - n] \quad (1)$$
$$y_{\text{low}}[k] = \sum_n x[n]h[2k - n] \quad (2)$$

Where $y_{\text{high}}[k]$ and $y_{\text{low}}[k]$ are the outputs of the high pass and low pass filters, after sub-sampling by a factor of two. As shown in figure 2. Encoding is done followed by interleaving, then data is converted to binary to decimal form and modulation is done. After modulation the pilot insertion and sub carrier mapping is done then the IDWT of the data is used which provides the orthogonality to the subcarriers. IDWT will convert time domain signal to the frequency domain. After passing through the channel at the receiver end DWT will be performed and then passed through pilot synchronization which is followed with demodulation. Demodulated data is converted from decimal to binary form and then de-interleaved and decoded to obtain the original data transmitted.

![Fig. 2: Wavelet based OFDM system design.](image)
IV. STANFORD UNIVERSITY INTERIM (SUI) CHANNEL MODELS

To get a perfect evaluation of the performance of the developed communication system, wireless channel is required to address its propagation, and then characterized by the factors like surrounding characteristics of fading, Path loss, delay spread of multipath, Doppler spread, Co-channel and adjacent channel interference [12]. An accurate description of the wireless channel is The Stanford University Interim (SUI) channel models are an extension of the earlier work by AT&T Wireless and Erceg et al [13]. SUI model is a set of six channels selected to address three different terrain types [14]. This model is used for simulation, design, and testing the technologies suitable for broadband wireless applications [15]. The parameters for the model were selected based on some statistical models.

The parametric view of the six SUI channels is depicted in the following table 1 and 2.

<table>
<thead>
<tr>
<th>Terrain</th>
<th>Environmental Description</th>
<th>SUI Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Flat/Light Tree Density</td>
<td>SUI-1, SUI-2</td>
</tr>
<tr>
<td>B</td>
<td>Flat/Moderate Tree Density</td>
<td>SUI-3, SUI-4</td>
</tr>
<tr>
<td>A</td>
<td>Hilly/Moderate to Heavy Tree Density</td>
<td>SUI-5, SUI-6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Doppler</th>
<th>Low Delay Spread</th>
<th>Moderate Delay Spread</th>
<th>High Delay Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>SUI-1, SUI-2</td>
<td>SUI-5</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>SUI-3, SUI-4</td>
<td>SUI-6</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3: Transmitter and receiver block diagram for SUI channel

The general structure of SUI channel model is shown in Figure 3. The structure is general for any MIMO (Multi-Input-Multi-Output) channel models have drawn considerable attentions. In MIMO system multiple antennas are used in the transmitter and in the receiver, which is a natural extension of the develop ments in antenna array based communication systems.

The basic components of the SUI channel models are (a) input mixing matrix, (b) tapped delay line, and (c) output mixing matrix as shown in Figure 3. (a) Input Mixing Matrix- This part models the correlation between input signals and the multipath fading. The multipath fading is modeled as a tapped delay line with 3 taps with non-uniform delay s. The gain associated with each tap is characterized by a distribution (Rician with a K-factor > 0, or Rakeleigh with K-factor = 0), and the maximum Doppler frequency. (b) Tapped Delay Line Matrix- This part models the correlation between output signals and multiple receiving antennas are used.

V. BER PERFORMANCE EVALUATION AND THE RESULTS

The simulation is done through SUI channel for different values of Signal to noise ratio (SNR). Using MATLAB performance characteristic of DFT based OFDM and DWT based OFDM results are obtained for different modulations, as shown in figures 4-11. Modulations that could be used for OFDM are QPSK, 4QAM, 8QAM, 16 QAM, 32QAM, 64 QAM, 128QAM and 256QAM (Up link and downlink). At very high speed QPSK does not carries data. Good quality signal to noise ratio (SNR) is a requirement for using higher modulation techniques. Clear shown in the figures (4-11) that the BER performance of wavelet based OFDM out performs than the DFT based OFDM.

Fig. 4. BER performance of wavelets and DFT based OFDM system using QPSK modulation and SUI channel.
Fig. 5. BER performance of wavelets and DFT based OFDM system using 4-QAM modulation and SUI channel.

Fig. 6. BER performance of wavelets and DFT based OFDM system using 8-QAM modulation and SUI channel.

Fig. 7. BER performance of wavelets and DFT based OFDM system using 16-QAM modulation and SUI channel.

Fig. 8. BER performance of wavelets and DFT based OFDM system using 32-QAM modulation and SUI channel.
Fig.9. BER performance of wavelets and DFT based OFDM system using 64-QAM modulation and SUI channel.

Fig.10. BER performance of wavelets and DFT based OFDM system using 128-QAM modulation and SUI channel.

Fig.11. BER performance of wavelets and DFT based OFDM system using 256-QAM modulation and SUI channel.

VI. CONCLUSION
In this paper, the performances of wavelet based OFDM and the DFT based OFDM system has been analyzed and compared. From performance curve obtained, it has been observed that the BER curves of wavelet based OFDM are better than that of DFT based OFDM. Modulation techniques used for implementation are QPSK, 4QAM, 8QAM, 16 QAM, 32QAM, 64 QAM, 128QAM and 256QAM, using SUI channel which are used in LTE. Daubechies2 and haar wavelets are used; both provide their better performances at different intervals of SNR.

REFERENCES


