Comparison of Bit Error Rate Performance of Orthogonal Frequency Division Multiplexing and Discrete Wavelet Transform based Orthogonal Frequency Division Multiplexing over AWGN Channel

Saurabh Gaur¹ Ankita Goyal²
¹M.E ²M.E Scholar
¹,²MIT Ujjain, India.

Abstract— Reliable and high speed communication over AWGN requires a robust modulation scheme, like a Discrete Wavelet Transform (DWT) based modulation technique, hence the quality of data communication over the noisy in-home power line network can be improved. This paper investigates the performance of conventional Orthogonal Frequency Division Multiplexing (OFDM) and Discrete Wavelet Transform-based OFDM (DWT-OFDM) systems in the presence of noise in multipath AWGN as a communication channels. The time and frequency localization properties of the wavelet transform mitigates narrowband and heavy impulsive noise in the power lines which results in performance improvement. Simulation results in terms of PAPR, PSD, and Bit Error Rate (BER) show that DWT-OFDM is more robust against interference and multipath effects compared to DFT-OFDM, and increasing the length of the basis function improves BER and PAPR.

Key words: Comparison, District wavelet, Channel.

I. INTRODUCTION

Communication is one of the integral parts of science that has always been a focus point for exchanging information among parties at locations physically apart. After its discovery, telephones have replaced the telegrams and letters. Similarly, the term ‘mobile’ has completely revolutionized the communication by opening up innovative applications that are limited to one’s imagination. Today, mobile communication has become the backbone of the society [1]. All the mobile system technologies have improved the way of living. It main plus point is that it has privileged a common mass of society.

Orthogonal Frequency Division Multiplexing (OFDM) is becoming a very common multi-carrier modulation technique for transmission of signals over wireless channels in diverse environments. OFDM divides the high-rate stream into parallel lower rate data and hence prolongs the symbol duration, thus helping to eliminate Inter Symbol Interference (ISI) [12]. In an OFDM system the sub-channels overlap with each other to a certain extent as can be seen in figure.1 in which leads to the reduced use of bandwidth and since these carriers are orthogonal to each other Inter Carrier Interference (ICI) is also reduced.

The input data sequence is mapped into symbols [11, 12], which are distributed and sent over the N parallel sub-channels, one symbol per channel. To permit dense packing and still guarantee that a minimum of interference between the sub-channels is encountered, the carrier frequencies must be chosen carefully. In OFDM the data is modulated using multiple numbers of sub-carriers that are orthogonal to each other because of which the problems associated with other modulation schemes such as Inter Symbol Interference (ISI) and Inter Carrier Interference (ICI) is reduced.

Fig. 1: (A) Conventional multicarrier technique (FDM) (B) Orthogonal Frequency Division multiplexing Technique

A wavelet is a waveform of effectively limited duration that has an average value of zero. The comparative difference between wavelets and sine waves, which are the basis of Fourier analysis is that sinusoids do not have limited duration [19], they extend from minus to plus infinity and where sinusoids are smooth and predictable, wavelets tend to be irregular and asymmetric [18]. As the well known technique of signal analysis Fourier analysis consists of breaking up a signal into sine waves of various frequencies, similarly, wavelet analysis is the breaking up of a signal into shifted and scaled versions of the original (or mother) wavelet [18, 19]. The Discrete Wavelet Transform (DWT) is used in a variety of signal processing applications, such as video compression, Internet communications compression, object recognition and numerical analysis [19]. The advantage of wavelet transform over other transforms such as Fourier transform is that it is discrete both in time as well as scale [18]. The transform is implemented using filters.
One filter of the analysis (wavelet transform) pair is a low-pass filter (LPF), while the other is a high-pass filter (HPF) [17]. Each filter has a down-sampler after it, to make the transform efficient.

![DWT-OFDM](image)

**Fig. 2: DWT-OFDM**

### III. ADDITIVE WHITE GAUSSIAN NOISE (AWGN) CHANNEL

Additive white Gaussian noise (AWGN) is a basic noise model used in Information theory to mimic the effect of many random processes that occur in nature [30]. The modifiers denote specific characteristics:

‘Additive’ because it is added to any noise that might be intrinsic to the information system. ‘White’ refers to the idea that it has uniform power across the frequency band for the information system. It is an analogy to the color white which has uniform emissions at all frequencies in the visible spectrum. ‘Gaussian’ because it has a normal distribution in the time domain with an average time domain value of zero. AWGN is often used as 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 per hertz of bandwidth) and a Gaussian distribution of amplitude [29]. The model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion [27]. However, it produces simple and tractable mathematical models which is useful for gaining insight into the underlying behavior of a system before other phenomena is considered [29]. The AWGN channel is a good model for many satellite and deep space communication links [33]. It was not a good model for most terrestrial link because of multipath, terrain blocking and interference, etc. However, for a terrestrial path modeling, Additive White Gaussian Noise was commonly using to simulate background noise of the channels, in addition to multipath, terrain blocking and interference, ground clutter and self interference that modern radio systems encounter in terrestrial operation.

### IV. SIMULATION MODEL & RESULTS

In DFT-OFDM system, the data bit stream is first mapped onto QAM constellation to form a complex symbol followed by S/P. Then it is modulated onto orthogonal subcarriers using IDFT. After P/S, a Cyclic Prefix (CP) (that is 25% of each symbol in practical systems) is wrapped to the symbols. Then the signals are passed through the power-line as a communication channel, followed by three noises. At the receiver, the CP is discarded. The resulting signal is demodulated to recover the original data bits.

DWT is a class of generalized Fourier transforms with basis function being localized well both in the time and frequency domains. They are constructed by means of Quadrature Mirror Filter (QMF) pairs [14-15]. It has been shown that DWT-OFDM is more robust to narrowband interference and multipath propagation loss, than DFTOFDM [16]. In DWT-OFDM transmitter, the incoming signal is first converted from serial to parallel.

![Simulation model of DFT-OFDM](image)

**Fig. 3: Simulation model of DFT-OFDM**

<table>
<thead>
<tr>
<th>S. n</th>
<th>PARAMETER</th>
<th>LENGTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Length of Input Signal</td>
<td>520000 bits</td>
</tr>
<tr>
<td>2.</td>
<td>Nature of Input Signal</td>
<td>Random Signal</td>
</tr>
<tr>
<td>3.</td>
<td>Modulation Technique</td>
<td>16-QAM</td>
</tr>
<tr>
<td>4.</td>
<td>IFFT/FFT</td>
<td>64</td>
</tr>
<tr>
<td>5.</td>
<td>No. of Subcarriers</td>
<td>64</td>
</tr>
<tr>
<td>6.</td>
<td>Spacing between two Subcarriers</td>
<td>312.5KHz</td>
</tr>
<tr>
<td>7.</td>
<td>Type of Channel</td>
<td>AWGN</td>
</tr>
</tbody>
</table>

Table1 Simulation Parameters

Consequently, DWT-OFDM does not require P/S in the transmitter and S/P in the receiver. In our study, wavelets such as Daubechies (db) and Symlet (sym) are evaluated. When analysis bank is exchanged with the synthesis bank, the system will be still a Perfect Reconstruction (PR) [18]. Fundamentally, DFT-OFDM and DWT-OFDM have many similarities as both use orthogonal waveforms as subcarrier. The main difference between DFT-OFDM and DWT-OFDM is on the shape of the subcarrier and in the way they are created. One important property of wavelet is that the waveforms being used in general are longer than the transform duration of each symbol [19-20]. This causes DWT-OFDM symbols to overlap in the time domain. Longer waveforms allow better frequency localization of DWT-OFDM’s subcarriers while in DFT-OFDM the rectangular shape of DFT window generates large side lobes. Fig. 5-a and Fig. 5-b illustrate the spectra of 8 adjacent subcarriers for DWT(db16)-OFDM and DFTOFDM transceiver, respectively.
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Table 2 shows the values of BER when SNR is varied from 0-10dB with the difference of 0.5dB. The comparison of BER performance of OFDM and DWT-OFDM is shown in fig 4.2 and table 4.3.

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>Signal to noise ratio[SNR] in db</th>
<th>Bit Error Rate[BER] of OFDM</th>
<th>Bit Error Rate[BER] of DWT-OFDM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0.0786</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2.5</td>
<td>0.0297</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>0.0060</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>7.5</td>
<td>0.0004</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>0.0000038</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: BER v/s SNR of DFT-OFDM

Fig. 4: BER v/s SNR graph

V. CONCLUSION

In this thesis DFT-OFDM and DWT-OFDM systems over AWGN channel using 16 QAM are simulated and Bit Error Rate Performance is compared.
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Rate Performance Of both systems are evaluated and then compared. DWT-OFDM shows better BER performance than that of DFT-OFDM. At 1dB SNR the BER of DFT-OFDM is 0.0563 and that of DWT-OFDM is 0.0142. At 5dB SNR the BER of DFT-OFDM is 0.0060 and that of DWT-OFDM is 0.0002. At 8dB SNR the BER of DFT-OFDM is 0.0002 and that of DWT-OFDM is 0.00000625. To obtain BER of 0.0002 the SNR required in DFT-OFDM is 8dB and the SNR required in DWT-OFDM is 5dB.

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