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BER PERFORMANCE ANALYSIS OF FFT AND DWT OFDM USING DPSK IN THE PRESENCE OF CFO

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation scheme which has been adopted in many wireless communication standards. Conventional OFDM uses Inverse Fourier Transform (IFFT) in the transmitter side and Fast Fourier Transform (FFT) in the receiver side. One of the drawback of FFT OFDM is the performance degradation in the presence of Carrier Frequency Offset (CFO). Many research works proven that replacing the Fast Fourier Transform (FFT) by Discrete Wavelet Transform (DWT) shows better performance. IFFT is replaced by Inverse Discrete Wavelet Transform (IDWT) and FFT is replaced by DWT (Discrete Wavelet Transform) in the conventional OFDM.DPSK modulation scheme is used in this work. In this paper both FFT OFDM and DWT OFDM are compared in the presence of Carrier Frequency Offset (CFO) in Additive White Gaussian Noise (AWGN) channel. Bit Error Rate (BER)of both FFT OFDM and DWT OFDM is compared in the presence of CFO. The result shows that DWT OFDM out performs FFT OFDM.

KEYWORDS: OFDM (Orthogonal Frequency Division Multiplexing), IFFT (Inverse Fast Fourier Transform), FFT (Fast Fourier Transform) OFDM, DWT (Discrete Wavelet Transform) OFDM, CFO (Carrier Frequency Offset),ICI (Inter Carrier Interference), BER (Bit Error Rate)

INTRODUCTION

OFDM (Orthogonal Frequency Division Multiplexing) is nowadays used in many applications where high data rate is needed. Many wireless communication systems uses OFDM as their modulation technique such as wireless local area networks (WLAN), mobile worldwide interoperability for microwave access (Mobile Wi-MAX), 3rd generation partnership project long term evolution (3GPP LTE), wireless fidelity Wi-Fi, digital audio broadcasting (DAB) and digital video broadcasting (DVB) wireless standards[11]. The conventional OFDM has some drawbacks , performance degrades in the presence of some factors. One such factor is the Carrier Frequency Offset (CFO)[1]. OFDM is more sensitive to carrier frequency offsets in the received signal due to instabilities in the local oscillators. That is carrier Frequency Offset is nothing but the difference between the local oscillator frequencies in the transmitter as well as in the receiver.CFO can occur due to the doppler shifts[3]. This difference may destroy the orthogonality among the subcarriers which is the key factor of OFDM and leads to the Inter Carrier Interference (ICI)[4][7].

In this paper we are comparing the effects of both FFT OFDM and DWT OFDM in the presence of CFO. For that the paper is considered in such a way that the next section gives the block description and details about the FFT and DWT OFDM. In the third section the effect of CFO in the orthogonality of OFDM is discussed. The fourth section shows the simulation results and final section gives the conclusion.

OFDM SYSTEM MODEL

OFDM is a special case of FDM in which the available bandwidths are divided into much narrower individual bands (subcarriers) which tend to overlap each other. In OFDM the subcarriers are orthogonal to each other .A basic block diagram of OFDM system is shown in the Figure .1. First the serial data stream is converted into N parallel data stream and then suitable modulation scheme. Here we are using Differential Phase Shift Keying(DPSK)[9] modulation since it doesn't not need carrier signal estimation. After the appropriate modulation an efficient method for implementation of transmitter is using IFFT operation. The output from the IFFT block is the OFDM signal. By performing IFFT in conventional OFDM the output is obtained in the time domain which is represented by,

$$X_k(n) = \frac{1}{\sqrt{N}} \sum_{i=0}^{N-1} X_m(i)\, e^{\left(\frac{j2\pi ni}{N}\right)} \qquad (1)$$

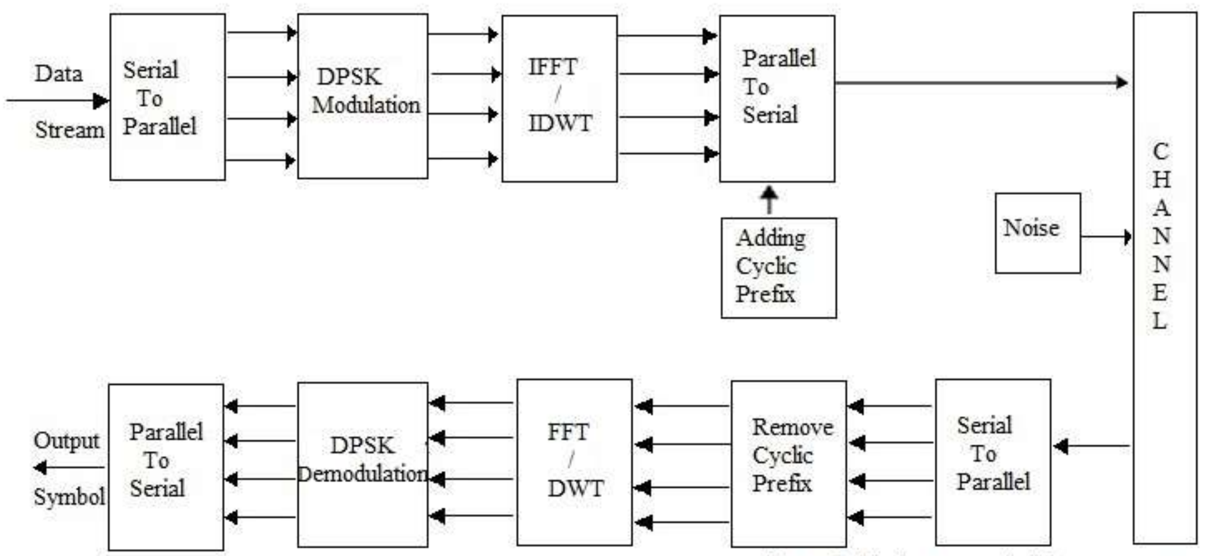

Figure.1 OFDM block diagram

After the N parallel data undergoes IFFT operation , cyclic prefix is added in order to prevent the inter carrier interference. Cyclic prefix is nothing but the tail bits of the data added to the front end and thus extending the length of the data. Then the parallel samples are combined together and transmitted through the channel. Here we are considering Additive White Gaussian Noise(AWGN) channel . In AWGN channel only linear addition of white noise with a constant spectral density is there and it doesn't count fading effects, interferences and frequency selectivity.

At the receiving side first process is the removal of cyclic prefix . After that, the data is given to FFT block. The data which is recovered from the FFT block of receiver is expressed as:

$$X_m(i) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_k(m) e^{-\left(\frac{j2\pi ni}{N}\right)} \qquad (2)$$

In wavelet OFDM the IFFT block is replaced by IDWT block in the transmitter side and the FFT block is replaced by DWT block in the receiver side. To do the wavelet decomposition only two filters are required, a low-pass filter (g[n]) and a high-pass filter (h[n]) [8].

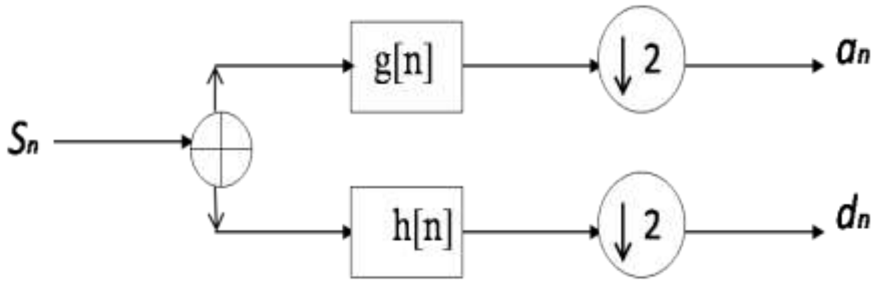

Figure.2 DWT computation

The Figure.2 [13] shows the wavelet decomposition. Low pass filter produces approximate information which is represented by a_n known as scaling function and high pass filter (h[n]) produces detailed information d_n which is known as wavelet function[2]. Filter coefficients of both filters are determined according to the wavelet family used[10]. Half of the frequency components have been filtered out at filter outputs and hence can be down-sampled[12]. The process splits the signal into two equal halves for the analysis of low and high frequency components. The output of the filters are then down sampled. This process is iterative.

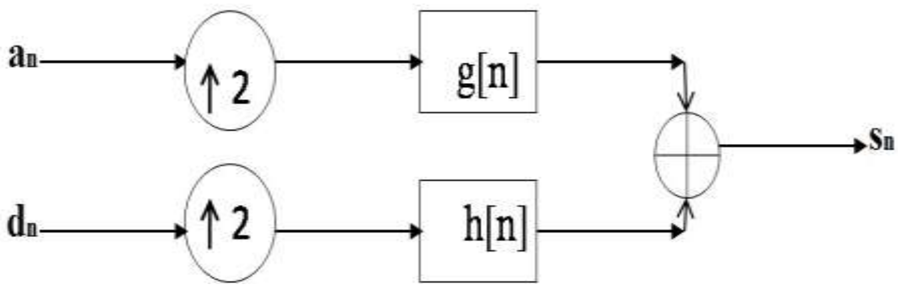

Figure.3 IDWT computation

IDWT process in the transmitter side includes the same filtering with up sampling(Figure.3). First n^{th} OFDM symbol obtained after modulation is up sampled and then filtered using the low-pass filter (g[n]) to get approximate coefficients, which represents the data. To get the wavelet coefficients, it is also up sampled and filtered but using the high-pass filter (h[n]). Then the filter outputs are added together and we obtain the signal S_n. The process is also iterative .

The characteristics of filters are actually determined by the type of mother wavelet (ψ) chosen and its scaling function (φ). We are using Haar wavelet [6] which is the most simplest wavelet and its wavelet function can be represented as

$$\Psi(t) = \begin{cases} 1 & 0 \leq t < \frac{1}{2} \\ -1 & \frac{1}{2} \leq t < 1 \\ 0 & otherwise \end{cases} \qquad (3)$$

Its scaling function Φ(t) is,

$$\Phi(t) = \begin{cases} 1 & 0 \leq t < 1 \\ 0 & otherwise \end{cases} \qquad (4)$$

The data revival in the receiver side involves DWT process. The filters used for this purpose (g[n] and h[n] known as analysis filter) is having matched characteristics with that of the filters used in the IDWT block (g[n] and h[n] known as synthesis filter) of the transmitter. As shown in Figure.2 the received signal is filtered twice, once with the low pass filter and once with the high pass filter. The number of iterations depend on the number of iterations we used in the IDWT block. The output of the low pass filter is always given as the input signal for the next iteration

Cyclic prefix addition is not needed in the case of DWT OFDM because of the nature of DWT and hence ICI can be avoided[2]. Cyclic prefix is actually the redundant bits which restrict the data rate. By avoiding cyclic prefix block complexity, data rate and efficiency can be improved [5].

EFFECT OF CFO OVER OFDM

One of the degrading factor which affect the performance of OFDM is Carrier Frequency Offset(CFO)[7] .The factors which causes CFO are frequency drifts in transmitter and receiver oscillators, radio propagation and the tolerance of the electronics elements in local oscillators of the transmitter and also doppler shift[11]. So considering the effect of CFO in OFDM system ,the received sequence [2]can be expressed as,

$$Y(n) = H[n]X(n)\frac{\sin(\pi\varepsilon)}{N\sin(\frac{\pi\varepsilon}{N})}e^{-(\frac{j\pi\varepsilon(N-1)}{N})} + \sum_{m=0,m\neq n}^{N-1} H[m]X(n)\frac{\sin[\pi(m-n+\varepsilon)]}{N\sin[\frac{\pi(m-n+\varepsilon)}{N}]}e^{-(\frac{j\pi(m-n+\varepsilon)(N-1)}{N})} + w(n) \qquad (9)$$

Where ε is the normalized frequency offset =(f_o /Δf). In the equation 7 the effect of ICI is described by the second part and the first part $\frac{\sin(\pi\varepsilon)}{N\sin(\frac{\pi\varepsilon}{N})}$ is the attenuation factor of the amplitude. $e^{-(\frac{j\pi\varepsilon(N-1)}{N})}$ is the amount of phase shift the signal under goes.CFO destroys the orthogonality among the carriers[7].

SIMULATION PARAMETERS

The simulation of both FFT OFDM and DWT OFDM is performed using MATLAB. Simulation parameters are given below:

- Modulation used: DPSK
- No of subcarriers:256
- Frame length:1000
- Channel used: AWGN
- Wavelet used : Haar wavelet

RESULTS

BER vs E_b/N_0 simulation in the presence of CFO is carried out for ε values 0.1 and 0.2 for both DWT and FFT OFDM in AWGN channel. Figure 4 and 5 shows the BER plot for the ε values 0.1 and 0.2 respectively. It is obvious from the plot that in Figure.4 DWT OFDM has better performance than FFT OFDM after 13dB of SNR. At SNR 25db BER of FFT OFDM is 0. 01 whereas for DWT is 0.001. In Figure.5 upto 14dB of SNR the effects are same for both FFT and DWT OFDM but after that, the DWT OFDM renders better performance and BER at 28db for DWT is 0. 001 where as for FFT it is 0. 01.

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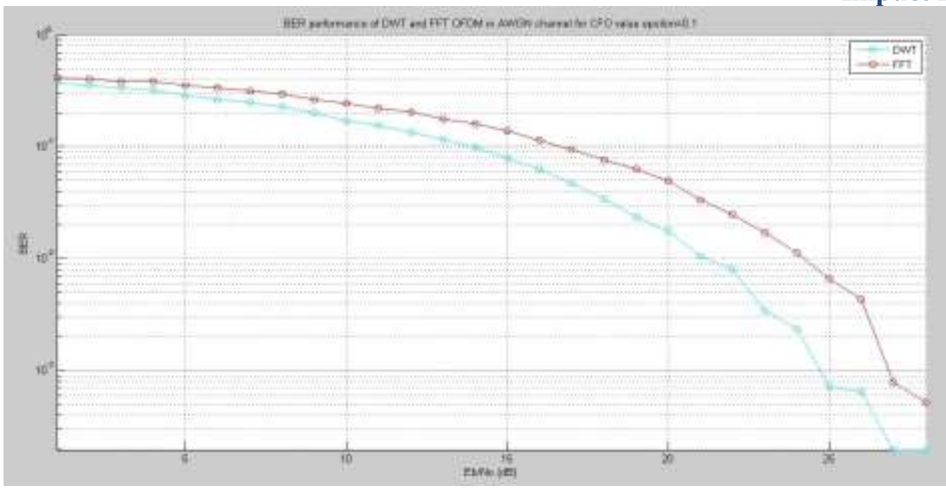

Figure.4 BER plot for DWT and FFT OFDM in the presence of CFO for ε=0.1

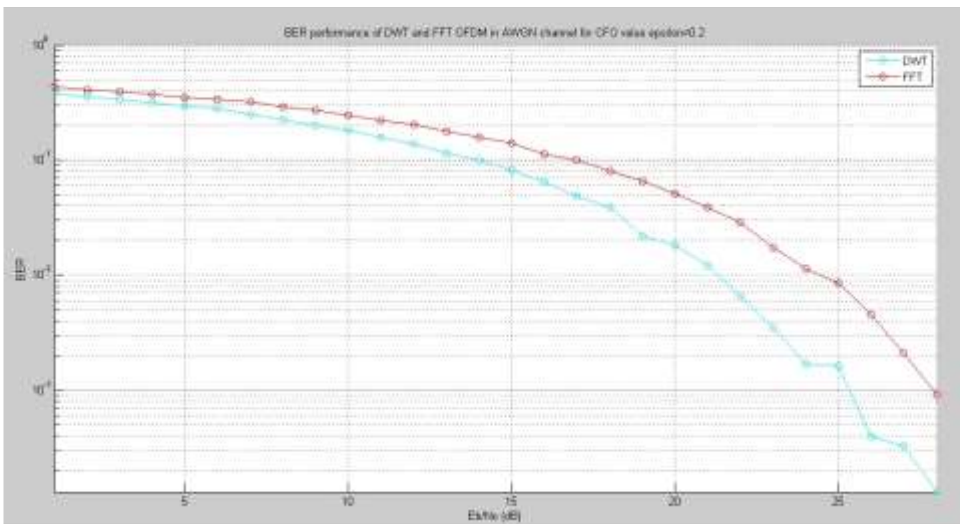

Figure.5 BER plot for DWT and FFT OFDM in the presence of CFO for ε=0.2

To conclude the analysis the results shows that DWT OFDM fairly outperforms in the presence of CFO than FFT OFDM

CONCLUSION

In this paper we have studied the performance of both FFT and DWT OFDM in the presence of Carrier Frequency Offset(CFO).It is clearly proven that DWT OFDM outperforms FFT OFDM for different ε values using Differential Phase Shift Keying(DPSK) modulation in the presence of Additive White Gaussian Noise(AWGN).This paper can be further extended by using different modulation schemes ,channel conditions and wavelets.

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