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Simulation Models of FFT & DWT based MB-OFDM for short range indoor wireless environment

Ms. Surabhi S. Tankkar [1], Mrs. Bhosale J.D. [2]
Electronics Department[1], Electronics & Telecommunication Department[2] ,PIIT,New Panvel[1], PIIT, New Panvel[2]
Email: surabhi.tankkar@gmail.com[1],jbhosale@gmail.com[2]

Abstract- Growth in technology has led to unprecedented demand for high speed architectures for complex signal processing applications. In 4G wireless communication systems, bandwidth is a precious commodity, and service providers are continuously met with the challenge of accommodating more users with in a limited allocated bandwidth. To increase data rate of wireless medium with higher performance, OFDM (orthogonal frequency division multiplexing) is used. Recently DWT (Discrete wavelet transforms) is adopted in place of FFT (Fast Fourier transform) for frequency translation. Multiband Orthogonal Frequency Division Multiplexing (MB-OFDM) approach using UWB signals with short duration of pulses provide unique advantages in short-range high data rate wireless applications which include easy penetration through obstacles, high precision ranging and low processing power. The conventional FFT MB-OFDM system for designing the discrete wavelet packet based MB-OFDM system using UWB for indoor wireless environment is studied. Due to the extinction of CP the spectral efficiency drastically improved which leads to the better power lowering in the side lobes in the actual directivity of the signal which is again helps in the better penetration of the signal through the object. Simulation models of DWT based MB-OFDM is designed using simulation approach. PAPR , SNR v/s BER, frequency offset plots of DWT based MB-OFDM are studied.

Index Terms- DWT, FFT, OFDM, MB-OFDM, PAPR, SNR, BER

1. INTRODUCTION

In 2002, the Federal Communications Commission (FCC) allocated a large spectral mask from 3.1 GHz to 10.6 GHz for unlicensed use of commercial UWB communication devices [1]. Since then, UWB systems have gained high interest in both academic and industrial research community. UWB was first used to directly modulate an impulse like waveform with very short duration occupying several GHz of bandwidth [3]. 'Multi-banding' consists in dividing the available UWB spectrum into several sub-bands, each one occupying approximately 500 MHz (minimum bandwidth for a UWB system according to FCC definition) [4]. By interleaving symbols across different sub-bands, UWB system can still maintain the same transmit power as if it was using the entire bandwidth. Narrower sub-band bandwidths also relax the requirement on sampling rates of ADCs consequently enhancing digital processing capability. Multiband-OFDM (MB-OFDM) is one of the promising candidates for PHY layer of short-range high data-rate UWB communications. It combines Orthogonal Frequency Division Multiplexing (OFDM) with the above multi-band approach enabling UWB transmission to inherit all the strength of MB-OFDM technique which has already been proven for wireless communications. The wavelet based MB-OFDM or Wavelet Packet Modulation (WPM) is an alternate approach to the conventional MB-OFDM that exploits the self and mutual orthogonality properties of wavelet packet basis functions [5]. Unlike the traditional FFT MB-OFDM which divides the whole bandwidth into several orthogonal and overlapping sub-bands of equal bandwidths, WPM uses discrete wavelet packet transform to multiplex transmission. DWPM improves spectral efficiency due to the exclusion of CP. Nevertheless, it requires an efficient equalization technique to counter the ISI and ICI. [7]. With the help of OFDM, sufficient robustness can be achieved to provide large data rates to radio channel impairments. In an OFDM scheme, a large number of orthogonal, overlapping narrowband sub-channels or sub-carriers transmitted in parallel by dividing the available transmission bandwidth. Compact spectral utilization with utmost efficiency is achieved with the help of minimally separated sub-carriers. Main attraction of OFDM lies with how the system handles the multipath interference at the receiver end. OFDM is multicarrier modulation (MCM) technique which provides an efficient means to handle high speed data streams on a multipath fading environment that causes ISI. Normally OFDM is implemented using FFT and IFFT's. To decrease the BW waste brought by adding cyclic prefix, wavelet based OFDM is employed.

2. IMPLEMENTATION

I. FFT based MB-OFDM

The system looks like a normal OFDM system except that the carrier frequency changes from Symbol to symbol according to a sub-band hopping scheme. The convolutional code with interleaving is used to combat multipath fading. Coded bits map to a QPSK constellation. The OFDM modulation is performed by an inverse fast Fourier transform (IFFT) and a cyclic prefix (CP) is added to cancel inter-block interference (IBI) and inert-channel interference (ICI). A guard interval of silence is also added to allow the transmitter and receiver to switch from one sub-band to another. The signal is then is fed into a D/A converter and sent to the RF section. At the receiver the signal is sampled after down conversion and filtering. Demodulation is performed using a Fast Fourier transform (FFT) followed by one-tap frequency domain equalization and decision.

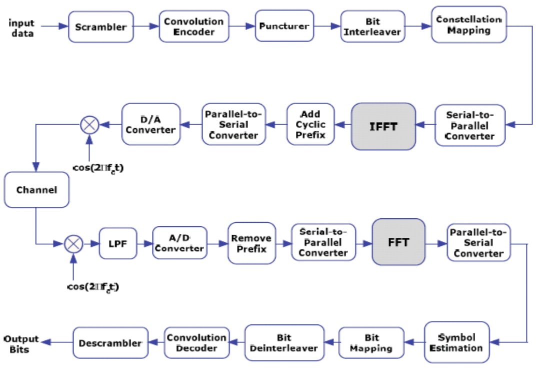

Figure 1 : Block Diagram of FFT based MB-OFDM

II.DWT based MB-OFDM

The good frequency characteristics and greater flexibility of wavelet packet transform make it a choice for MB-OFDM. Figure 2 shows the transmitter and receiver part of DWPTMB-OFDM. This differs from the conventional MB-OFDM in the sense that IFFT and FFT block is replaced by IDWPT and DWPT respectively. It can also be seen that cyclic prefix block has been excluded due to use of discrete wavelet packet transform, so this increases the spectral efficiency compared to conventional MB-OFDM. In DWPT MB-OFDM transmitter the data symbols are converted from serial to parallel and then transmultiplexed by IDWPT block. At the receiver part the data is converted from serial to parallel and then discrete wavelet packet transform is performed. The suggested discrete wavelet based MB-OFDM improve BER performance of transreceiver.

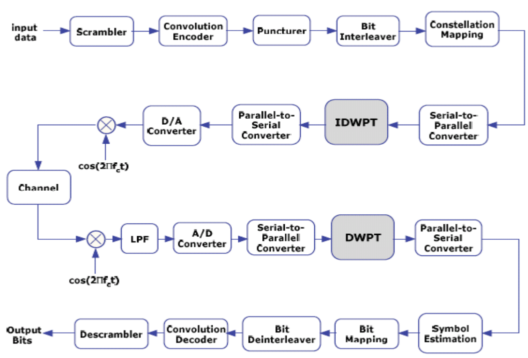

Figure 2 : Block Diagram of DWT based MB-OFDM

3. SOFTWARE FRAMEWORK DEVELOPMENT

I. Development of FFT based MB-OFDM:

A block-set approach is carried out for the simulation of the FFT based MB-OFDM. This is as per the figure 3 shown below In this set of transmitter -receiver pair is used along with the MB-OFDM transmitter receiver pair to suppress the CP to achieve the low power in the processing. The result is seen in the scope through the AWGN channel.

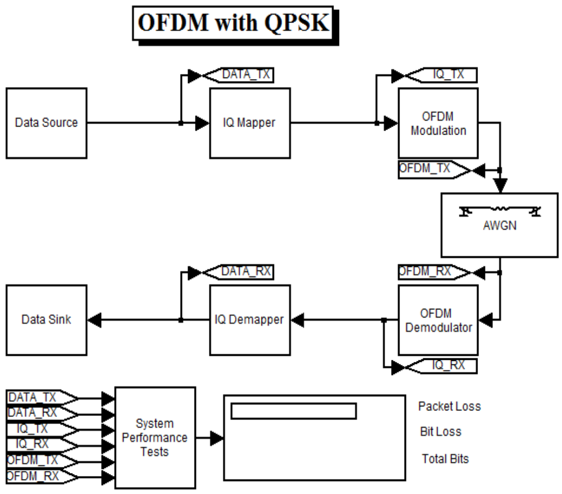

Figure 3: Simulation Model of FFT based MB-OFDM

II . Developement of DWT based MB-OFDM

Simulation Model is designed using the MATLAB script by defining the simulation parameters as mentioned below and the simulation plots for RMS error with frequency offset, BER computation, the cumulative distribution of PAPR from each OFDM symbol, frequency offset estimate using 802.11a short preamble are studied

Simulation Parameters	Value
DWT size : nDWT	64
Number of used subcarriers : nDSC	52
DWT Sampling frequency	20MHz
Subcarrier spacing	312.5kHz
Used subcarrier index	{-26 to -1, +1 to +26}
Cylcic prefix duration, Tcp	0.8us
Data symbol duration, Td	3.2us
Total Symbol duration, Ts	4us

Table 1: Simulaion Parameters for DWT MB-OFDM

4. RESULT & DISCUSSION

I. Simulation results for FFT based MB-OFDM

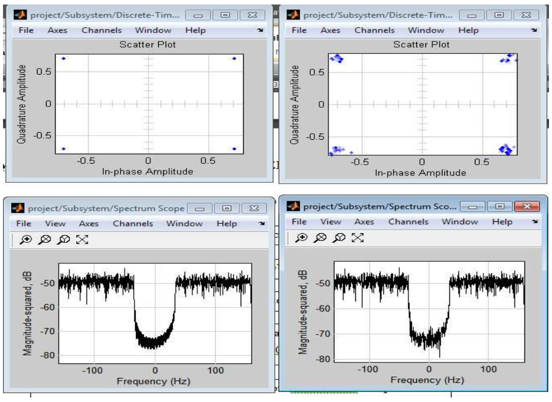

Figure4: Transmitted & Recovered gain plots & scatter plots for SNR = 30 dB

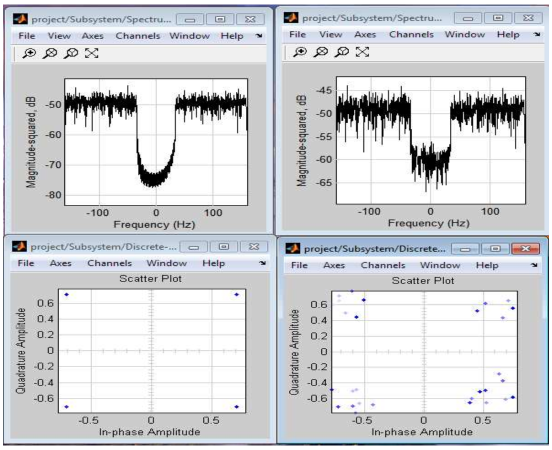

Figure5: Transmitted & Recovered gain plots & scatter plots for SNR = 15 dB

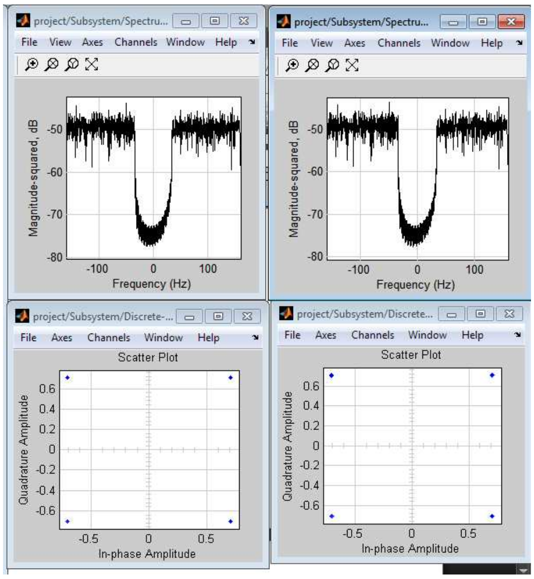

Figure6: Transmitted & Recovered gain plots & scatter plots for SNR = 60 dB

Figure 4 shows the transmitted & recovered QPSK constellation and the transmitter & receiver gain plots for a SNR of 30dB. No packet and bit loss is observed through the simulation model. However for SNR of 15 dB there is a packet and bit loss at the receiver end and the recovered constellation can be seen in Figure 5.From Figure 6 it can be concluded that for SNR of 60 dB the transmitted and recovered gain plots and scatter plot look alike which implies that proper transmission takes place at the receiver end without any bit loss and packet loss.

II. Simulation results for DWT based MB-OFDM

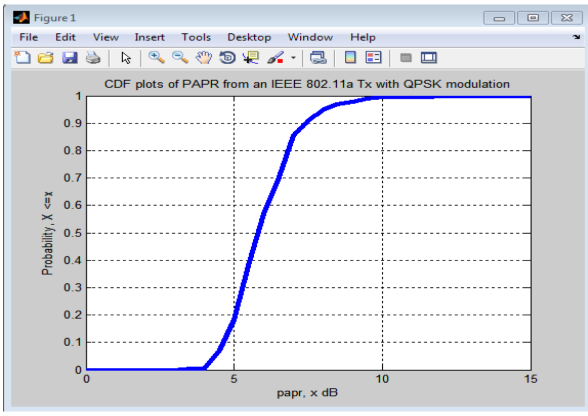

Figure7: Cumulative distribution (CDF) plot of PAPR from a random QPSK signal

As per the IEEE 802.11a specifications, we have used 52 sub-carriers by which the maximum expected PAPR is 52 (around 17dB). However due to the scrambler, all the subcarriers in an OFDM symbol being equally modulated is unlikely. From the figure it is observed that the PAPR seems to be distributed from around +3.5dB to a maximum value of 10dB.

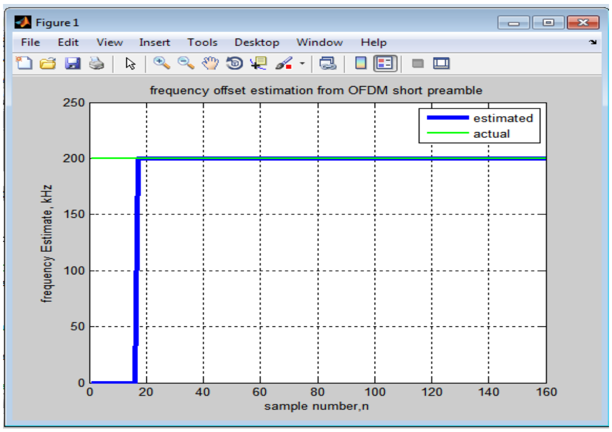

Figure8: Plot of frequency offset estimate using 802.11a short preamble

Each OFDM packet has a preamble structure formed using 10 short preambles of duration 0.8µsec each. This short preamble is constructed by defining 12 subcarriers only (out of the available 52 subcarriers) where the modulation of individual subcarriers ensure a low peak to average power ratio. It can be observed from the plot that starting from sample number 17 (and till samples number 160 (8µsec ,f_s =20MHz) the frequency offset estimate is available.

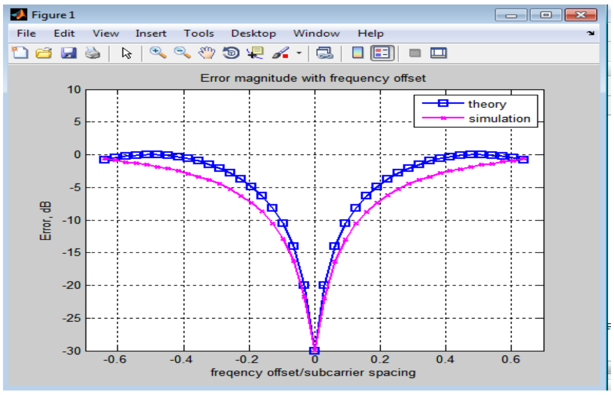

Figure9: Error Magnitude v/s frequency offset for OFDM

The theoretical results are computed by

$$\sum_{m} \frac{1}{j2\pi(k+\delta-m)} e^{j2\pi(k+\delta-m)}$$

Quite likely the simulated results are slightly better than theoretical results because the simulated results are computed using average error for all subcarriers and the subcarriers at the edge undergo lower distortion.

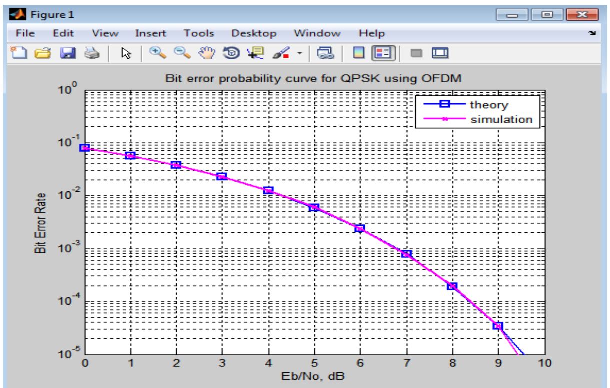

Figure10: Bit Error Rate plot for QPSK using OFDM modulation

Here the simulated bit error rate is in good agreement with the theoretical bit error rate for QPSK modulation

$P_{e(QPSK)}$ = ½ erfc $\sqrt{Eb/No}$

5. CONCLUSION

The conventional FFT MB-OFDM system for designing the discrete wavelet packet based MB-OFDM system using UWB for indoor wireless environment is studied. Due to the extinction of CP the spectral efficiency drastically improved which leads to the better power lowering in the side lobes in the actual directivity of the signal which is again helps in the better penetration of the signal through the object. Simulation models of FFT and DWT based MB-OFDM are designed using simulation approach. Scatter plots and gain plots based on various values of Signal to Noise Ratio are studied for the FFT MB-OFDM and PAPR ,SNR v/s BER, frequency offset plots of DWT based MB-OFDM are studied. From the results achieved we can conclude that the DWT MB-OFDM is a good technical solution to be used as UWB PHY layer for short range high data rate wireless applications. This paper presents the simulation approaches of DWT-OFDM as alternative substitutions for FFT OFDM. From the analysis and design simulation we found that the designed simulation model of DWT MB-OFDM is trustworthy rather than the FFT based MB-OFDM which introduces bit losses and packet losses.

The next objective of this work is to design and implement a base band OFDM transmitter and receiver on FPGA hardware. This paper concentrates on developing discrete wavelet transform (DWT) and Inverse Discrete wavelet transform (IDWT) OFDM transmitter & receiver. For FPGA implementation first complete Simulink models of FFT-OFDM and DWT-OFDM have to be tested. By using HDL code generation or by using appropriate Xilinx block sets it can then be implemented into Spartan-3 environment.

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