

PERFORMANCE ANALYSIS OF DWT-OFDM AND FFT-OFDM SYSTEMS

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Abstract Performance of Orthogonal Frequency Division Multiplexing (OFDM) systems using Fast Fourier Transforms (FFT) and Discrete Wavelet Transform (DWT) are analyzed in this paper. The performance of DWT-OFDM is assessed by various parameters such as BER, eye diagram and constellation diagram. BER is the ratio of the no. of bits with error to the total no. of bits transmitted through the channel. From the Eye diagram, we can find the eye height through which the interference can be calculated. By varying the different wavelets and the different modulation schemes the BER is calculated and the eye diagram and the constellation diagram are plotted with the aid of MATLAB-SIMULINK. In this work, performance of most widely used wavelet based OFDM systems Haar, Daubechies, Biorthogonal, and Reverse Biorthogonal wavelets are studied and wavelet basis suitable for optimum OFDM system is investigated. Bit Error Rate (BER) versus Signal to Noise Ratio (SNR) is used as system parameter.

Index Terms— OFDM- Orthogonal Frequency Division Multiplexing, DWT- Discrete Wavelet Transform, FFT-Fast Fourier Transform, BER- Bit Error Rate, SNR- Signal to Noise Ratio, PAPR- Peak to Average Power Ratio, AWGN –Additive White Gaussian Noise

I. INTRODUCTION

OFDM-ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING is a combination of both modulation and multiplexing technique. Frequency Division Multiplexing (FDM) divides the available bandwidth into several subcarriers which does not overlap with each other, but the orthogonality in the OFDM provides the subcarriers to overlap with each other, thus providing high spectral efficiency.

This OFDM technique can be implemented effectively by using Fast Fourier transform (FFT) but it has got some disadvantages such as a very high Peak to Average Power Ratio (PAPR) and the use of Cyclic Prefix, which is used to reduce the Inter Symbol Interference (ISI), reduces the spectrum efficiency. In order to overcome the above disadvantages, we go for the Discrete Wavelet Transform (DWT). OFDM provides an efficient means to handle high speed data streams over a multipath fading environment. Conventional OFDM systems use FFT filters for modulation and demodulation. Due to superior spectral containment properties of wavelet filters, DWT based OFDM systems have improved performance.

II. FAST FOURIER TRANSFORM

The Fourier transform is the most popular transform used to obtain frequency spectrum of signals. Fast Fourier Transform is an algorithm which is used to find the Discrete Fourier Transform in a faster way and with reduced complexity. It is best suited for signals whose frequency components do not change with time. The data generator used is of bit stream and it is modulated using M-PSK or M-ary QAM modulators to map input data into symbols. These symbols are sent to IFFT block to generate N- parallel data streams, since OFDM transmits parallel data streams simultaneously over the subcarriers.

For a given finite sequence of data,

$$x[n], n = 0 \text{ to } N - 1 \quad (1)$$

We define the FFT of $x[n]$ i.e., the output in frequency domain as

$$X[k] = \sum_{n=0}^{N-1} x[n] e^{-jk\left(\frac{2\pi}{N}\right)n}, k = 0 \text{ to } N - 1 \quad (2)$$

$X[k]$ is the component of the spectrum due to the frequency.

$$F = \frac{kF_s}{N} \quad (3)$$

The transformed output is added with cyclic prefix to decrease ISI effects of channel. It is usually 25% of the last part of the original transformed signal.

In the receiver, the reverse operation is performed by removing the cyclic prefix, FFT modulation and demodulation to obtain the original data back.

The IFFT i.e., the output in discrete domain as

$$x[n] = \frac{1}{N} \sum_{k=0}^{N-1} X[k] e^{jk(\frac{2\pi}{N})}, n = 0 \text{ to } N - 1 \tag{4}$$

III. DISCRETE WAVELET TRANSFORM

A wavelet is a small portion of a continuous signal. Discrete wavelet has got its name, since the samples are discretely sampled and the most important fact is that it provides both time and frequency domain information. There are several types of wavelet transforms widely used such as HAAR, DAUBECHIES, BI-ORTHOGONAL, etc. The Wavelet Transform should satisfy orthonormal basis property and the perfect reconstruction property. The wavelet Transform decomposes the signal into small wavelets by using the wavelet function and the basis function, so a wavelet transform has got two functions as named above. The filters in the Discrete Wavelet Transform have got both low pass and high pass filters which actually acts as the Quadrature Mirror Filters (QMF). The low pass filter coefficients is called as approximated coefficients and the high pass filter coefficients is called as detailed coefficients.

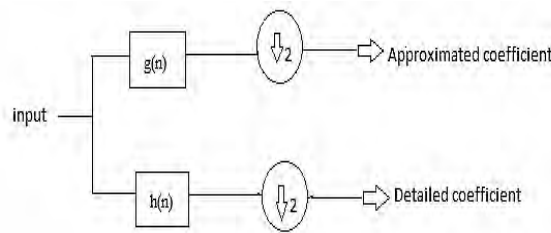


Figure 1.FILTER SPLITTING

The input is first passed through the low pass filter $g(n)$ and its output is the approximated coefficient and then the same input passed through the high pass filter $h(n)$ produces the output as the detailed coefficient. This is how the signal is decomposed by the wavelet. The mathematical expression for this decomposition is described below.

$$F1(k) = \sum_{n=0}^{\infty} x[n]g[2k - n] \tag{5}$$

$$F2(k) = \sum_{n=0}^{\infty} x[n]h[2k - n] \tag{6}$$

IV. STRUCTURE OF FFT OFDM AND DWT OFDM

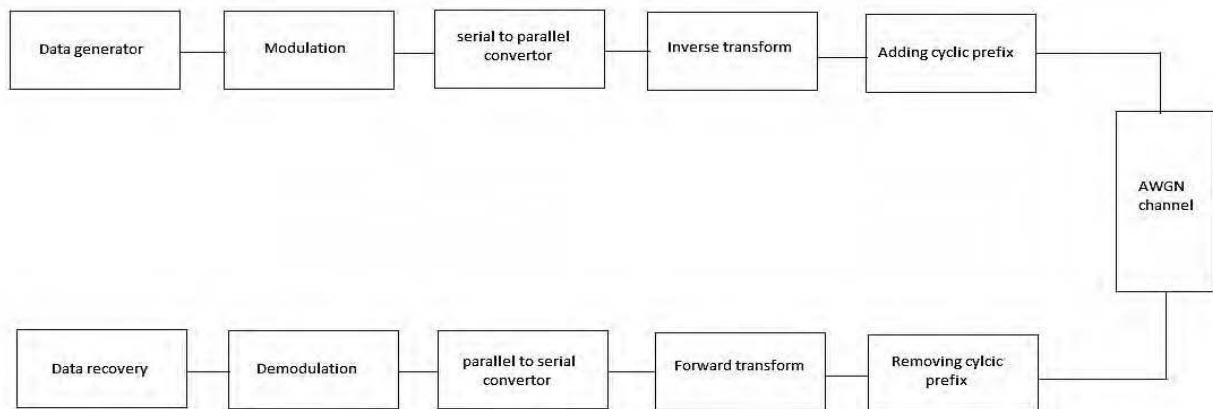


Fig.2. FFT WITH CYCLIC PREFIX

In the above block diagram data generator generates the data which is modulated and mapped into the symbol and the serial to parallel converter converts the high speed data into low speed parallel data stream then the inverse transform is performed into the modulated symbol then the cyclic prefix is added to it and then it is passed over the Additive White Gaussian Noise (AWGN) channel and at the receiver the inverse operation is performed.

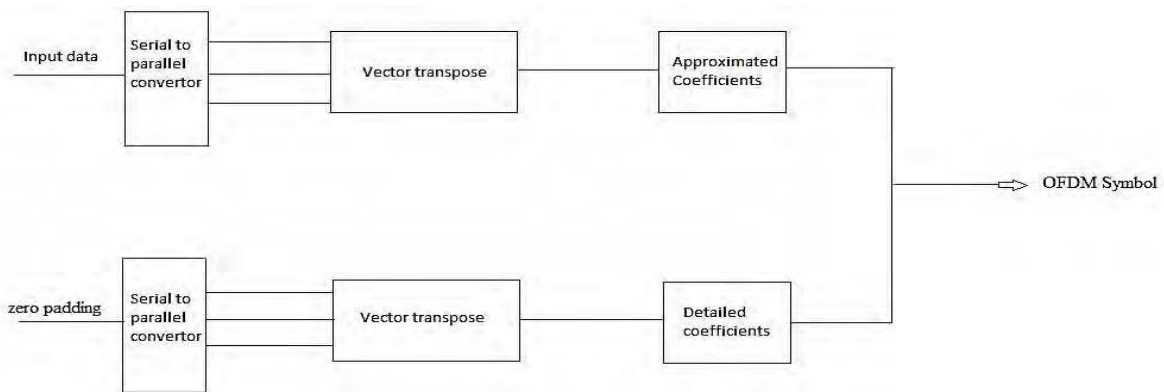


Figure 3.DWT TRANSMITTER

The high input data stream is converted to low parallel data stream by using the serial to parallel conversion and it is transposed then it is passed through the low pass and the high pass then finally the output of it is the OFDM symbol which has to be transmitted over the AWGN channel.

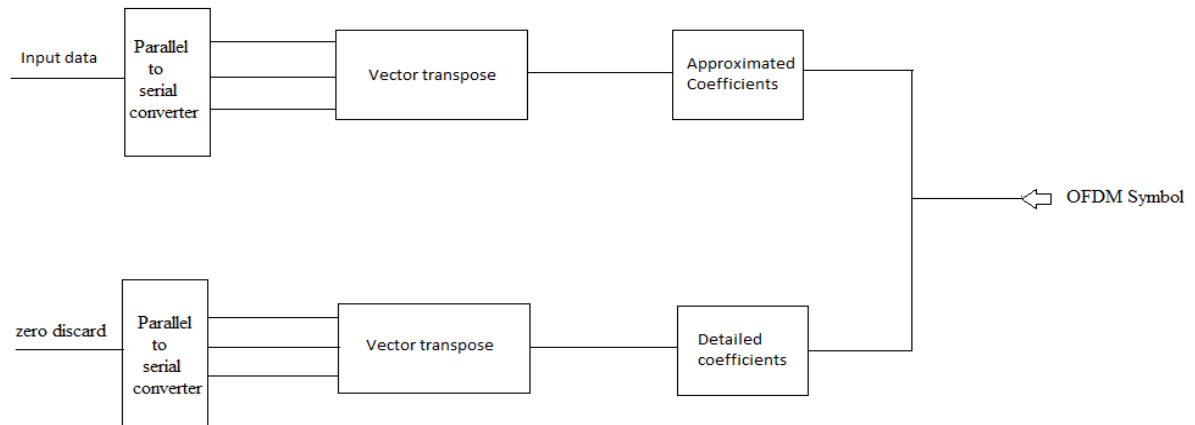


Figure 4.DWT RECEIVER

Generally zero padding in time domain increases the number of samples whereas zero padding in the frequency domain results in an increased sampling rate in the time domain. In DWT Transmitter zero padding is done and at the receiver zero is discarded.

V. SIMULATION RESULTS

Table I.BER FOR BPSK MODULATION

Eb/N0	FFT	HAAR	DB4	BIOR 5.5	RBIOR 3.3
0	0.5004	0.4148	0.5010	0.5052	0.5051
3	0.5003	0.3777	0.5005	0.5039	0.5030
5	0.5003	0.3481	0.4997	0.5005	0.4997
10	0.4998	0.2426	0.4996	0.4992	0.4995
20	0.4998	0.0117	0.4995	0.4992	0.4991
50	0.4996	0	0.4995	0.4991	0.4990
100	0.4996	0	0.4995	0.4989	0.4985

Table II.BER FOR DBPSK MODULATION

Eb/No	FFT	HAAR	DB4	BIOR 5.5	RBIOR 3.3
0	0.5021	0.4874	0.4998	0.5016	0.5003
3	0.5020	0.4766	0.4984	0.5004	0.5006
5	0.5020	0.4622	0.4999	0.5020	0.5022
10	0.5017	0.3888	0.5	0.4967	0.4983
20	0.5016	0.0388	0.4950	0.5014	0.4971
50	0.5010	0	0.4948	0.5003	0.4916
100	0.5010	0	0.4938	0.5001	0.4937

Table III.BER FOR QPSK MODULATION

Eb/No	FFT	HAAR	DB4	BIOR 5.5	RBIOR 3.3
0	0.7493	0.6506	0.7519	0.7584	0.7535
3	0.7493	0.6088	0.7530	0.7570	0.7524
5	0.7493	0.5710	0.7563	0.7566	0.7520
10	0.7493	0.4227	0.7541	0.7574	0.7529
20	0.7395	0.0245	0.7519	0.7567	0.7540
50	0.7397	0	0.7495	0.7545	0.7487
100	0.7396	0	0.7479	0.7551	0.7509

Table IV.BER FOR DQPSK MODULATION

Eb/No	FFT	HAAR	DB4	BIOR 5.5	RBIOR 3.3
0	0.7489	0.7298	0.7343	0.7409	0.7546
3	0.7460	0.7143	0.7185	0.7310	0.7539
5	0.7465	0.6957	0.7069	0.7219	0.7498
10	0.7463	0.5983	0.6570	0.6819	0.7352
20	0.7455	0.0947	0.5377	0.5447	0.6725
50	0.7454	0	0.5206	0.5145	0.5254
100	0.7450	0	0.5207	0.5143	0.5243

Table V.BER FOR OQPSK MODULATION

Eb/No	FFT	HAAR	DB4	BIOR 5.5	RBIOR 3.3
0	0.7495	0.7415	0.7446	0.7465	0.7525
3	0.7494	0.7415	0.7441	0.7464	0.7510
5	0.7486	0.7407	0.7439	0.7462	0.7476
10	0.7483	0.7401	0.7428	0.7457	0.7475
20	0.7389	0.7398	0.7421	0.7454	0.7468
50	0.7381	0.7387	0.7417	0.7449	0.7467
100	0.7375	0.7385	0.7410	0.7441	0.7460

Table VI.BER FOR 16 – QAM MODULATION

Eb/No	FFT	HAAR	DB4	BIOR 5.5	RBIOR 3.3
0	0.9401	0.9287	0.9361	0.9381	0.9403
3	0.9410	0.9257	0.9359	0.9379	0.9399
5	0.9399	0.9223	0.9355	0.9379	0.9386
10	0.9388	0.9108	0.9352	0.9375	0.9380
20	0.9385	0.8364	0.9350	0.9370	0.9363
50	0.9396	0.4709	0.9345	0.9367	0.9378
100	0.9396	0.4709	0.9343	0.9365	0.9378

EYE HEIGHT

The eye height is inversely proportional to the interference level. So, higher the eye height, lower is the interference level. The maximum height is for the HAAR Wavelet, which has got the maximum height under the BPSK Modulation Scheme. So, the interference level is less for DWT-OFDM when compared with the FFT-OFDM System. Below are the eye diagrams and constellation plots for various wavelet transforms.

Table VII. EYE HEIGHT

EYE HEIGHTS	FFT	HAAR	DB4	BIOR 5.5	RBIOR 3.3
BPSK	0.171	0.043	0.028	0.031	0.032
DBPSK	0.180	0.043	0.035	0.023	0.025
QPSK	0.188	0.019	0.038	0.020	0.038
DQPSK	0.3	0.017	0.031	0.030	0.031
OQPSK	0.195	0.019	0.017	0.034	0.025
16-QAM	1	0.094	0.219	0.156	0.188
64-QAM	1.875	0.25	0.266	0.313	0.125

Figure 5.EYE DIAGRAM FOR BPSK BIOR 5.5

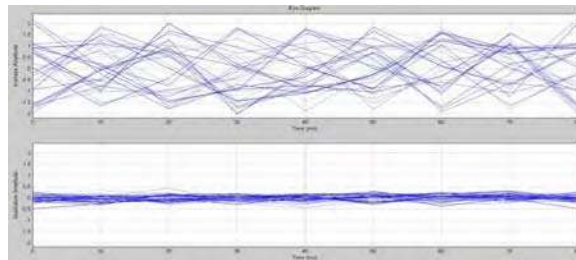


Figure 6.EYE DIAGRAM FOR BPSK DB4

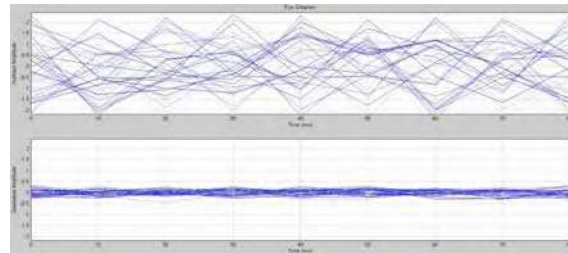


Figure 7.EYE DIAGRAM FOR BPSK HAAR

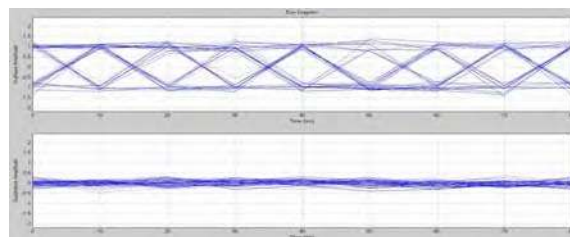


Figure 8.EYE DIAGRAM FOR BPSK RBIOR 3.3

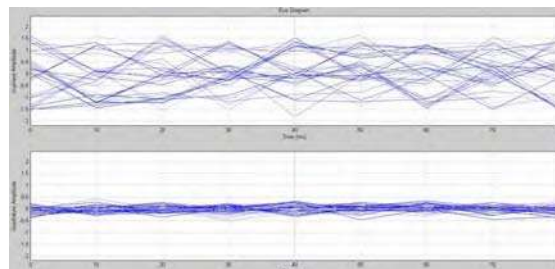


Figure 9.CONSTELLATION DIAGRAM FOR BPSK BIOR 5.5

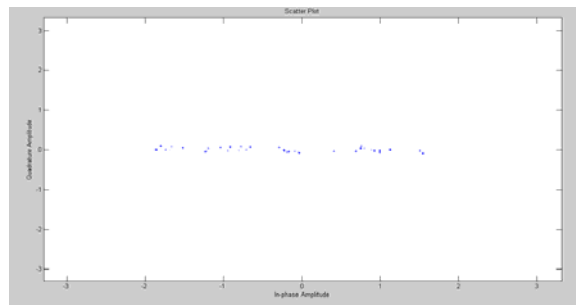


Figure 10.CONSTELLATION DIAGRAM FOR BPSK DB4

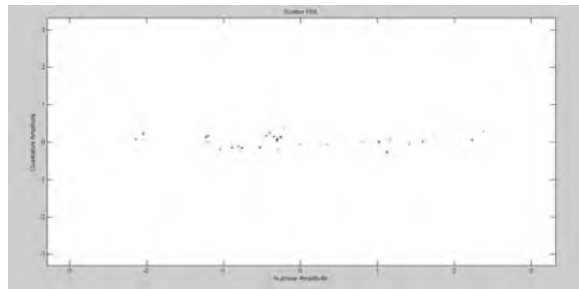


Figure 11.CONSTELLATION DIAGRAM FOR BPSK HAAR

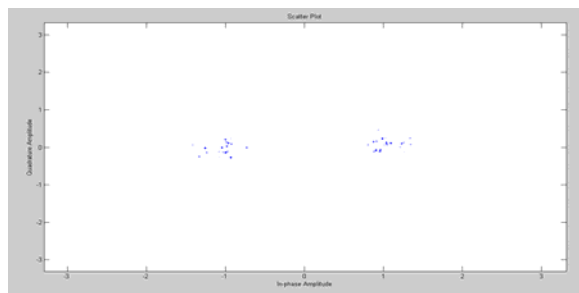


Figure 12.CONSTELLATION DIAGRAM FOR BPSK RBIOR 3.3

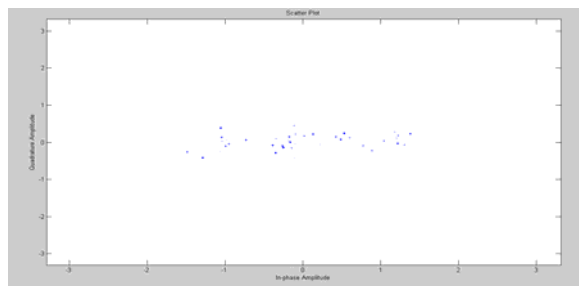


Table VIII. BER VARYING WAVELET TRANSFORMS ON BOTH SIDES

Eb/N0	HAAR	RBIOR 3-3	BIOR 5-5
0	0.4758	0.4991	0.4976
3	0.4725	0.4978	0.4979
5	0.4690	0.4984	0.4976
10	0.4633	0.5022	0.5005
20	0.4950	0.5032	0.4983
50	0.5018	0.5029	0.4983
100	0.5018	0.5029	0.4984

VI. CONCLUSION

The DWT-OFDM has a very great advantage over the FFT-OFDM and the performance parameters that we have considered proves the same. Especially, the HAAR wavelet under the BPSK modulation provides a very good platform for the wireless communication with the minimum BER, less INTER SYMBOL INTERFERENCE (ISI), and generally with the less PAPR. The wavelet transform has been varied in the transmitter and at the receiver. The DAUBECHIES 4 has been used at the receiver to take the forward transform and the minimum BER is obtained when the HAAR wavelet is used at the transmitter at an SNR of 10db. So, with this, we can conclude that the aim of our paper is to provide the wavelet, with which the best performance in wireless communication can be obtained.

VII. REFERENCES

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