

## ANALYSIS OF FFT AND DWT BASED OFDM

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### ABSTRACT

This paper examines the performance of Discrete Wavelet Transform based OFDM (DWT-OFDM) and Fast Fourier based OFDM (FFT-OFDM) system. A new interleaving scheme is applied to system for efficient data transmission over AWGN channel. The performance of the approach is evaluated on the DWT-OFDM and FFT-OFDM with interfacing and without interleaving process. Signal to Noise ratio (SNR) and Bit Error Rate (BER) is used as system parameter to evaluate the performance of the OFDM system. The simulation result of new interleaving scheme using PN sequence generator and different gain input gives better bit error rate of DWT based OFDM system.

### KEYWORDS:

FFT, DWT, OFDM, Chaotic Baker Maps, Sequence Generator, Simulink

### 1. INTRODUCTION

Orthogonal Frequency Divisional Multiplexing (OFDM) is a combination of modulation and multiplexing scheme that allows efficient and reliable transmission of digital data over a radio channel. OFDM transmits data by using a large number of narrow bandwidth carriers. In OFDM, frequency spacing and time synchronization of the carriers is chosen in such a way that the carriers are orthogonal to each other [1][4]. The orthogonality in individual sub carrier enables the easy separation at the receiver end of the system. OFDM communication system have received a considerable interest due to their high spectral efficiency, simple implementation of equalizer and robustness in frequency selective fading [3][15]. OFDM system is realized using FFT and IFFT. To reduce the BW decay brought

by cyclic prefix, discrete wavelet transform based OFDM is used. Because of wavelet transform the transmission power is minimized. Zero padding and vector transposing is used for the transmission of modulated signal in DWT based OFDM [5]. Many researcher have done the comparison of DWT based OFDM and FFT based OFDM and found that DWT based OFDM has more advantage than FFT based OFDM system. Multipath fading is the main problem in designing the communication system through a wireless link which causes degradation in reliability of the link and data rate [8]. Inter symbol interference (ISI) and inter carrier interference (ICI) decreases the system performance in case of multipath environment. The Multiple Input Multiple Output (MIMO) and beamforming technique in wireless communication improve the efficiency of data transmission. Beamforming technique can be used for the interference reduction in the system. These new techniques can achieve a high efficient data transmission but with increased cost and complexity [7][12][13]. Another approached which has been used is data interleaving. Chaotic interleaving with the strong ability of chaotic

maps combat the channel effect without any need of complicated error detection coding schemes. This paper compares the chaotic interleaving with interleaving process with PN sequence generator on FFT and DWT based OFDM system and DWT based OFDM provide better transmission with less error rate as shown in figure7.

## 2. LITERATURE SURVEY

Anwarul Azim [1] discuss an intuitive comparison of the computational performance of orthogonal frequency division multiplexing (OFDM) system which has been made in terms of complex calculation required using the different fourier transform techniques. The different transform techniques are introduced such as discrete fourier transform (DFT) and various types of fast fourier transform as radix2 FFT, Radix4 FFT and very fast fourier transform (VFFT).VFFT increased the speed of OFDM system with the drawbacks of non-uniformity of power spectral density and non-uniformity of signal to noise ratio(SNR) among the sub carrier.

G.Gowri [2] discuss the performance of OFDM systems using the FFT and DWT using the various modulation schemes and different method .The performance of DWT OFDM is assessed by various parameters such as Bit Error Rate (BER),eye diagram ,constellation diagram and filter splitting. Binary Phase Shift keying(BPSK),Differential phase shift keying(DPSK),Quadrature Phase shift keying (QPSK),Offset QPSK. HAAR, Daubechies, Biorthogonal and Reverse biorthogonal wavelets are studied in it.The eye diagram using the eye height interference is calculated.The eye height is inversely proportional to the interference level.

Zahraa Abd El Hamid [3] presents a new interleaving scheme for the analysis of FFT and DWT based OFDM system. Chaotic baker Maps a new interleaving scheme provides a effective data transmission over different fading channels. The binary data is interleaved with the proposed approach prior to the modulation step. In addition to minimize the channel effects on the transmitted data, the chaotic interleaving approach adds a degree of encryption to the transmitted signal. Due to the strong interleaving ability of chaotic maps ,it can combat the channel effects without a need for complicated coding schemes for error detection.

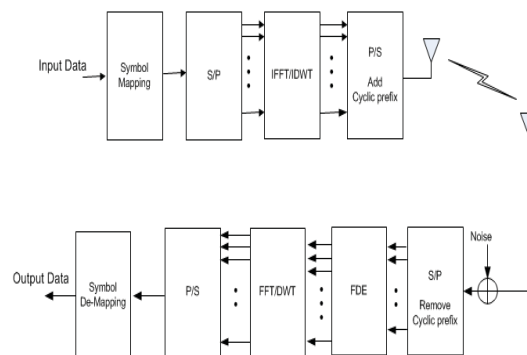
VeenaM.B[5]proposed the implementation of DWT based OFDM and FFT based OFDM on FPGA. The DWT based OFDM is implemented on FPGA using the Lifting scheme architecture. The main feature of the lifting based wavelet transform is to break-up the high pass and low pass wavelet filter into sequence of small filters. This architecture needs fewer computation so the computation complexity is minimized.

### 2.1 OFDM SYSTEM MODEL

### 2.2 FFT BASED OFDM SYSTEM

Figure 1 shows the transceiver model of OFDM.  $d_n$  is binary form input data and QPSK modulator is used to map the binary data to appropriate QPSK symbols. The high speed data symbol is converted into parallel data of  $n$  sub channels. Suppose  $d(k)$  is the serial data symbols streams to be transmitted using OFDM modulation scheme,

$$d(k) = (d_1, d_2, d_3, \dots, d_n)$$



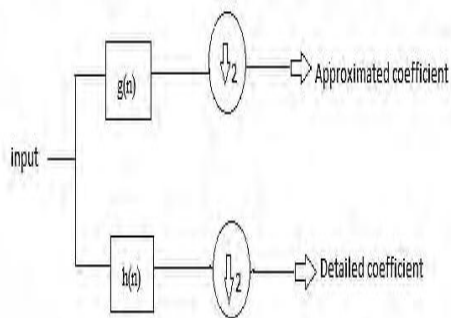
**Figure 1: Block diagram of the conventional OFDM system [3].**

Where,  $k$  and  $n$  represents the time index and the vector length, respectively. Converting  $d(k)$  from serial data form to parallel data form, construct a 1-D vector containing the data symbols to be transmitted. Let  $d_k$  be the transmitted data symbols of each parallel sub-channel. These parallel data symbols are applied into an Inverse Fast Fourier Transform (IFFT) for the generation of the multi-carrier OFDM signal [3][11].

$$x_n = \frac{1}{N} \sum_{k=0}^{N-1} d_k e^{\frac{j2\pi kn}{N}}, 0 \leq n \leq N - 1$$

### 2.3 DWT BASED OFDM SYSTEM

A wavelet is a small portion of a continuous signal. Discrete wavelet has samples that are discretely sampled and the most important fact is that it provides both time and frequency domain information. The Wavelet Transform must satisfy perfect reconstruction and orthonormal basis property. The wavelet Transform decomposes the signal into small wavelets by using the wavelet function and the basis function. The filters in the Discrete Wavelet Transform have both low pass and high pass filters which actually acts as the Quadrature Mirror Filters (QMF). The low pass filter coefficients are called as approximated coefficients and the high pass filter coefficients are called as detailed coefficients[2].



**Figure 2: Filter Splitting [2]**

The input data 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 which is known as the detailed coefficient as shown in figure 2. This is how the signal is decomposed by the wavelet. The mathematical expression for this decomposition is described below:

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

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

## 2.4 CHAOTIC BAKER MAPS

The channel error produced by the mobile wireless channel are bursty in nature, in that case interleaving is must in communication system. Various interleaving schemes have been propounded. The elementary and most accepted of such schemes is the block interleaving scheme. This interleaving scheme is not effective with 2-D error bursts. Because of this, advanced interleavers required for this task. The 2-D discretized chaotic Baker map is used for this purpose [3].

The Baker map is a chaotic map that generates a permuted version of a square matrix. In its discretized form, the Baker map is an efficient tool to randomize a square matrix of data. The discretized map can be represented for an  $M \times M$  matrix as follows [5][9][10][14]:

$$B(r,s) = \begin{bmatrix} \frac{M}{n_i} (r - M_i) + s \bmod \left(\frac{M}{n_i}\right), \\ \frac{n_i}{M} \left( s - s \bmod \left(\frac{M}{n_i}\right) \right) + M_i \end{bmatrix}$$

Where  $B(r,s)$  are the new indices of the data element at  $(r,s)$

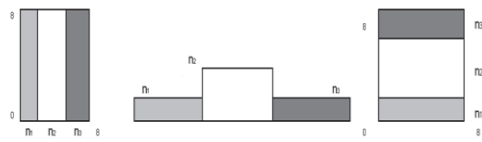
$$M_i \leq r < M_i + n_i, 0 < s < M$$

$$\text{and } M_i = n_1 + n_2 + \dots + n_i$$

In steps, the chaotic interleaving is performed as follows:

1. An  $M \times M$  square matrix is partitioned into  $k$  vertical rectangles of height  $M$  and width of  $N_i$ .
2. These vertical rectangles are extended in the horizontal direction and reduced vertically to obtain an  $N_i \times M$  horizontal rectangle.
3. These rectangles are stacked as shown in Figure (3a), where the left one is set at the bottom and the right one is set at the top.
4. Each  $N_i \times M$  vertical rectangle is partitioned into  $N_i$  boxes of dimensions  $M = N_i \times N_i$  containing exactly  $M$  points.
5. Each of these boxes is mapped column by column into a row as shown in Figure (3b)[7].

Figure 3 shows an example of chaotic interleaving of an  $(8 \times 8)$  square matrix. The dimension of secret key used in it is ,  $S_{key} = (n1, n2, n3) = (2, 4, 2)$ .



(a)

S1	S2	S3	S4	S5	S6	S7	S8
S9	S10	S11	S12	S13	S14	S15	S16
S17	S18	S19	S20	S21	S22	S23	S24
S25	S26	S27	S28	S29	S30	S31	S32
S33	S34	S35	S36	S37	S38	S39	S40
S41	S42	S43	S44	S45	S46	S47	S48
S49	S50	S51	S52	S53	S54	S55	S56
S57	S58	S59	S60	S61	S62	S63	S64

S31	S23	S15	S7	S32	S24	S16	S8
S63	S55	S47	S39	S64	S56	S48	S40
S11	S3	S12	S4	S13	S5	S14	S6
S27	S19	S28	S20	S29	S21	S30	S22
S43	S35	S44	S36	S45	S37	S46	S38
S59	S51	S60	S52	S61	S53	S62	S54
S25	S17	S9	S1	S26	S18	S10	S2
S57	S49	S41	S33	S58	S50	S42	S34

(b)

**Figure 3: Chaotic interleaving (a) Discretized Baker map. (b) Randomization of an 8 × 8 block.**

### 3. PROPOSED SYSTEM MODEL

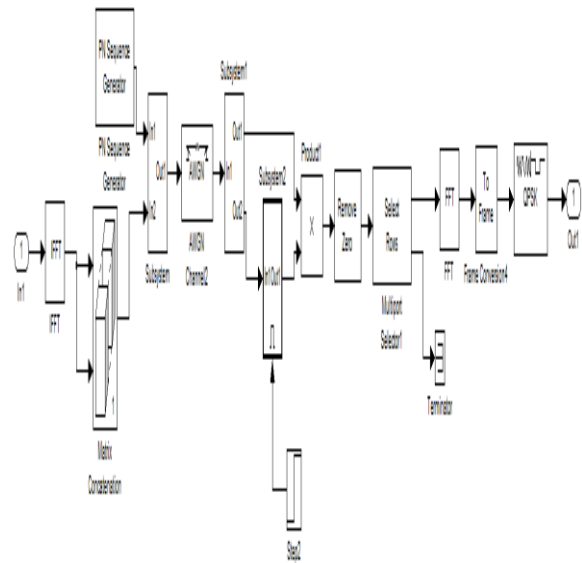
#### 3.1 FFT BASED PROPOSED MODEL

In this FFT proposed model(interleaving with PN sequence generator ) instead of applying the secret key as we used in the chaotic interleaving process, PN sequence generator is used for the interleaving process .The output of the inverse Fast Fourier transform is exerted to the two terminals of the output port and matrix concatenation performed on that data. Matrix concatenation with PN sequence, zero padding and cyclic prefix is applied before the data is transmitted through the AWGN channel. Similarly at the receiver end the zero padding and cyclic prefix is removed to obtain the original data and a inverse PN sequence is applied at this end to obtain the same data which is applied at the transmitter end. FFT based proposed OFDM model provide better result then the FFT based OFDM and DWT based OFDM system as shown in figure 8 and figure 9.

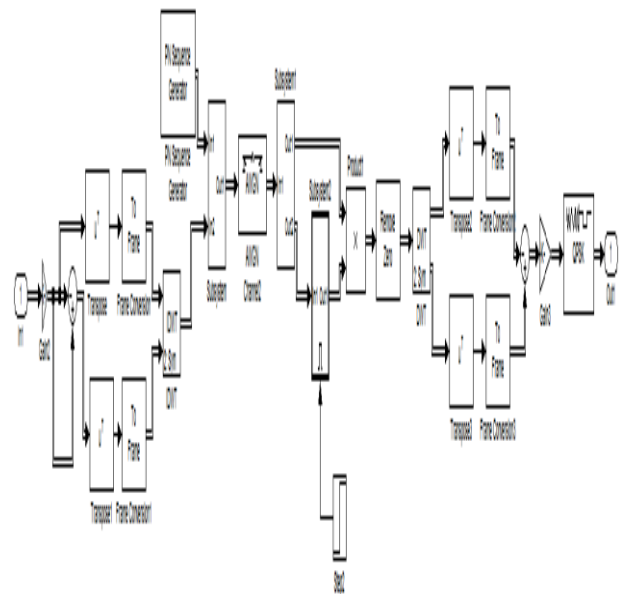
#### 3.2 DWT BASED PROPOSED MODEL

In case of proposed1 model (interleaving process with PN sequence generator) interleaving is applied as same as in FFT proposed model. In case of proposed2 model where different gain input is applied to the system has the same process of interleaving as in proposed 1model of FFT and achieve better result than any other system. DWT based proposed OFDM model provide very low

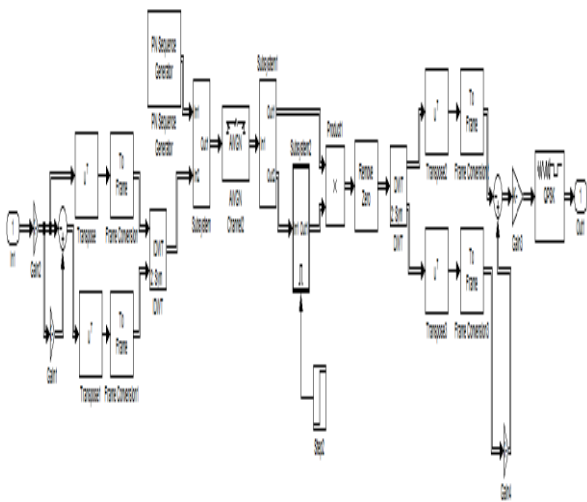
error rate than any other FFT based OFDM and DWT based OFDM.



**Figure 4: Simulink model of FFT chaotic interleaving with PN sequence generator.**



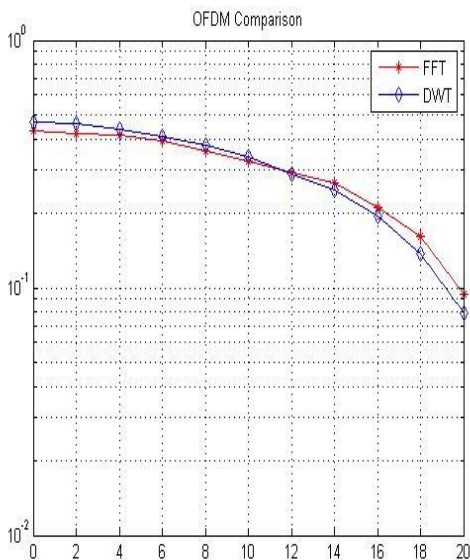
**Figure 5: Simulink model of DWT chaotic interleaving with PN sequence generator.**



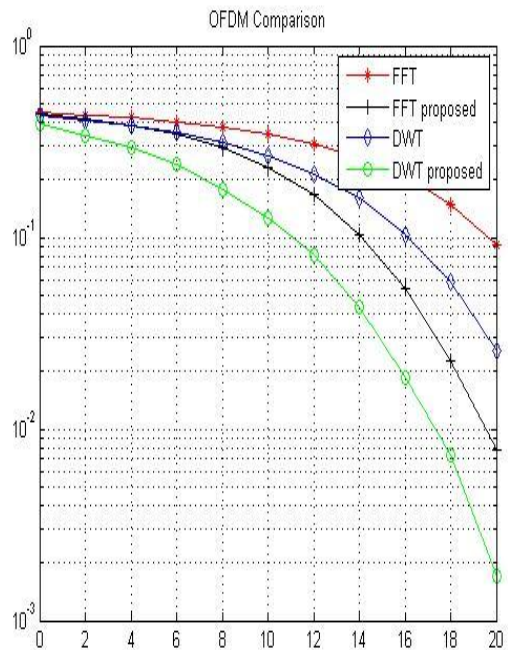
**Figure 6: Simulink model of DWT chaotic interleaving with different gain input.**

#### 4. SIMULATION RESULT

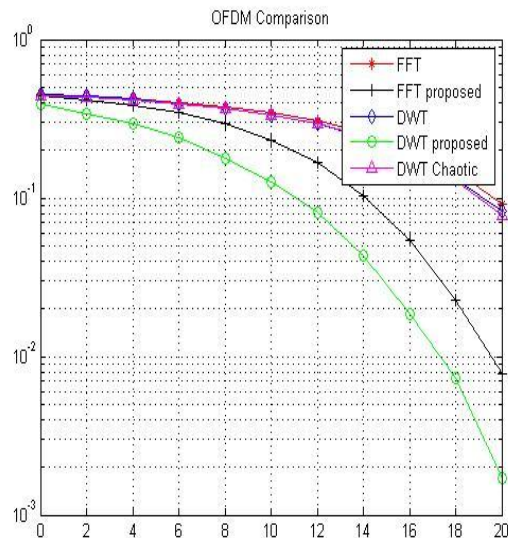
Computer simulations used in this section is performed to analyse and test the chaotic interleaving scheme, proposed chaotic interleaving scheme and to compare it with normal OFDM. The Two types of OFDM systems which were simulated: FFT based OFDM and DWT based OFDM which were simulated with interleaving and without interleaving process using MATLAB. The graphical results shows the variation of the BER with the SNR for the systems. The channel model considered is AWGN. From these results, it is clear that proposed interleaving scheme achieves the best results with DWT-OFDM.



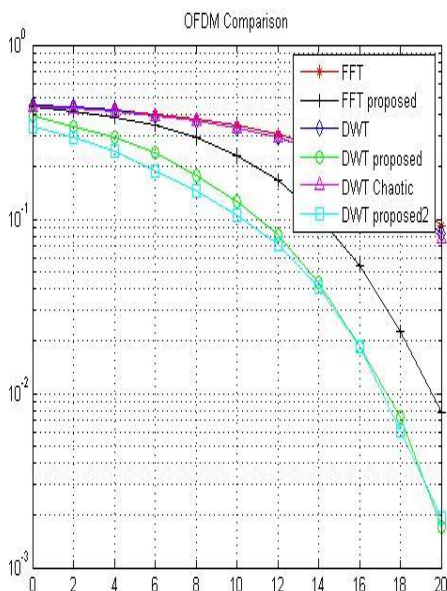
**Figure 7: BER performance for FFT and DWT based OFDM system over an AWGN channel.**



**Figure8: BER performance for FFT based OFDM system, FFT based proposed chaotic OFDM system and DWT based OFDM ,DWT based OFDM System and DWT based Proposed OFDM system.**



**Figure 9: BER performance for FFT based OFDM, FFT based proposed chaotic OFDM and DWT based OFDM, DWT based proposed chaotic OFDM over an AWGN channel.**



**Figure 10: BER performance for FFT based OFDM, FFT based proposed chaotic OFDM and DWT based OFDM, DWT based proposed 2 chaotic OFDM over an AWGN channel.**

## 5. CONCLUSION

In this work, the simulation result is obtained for DWT based OFDM as an alternative form for FFT based OFDM system. It is seen that as fourier based system require addition of cyclic prefix whereas DWT based OFDM system do not require cyclic prefix because of overlapping nature and thus increasing the bandwidth efficiency .It is seen that DWT based OFDM outperformed the FFT based OFDM system. By use of PN sequence generator and different gain input in interleaving scheme provide better result and having very less error in the DWT based OFDM system.

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