ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING BASED ON MULTIWAVELETS

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ABSTRACT

In this paper a new proposed structure for the Orthogonal Frequency Division Multiplexing (OFDM) system will be studied, which will be based on a different approach, an OFDM system was modeled using MATLAB to allow various parameters of the system to be varied and tested. The aim of doing that simulation is to measure the performance of OFDM under different channel conditions.

1. Introduction

The Fourier based OFDM (FFT-OFDM) use the complex exponential bases functions and it's replaced by an orthonormal wavelets in order to reduce the level of interference. It is found that OFDM based on Haar-based orthonormal wavelets (DWT-OFDM) are capable of reducing the inter symbol interference ISI and inter carrier interference ICI, which are caused by the loss in orthogonality between the carriers [1] [2].

Further performance gains can be made by looking at alternative orthogonal bases functions and found a better transform rather than Fourier and wavelet transform. In this paper a new proposed OFDM system will be introduced that based on Multifilters called Multiwavelets (DMWT-OFDM). It has two or more lowpass and highpass filters. The purpose of this multiplicity is to achieve more properties which can not be combined in other transforms (Fourier and wavelet) [3].

A very important Multiwavelets filter is the GHM filter proposed by Geronimo, Hardian, and Massopust. In Multiwavelets setting, GHM multiscaling and Multiwavelets functions coefficients are 2X2 matrices, and during transformation step they must multiply vectors (instead of scalars). This means that multifilter bank need 2 input rows. The aim of preprocessing is to associate the given scalar input signal of length N to a sequence of length-2 vectors in order to start the analysis algorithm, and to reduce the noise effects. In the one dimensional signals the "repeated row" scheme is convenient and powerful to implement [4] [5].

2. Proposed System for DMWT-OFDM

The block diagram of the proposed system for OFDM is depicted in figure (1).

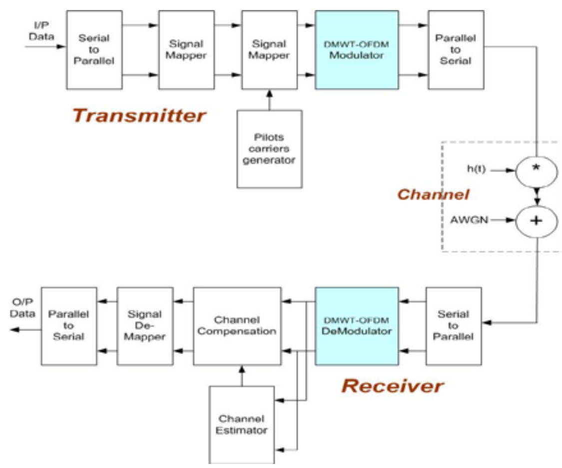
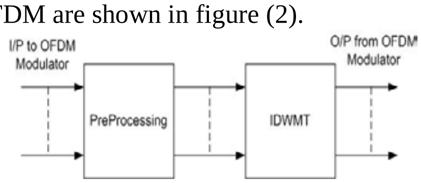
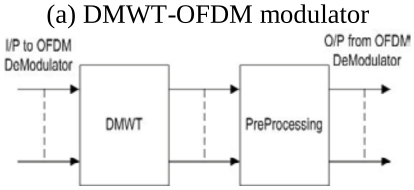


Figure 1: Block Diagram of DMWT-OFDM System

The OFDM modulator and demodulator of DMWT-based OFDM are shown in figure (2).



(a) DMWT-OFDM modulator



(b) DMWT-OFDM demodulator

Figure 2: DMWT-OFDM modem system

The processes of the S/P converter, the signal demapper and the insertion of training sequence are the same as in the system of DMWT-OFDM. After that a computation of IDMWT for 1-D signal is achieved by using an over-sampled scheme of preprocessing (repeated row), the Inverse Discrete Multiwavelets Transform (IDMWT) matrix is doubled in dimension compared with that of the input, which should be a square matrix NxN where N must be power of 2. Transformation matrix dimensions equal input signal dimensions after preprocessing. To compute a single-level 1-D discrete multiwavelets transform, the next steps should be followed:

1. Checking input dimensions: input vector should be of length N, where N must be power of 2.

2. Constructing a transformation matrix, *W*, using GHM low and high pass filters matrices given in 1 and 2, the transformation matrix can be written as equation 3. after substituting GHM matrix filter coefficients values, a 2NX2N transformation matrix results.

$$H_0 = \begin{bmatrix} \frac{3}{5\sqrt{2}} & \frac{4}{3} \\ -\frac{1}{20} & -\frac{3}{10\sqrt{2}} \end{bmatrix} \quad H_1 = \begin{bmatrix} \frac{3}{5\sqrt{2}} & 0 \\ \frac{9}{20} & \frac{1}{\sqrt{2}} \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

$$H_2 = \begin{bmatrix} 0 & 0 \\ \frac{9}{20} & -\frac{3}{10\sqrt{2}} \end{bmatrix} \quad H_3 = \begin{bmatrix} 0 & 0 \\ -\frac{1}{20} & 0 \end{bmatrix}$$

$$G_0 = \begin{bmatrix} -\frac{1}{20} & -\frac{3}{10\sqrt{2}} \\ \frac{1}{10\sqrt{2}} & \frac{3}{10} \end{bmatrix} \quad G_1 = \begin{bmatrix} \frac{9}{20} & -\frac{1}{\sqrt{2}} \\ \frac{9}{10\sqrt{2}} & 0 \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$G_0 = \begin{bmatrix} \frac{9}{20} & -\frac{3}{10\sqrt{2}} \\ \frac{9}{10\sqrt{2}} & -\frac{3}{10} \end{bmatrix} \quad G_3 = \begin{bmatrix} -\frac{1}{20} & 0 \\ -\frac{1}{10\sqrt{2}} & 0 \end{bmatrix}$$

$$W = \begin{bmatrix} H_0 & H_1 & H_2 & H_3 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 \\ 0 & 0 & H_0 & H_1 & H_2 & H_3 & \cdots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ H_2 & H_3 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & H_0 & H_1 \\ G_0 & G_1 & G_2 & G_3 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 \\ 0 & 0 & G_0 & G_1 & G_2 & G_3 & \cdots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 & 0 & \cdots & G_0 & G_1 & G_2 & G_3 \\ G_2 & G_3 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & G_0 & G_1 \end{bmatrix} \quad \ldots.(3)$$

3. Preprocessing the input signal by repeating the input stream with the same stream multiplied by a constant α , for GHM system functions $\alpha = 1/\sqrt{2}$.

4. Transformation of input vector which can be done by apply matrix multiplication to the 2NX2N constructed transformation matrix by the 2NX1 preprocessing input vector.

3. Results of Proposed Systems

In this section the simulation of the proposed DMWT-OFDM system in MATLAB version 7 are achieved. And the bit error rate (BER) performance of the OFDM system considered in different channel models, the additive white Gaussian noise (AWGN) channel, the flat fading channel, and the selective fading channel [6]. Table (1) shows the parameters of the system that are used in the simulation, the bandwidth used was 5MHz.

Modulation Type	**BPSK**
No. of Sub-carriers	**64**
Channel Model	**AWGN**
	Flat Fading
	Selective Fading

Table 1 Simulation Parameters

A. Performance of DMWT-OFDM in AWGN channel

In this section, the result of the simulation for the proposed DMWT-OFDM system is calculated and shown in figure (3), which give the BER performance of DMWT-OFDM in AWGN channel. It is shown clearly that the DMWT-OFDM is much better than the two previous system FFT-OFDM and DWT-OFDM. This is a reflection to the fact that the orthogonal bases of the multiwavelets is much significant than the orthogonal bases used in FFT-OFDM and DWT-OFDM.

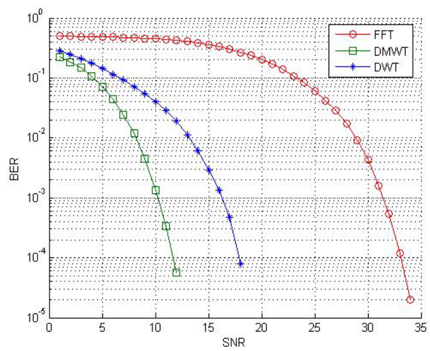


Figure 3: BER performance of DMWT-OFDM in AWGN channel model.

B. BER Performance of DMWT-OFDM in Flat Fading Channel.

In this type of channel, the signal will be affected by the flat fading with addition to AWGN, in this case all the frequency components in the signal will be effect by a constant attenuation and linear phase distortion of the channel, which has been chosen to have a Rayleigh's distribution. A Doppler frequency of 5 Hz is used in this simulation. From figure (4), it can be seen that for BER=10^{-4} the SNR required for DMWT is about 35dB, while in DWT-OFDM the SNR about 40dB and for FFT-OFDM have BER about $5*10^{-3}$ at SNR 40, therefore a gain of 6dB for the DMWT against DWT. As shown in figure (4) it was found that the DMWT-OFDM is outperform significantly other than the two systems for this channel model.

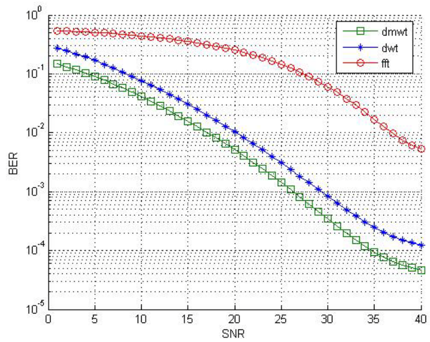


Figure 4: The BER performance of DMWT-OFDM in Flat Fading Channel at Max. Doppler Shift=5Hz.

An alternative Doppler Shift are used, the values taken is 500Hz, 1100Hz and the BER vs. SNR are given in the two figures below.

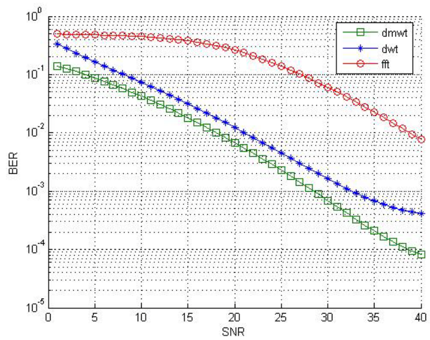


Figure 5: The BER performance of DMWT-OFDM in Flat Fading Channel at Max. Doppler Shift=500Hz.

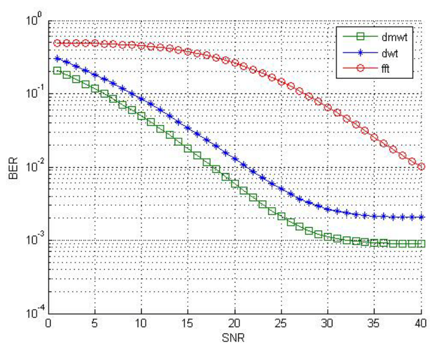


Figure 6: The BER performance of DMWT-OFDM in Flat Fading Channel at Max. Doppler Shift=1100Hz.

C. BER Performance of DMWT-OFDM in Selective Fading Channel.

In this section, the channel model is assumed to be selective fading channel, where the parameters of the channel in this case corresponding to multipaths where two paths are chosen the LOS and second path the LOS path have Average Path Gain equal 0dB and Path Delay 0, where the second path have Average Path Gain -10dB and path Delay one sample.

In figure (7), it is shown clearly that BER performance of DMWT-OFDM is better also than the two systems which are DWT-OFDM and FFT-OFDM. The DMWT-OFDM has BER performance 10^{-2} at SNR 30dB and the FFT-OFDM have the same BER performance at 39dB.

Where the DWT-OFDM is become constant after a certain SNR. For this case it was constant to $3*10^{-2}$ after SNR 25 dB. From this results it can be concluded that the DMWT-OFDM is most significant than the two systems based of DWT and FFT in the different channels that have been assumed. Next, the three systems are tested on other different parameter by changing first the Maximum Doppler Shift, setting it the parameter to 500Hz and then to 1100Hz, the values shown in figures 8 and 9.

For Doppler Shift parameter test, the OFDM based on Multiwavelet is perform much better than the conventional OFDM based on FFT and DWT.

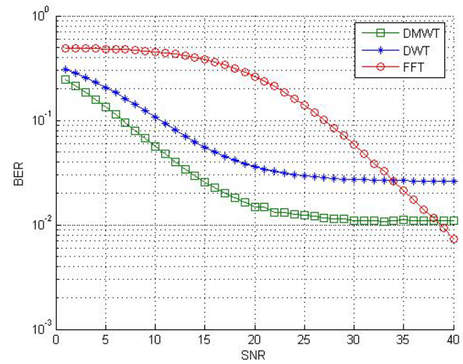


Figure 7: The BER performance of DMWT-OFDM in Selective Fading Channel at Max Doppler Shift=5Hz.

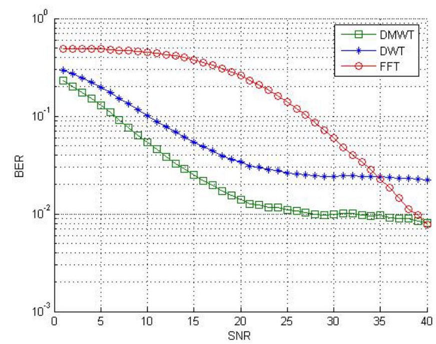


Figure 8: The BER performance of DMWT-OFDM in Selective Fading Channel at Max Doppler Shift=500Hz.

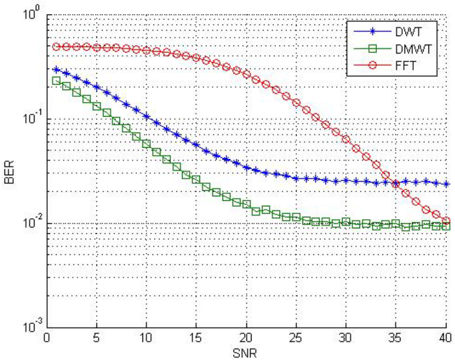


Figure 9: The BER performance of DMWT-OFDM in Selective Fading Channel at Max Doppler Shift=1100Hz.

Now, a different values for the path gain are taken for discuss the BER performance of the systems according the effects of the parameter, and still the Multiwavelet based OFDM outperform the two other structures. As shown in the figures below where a four values are taken when the path gain is -1dB, -5dB, -12dB and -20dB for Maximum Doppler Shift =5Hz.

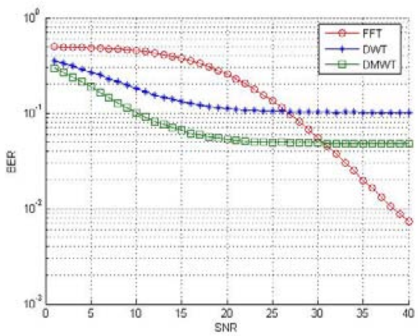


Figure 10: The BER performance of DMWT-OFDM in Selective Fading Channel at Path Gain=-1dB.

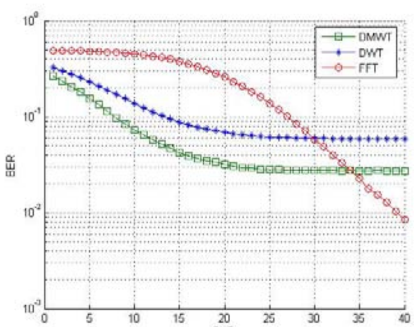


Figure 11: The BER performance of DMWT-OFDM in Selective Fading Channel at Path Gain=-5dB.

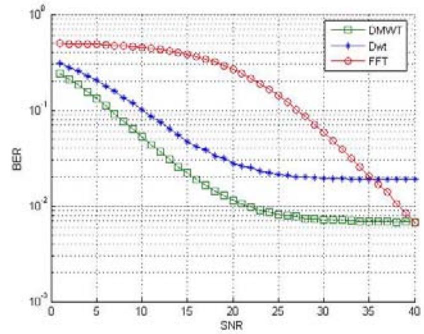


Figure 12: The BER performance of DMWT-OFDM in Selective Fading Channel at Path Gain=-11dB.

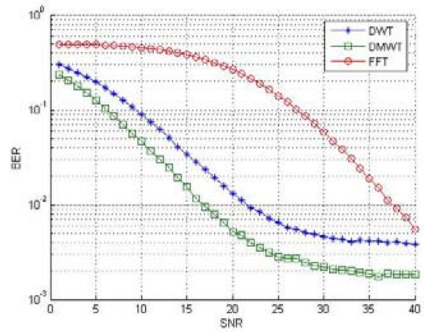


Figure 13: The BER performance of DMWT-OFDM in Selective Fading Channel at Path Gain=-20dB.

4. Conclusion

In this paper, the Multiwavelet OFDM structure was proposed and tested. These tests were carried out to verify its successful operation and its possibility of implementation. It can be concluded that this structure achieves much lower bit error rates assuming reasonable choice of the bases function and method of computation. It gave in AWGN channel BER 10^{-4} at 11.5 dB in comparison with wavelet based OFDM and FFT based OFDM that gave the same BER at SNR 18 and 33 respectively. In flat fading channel and selective fading channel the Multiwavelet based OFDM outperform the other two OFDM systems.

Therefore this structure can be considered as an alternative to the conventional OFDM. It can be concluded from the results obtained, that S/N measure can be successfully increased using the proposed Multiwavelet designed method within a desired Multiwavelet bases function. Thus Multiwavelet based OFDM was outperforms the conventional once.

5. References

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