Performance Analysis of Discrete Wavelet Transform Based Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing System for Different Wavelets in Different Channel Environment

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ABSTRACT

Multiple Input Multiple Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) are the two assuring technologies that offers high data rate as required for the 4G wireless systems. Conventionally OFDM is Fast Fourier Transform (FFT) based system. It uses IFFT (Inverse FFT) blocks in the transmitter and FFT blocks in the receiver. OFDM combined with MIMO gives increased throughput and better system performance and hence FFT based MIMO OFDM systems are widely used in 4G wireless schemes. Recent researches shows that replacing the FFT with Discrete Wavelet Transform (DWT) the system performance can be further improved. This leads to a new scenario DWT based MIMO OFDM system. In this study one such system is simulated and the Bit Error Rate (BER) performance of the system is analysed for the different types of wavelets under different channel environments.

1. INTRODUCTION

The evolving 4G wireless system demands very high data rate that can only be meet out by some multicarrier systems. OFDM is one such modulation scheme that can efficiently handle data within the limited resource of bandwidth. In this scenario if diversity of the system gets increase then the throughput will also increase and that can be done by implementing MIMO. OFDM combined with MIMO renders, better coverage and spectrum efficiency, increased diversity gain, high throughput with good quality of service and so on (Bolcskei, 2006). In this conventional MIMO OFDM scheme the basic building block used for OFDM modulation is IFFT and for demodulation is FFT. In recent times it has been established that by replacing the IFFT/FFT blocks with IDWT/DWT blocks considerable amount of increase in the performance can be achieved (Abdullah and Hussain,

2009; Asif *et al*., 2012). Also for DWT based OFDM there is no need for cyclic prefix as in the case of conventional FFT based system. This further increases the throughput of the system. This study analyses the BER performance of one such system under different circumstances for finding out the best suited wavelet type and the best channel environment for the system. This study is organised as five sections. The second section explains the system model. The third one deals with the different wavelet types. Next portrays the simulation and results. The last one is conclusion.

2. THE SYSTEM MODEL

The transmitter of the DWT MIMO OFDM system is as shown in the **Fig. 1**. In this system the data stream after suitably modulated using a constellation mapper will be carried over by the wavelet carriers.

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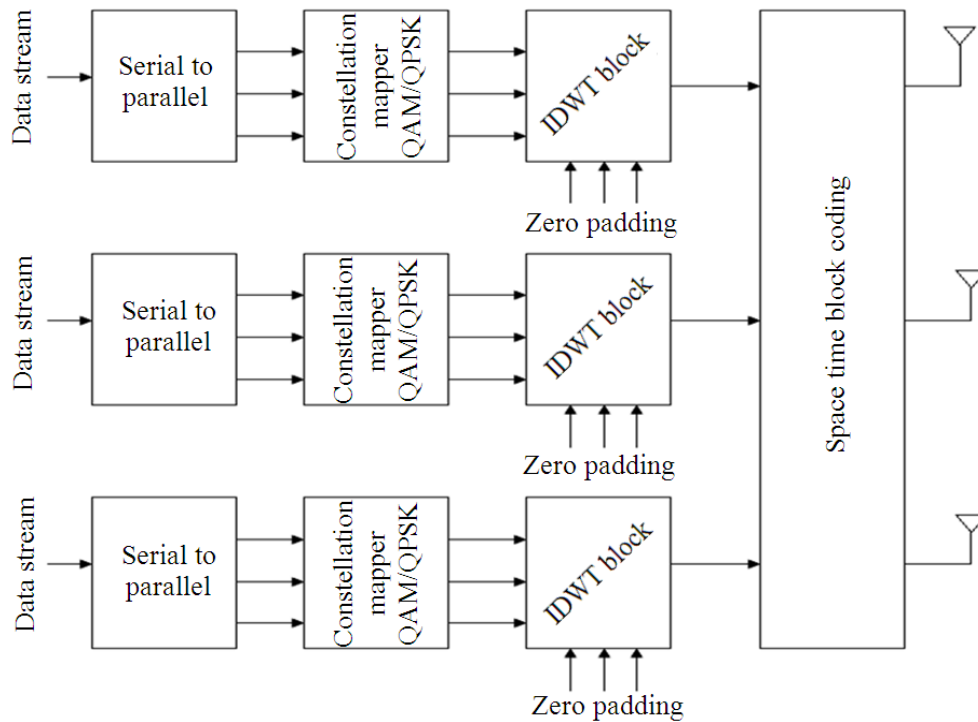
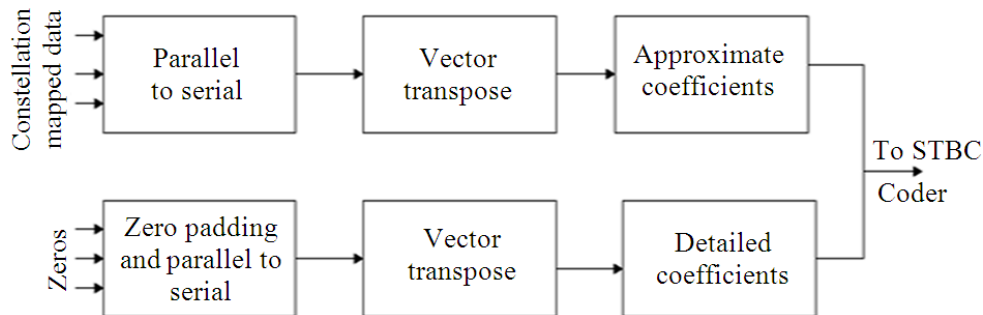**Fig. 1.** DWT-MIMO OFDM system transmitter model

Fig. 2. IDWT block of the transmitter

Wavelet carriers are nothing but the DWT coefficients which are of two types, Viz., (1) Detailed coefficients and (2) Approximate coefficients. These coefficients are obtained from the mother wavelet ψ(t) expressed as Equation 1:

$$\psi_{i,l}(t) = 2^{-i/2}\psi(2^{-i}t - l) \qquad (1)$$

Where:
'i' = The scaling index
l = The time location

The DWT coefficients from the IDWT block is the required multicarrier modulated information needed to be transmitted using the MIMO systems. Here Space Time Block Coding (STBC) technique is used to convert the output in a format suitable for transmission through multiple transmitting antennas. IDWT block in the transmitter is the main setup which makes the system model to differ from conventional MIMO OFDM scheme. Multi resolution algorithm aka Sub band coding is used to create a series of DWT coefficients from the modulated information.
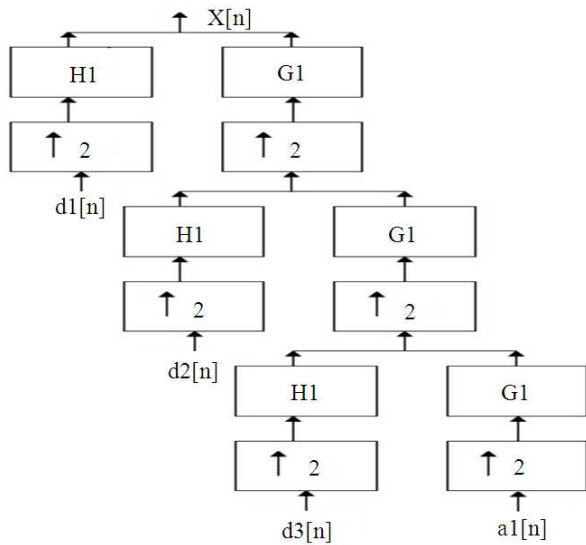
Fig. 3. Concept of composing IDWT using wavelet filter banks

The functioning of IDWT is shown in **Fig. 2**. In this, N parallel data stream (after QAM /QPSK modulation) is used to construct the wavelet carriers having orthonormal (orthogonal as well as normal) properties. To achieve this first the parallel data stream is converted into serial and vector representation of the same is made. Then the vector transposing converts the vector in to a parallel matrix. Here after it undergoes a series of up-sampling and low pass filtering which results in approximate coefficients. Same process takes place on the other side with zero padding and high pass filtering, which results in detailed coefficients.

The concepts of computing discrete time sequence x[n] using the wavelet filter banks is as shown in the **Fig. 3**. Here G1 and H1 are the low pass filter and high pass filter respectively. These are the synthesis filter at every stage follows an up-sampler. The detailed coefficients and approximate coefficients are up-sampled by 2 before they under goes filtering. The filters used in these transmitters are having some unique features which make them to be identified as orthonormal DWT filter banks. Some of the important things are (Chun-Lin, 2010):

- The coefficients of the orthogonal filters are real numbers
- The filters are of same length and un symmetric
- The high pass filter H1 and low pass filter G1 are related as Equation 2:

$$H_1(Z) = Z^{-N} G_1(-Z^{-1})\qquad(2)$$

This means the two filters are alternated flip of each other, which is the prime requirement of perfect reconstruction property.

In the receiver side the system is arranged as shown in **Fig. 4**. The multiple antennas in the receiving side receive the STBC coded message from the transmitter. This is actually several replica of the same information transmitted through the different transmitting antenna. This increases the spatial diversity and there by reduces the probability of losing the information due to fading (Cortes-Penna, 2009). This is termed as Diversity gain and potentially it is equal to $N_t \times N_r$, where N_t is the number of transmitting antenna and N_r is the number of receiving antenna

The output of the STBC decoder is fed to the DWT block. **Figure 5** shows the DWT block at the receiver side. The reverse process of IDWT is carried over here to recover the modulated data. In this process vector transposing is done over both approximate and detailed coefficients. This converts the parallel matrix into serial form. So a serial to parallel converter is used to get back the modulated data. In this action the yield of approximate coefficients are the required data those are taken to the de-mapper and that of detailed coefficients are zeros which are discarded.

The concept of recovering the wavelet coefficients from the discrete time sequence X[n] is as shown in the **Fig. 6**. Here the computation of DWT involves a set of High pass and Low pass filters. These are said to be the analysis filters whose output are down sampled by 2 before applying to the succeeding stage. These Ho and Go are also having the same characteristics, as that of H1 and G1 used in the transmitter stage. Not only the Ho and Go are alternate flip, but also interchangeable with H1 and G1. That means the filters are selected such that they satisfy the perfect orthonormal characteristics.

3. DIFFERENT WAVELET TYPES

In order to obtain the wavelet transformation some basis function should be used as a mother wavelet. Using translation and scaling process we can produce all the wavelet functions from the mother wavelet. Depending upon the application needs suitable mother wavelet should be chosen so that the wavelet transform can be used efficiently.
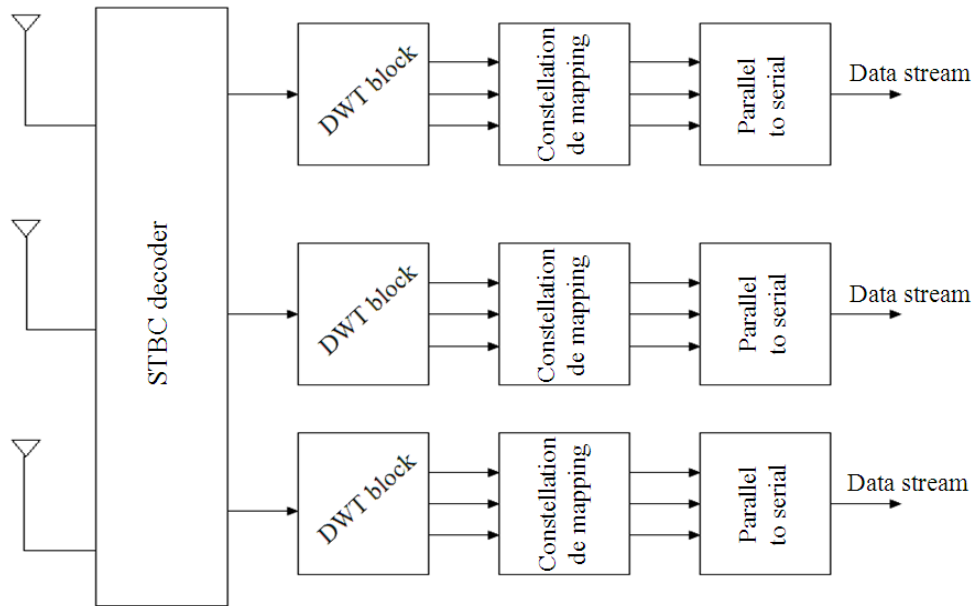
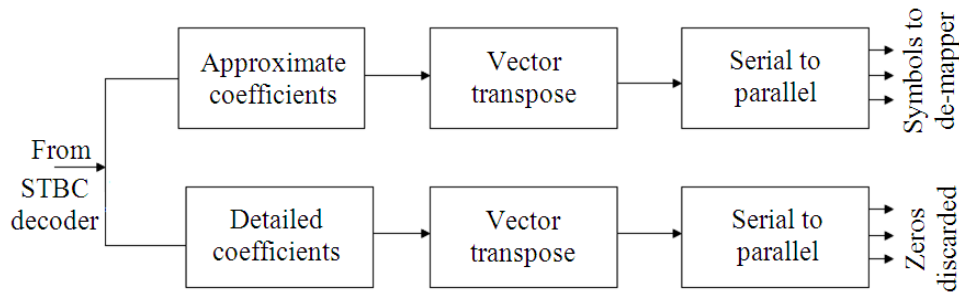**Fig. 4.** DWT-MIMO OFDM system receiver model

Fig. 5. DWT block of the receiver

Some of the wavelets those are having orthonormal properties (Misiti *et al.*, 2009) and hence suitable for data transmission purpose are Haar wavelet, Daubechies wavelet, Symlets and Coifelts wavelets. The mother wavelet function of these wavelets and some of their properties are described below.

Haar wavelet's mother wavelet function ψ (t) can be written as Equation 3:

$$\psi(t) = \begin{cases} 1 & 0 \le t < 11/2 \\ -1 & \frac{1}{2} \le t < 1 \\ 0 & \text{other wise} \end{cases} \qquad (3)$$

This is the simplest wavelet and easiest to use in analysis and also very much serves the practical purpose. The next important thing in this series is Daubechies wavelet usually referred as dbN, where N is an integer. In fact Haar wavelet is nothing but db1. **Figure 7** shows the wavelet function ψ of Haar, db2 and db4 wavelets (WPB, 2013). Coifelts and Symlets wavelets are also having equal importance in orthogonal wavelets category. These functions are shown in **Fig. 8**.

The common properties among all the four wavelets are, (i) orthogonal nature, (ii) Bi-orthogonal nature, (iii) desirable support width and filter length (iv) Compactly supported with highest number of vanishing moments. (Having N vanishing moments means that wavelet-coefficients for Nth order polynomial will be zero.
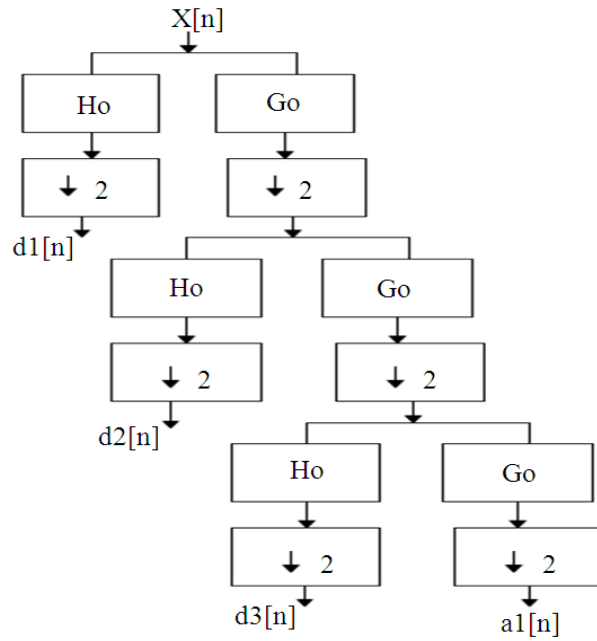
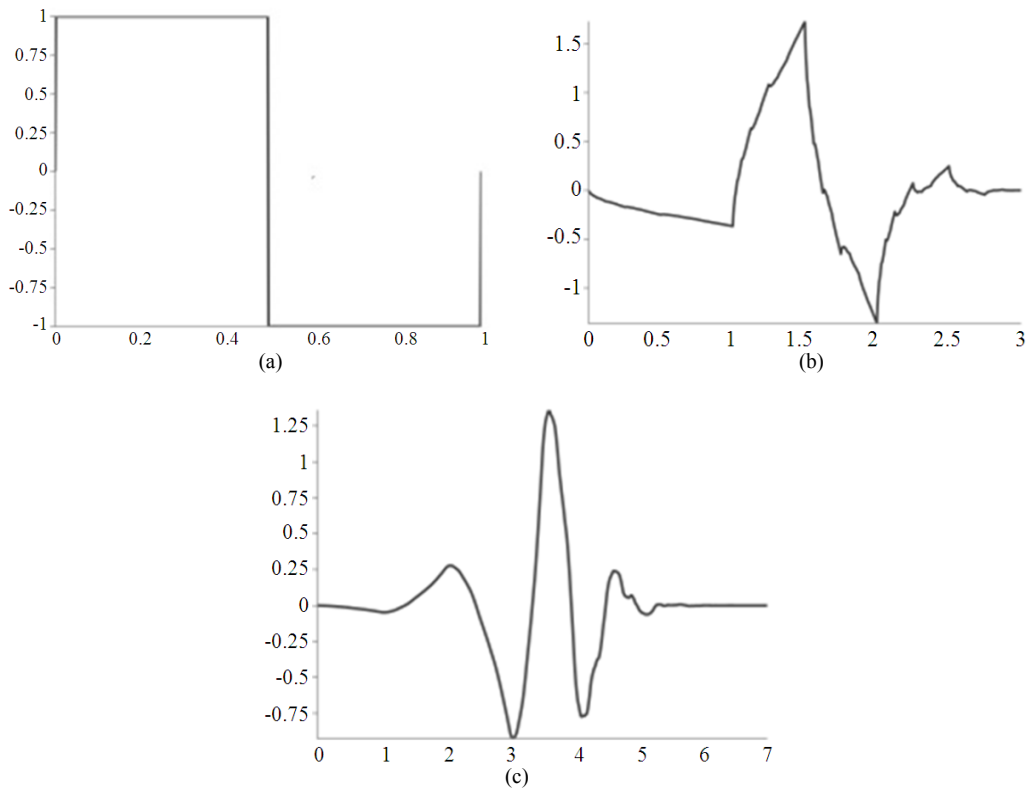**Fig. 6.** Concept of composing DWT using wavelet filter

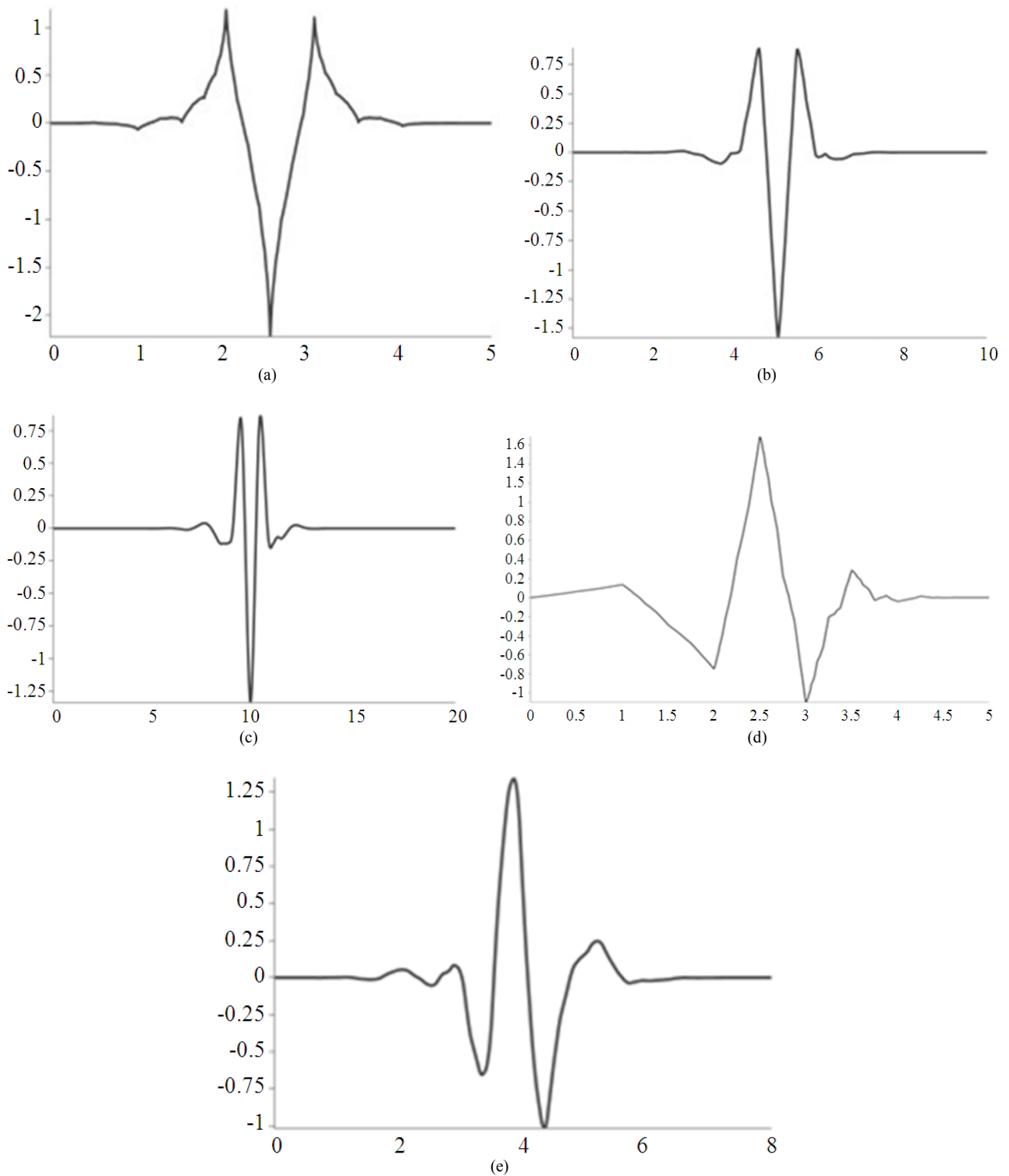**Fig. 7.** Wavelet functions of (a) Haar (b) db2 and (c) db4

Fig. 8. Wavelet functions of Coifelts and Symlets wavelets (a) coif 1 (b) coif 2 (c) coif 4 (d) Symlets 3 (e) Symlets 5
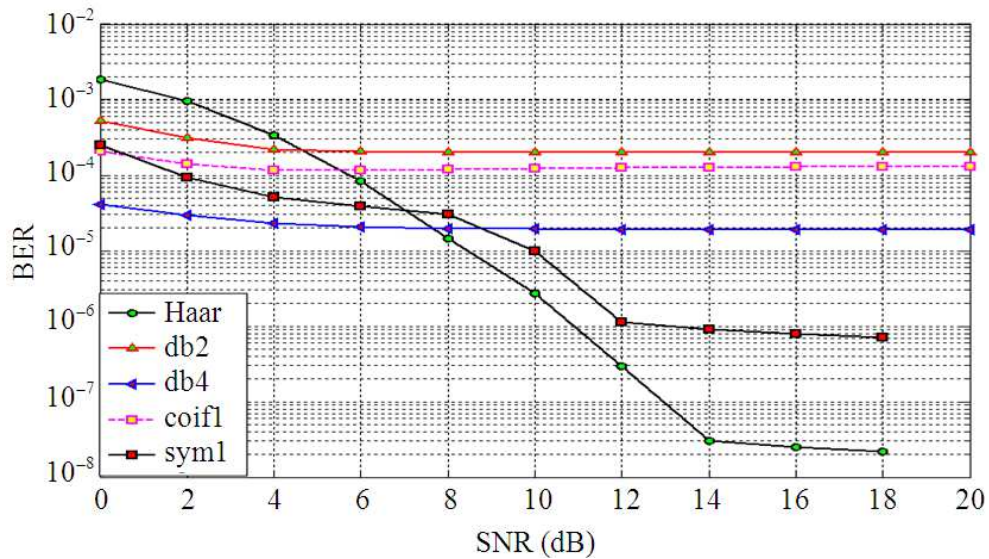
Fig. 9. BER Performance of DWT based MIMO OFDM System for different wavelet functions
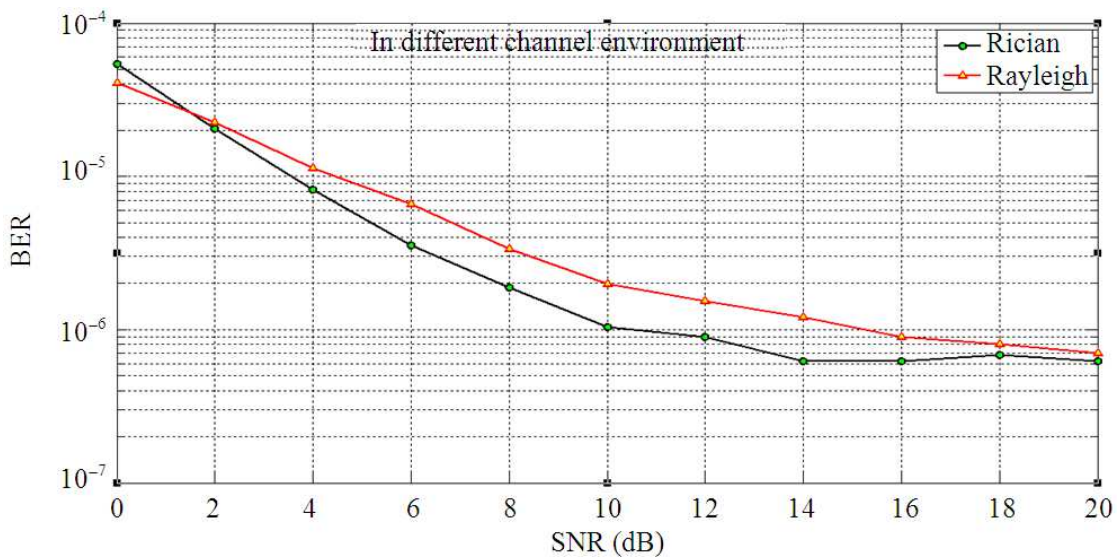
Fig. 10. BER Performance of DWT based MIMO OFDM system for different channel conditions

Table 1. Simulation parameters

Parameters	Type/value(s)
Type of Modulation	QPSK
Number of constellations	4
Data length	1024
Block size	8
Number of DWT Points	8
Number of MIMO transmitters	3
Number of MIMO receivers	3

That is, any polynomial signals up to order N-1 can be represented completely in scaling space. In theory, more vanishing moments means that scaling function can represent more complex signals accurately (EMS, 2012).

4. SIMULATION AND RESULTS

Matlab simulation is carried over for DWT based MIMO OFDM system with different wavelet

functions and the result is as shown in the **Fig. 9**. The simulation parameters for which the plot is obtained is as listed in the **Table 1**.

Even though all the four different wavelet functions can be used for generating DWT coefficients for MIMO OFDM transmission, from the simulation result it is obvious that Haar wavelet is the best suited for the purpose. So using Haar wavelet function with the same parameters as in the **Table 1**, another simulation is done for two different channel environments. That is for Rician and Rayleigh channels. The result is depicted in **Fig. 10**.

For all the other parameters same, the difference between the Rician and Rayleigh channels is the Rician factor which represents the Line of Sight (LOS) component. Even though both the channels are so close in BER performance, due to LOS component Rician gives some better figures comparatively.

5. CONCLUSION

From the simulation results it can be concluded that, the evolving DWT based MIMO OFDM system will be showing the best BER performance with Haar wavelet in it. At lower SNR levels symlet1 wavelet can be considered as a better alternative for Haar wavelet. The BER performance based upon channel environment, the Rician channel is the best suited due to its line of site nature. The Rayleigh channel also exhibits the nearby 'catching competitor' type of results. Depending upon the variations in other channel parameters (like Doppler shift, noise level) the results may slightly vary. For practical implementation purpose, availability of resources, system complexity and cost are some of the other factors needed to be considered.

6. REFERENCES

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