

Performance Analysis Comparison of FFT and Discrete Wavelet Packet Transform (DWPT) Based MIMO-OFDM Systems

SOUKAINA ETTARFAOUI
LIMIARF, Faculty of Sciences
Mohammed-V University
Rabat, Morocco
settarfaoui@gmail.com

HAITHAM JABBAR TAHA
Department of Electrical Engineering
University of Technology
Baghdad/ Iraq
haithm1969@yahoo.com

MOHAMMED MAJID HIMMI
LIMIARF, Faculty of Sciences
Mohammed-V University
Rabat, Morocco
himmi@fsr.ac.ma

Abstract: - Multiple Input Multiple output (MIMO) antennas can be combined with orthogonal frequency division multiplexing (OFDM) to ensure spatial diversity gain and/or to increase spectral efficiency. MIMO communication system with Alamouti methods can improve the bit error rate (BER) and signal to noise ratio (SNR) thus distortions are reduced for higher data rate. Conventionally OFDM is Fast Fourier Transform (FFT) based system, it uses IFFT (Inverse FFT) blocks in the transmitter and FFT blocks in the receiver. Replacing the FFT with Discrete Wavelet Packet Transform (DWPT) makes the system's performance further improved. This leads to a new scenario of DWPT based MIMO OFDM system. In this work, the STBC-MIMO-OFDM under the scenario of having multiple antennas system, with QAM in Rayleigh fading channel for different values of Quadrature Amplitude Modulation (QAM) points (8, 32 and 64) are implemented. By evaluating the BER performance and the transmission capacity, it turns out that the DWPT based MIMO-OFDM system is superior compared with the FFT-MIMO-OFDM system. BER performance of the system is analyzed under different channel environments to assess the WPT based MIMO-OFDM performance in order to compare it with FFT based MIMO-OFDM system.

.In this paper the numerical results of the simulation consist a new contribution and are obtained using MATLAB. The simulation of DWPT-OFDM was accomplished with Haar mother based multicarrier. Whereas for both the latter and the conventional FFT-OFDM were subjected to the same conditions, for the multi-antenna system channel capacity and QAM modulation (8, 32, and 64) points in flat fading channels with AWGN and selective fading channel with AWGN. Computer simulation results demonstrate that the proposed wavelet based MIMO-OFDM system outperforms in Alamouti (two transmit antenna and two receive antenna) due to the overlapping nature of DWPT dispensing the addition of cyclic prefix and less hardware complexity as in FFT based MIMO-OFDM.

Key- Words: - DWPT, FFT, OFDM, MIMO, Alamouti STBC.

1 Introduction

MIMO technology multiplies capacity by transmitting different signals over multiple antennas, and OFDM which divides a radio channel into a large number of closely spaced sub channels to provide more reliable communications at high speeds are the two assuring technologies that offers high data rate as required nowadays. Conventionally OFDM is a FFT based system, it uses IFFT at the transmitter and FFT at the receiver, replacing by IDWPT/DWPT leads to increase performance and also can operate without a cyclic prefix (CP).

The solution to obtain significant higher data rates and increase range performance at the same time is MIMO-OFDM. MIMO-OFDM increases the link capacity by simultaneously transmitting multiple data streams using multiple transmit and receive antennas [1]. MIMO systems have been recently under active consideration because of their potential for achieving higher data rate and providing more reliable reception performance compared with traditional single-antenna systems for wireless communications [2]. MIMO schemes and OFDM can complement one another at the high-throughput (HT) mode, or the diversity mode, or even both in fading environments [3].

MIMO-OFDM which is a multi-user OFDM that allows multiple accesses combining TDM and FDM on the same channel widely employed in the next generation wireless communication systems such as WLAN, WMAN, WiMAX and 3G-LTE standard in order to accommodate many users in the same channel at the same time. STBCs are simple, but effective tool to obtain transmit diversity in MIMO communication channel. Orthogonal STBCs designed for more than two antennas can achieve full diversity order but they have code rate less than unity [4-6].

In these recent years were proposed many systems that compares the performances of wavelet with FFT based OFDM systems focusing on effects of noise, error performances, and computational complexity, etc. [7-10]. But, in [6] gives the BER analysis of BPSK signal in MIMO and MIMO-OFDM using MATLAB Simulink. In [11], proposes a model of MIMO-OFDM. While In [12], uses Space Time Frequency coded communication system using diversity schemes like MIMO and MISO and their performance is evaluated over a fading channel having inherent noise.

In 2010, A Khatoon et al, [13] analyzes the symbol error performance of a wireless communication system using diversity combining scheme in Rayleigh fading channels. While in [14], a modified MIMO OFDM

system has been introduced that is capable to mitigate fading channel distortion even in its worst conditions. In [15], the performance of Wavelet based Multi-User MIMO OFDM (MU- MIMO OFDM) systems and a comparison is made with classical FFT based multiuser MIMO OFDM system. In [16], the performance of STBC-OFDM is analyzed under different constraints in Rayleigh fading channels. In [5], discussed the design of MIMO-OFDM for wireless broadband communication. MIMO-OFDM is considered for different modulation schemes which are used to encode and decode the data stream in wireless communication over AWGN channel for unknown transmitter and known receiver.

In [17], several aspects in the direction of Space-time coding in MIMO-OFDM systems with multiple antennas were discussed. STBC provide diversity gain, with very low decoding complexity, whereas STTC provides both diversity and coding gain at the cost of higher decoding complexity. While in [18], the BER performance of the system is analyzed for the different types of wavelets under different channel environments. In [19], the BER performance of STBC OFDM system using 16 QAM modulation schemes for SISO, MISO, MIMO (2X2) antenna schemes over Rayleigh Channels. In [20], the impact of a Radio over- Fiber (RoF) optical sub-system on the BER performances of OFDM and MIMO were assessed in the presence of phase noise. While in [21], the analyzed of results for BER and Channel capacity for (Single Input Single Output) SISO, MIMO-OFDM and AMUD MIMO-OFDM with 4-QAM, 16-QAM, 64-QAM, 256-QAM, 512-QAM, 1024-QAM.

In this paper compares the performances of FFT and DWPT based MIMO-OFDM systems in terms of error performance and through an extensive computer simulation it is shown that FFT and DWPT based MIMO-OFDM systems.

The rest of this paper is organized as follows: in the second section the chapter related to Orthogonal Frequency Division Multiplexing (OFDM) Technology. In section 3 Multiple Input Multiple output (MIMO) Technology. In section 4 Space Time Block Coding (STBC) is presented. Section 5 is dedicated to the Discrete Wavelet Packet Transform (DWPT). In section 6 a new model of MIMO-OFDM System is displayed. In section 7 the simulation results of the new system model, Finally, Conclusion is presented and discussed in section 8.

2 Orthogonal Frequency Division Multiplexing (OFDM) Technology

OFDM is essentially a discrete implementation of multicarrier modulation, which divides the transmitted bit stream into many different sub streams and sends them over many different sub channels. Typically, those sub channels are orthogonal and their numbers are chosen such that each one has a bandwidth much less than the coherence bandwidth of the channel. Thus, inter-symbol interference (ISI) on each sub channel is very small. For this reason, OFDM is widely used in many high data rate wireless systems [22].

The OFDM transceiver chain is shown in Figure 1, the input data stream is first mapped into the QAM modulation scheme according to the QAM constellation mapping. Then the complex number output is converted from serial to parallel into N points IFFT to generate the OFDM symbols. The output data from IFFT is now converted from parallel to serial and a cyclic prefix is added to the data. The data are sent via wireless channel after being converted to frame structure (serial data stream). The frame structure consists of the modulated data and the pilot signal which is used for channel estimation and compensation. The channel consists of a multipath fading (flat fading channel or frequency selective fading channel) with AWGN.

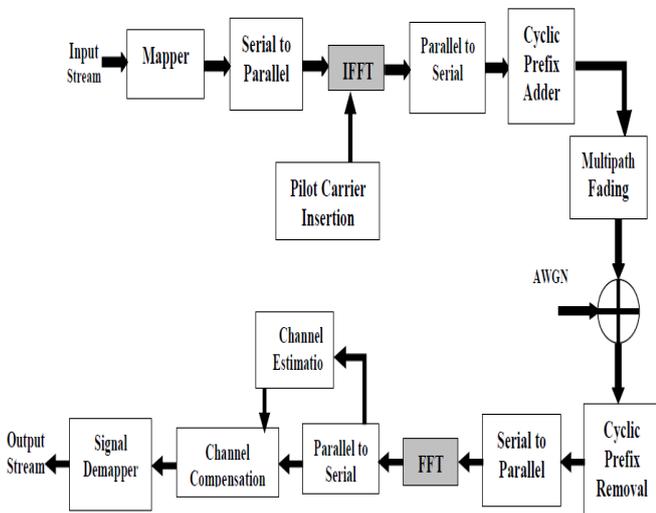


Fig. 1: Block diagram of FFT-OFDM System [23].

At the receiver the reverse operations of the encoding processes are employed. The cyclic prefix is removed and a serial to parallel conversion is done for the signal. A FFT with N points is used to convert the signal from

time to frequency domain. Then the effective channel is compensated after the OFDM demodulation, the signal de-mapper is used to recover the transmitted signal [23].

In the baseband of multicarrier system, OFDM multiplexing scheme is used to divide a selected wideband spectrum into many smaller narrow bands. This is achieved using the fast Fourier transform (FFT). Over a frequency selective channel, a predefined length of the symbol is used to overcome ISI for channel impulses with long delay. This symbol length, usually called the cyclic prefix (CP) is usually longer (or least equal to) the length of the worst delay in time. In time domain, an N-point FFT-OFDM system can be defined as [24]:

$$b[n] = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} B_{(k,l)} e^{j2\pi nk/N}, \quad n = 0, 1, 2, 3 \dots N - 1 \quad (1)$$

Where, N is the number of narrowband sub channels, 1/N is a scaling factor with n as the index of the prevalent subcarrier, B(k,l) is the kth sub-channel input symbol of the lth - constellation mapped using, for instance, QPSK. Meanwhile, the number of FFT points adopted in the design of any specific OFDM structure provides the number of narrowband sub-channels over which the input symbols are multiplexed [24].

3 Multiple Input Multiple Output (MIMO) Technology

In MIMO technology numbers of multiple antennas are numerous at transmitter and multiple antennas at receiver side to improve communication system. MIMO antenna is regarded as efficient solution to meet the needs of high capacity, fading, improving link reliability without loss of bandwidth efficiency as shown in figure 2 [21].

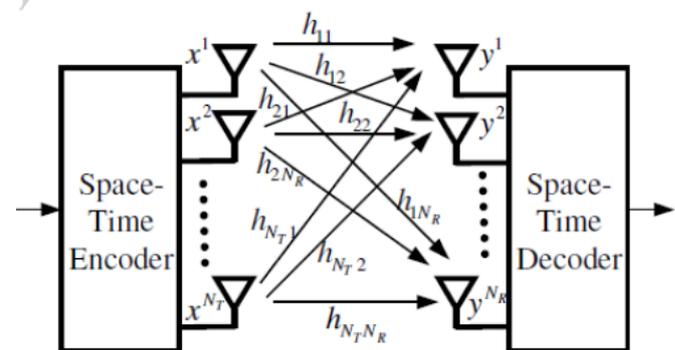


Fig. 2: Block diagram of MIMO System.

MIMO wireless communication refers to the transmissions over wireless links formed by multiple antennas equipped at both the transmitter and receiver. The key advantages of employing multiple antennas lies in the more reliable performance obtained through diversity and the achievable higher data rate through spatial multiplexing [25].

4 Space Time Block Coding (STBC)

In OFDM communication system using n_t transmit antennas and n_r receive antennas. Such a system could be implemented using a single space-time encoder employing a code for n_t transmit antennas. The space-time encoder takes a single stream of binary input data and transforms it into n_t parallel streams of baseband constellation symbols. Each stream is broken into OFDM blocks with the n^{th} block for the n^{th} stream denoted by $t_i[n,k], k=0, \dots, k-1$. Each OFDM block of constellation symbols is transformed using an inverse fast Fourier transform (IFFT) and transmitted by the antenna for its corresponding stream. Thus, all n_t transmit antennas simultaneously transmit the transformed symbols. The received signals at each antenna are similarly broken into blocks and processed using an FFT.

After FFT processing, the n^{th} block at receive antenna j is denoted by $t_j[n,k], k=0, \dots, k-1$. At the receiver, a single space-time decoder employs maximum likelihood sequence estimation (MLSE) algorithm to jointly decode the data blocks based on the observations from the n_r receive antennas. Alternatively, could employ n_g individual space-time encoders, where each encoder is designed to use n_t/n_g transmit antennas, as shown in Figure 3, [26].

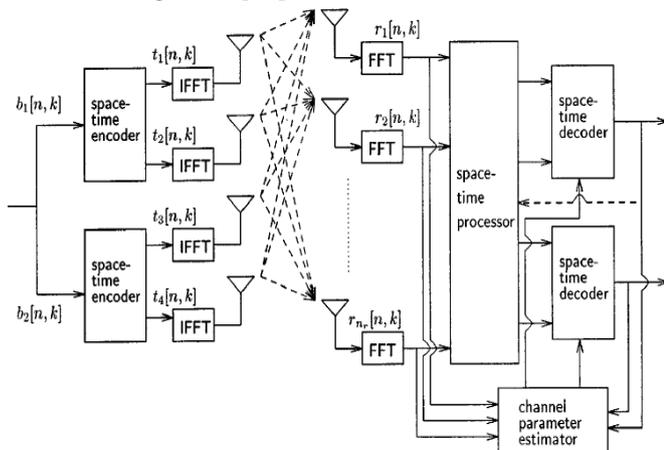


Fig. 3: MIMO system [26].

4.1 Alamouti STBC Scheme

STBC is based on the scheme presented by Alamouti in 1998. This scheme provides transmit and receive diversity to MIMO system. Using two transmit antennas and one receive antenna the scheme provides the same diversity order as maximal-ratio receiver combining (MRRC) with one transmit antenna and two receive antennas. Figure 4 shows the block diagram of base band representation of the Alamouti's two branch transmit diversity scheme.

The scheme is defined by the three functions such as encoding and transmission sequence of information symbols at the transmitter, combining scheme at the receiver and decision rule for maximum likelihood detection. In encoding and transmission sequence, two signals are simultaneously transmitted from the two antennas at a given symbol period. The signal transmitted from antenna zero is denoted by S_0 and from antenna one by S_1 . During the next symbol period, signal $(-S_1^*)$ is transmitted from antenna zero and signal S_0^* is transmitted from antenna one where $*$ is the complex conjugate operation. In Alamouti scheme, the encoding is done in space and time (space-time coding) and such encoding may also be done in space and frequency [27].

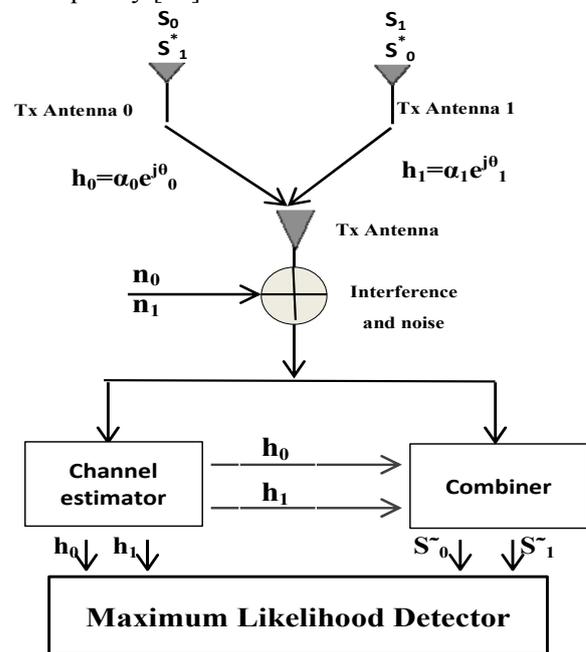


Figure 4: Conceptual block diagram of Alamouti space-time block coding scheme [28].

In STBC encoder input symbols are divided into 2 groups. $\{S_0, S_1\}$ Symbols of each group will be transmitted as shown in Figure 5[28].

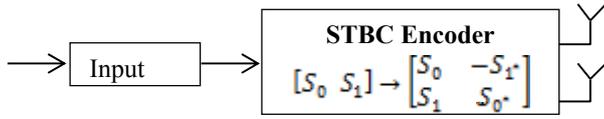


Fig. 5: The system equation [28].

$$R=HS+W \tag{2}$$

$$\begin{bmatrix} r_{00} & r_{01} \\ r_{10} & r_{11} \end{bmatrix} = \begin{bmatrix} h_{00} & h_{01} \\ h_{10} & h_{11} \end{bmatrix} \begin{bmatrix} S_0 & -S_1^* \\ S_1 & S_0^* \end{bmatrix} + \begin{bmatrix} w_0 & w_1 \\ w_2 & w_3 \end{bmatrix} \tag{3}$$

The above matrix shows that the two rows/columns of STBC matrix, that are orthogonal to each other. r_{00} and r_{01} denotes receiver 1 and r_{10} and r_{11} denotes receiver 2. H is the channel matrix and W is the white Gaussian noise. The S_0 and S_1 symbols along with their conjugates are placed on OFDM subcarrier for further transmission through channel, [28].

The channel at time t may be modeled by a complex multiplicative distortion $h_0(t)$ for transmit antenna zero and $h_1(t)$ for transmit antenna one [27].

$$\begin{aligned} h_0(t) &= h_0(t+T) = h_0 = \alpha_0 e^{j\theta_0} \\ h_1(t) &= h_1(t+T) = h_1 = \alpha_1 e^{j\theta_1} \end{aligned} \tag{4}$$

Where, T is the symbol duration. The received signals can then be expressed as

$$\begin{aligned} r_0 &= r(t) = h_0 s_0 + h_1 s_1 + n_0 \\ r_1 &= r(t+T) = -h_0 s_1^* + h_1 s_0^* + n_1 \end{aligned} \tag{5}$$

Where r_0 and r_1 are the received signals at time t and $(t+T)$ and are n_0 and n_1 complex random variables representing receiver noise and interference [27].

5 Discrete Wavelet Packet Transform (DWPT)

Wavelet packets transform has been first introduced for data compression due to its functions are localized in both time and frequency domains. The construction of a wavelet packets basis starts from a pair of quadrature mirror filters (QMF), g_1 and g_0 , satisfying the following conditions [23];

$$\sum_{n=-\infty}^{\infty} g_1(n) = 2 \tag{6}$$

$$\sum_{n=-\infty}^{\infty} g_1(n) g_1(n-2k) = 2\delta(k) \tag{7}$$

$$g_0(n) = (-1)^n g_1(L-n-1) \tag{8}$$

The sequence of functions $\varphi_n(x)$, called wavelet packets, are recursively defined by the QMF $g_1(n)$ and $g_0(n)$ as [23];

$$\varphi_{2n}(x) = \sum_{k \in \mathbb{Z}} g_1(k) \varphi_n(2x-k) \tag{9}$$

$$\varphi_{2n+1}(x) = \sum_{k \in \mathbb{Z}} g_0(k) \varphi_n(2x-k) \tag{10}$$

The first two functions of this sequence $\varphi_0(x)$ and $\varphi_1(x)$ are exactly the scaling function and its corresponding wavelet function from a multiresolution analysis. Since the two functions $\varphi_{2n}(x)$ and $\varphi_{2n+1}(x)$ are generated from the same function $\varphi_n(x)$, they are called the “children” functions of the “parent” $\varphi_n(x)$. The two operators, also known as filtering-down sampling processes using the QMF $g_1(n)$ and $g_0(n)$, are defined as [23]:

$$G_1\{x\}(2n) = \sum_{k \in \mathbb{Z}} x(k) g_1(k-2n) \tag{11}$$

$$G_0\{x\}(2n) = \sum_{k \in \mathbb{Z}} x(k) g_0(k-2n) \tag{12}$$

These two operators are used to decompose (analyze) any discrete function $x(n)$ on the space $l^2(\mathbb{Z})$ into two orthogonal subspaces $l^2(2\mathbb{Z})$. In each step two coefficient vectors has a length half of the input vector are produced. Thus, the total data length remains unchanged. The process continues and stops at any desired step. The output coefficient vectors become scalars for the deepest decomposition level. This decomposition process is named as Discrete Wavelet Packet Transform (DWPT). The transformed coefficient vectors are orthogonal and the original signal $x(n)$ can be recovered from the coefficient vectors by the inverse transform. This process is defined as a series of up-sampling-filtering using the reversed filters $g_1(-n)$ and $g_0(-n)$. The wavelet packets function set defined in Eq. (9) and Eq. (10) can also be constructed using the Inverse DWPT (IDWPT) with the dual operators of Eq. (11) and (12) are defined as [23];

$$G_1^{-1}\{x\}(2n) = \sum_{k \in \mathbb{Z}} x(k) g_1(n-2k) \tag{13}$$

$$G_0^{-1}\{x\}(2n) = \sum_{k \in \mathbb{Z}} x(k) g_0(n-2k) \tag{14}$$

The process of constructing a wavelet packet function set can be more clearly seen via the wavelet packet construction tree shown in Figure 6.

Each wavelet packet function is constructed starting from a leaf of this binary tree with an impulse $\delta(n)$ going up node by node until reaching the root of the tree. The operator from one node to an upper layer node is one of the above operators G_1^{-1} and G_0^{-1} depending on the left/right direction [23].

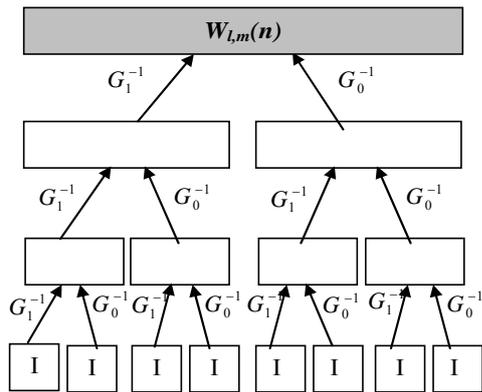


Fig. 6: Wavelet packet construction tree [23].

6 New Model of MIMO-OFDM System

Future broadband wireless systems should provide high data rate and high performance over very challenging channels that may be time selective and frequency-selective. The combination of MIMO and OFDM has the potential of meeting this stringent requirement since MIMO can boost the capacity and the diversity and OFDM can mitigate the detrimental effects due to multipath fading.

A New Model of MIMO-OFDM system is shown in Figure 7, where M_t transmits antennas, M_r receives antennas, and N -tone OFDM is used. First, the incoming bit stream is mapped into a number of data symbols via some modulation type such as QAM-modulation. Then a block of N_s data symbols.

6.1 FFT based MIMO-OFDM with Alamouti STBC

The input data stream is first mapped into the QAM modulation scheme according to the QAM constellation mapping, and then the complex number output is converted from serial to parallel into N -points IFFT to generate the OFDM symbols.

The FFT-OFDM signal can be characterized as:

$$s(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} S_k e^{j2\pi \frac{nt}{T}} \quad , 0 \leq t \leq T \tag{15}$$

Where \sqrt{N} is a scaling factor with N as number of the narrowband sub-channels, T is the signal period and n is the index of the prevalent signal frame.

The output data from IFFT is converted from parallel to serial and a cyclic prefix is added to the data. The data are sent via wireless channel after being converted to frame structure (serial data stream). The frame structure consists of the modulated data and the pilot signal which is used for channel estimation and compensation. The channel consists of multipath fading (flat fading channel or frequency selective fading channel) with AWGN.

At the receiver the reverse steps of the encoding processes are employed, the cyclic prefix is removed and a serial to parallel conversion is established, FFT with N points is used to convert the signal from time to frequency domain. Then the effective channel is compensated after the OFDM demodulation, the signal de-mapper is used to recover the transmitted signal as shown in Figure 8.

But, in a 2×2 MIMO channel as shown in Figure 9, used 2 transmit antennas, a transmission sequence, for example $\{x_1, x_2, \dots, x_n\}$. In normal transmission, will be sending x_1 in the first time slot, x_2 in the second time slot, x_3 and so on. However, have 2 transmit antennas; may group the symbols into groups of two. In the first time slot, send x_1 and x_2 from the first and second antenna. In second time slot, send x_3 and x_4 from the first and second antenna; send x_5 and x_6 in the third time slot and so on. Notice that as are grouping two symbols and sending them in one time slot, and need only $(n/2)$ time slots to complete the transmission-data rate is doubled. This forms the simple explanation of a probable MIMO transmission scheme with 2 transmit antennas and 2 receive antennas.

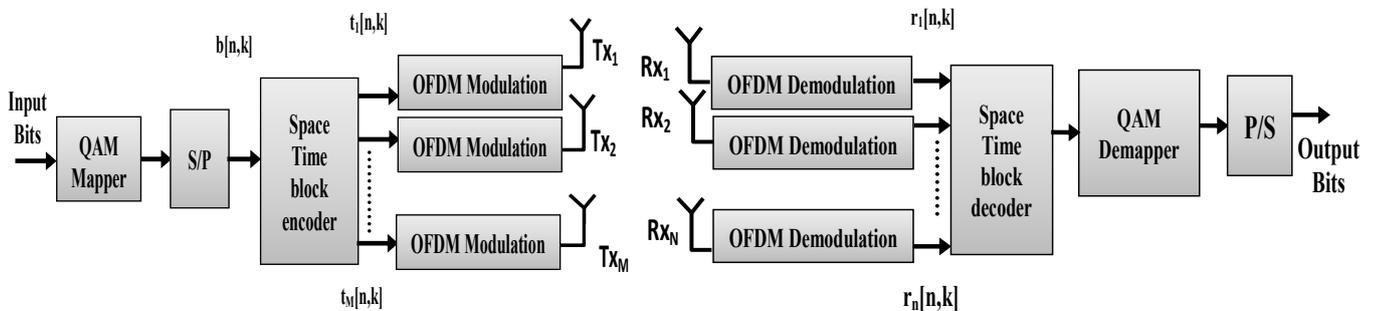


Fig. 7: Block Diagram for a New Model of MIMO-OFDM System

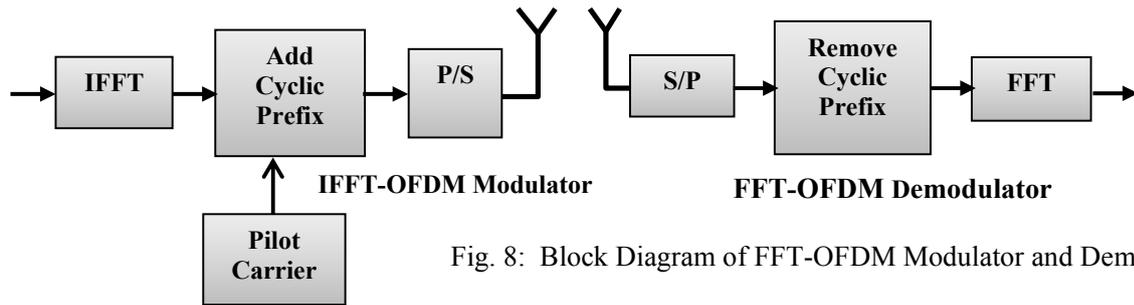


Fig. 8: Block Diagram of FFT-OFDM Modulator and Demodulator

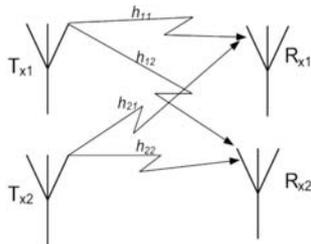


Fig. 9: Two Transmit and Two Receive (2x2) MIMO channel

6.2 DWPT based MIMO-OFDM with Alamouti STBC

The idea of a wavelet was first introduced for data compression because functions are localized in both time and frequency domains. It ensures translation along the time and frequency planes by shifting and scaling respectively, unlike the Fourier transform. Thus, when using the DWPT, the observed signal is allowed variation in both time and frequency by multiresolution according to the performed shifting and scaling. This property gives wavelet-based multicarrier systems signals greater robustness against high Doppler shifts than the FFT. Unlike the Fourier transform that applies a constant window to the signal, the DWPT uses a varied-sized windowing. This method allows for discontinuities in the signal to be identified as shown in Figure 10.

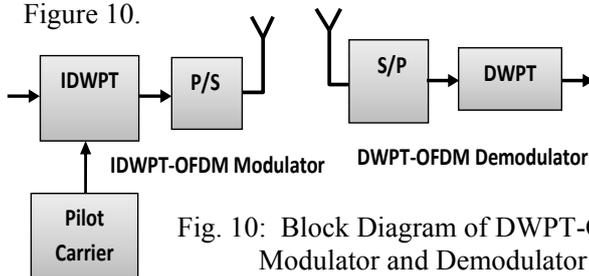


Fig. 10: Block Diagram of DWPT-OFDM Modulator and Demodulator

7 Simulation Results

In this section, the simulation results are presented which show the performance comparison of FFT and DWPT based MIMO-OFDM systems in terms of BER in various wireless channels.

The both FFT and DWPT based MIMO-OFDM systems are developed, analyzed, and simulated in MatLab.

The performance results of the system in AWGN channel, Flat Fading channel and Selective Fading channel are obtained using the MIMO-OFDM parameters as listed in Table 1. The bit rate used in this simulation is 5000 Mbps.

Table 1: Simulation Parameters

Parameter	FFT based MIMO-OFDM	DWPT based MIMO-OFDM
Data Rate	5000Mbps	5000Mbps
Modulation	QAM (16, 32 and 64)	QAM (16, 32 and 64)
No. of sub-carriers	32	32
Doppler Frequency	500 Hz	500 Hz
Diversity Schemes	2X2 antennas	2X2 antennas
No. of bits per Symbol	32	32
No. of FFT points	64	-
Wavelet	-	Haar
Channel Model	AWGN	
	Flat fading +AWGN	
	Frequency selective fading +AWGN	

During simulation, the perfect synchronization between the transmitted and the received signals has been considered with available channel state information at the receiver. The channel coefficients are assumed to be static during two consecutive transmitted symbols in the diversified channels. The performance of the proposed system was tested in different channels.

There are some restrictions and disadvantages in digital wireless communication systems between transmitter and receiver where received signals

arrive at receiver with different power and time delay due to reflection, diffraction and scattering effects. For this reasons Bit Error Rate (BER) value is relatively high.

7.1 FFT based MIMO-OFDM system

In a FFT based MIMO-OFDM system with M_t transmit antennas and M_r receive antennas, if the channels for any pair of transmit-receive antennas are independent and experience flat fading, the maximum or full diversity gain is $M_t M_r$. A common way of achieving the full diversity is through STBC.

A. BER Performance in FFT based MIMO-OFDM system at the AWGN Channel

The comparison is made of the FFT based MIMO-OFDM system between the QAM points of 16, 32 and 64 over the AWGN channel. The performance gain is wide between the systems that use 16 QAM points to the system with 64 points for higher SNR values. Higher performance gains are also observed when the SNR increases, as shown in figure 11.

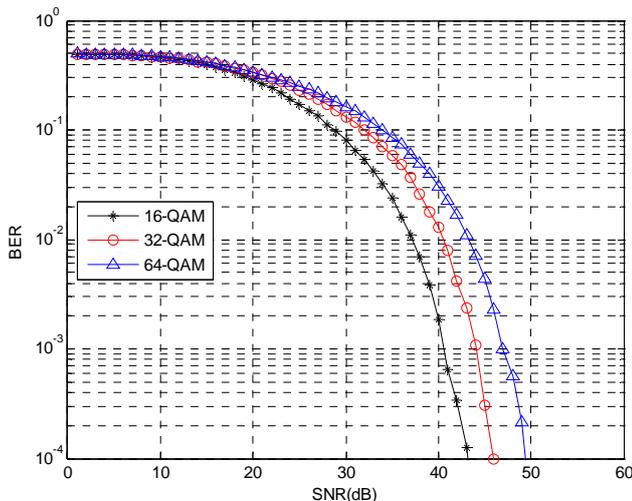


Fig. 11: BER performance of FFT based MIMO-OFDM system with STBC Alamouti (AWGN channel)

B. BER Performance in FFT based MIMO-OFDM system at the Flat Fading Channel

In this section, the channel model used is the flat fading channel, where the bandwidth of the transmitted signal is smaller than the coherence bandwidth of the channel. Then, all frequency components of the transmitted signal undergo the same attenuation and phase shift in transmission through the channel. The value of the Doppler frequency is used in this simulation 500 Hz. The BER performance of FFT based MIMO-OFDM

system with QAM of 16, 32 and 64 is shown in Figure 12. The performance is reduced as the number of constellation mapping points increased from 16 to 64-point.

This section has clearly shown that the performance of the FFT based MIMO-OFDM system is affected by Doppler frequency as well as the value of QAM constellation points. The FFT based MIMO-OFDM system simulated in flat fading channel performs better at the lower Doppler frequency as compared to its performance at the higher Doppler frequency.

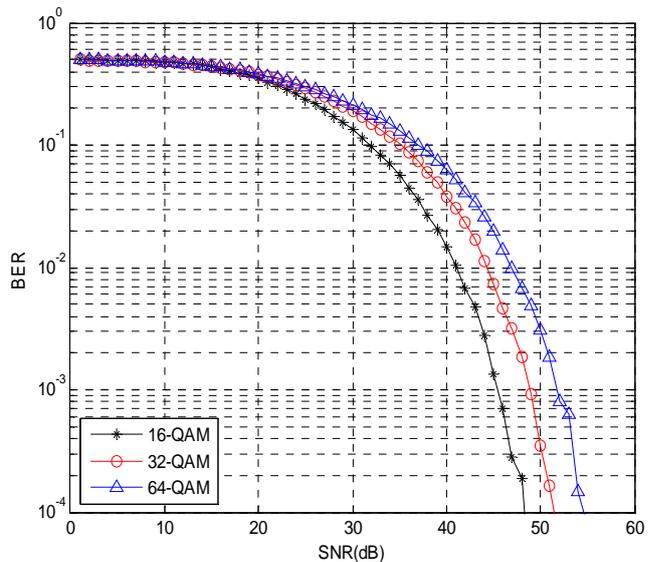


Fig. 12: BER performance of FFT based MIMO-OFDM system (STBC Alamouti) at the Flat Fading Channel (500 Hz) and (16,32,64 QAM)

C. BER Performance in FFT based MIMO-OFDM system at the Selective Fading Channel

The BER performance of the FFT based MIMO-OFDM system in the frequency selective fading channel is presented in this section. This channel indicates that the transmitted signal has a bandwidth greater than the coherence bandwidth of the channel. The frequency components of the transmitted signal with frequency separation exceeding the coherence bandwidth are subjected to different gains and phase shifts. The path gain 8 dB and the path delay is 1 sample.

The BER performance of FFT based MIMO-OFDM system with QAM of 16 and 64 is shown in Figure 13. It shows that FFT based MIMO-OFDM system performs better with QAM constellation mapping 16-points as compared to its performance at the 32, 64-point. This shows that FFT based MIMO-OFDM system in the selective fading channel performs well at

the number of constellation mapping 16-points compared to its performance at the 32, 64-point. The performance is reduced as the number of constellation mapping points increased from 16 to 64-point.

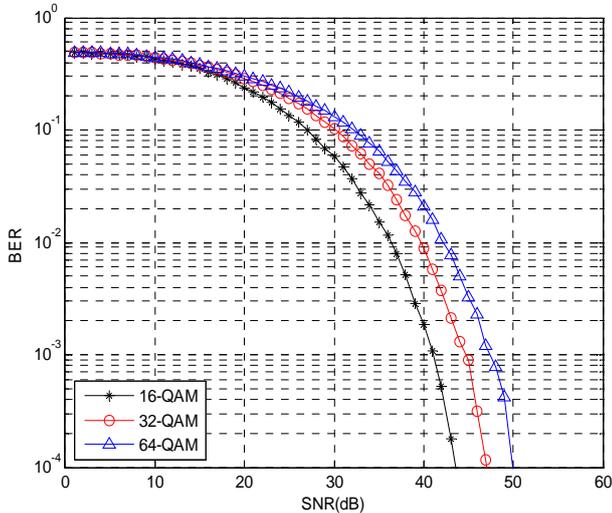


Fig. 13: BER Performance of FFT based MIMO-OFDM system at the Selective Fading Channel (500 Hz) and (16,32 and 64 QAM).

7.2 DWPT based MIMO-OFDM system

A. BER Performance in DWPT based MIMO-OFDM system at the AWGN Channel

Figure 14 shows results for the DWPT based MIMO-OFDM system that uses QAM points of 16, 32 and 64 over AWGN channel.

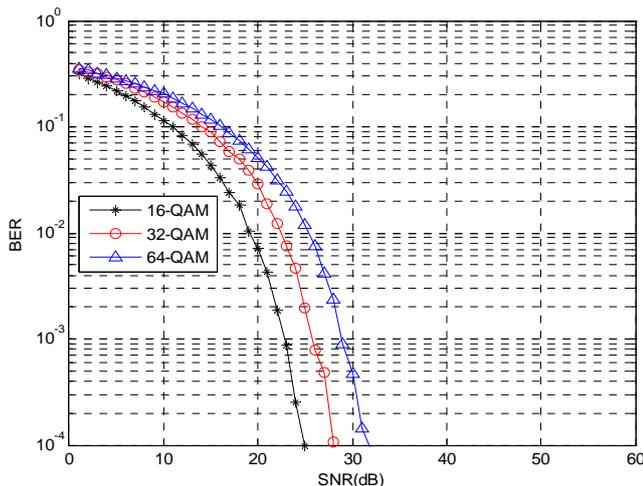


Fig. 14: BER performance of DWPT based MIMO-OFDM system with STBC Alamouti (AWGN channel)

The performance gain is wide between the systems that use 16 QAM points to the system with 64 points for

higher SNR values. Higher performance gains are also observed when the SNR increases. In the DWPT based MIMO-OFDM system, the BER performance at 16 point better than from 64 point.

B. BER Performance in DWPT based MIMO-OFDM system at the Flat Fading Channel

This section has clearly shown that the performance of the DWPT based MIMO-OFDM system is affected by Doppler frequency as well as the value of QAM constellation points. The DWPT based MIMO-OFDM system simulated in flat fading channel performs better at the lower Doppler frequency (500Hz) as compared to its performance at the higher Doppler frequency.

Figure 15 shows the BER performance of the DWPT based MIMO-OFDM system using QAM 16 constellation mapping points over Flat Fading channel. From this figure it clearly shown that the performance of DWPT based MIMO-OFDM system is better than the FFT based MIMO-OFDM system at same QAM point.

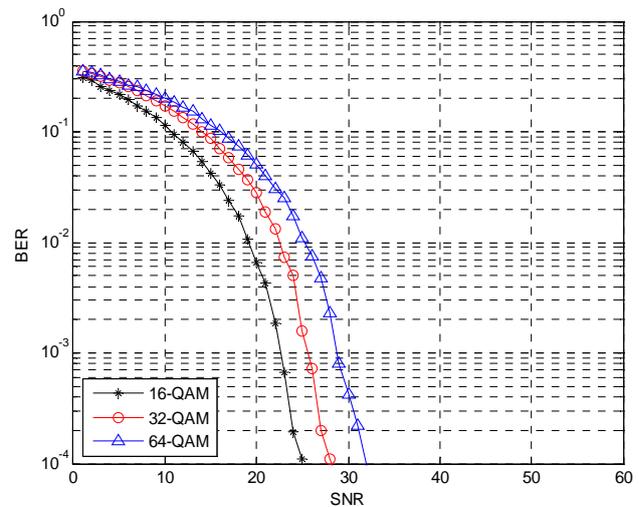


Fig. 15: BER performance of DWPT based MIMO-OFDM system with STBC Alamouti (Flat Fading channel) at 500 Hz and (16,32 and 64 QAM)

C. BER Performance in DWPT based MIMO-OFDM system at the Selective Fading Channel

In this section, if the bandwidth of the signal of interest exceeds the coherence bandwidth of the channel, the signal undergoes frequency selective fading (i.e. $B_s > B_c$). Viewed in the frequency domain, the channel causes different levels of attenuation for different frequency components of the signal. Frequency

selective fading is caused by multipath delays which approach or exceed the symbol period of the transmitted symbol (i.e. $T_s < \sigma_\tau$) where σ_τ is still the rms delay spread of the channel. In practice, $T_s \leq 10\sigma_\tau$ will result in a frequency selective channel; the channel introduces ISI.

In Figure 16, the BER performance of the DWPT based MIMO-OFDM system in the frequency selective fading channel. The frequency components of the transmitted signal with frequency separation exceeding the coherence bandwidth are subjected to different gains and phase shifts. The path gain -8 dB and the path delay is 1 sample.

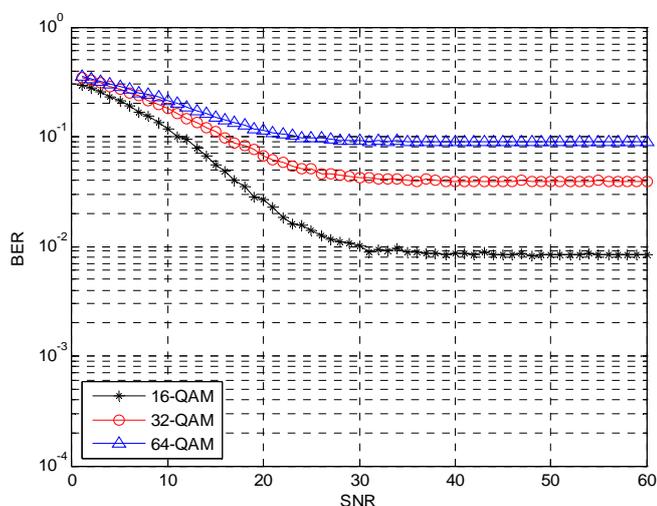


Fig. 16: BER performance of DWPT based MIMO-OFDM system with STBC Alamouti (Selective Fading channel) at 500 Hz and (16, 32 and 64 QAM)

8 Conclusions

In this section a sum up of what novelties brings this paper. This work presents the performance analysis of FFT based MIMO-OFDM system and DWPT based MIMO-OFDM system in various fading channels. Their performance is also affected by the number of QAM points. Performance comparison in term of BER for both DWPT and FFT based MIMO-OFDM systems over AWGN channel, Flat Fading channel and Selective Fading channel is carried out according to the SNR. We can conclude then that DWPT based MIMO-OFDM system performs better than FFT based MIMO-OFDM system.

This contribution introduces a new transmission scheme for MIMO-OFDM systems. This scheme is based on channel coding using estimated channel parameters from a transmitted pilot data at the receiver end. Consequently, the prior information used by the coding

scheme, will help the transmitted signal to adapt to the channel impairments and be more resilient to noise and interference. Simulation results confirm the high performance and the low complexity of the proposed scheme when compared to the conventional MIMO-OFDM system using Alamouti STBC Coding. The paper analyses the performance of FFT and DWPT based MIMO-OFDM systems under different constraints in Multi path fading channels. The simulation results are performed in terms of BER & SNR. It is found that the BER performance of the system decreases on increase in modulation order (number of constellation points). Performance of DWPT based MIMO-OFDM system with STBC get improves with unequal power conditions and with antenna selection technique. The DWPT based MIMO-OFDM system analysis is more immune to impulse and narrowband noises than conventional FFT based MIMO-OFDM system, also improves spectral efficiency and saves transmission power. DWPT based MIMO-OFDM system is more reliable than FFT based MIMO-OFDM system without putting any restriction on the number of antennas manipulated at the base station as well as at the receiver ends.

The results in terms of BER show that DWPT based MIMO-OFDM system are more efficient rather than the traditional FFT based MIMO-OFDM system. The performance gain is wider between the systems that use 16 QAM points to the system with 64 points for higher SNR values. Higher performance gains are also observed when the SNR increases. The performance results indicate that DWPT is a viable alternative to FFT but at the cost of higher complexity of equalization. Although, FFT offers a low complexity structure than DWPT, however, the use of CP reduces its spectral efficiency and wastes transmit power.

References:

- [1] Richard Vanne, V.K. Jones, Geert Awater, Allert Van Zelst, James Gardner and Greg Steele, "The 802.11n MIMO-OFDM Standard for Wireless LAN and Beyond", *Wireless Personal Communications*, 37, 2006, pp.445–453.
- [2] Wei Zhang, Xiang-Gen Xia and Khaled Ben Letaief, "Space-Time/Frequency Coding For MIMO-OFDM in Next Generation Broad and Wireless Systems", *IEEE Wireless Communications*, June 2007, pp.32-43.
- [3] Jie Gao, O. Can Ozdural, Sasan H. Ardalan, and Huaping Liu, " Performance Modeling of MIMO OFDM Systems via Channel Analysis", *IEEE*

- Transactions on Wireless Communications*, Vol. 5, NO. 9Sept. 2006, pp. 2358-2362.
- [4] R. Suresh Babu, M. Suganthi and K. Ramasamy, "Ber Performance Comparison Of Multiple Antenna Using Space Time Block Coded Ofdm System In Multipath Fading Environment", *ICTACT Journal On Communication Technology*, Vol: 02, Issue: 01, March 2011.
- [5] M. Vani Divyatha, B. Siva Reddy, "Design and BER Performance of MIMO-OFDM for Wireless Broadband Communications", *International Journal of Modern Engineering Research (IJMER)*, Vol.3, Issue.3, May-June. 2013, pp-1382-1385.
- [6] Niharika Sethy, Subhakanta Swain, "BER analysis of MIMO-OFDM system in different fading channel", *IJAIEEM*, Volume 2, Issue 4, April 2013P.
- K. Visscher, "How Self-Organization Evolves," *Nature*, vol. 421Feb.2003, pp. 799–800.
- [7] K. Abdullah and Z. M. Hussain, "Studies on DWT-OFDM and FFT-OFDM Systems", *IEEE International Conference on Communication, Computer and Power*, February 15-18, 2009.
- [8] W. Saad, N. El-Fishawy and *et. al*, "An Efficient Technique for OFDM System Using Discrete Wavelet Transform", *Springer-Verlag Berlin Heidelberg*, 2010, pp. 533–541.
- [9] K. Abdullah and Z. M. Hussain, "Impulsive Noise Effects on DWT- and WPTOFDM versus FFT-OFDM", *International Conference on Communication, Computer and Power (ICCCP'09)*, (2009) February 15-18.
- [10] D. Gupta, T. Harris, V. B. Vats, K. K. Garg, "Performance Analysis of DFTOFDM, DCT-OFDM and DWT-OFDM Systems in AWGN Channel", *The fourth ICWMC 2008*, *IEEE Computer Society Washington, USA*, 2008.
- [11] Jiang Xuehua, Chen Peijiang, "Study and Implementation of MIMO-OFDM System Based on Matlab", *International Conference on Information Technology and Computer Science*, 2009.
- [12] R. Veeranna Sake Pothalaiah Prof. K. Ashok Babu, "Implementation Of MIMO-OFDM Stf Coding Framework For Wireless Communication System", *International Journal of Engineering Science and Technology* Vol. 2 (12), 2010, pp.7423-7436.
- [13] A. Khatoon, M. S. Rahman, "Symbol Error Performance Analysis and Comparison between Alamouti and MRRC Diversity Combining Scheme for Wireless Communication", *Journal of Scientific Research*, J. Sci. Res. 2 (1), 2010, pp-54-66.
- [14] Nelly M. Shafik, "Wavelet Transform Effect on MIMO-OFDM System Performance", *Multidisciplinary Journals in Science and Technology, Journal of Selected Areas in Telecommunications (JSAT)*, September Edition, 2011, pp. 46-50.
- [15] Mahmudul Hasan, "Performance Comparison of Wavelet and FFT Based Multiuser MIMO OFDM over Wireless Rayleigh Fading Channel", *International Journal of Energy, Information and Communications*, Vol. 3, Issue 4, 2012, pp. 1-8.
- [16] Gunjan Manik, Alka Kalra, Sanjeev Kalra, "Performance Analysis of STBC- OFDM System Under Multipath Fading Channel", *International Journal of Soft Computing and Engineering (IJSCE)*, Volume-1, Issue-6, 2012, pp.87-90.
- [17] Jitendra Kumar Daksh, Ravi Mohan, Sumit Sharma, "Performance Analysis with Space-time coding in MIMO-OFDM Systems with Multiple Antennas", *International Journal of Advanced Computer Research* Vol.3 No.2 Iss.10 June-2013.
- [18] Hariprasad Nagarajan and AlameluNachiappan, "Performance Analysis of Discrete Wavelet Transform Based Multiple Output Orthogonal Frequency Division Multiplexing System for Different Wavelets in Different Channel Environment", *American Journal of Applied Sciences* Vol.10, No.12, 2013, pp.1521-1528.
- [19] Vibha Rao and T. Malavika, "Performance analysis of MIMO-OFDM for multiple antennas", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, Vol. 3, Iss.5, 2014, pp.9349-9355.
- [20] B.AnandaKiran, and *et. al*, "Performance of OFDM MIMO Based Radio over Fiber Systems in The Presence of Phase", *International Journal of Engineering Trends and Technology (IJETT)*, Vol.14 No.2, Aug 2014, pp. 97-100.
- [21] Monica Lamba and Charanjit Singh, "BER and Channel Capacity Improvement of MIMO-OFDM and Adaptive MIMOOFDM System by Modulation Technique (QAM)", *International Journal of Computer Science & Engineering Technology (IJCSET)*, Vol. 5 No. 06, Jun 2014, pp. 734-742.
- [22] Wei Zhang, Xiang-Xia and Khaled Ben Letaief, "Space Time/Frequency Coding for MIMO-OFDM in Next Generation Broadband Wireless Systems", *IEEE Wireless Communications*, 2007, pp.32-43.
- [23] Haitham J. Taha and M. F. M. Salleh, "Performance Comparison of Wavelet Packet Transform (WPT) and FFTOFDM System Based

on QAM Modulation Parameters in Fading Channels", *WSEAS, Transactions on Communications*, Issue 8, Vol. 9, August 2010, pp.453-462.

- [24] K. O. O. Anoh, R. A. Abd-Alhameed, Y. A. S. Dama, S. M. R. Jones, T. S. Ghazaany, J. Rodrigues and K. N. Voudouris, "Improved QO-STBC OFDM System Using Null Interference Elimination", *International Journal of Advanced Computer Science and Applications (IJACSA)*, Vol. 4, No. 8, 2013, pp. 248-253.
- [25] Wei Zhang, Xiang-Xia and Khaled Ben Letaief, "Space Time/Frequency Coding for MIMO-OFDM in Next Generation Broadband Wireless Systems", *IEEE Wireless Communications*, June 2007, pp.32-43.
- [26] Rick S. Blum, Ye (Geoffrey) Li, Jack H. Winters, and Qing Yan, "Improved Space-Time Coding for MIMO-OFDM Wireless Communications", *IEEE Transactions on Communications*, Vol. 49, No. 11, Nov. 2001, pp.1873-1878.
- [27] Md. Matiquel Islam, M. Hasnat Kabir and Sk. Enayet Ullah, "Performance Analysis of Wavelet Based MC-CDMA System with Implementation of Various Antenna Diversity Schemes", *International Journal of Research and Reviews in Computer Science (IJRRCS)*, Vol. 2, No. 2, April 2011, pp. 271-274.
- [28] Vibha Rao and T. Malavika, " Performance analysis of MIMO-OFDM for multiple antennas", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, Vol. 3, Issue 5, May 2014, pp.9349-9355.