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PERFORMANCE ANALYSIS OF STBC-MIMO OFDM SYSTEM WITH DWT & FFT

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Abstract— **In today's wireless communication system demand for higher data rates, higher transmission capacity and better quality of service is increasing. These challenges can be overcome by one of the key technology Orthogonal Frequency Division Multiplexing (OFDM). Generally, OFDM system is implemented using Fast Fourier Transform (FFT) but it has some drawbacks which can be reduces using one of emerging technology Discrete Wavelet Transform (DWT). In this paper, comparative performance analysis of OFDM system using FFT and DWT is done with STBC-MIMO system. Modulation technique used is 16-QAM under AWGN and Rayleigh channel. DWT-OFDM is simulated using Haar wavelet. BER vs SNR performance analysis is done using Matlab Simulink.**

Index Terms— **BER (bit error rate); DWT (Discrete wavelet transform); OFDM (orthogonal frequency division multiplexing); SNR (signal to noise ration).**

I. INTRODUCTION

Wireless communication environment a demand for high data rate, reliable high speed is increasing rapidly. Wireless communication systems use many modulation technologies for the transmission, reception and processing of signal. One such modulation technique is orthogonal frequency division multiplexing (OFDM). In OFDM, the data to be transmitted is split up in to some number of parallel data streams (subcarriers). OFDM subcarriers are placed orthogonal to each other to avoid interference between them. OFDM is normally implemented using the Fast Fourier Transform (FFT) to create and detect the different subcarriers. This transform however has the drawback that it uses a rectangular window, which creates high side lobes, this technique also required a cyclic prefix (CP) insertion which is added to each OFDM symbol in order to compensate for the ISI which wastes up to 25% of the bandwidth [1]. To get more improvement of transmission through wireless channel and to keep up with the rapid increase in demand of the wireless technologies without using the CP extension, wavelet transform is the alternative method to the conventional FFT required in OFDM systems. In wavelet-based OFDM, the wavelet transform replaces IFFT/FFT block. This system has better spectrum efficiency over the conventional FFT based OFDM since the subcarriers are necessarily need no guard interval.

Nowadays, the MIMO technology attracts more attention in wireless communication system compared with other system, MIMO system uses multiple antennas at both transmitters and receivers to improve performance of system. MIMO system offers significantly better data throughput without additional bandwidth or increased transmitted power because it transmits multiple bit streams through the multiple antennas in parallel and spreading the total transmitted power over the multiple antennas [1] [2]. In MIMO system diversity coding is one of the useful technologies to combating fading. In most scattering surrounding, antenna diversity is a very practical and effective hence, it is a widely applied technique for reducing the effect of multipath fading. In diversity coding signal is coded using space time block coding (STBC) technique. Using STBC multiple copies of data stream are transmit across multiple antenna to improve the reliability of data transfer. It is fact that, transmitted signal traverse through various difficult environment with scattering, reflection, refraction and so on means that some of the received copies of the data will be better than other. The combination between MIMO and OFDM modulation gives advantage of improves in the BER performance of wireless communications systems hence increase in data rate of system [3]- [8].

The other part of paper is divided as follows. Section II explain basics and implementation block diagram of FFT based OFDM system. Section III describes the wavelet based OFDM system. Section IV describes the STBC-MIMO OFDM system. In section V simulation parameters and results are presented. Section VI is conclusion.

II. FFT BASED OFDM SYSTEM

In FFT based OFDM system, generated input signal is mapped using digital modulation technique like QAM at transmitter side in which serial binary data are converted into complex symbols representing constellation points. One or more bits from the channel coding step are assigned to each subcarrier. The FFT is applied at the receiver side to decode the signal. Then, each N symbols will be transmitted over N orthogonal subcarriers through the IFFT. The output of the IFFT block in discrete time domain with N used subcarriers is as follows in (1),

$$x(n) = \frac{1}{N}\sum_{k=0}^{N-1} x(k) e^{\frac{j2\pi n}{N}} \quad (1)$$

After the OFDM symbol being constructed, a guard interval is added to mitigate the effect of ISI. And cyclic prefix is added at each OFDM symbol. This output signal is transmitted over AWGN channel. Fig.1. shows the basic block diagram of OFDM system [4] using IFFT and FFT as shown below,

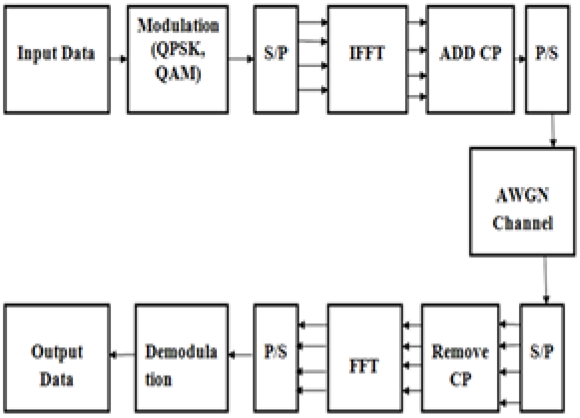

Fig. 1. Block diagram of FFT based OFDM system.

At the receiver side, the data are reversely reconstructed using the FFT block in order to get the initial transmitted bit stream. After removing cyclic prefix data is demodulated and transmitted signal is reconstructed. Equation (2) shows the output of the FFT block is,

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{\frac{-j2\pi k}{N}} \quad (2)$$

However, adding a CP reduces the spectral efficiency. Moreover, the high level side lobes create by the rectangular window of the FFT may cause interference in the frequency domain. These problems have to be overcome [2].

III. DWT BASED OFDM SYSTEM

A wavelet is a wave-like oscillation with a amplitude that begins at zero, increases, and then decreases back to zero. Wavelets can be combined, using a "reverse, shift, multiply and integrate" technique called convolution, with portions of a known signal to extract information from the unknown signal. It has the ability to identify frequency component, simultaneously with their locations in time, and it is capable of providing the time and frequency information simultaneously.

Wavelet transform use orthogonal wavelet as basic functions to process data instead of sinusoids orthogonal wave. A family of wavelets can be constructed from a function $\psi(x)$, sometimes known as a mother wavelet which is confined in a finite interval. Daughter wavelets $\Psi a, b\ (x)$ are then formed by translation *(b)* and contraction *(a)*. An individual wavelet can be defined as shown in (3),

$$\psi^{a,b}(x) = |a|^{-1/2}\, \psi\left(\frac{x-b}{a}\right) \quad (3)$$

Wavelet transform of the signal *X (t)* $\Psi a, b$ can be define as shown in (4),

$$w_{\varphi}(f)(b,a) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} f(t)\psi\left(\frac{t-b}{a}\right) dt \quad (4)$$

Fig.2. shows DWT implementation stages [1]. These are used in signal transmission system. The first stage is called analysis stage which corresponds to the decomposition process. In this process signal samples are reduced by two (down sampling). The second stage is called synthesis stage. This corresponds to the interpolation process. In this process the signal samples are increased by two (up sampling) [1] [4]. The low pass and high pass filter are used at every stage. Signal is first decomposed by a low-pass (LP) and a high-pass (HP) filter. Half of the frequency components have been filtered out at filter outputs and hence can be down-sampled. We get approximation and detail coefficients from filters [8].

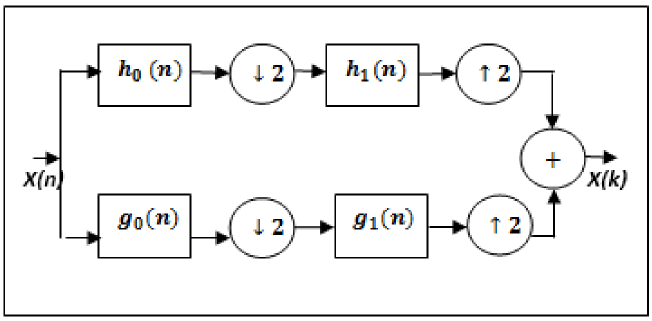

Fig. 2. One level decomposition and reconstruction of signal.

For perfect reconstruction the impulse responses of the synthesis and analysis filters must be related in following ways,

$$h_1(n) = (-1)^n g_0 \quad (5)$$

$$g_1(n) = (-1)^{n+1} h_0(n) \quad (6)$$

From (5) and (6), h_0 are high pass filter and g_0 are low pass filter. The low pass filter gives approximate information about the signal while the high pass filter produces detailed information. We mainly interest on the approximate coefficients where we can find most of the information. The low or approximate coefficients are down sampled and re-filtered. Fig.3.shows the block diagram of DWT based OFDM system [4] as shown below,

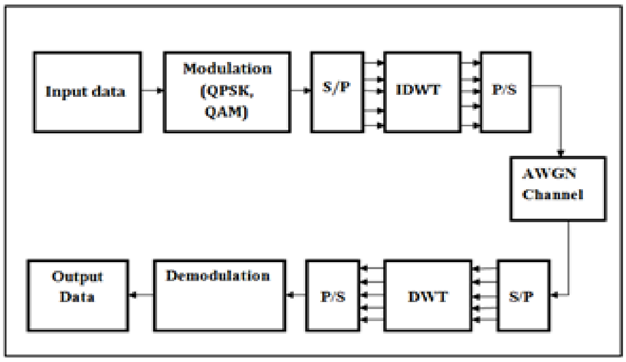

Fig.3. Block diagram of DWT based OFDM system

IDWT represents the key point of the multicarrier transmitter in which the orthogonal wavelet modulation is performed, while the DWT is represents the demodulator at the receiver .The main and the important difference between the conventional OFDM and DWT multicarrier system is the elimination of the cyclic prefix blocks in the transmitter or in the receiver parts. By not requiring the cyclic prefix, the available bandwidth would be more efficiently used, and hence high data rate can be achieved [2].

IV. STBC-MIMO OFDM SYSTEM

Space time block coding is a technique used in MIMO system to transmit multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer [4]. MIMO technology increases data throughput without additional bandwidth or transmit power. Therefore to get benefits of both the technologies, combination of MIMO with OFDM technique is a new trend in wireless communication system. OFDM can be extended to MIMO systems by performing the IFFT/FFT and IDWT/DWT operations at each of the transmitter and receiver antennas. Fig.4. shows 2x2 STBC-MIMO OFDM transceiver structures.

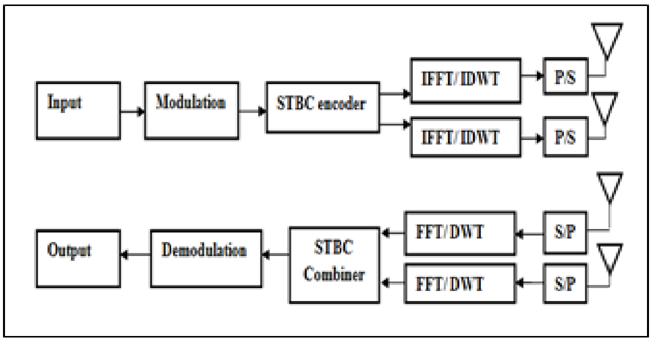

Fig.4. 2x2 STBC-MIMO OFDM System

V. SIMULATION RESULT AND DISCUSSION

In this section the performance of FFT based OFDM and DWT based OFDM system is studied over AWGN channel. After that OFDM system is simulated with STBC-MIMO system under Rayleigh channel using FFT and DWT and comparative performance analysis of both systems are done in terms of BER. The graph is plotted with respect to the SNR in db. Both FFT based and DWT based systems were implemented using MATLAB software. Analyses of both systems are done using same parameter. First FFT-OFDM is designed then FFT is replaced by DWT. After analysis of SISO-OFDM system multiple transmitter antenna and multiple receiver antenna is add into DWT-OFDM system.

Table I shows the parameter values used for the simulation.

TABLE I. SIMULATION PARAMETERS

PARAMETERS	**FFT-OFDM**	**DWT-OFDM**
No. of data carrier	72	72
No. of pilot carrier	12	12
No. guard carrier	44	44
Modulation type	16QAM	16QAM
MIMO order	Tx=1, 2 Rx=2	Tx=1, 2 Rx= 2
Channel type	AWGN, Rayleigh	AWGN, Rayleigh
Wavelet used	-	Haar

A. Simulation Result for SISO FFT and DWT OFDM system

In this section, BER performance analysis for FFT based OFDM system is shown. As Table1 define the simulation parameter of the system, OFDM model using FFT is implemented. Random integer generator generates the transmitted bits. These bits are mapped using different modulation techniques like 16QAM. After that transmitted bits are Serial to parallel converted and packing of parallel data carrier with pilot carrier and guard carrier is done. Parallel data is then go through IFFT transform, OFDM modulation achieves using IFFT of size 128 where, 72 are data carriers, 12 are pilot carriers and 44 guard carriers. 1/8 cyclic prefix added to transmitted data and finally after converting parallel to serial of data it passed through AWGN channel. At Receiver side reverse operation is performed to get the transmitted data back. Serial data first converted to parallel, cyclic prefix are removed; FFT transform was done, pilot, guard carrier removal and demodulation of received data are done to get final output data.

Fig.5. shows a comparison between the performance of SISO FFT and DWT OFDM system under AWGN channel. The BER performance has been obtained for 16-QAM constellation mapping points. From figure we can see that, at

10^{-3} BER, SNR value of FFT-OFDM system is 14.8dB and DWT-OFDM system is 13.5dB. So, it is clear that DWT-OFDM system has better performance than FFT-OFDM system.

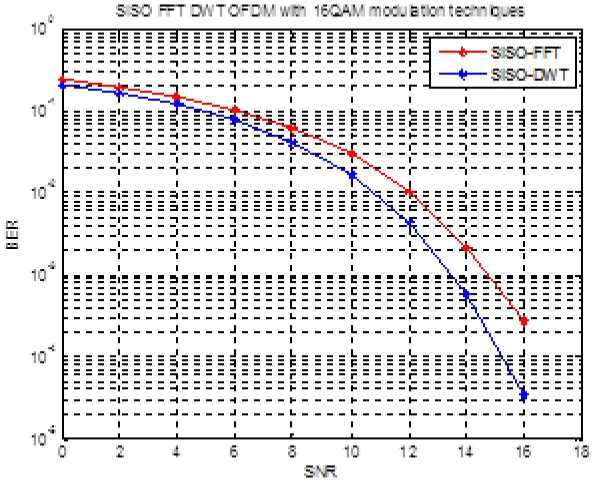

Fig. 5. Comparison of OFDM system with FFT & DWT under AWGN channel

C. Simulation Results for STBC-MIMO System

Fig.6. shows BER performance of STBC-MIMO system under Rayleigh channel using two transmitter antenna (Tx=2) and Two receiver antenna (Rx=1, 2). From figure, it is clear that there is improvement in BER performance when the number of receive antenna increases. Because when we receive the same signal more than once, and combine them at the receiver side, this causes to reduce the BER of the received signal.

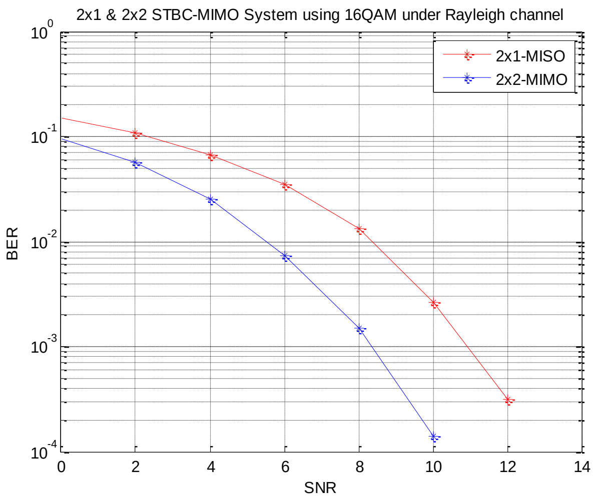

Fig. 6. STBC-MIMO system under Rayleigh channel

D. Simulation Results for STBC MIMO-OFDM System

Fig.9. is the comparative analysis of 2x2 FFT & 2x2 DWT MIMO-OFDM systems at 16QAM modulation technique. From Fig. we can see that, at 10^{-3} BER, SNR value of FFT OFDM system is 8.1 dB and for DWT OFDM system is 6.1dB. Hence, we can see that there is about 2dB performance gain using MIMO DWT-OFDM system.

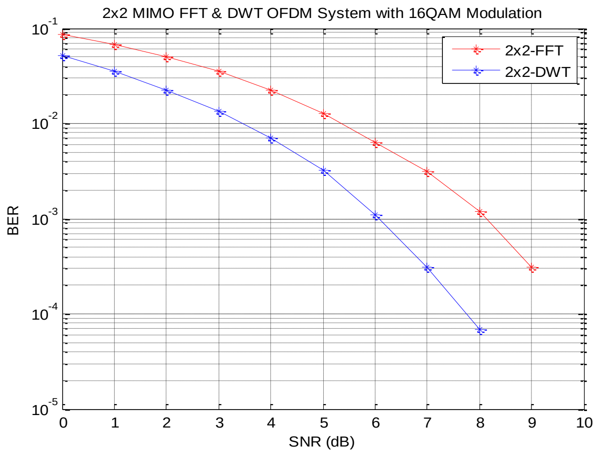

Fig. 7. Comparative analysis of 2x2 MIMO FFT& DWT OFDM Systems

E. Scatter plot diagrams of SISO and MIMO OFDM Systems

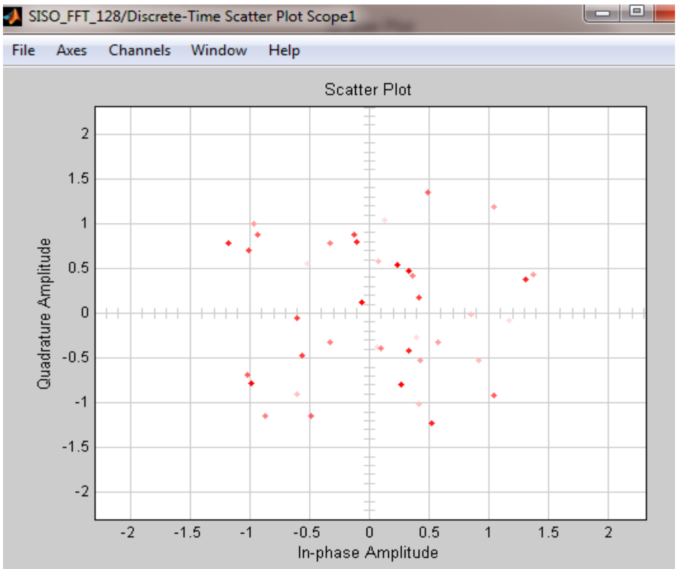

Fig. 8 Scatter plot of FFT-OFDM for 16QAM at SNR=8dB

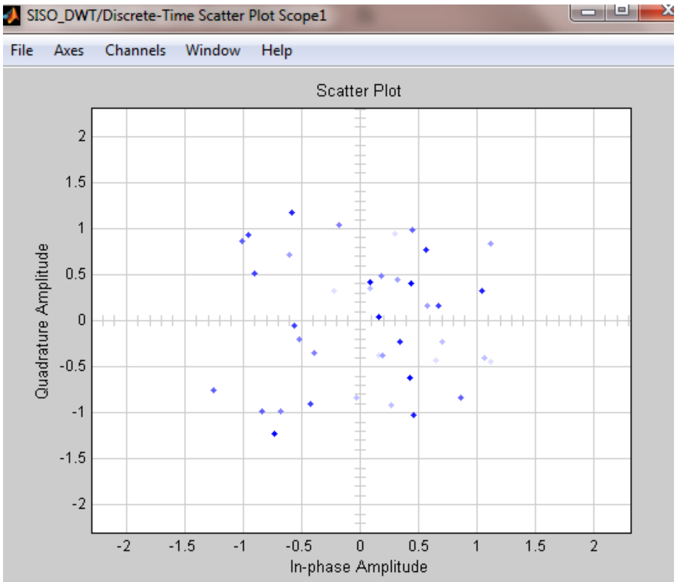

Fig. 9 Scatter plot of DWT-OFDM for 16QAM at SNR=8dB

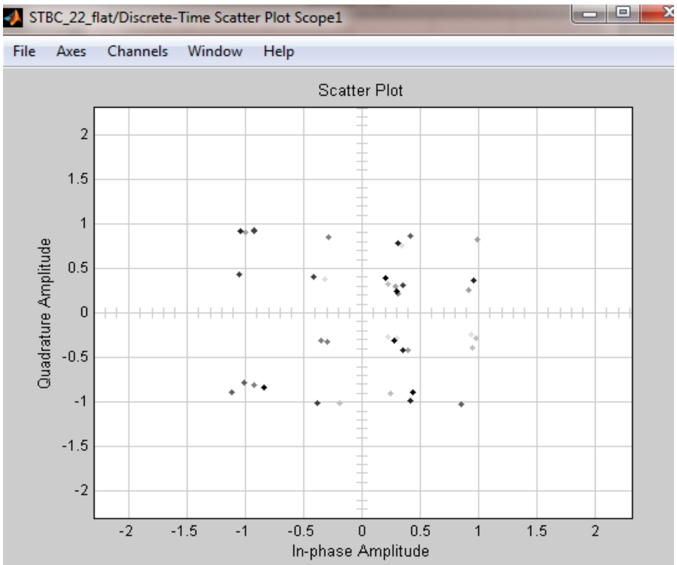

Fig. 10 Scatter plot of 2x2 STBC-MIMO for 16QAM at SNR=8dB

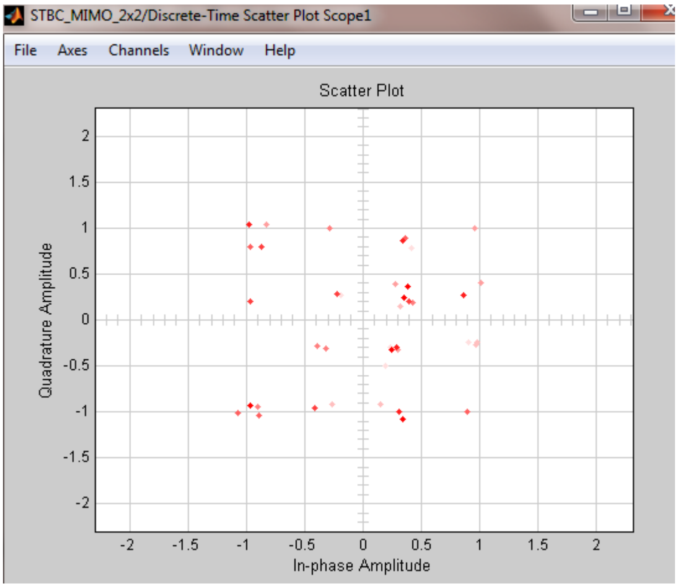

Fig. 11. Scatter plot of 2x2 STBC-MIMO, FFT-OFDM for 16QAM at SNR=8dB

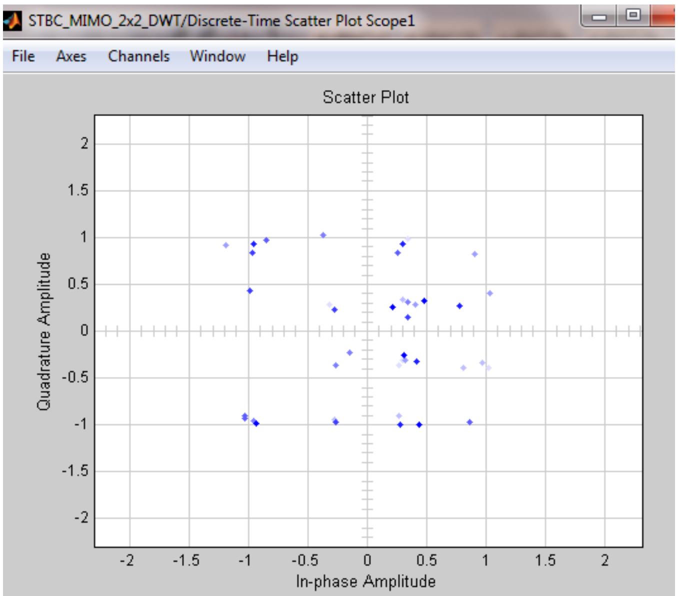

Fig.12. Scatter plot of STBC-MIMO DWT-OFDM for 16QAM at SNR=8dB

Fig. 8 and Fig. 9 is the scatter plot diagram of SISO-FFT and SISO-DWT OFDM systems. Fig. 10 is the scatter plot of 2x2 STBC-MIMO system. From Fig. 11 and Fig. 12, we can see that, scatter plot of 2x2 MIMO-OFDM system is less noisy than SISO OFDM systems.

E. Simulation Results for Comparative analysis of SISO & MIMO-OFDM System

Fig.8. is the comparative analysis of SISO FFT & DWT OFDM system with MIMO 2x2 FFT & DWT OFDM systems.

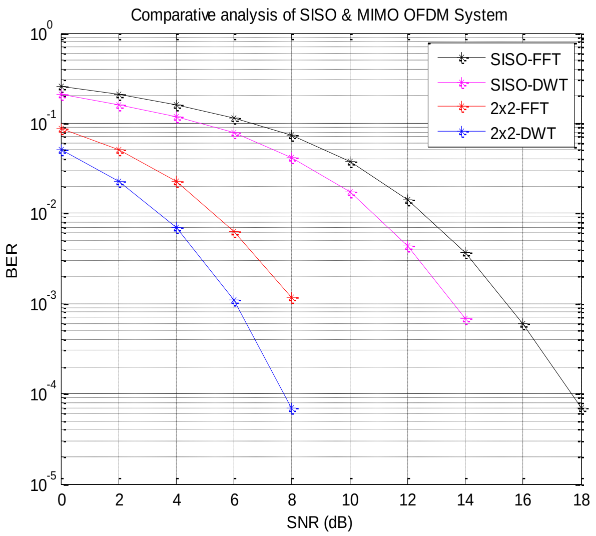

Fig. 13. Comparative analysis of SISO & MIMO OFDM system

According to Fig. 10^{-3} BER achieved by SISO-FFT system at SNR value of 15.5 dB, by SISO-DWT system is 13.8db, MIMO-FFT system is 8dB and MIMO-DWT system is 6dB. So, it is clear that combination of OFDM system with multiple antenna techniques improves performance of OFDM system in terms of bit error rate vs SNR, and DWT-OFDM system is better than FFT-OFDM system.

VI. CONCLUSION

In this paper, performance analysis of FFT-OFDM and DWT-OFDM is done using 16QAM under AWGN channel. Further STBC-MIMO system is implemented for two transmitter antennas and two receiver antennas. Simulation results show that BER vs SNR performance of DWT-OFDM system is better than FFT-OFDM system. In STBC-MIMO system as we increase number of receive antennas BER performance of system is improved. OFDM system is combined with STBC-MIMO system and comparative analysis of MIMO-OFDM system with FFT and DWT has been done. MIMO-OFDM systems are simulated by antenna order 2x2. From simulation results it is found that performance of OFDM system is improved by combining with MIMO system, and BER vs SNR performance of DWT-OFDM system is better than FFT-OFDM system. System complexity of DWT-OFDM system is reduces and the transmission rate increases. So, the combination of MIMO system and DWT-OFDM system will improve the BER performance of wireless communication system.

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