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Reliability Achievement of MIMO-OFDM Communication Systems

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Abstract – Wireless communication must have high spectral efficacy and the ability to resist fading channel in an environment of channel multipath, and it is difficult to achieve these requirements with traditional modulation techniques, but the Multiple system Input Multiple Output-Orthogonal Frequency Division Multiplexing (MIMO-OFDM) It can fulfill these requirements. Research offers a way to improve the performance of OFDM- MIMO system by decreasing the Bit Error Rate (BER) using both (DWT) Discrete Wavelet Transform and Convolutional Coding (CC). The OFDM system is modeled with a single antenna at the transmitting end and a single antenna at the receiving end (DWT) . Multiple Input Single Output (MISO) By adding a second antenna at the transmitting end, and then improving it with Output Multiple Input Single technology SIMO (by adding a second antenna at the receiving end, and with MIMO technology by adding a second antenna at the receiving end The transmitter and a second antenna at the receiving end, thus optimizing the OFDM-MIMO system using convolution coding, Then using DWT instead of FFT (Fast Fourier Transform). The research is based on the study of BER according to bit energy to noise energy density N0/Eb. The system was modeled and tested using the MATLAB program. The use of (DWT) and (CC) in OFDM-MIMO reduces N0/Eb (4.7) dB times in the item of the Rician fading channel and 3.2 dB times in the item of the Rayleigh fading channel when BER =10^{-3}.

Keywords – Multiple Input Multiple Output, Orthogonal Frequency Division Multiplexing, Discrete Wavelet Transform, Convolution Coding

I. INTRODUCTION

Historic wireless mobile communications developed from the first generation when the analogue system was only voice service. T he second generation)2G) for communication systems, which has acceptable performance using Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA) technologies, but the bandwidth is limited . Third generation(3G) promises to increase the flow of data, As a result of the successive improvement of applications used in multimedia, this has led to an increasing need for massive data speed. Fourth generation(4G) appeared, which achieved a high data rate and high reliability in transmitting this data using the system of MIMO-OFDM. The sent signal through the wireless communication channel suffers from the phenomenon of multipath. and therefore, each copy suffers from a periodic retardation, delay and comfort differently from another copy, and when collecting these different copies in the future. the signal quality may deteriorate, This is considered a great challenge to reduce this phenomenon. Another challenge is to provide high data transmission speeds within the limited available frequency range,

Using system of MIMO to provide a high-speed and reliable system of wireless communication without any increase in the bandwidth and transmission capacity. Utilizing MIMO more than one antenna at the and receiver and ransmitter, the multipath propagation environment in systems of the communication that require huge transimition for data that makes the channel frequency-selective, meaning that the frequency components of the signal will be affected differently from the other.

Which leads to the symbols overlapping with each other, which makes the receiver design greatly complicated, but the OFDM system splits the channel into N a sub-frequency-flat channel.

In 2009, Jiang Xuaeinia and Chen Peijiang, their article presented a study and simulation of the MIMO-OFDM system with Rayleigh dimming channel, using BPSK type modulation, and using rate bypass coding 1/2 coding. The system has a reliability , this reliability proportional with the number of antennas used in transmission, this is what the results showed. The results also showed that the increase in the number of frequency carriers decreases the reliability of the system because the interference between sub-carriers increases with the increase in the number of frequency carriers [1].

In 2012 Prof. Ketki Joshi, Miss Krupali N.Umaria, the results showed that using DWT in OFDM system achieves a transmission power saving of 12 db than the conventional OFDM system that uses FFT when it is BER = 10^{-3}. This study did not address MIMO system[2].

In 2013, Priyanka Dahiya and Kanchan Sharma they studied the system of MIMO-OFDM and worked to improve its performance by using a turbo coded with a coding rate of 2/3, knowing that the modification The user 16QAM and the communication channel AWGN, and the results showed Employing turbo coding in the system provides about of 4 dB times that provided by the non-coding MIMO-OFDM system when BER = 10^{-3}. This study did not address the Rayleigh and Rician fading channels [3].

II . MIMO-OFDM SYSTEM

The demand for achieving high data transmission rate and ensuring good quality of service has increased with the rapid development of multimedia applications and data transmitted over the wireless communication channel, and these requirements (high transmission data rate and low bit error rate) are difficult to achieve with traditional modulation techniques. But the MIMO-OFDM system can fulfill these requirements. Figure(1) shows the scheme of the system - (MIMO(2x2)- OFDM [4].

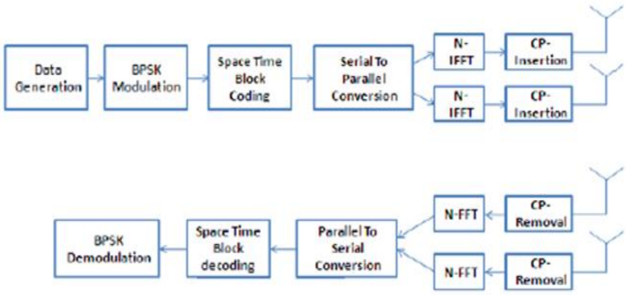

Figure .1 MIMO-OFDM System [4]

A. Convolutional Coding and State Diagram

The simplest way to explain this coding is to use a specific example, assuming we have a convolutional coder as shown in Figure(2).The information bits are moved by a register of length m=2 (registered with two binary memory elements). The result of the output sequence comes from the assembly of the functions (1) out and (2) out, and each output bit is generated by adding the current input bit and some daughters within the register, for example, the information sequence inp=(1, 1, 0, 1, 0, 0,..)stands for $out^{(1)}$ =1, 0, 0, 0, 1, 1,..) and $out^{(2)}$ =1, 1, 1, 0, 0. 0, 1, ..) and thus becomes the code sequence The generator after compiling $out^{(1)}$ and $out^{(2)}$ is out=(1,1,0, 1, 0, 1, 0, 0, 1, 0, 1, 1) [29].

$$outi1=inpi + inpi-1+ inpi-2 \quad (1)$$

$$outi2=inpi+inpi-2 \quad (2)$$

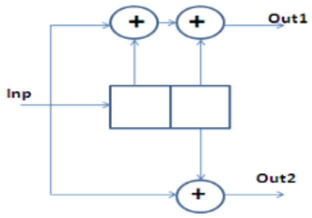

Figure (2) convolution encoder[5]

To determine the convolution notation, there are three parameters:

1. Code Rate: The ratio in our study, is 1/2, that means that every bit on input corresponds to two bits in output.

2- (Length of Constraint) K: Number of phases in which the input bit remains in the convoluation. For example K=3.

3- Generator polynomial: Defines the method of connecting the input sequence to the output modulation register register [6] [7].

$$G1(D)=1 + D+ D2 \quad (3)$$

$$G2 (D) = 1 + D2 \quad (4)$$

B. The state diagram of the convolution encoder

Figure 3 shows the state diagram of the convoluation encoder, evry node consist the state of the encoder. The binary obtaint of the memory components, and evry branch indicates the transition state to rest state according to the last input bit, and the two output bits corresponding to the present input bit are shown on the branch from specific case.

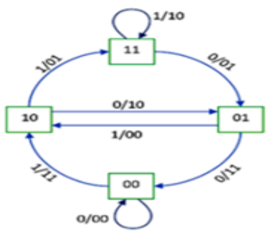

Figure . 3 State diagram of the convolution encoder

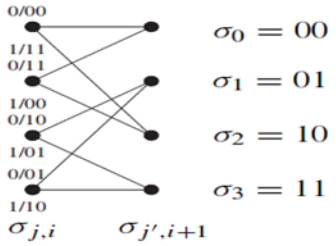

Figure . 4 Trellis diagram of convolution encoder

C. Viterbi Algorithm

It is one of the most common algorithms in convolution decoding, and this algorithm is applied in many other applications such as speech recognition, equalization, and others. [29] Suppose the convolution encoder output at the sending end is out=(11 01 01 00 01 01 11). These bits have arrived at the receiver due to the effect of the communication channel on the figure r = (01 01 10 01 10), How can decoding be accomplished so that possible transmission errors are corrected and the correct sequence of the transmitted bits are selected by the left-to-right trellis and path-finding.The optimum closest to the receiver bit sequence r (the term closest refers to the least Hamming distance). In the first transition level of the decoding process, as shown in Figure(5) [8], we have only two possible code parts 00,11Both parts differ from the first acceptor bits 10 with a single site. We store the corresponding distance, which is called node metric A σj,i where we specify the state j at the moment i, and we set the first node with A σj,i=0. The node metric for the other nodes is calculated from the sum of the node metric of the previous node with the Hamming distance between the two receiving bits and the two that represent output, so for the first transition:

A ($\sigma_{0,1}$)= A($\sigma_{0,0}$) + 1 =1

A ($\sigma_{2,1}$)= A($\sigma_{0,0}$) + 1 =1

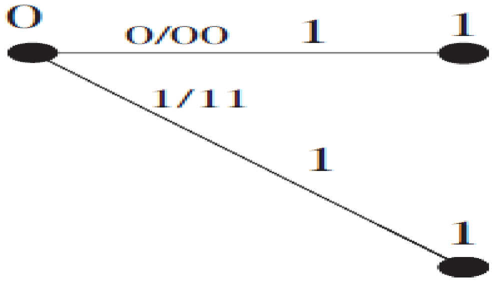

Figure. 5 first path

The figure (6) shows the second transition, the receiving bit is 01 and thus - node metric[9]

A (σ0,2)= A(σ0,1) + 1 =2

A (σ1,2)= A(σ2,1) + 2 =3

A (σ2,2)= A(σ0,1) + 1 =2

A (σ3,2)= A(σ2,1) + 0 =1

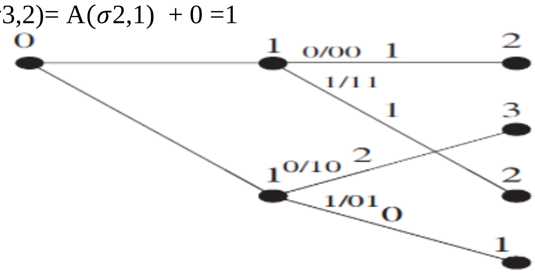

Figure . 6 Second path forward track

The case for the third transition differs in Figure(7) where each state is accessible from the two previous states. Since we want to choose the path closest to the structure of received bits we income the smaller of the metric values (spaces) as follows:

A(σ0,3) = min{ A(σ1,2) + 1, A(σ0,2) + 1} = min{3,4} =3

A(σ1,3) = min{A(σ2,2) + 2, A(σ2,2) + 0} = min{4,1} =1

A(σ2,3) = min{A(σ0,2) + 1, A(σ1,2) + 1} = min{3,4} =3

A(σ3,3) = min{A(σ2,2) + 0, A(σ3,2) + 1}= min{2,3} = 2

Visibly, the path with a larger metric value has more space for the receiving bits therefore it overrides this path since it can't be part of the dictated code sequence. In other words, the decoder ignores all transitions that do not correspond to a minimum metric value, and claims the only remaining path for each survivor. This path must be kept. Figure (7) shows all the available survivor parameter[10].

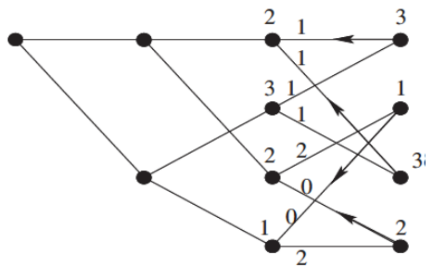

Figure . 7 Third path forward track

We continue with this procedure until we reach the final node of trellis= we repeat it with a number equal to the number of all received bits. To pass teles from right to left through the stored survivors (back path) as presented in Figure (8), thus obtaining the major transmitter code and thus the transmitted bits before the encoding process [11].

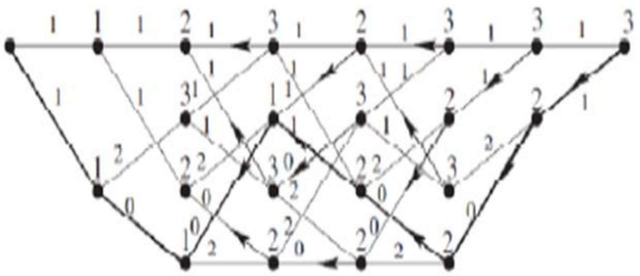

Figure. 8 Back path

The algorithm's working principle is as follows:
Step 1: The original node is given a value of $A(\sigma 0,0) = 0$, and a value of 1 for time i.
Step 2: Process each node $A(\sigma i,j)$ actively i as follows:
Step 3: The next level (i.e. we increase 1 by one) as long as : is equal or less than to the received block codes numbers, then we passage to step 4.
Step 4: To find the optimal path from the final node to the primitive node, (backward pass)

D. MIMO-OFDM Using Convolution Coding:

The convolution encoding has been added to the MIMO-OFDM system, provided that the encoding process is applied before the modification is made and the decoding process is applied after the mod is decoded, which leads to a decrease in the BER of the system. Figure(9) shows the box diagram system of the MIMO-OFDM optimized using convolution coding[19].

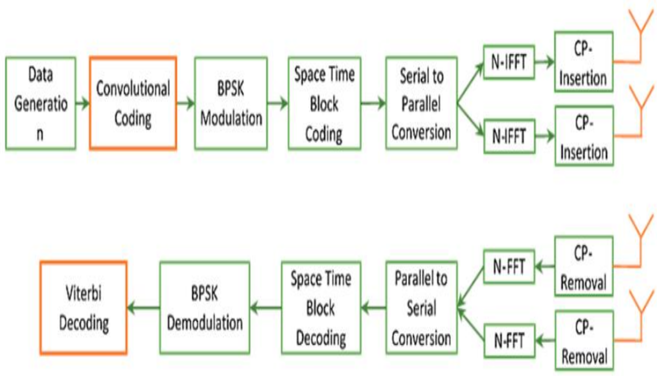

Figure . 9 MIOMO-OFDM with convolution cooding[12]

E. *Discete Wavelet Travsform*

In many signal processing applications, discrete wavelet transformation is used, such as image and video compression object detection, and this represents the effective form of signals especially those with local changes, a discontinuous shift in time and size.) (Wavelet transformation) is a low-pass filter (LPF) and the other is a high-pass filter (HPF) as shown in Figure (10) each filter is a bottom sampling device to make the conversion efficient, and Figure (11) shows the installation process There is a combination consisting An inverse low-pass filter (ILPF) and an inverse high-pass filter (IHPF) precede each higher sample [13].

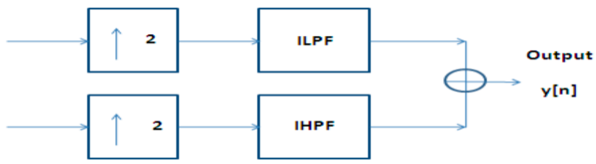

Figure . 10 Analysis filters

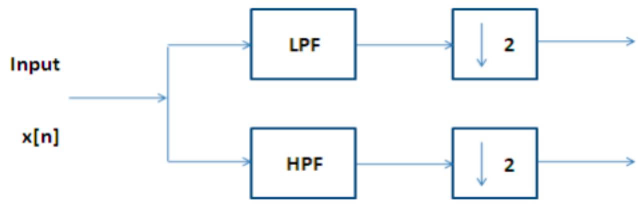

Figure . 11 Composition filters

The low-pass filter produces the medium signal, and the high-pass filter produces the detailed signal. For example, the low-pass filter has coefficients [1/2, 1/2] , which results in an output (x[n] + x[n + 1])/2 which is a two sample rate, and has a high-pass filter that matches Parameters {{-}, which results in an output of(10/2) and that's the difference between two samples, the average signal is very similar to the original signal but we need details to reconstruct the signal that is identical to the original signal.

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F. OFDM (DWT) System

In OFDM (FFT) system, the signals overlap only in the frequency domain, while the signals of OFDM (DWT) overlap in the frequency and time domains, OFDM (DWT) has the ability to reduce ISI and ICI and this leads to no need for periodic prefix in OFDM DWT this system It also reduces PAPR and we can say that it solves the traditional OFDM problem using FFT, but it should achieve full reconstruction properties and modulus rules [14]. The DWT creates a data ray of integer length raised to the power n and transforms it into a numerically different ray of the same length. In this article, we will deal with one of the wavelet transformation groups called Haar, because it is simplified. Haar waves in the time and frequency bands are given by the following relationships, correspondingly:

$$\varphi = \begin{cases} 1 & 0 \leq t \leq \frac{1}{2} \\ -1, & \frac{1}{2} \leq t \leq 1 \end{cases} \qquad (5)$$

$$\emptyset = j\frac{4}{w} sin\frac{4}{w}\ e^{j\frac{w}{2}} \qquad (6)$$

The OFDM (DWT) system is shown in the figure (12) where the serial data conversion process is done first, then the BPSK modification process. We get the wave in the time domain using the inverse discontinuous waveform transformation (IDWT), and it needs the approximate factors and the detailed coefficients and the zeros represent the detailed section. Then folding occurs among the outgoing signal and the communication channel[15][16].

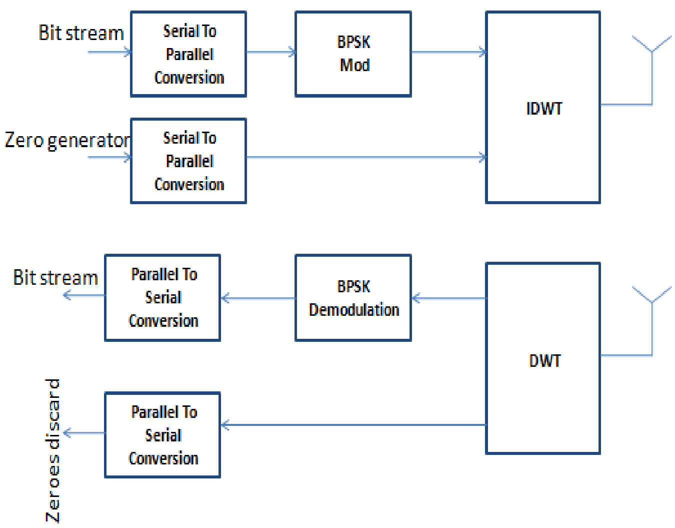

Figure . 12 SISO-OFDM (DWT) System Diagram

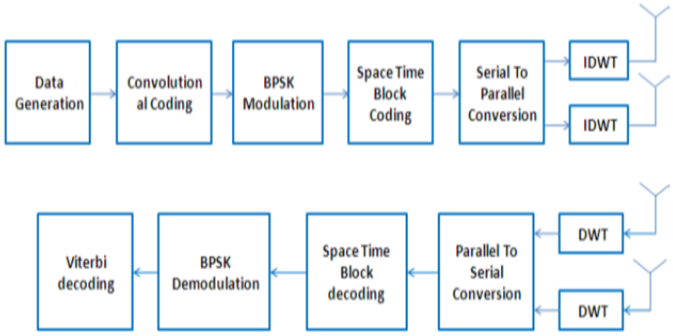

Figure. 13 MIMO-OFDM (DWT) System Diagram[16]

The figure (13) indications the box graph of the enhanced MIMO_OFDM system using Inverse Discrete Waveform Transform (IDWT) instead of (IFTT) at the transmitting end and Discrete Waveform Transform (DWT) instead of (FFT) at the receiving end, and from the above figure it is clear that there is no cyclic prefix[20].

G. MIMO-OFDM (DWT) (CC)System

In this paper and through our study of the convolutional coding and the wavelet transform, they can be added to the improved MIMO-OFDM system by using both the wavelet transform and the convolutional coding together. Figure (14) shows the schematic of the improved MIMO-OFDM system[18][19].

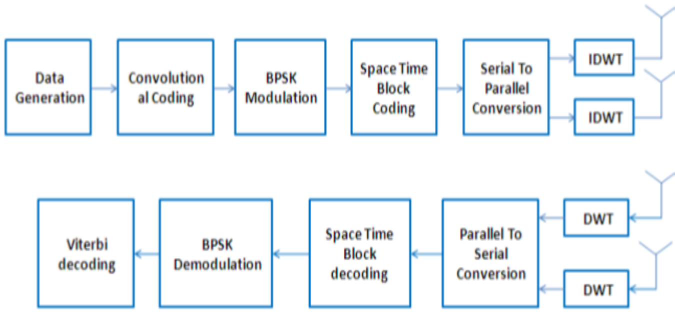

Figure .14 MIMO-OFDM (DWT) System with convolution Coding

III. RESULTS AND DISCUSSION

The system shown in Figure(9) has been modeled by adding the (CC) to the MIMO-OFDM system. Figure(16) shows that using the (CC) makes the BER reach zero at the value of Eb / Eo = 13 dB. Through modeling the system shown in Figure(13), the effect of using DWT instead of FFT on BER was studied, and the results showed that the BER value reaches zero when the value of Eb / Eo = 7 dB.Through simulation of the system shown in Figure(14) and studying the effect of each of the (CC) and the use of DWT, the results shown in

Figure(17) showed that the BER value reaches almost zero when the value of Eb / Eo = 5dB.

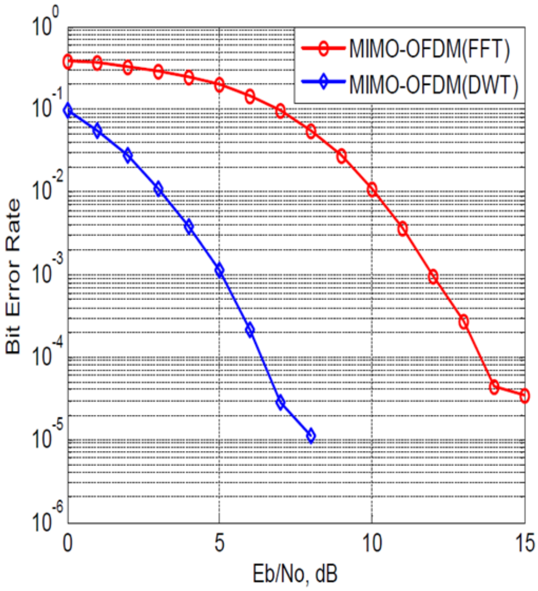

Figure .15 MIMO-OFDM-CC vs. MIMO-OFDM with Rician fading channel

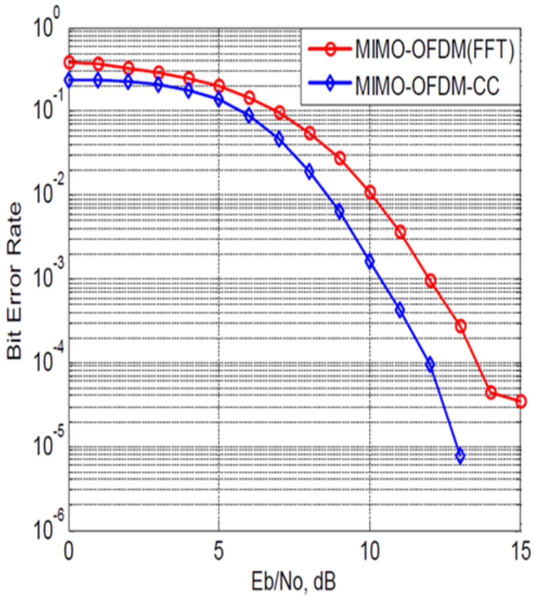

Figure. 16 MIMO-OFDM-DWT vs. MIMO- OFDM with Rayleigh fading Channel

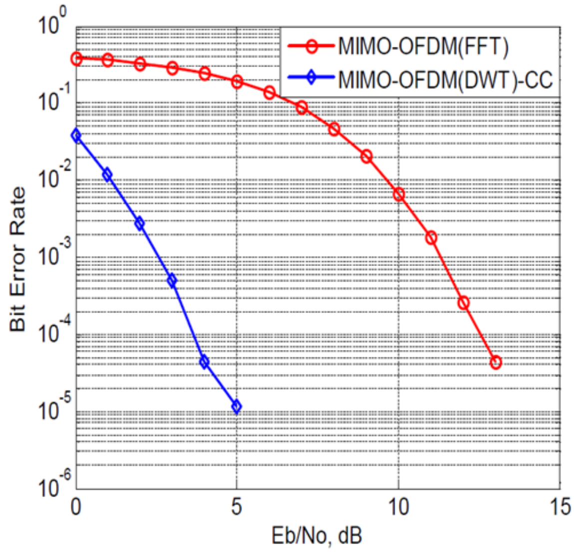

Figure. 17 Comparing MIMO_OFDM(DWT)_CC with MIMO-OFDM[FFT] under Rician fading channel

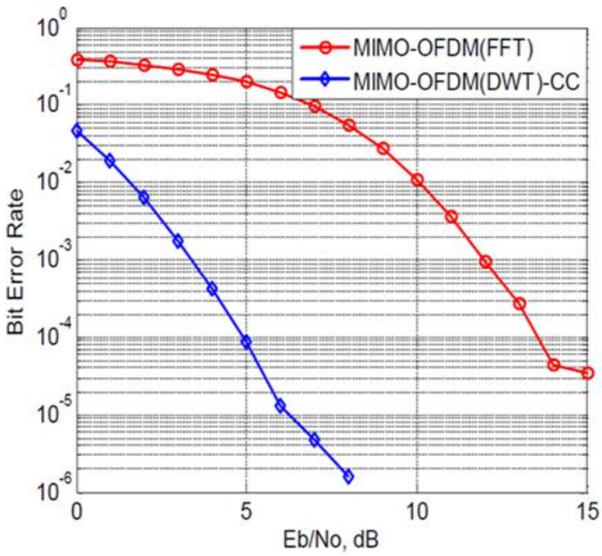

Figure. 18 Comparing MIMO_OFDM(DWT)_CC with MIMO-OFDM(FFT) under Rayleigh fading Channel

When comparing with reference studies [1] [2] [3] we can observe the following: Using both side coding and choppy wavelet transformation with MIMO-OFDM system achieves beast s performance of system than utilizing technology for antenna selection which achieved 1 dB energy of transmission savings Just. 25 times when BER = 10^{-3}, and from the use of asymmetric transmission power technology in the transmitting antennas achieved a power saving of only 1.33 dB when the BER = 10^{-10}, and from the turbo coding achieved an energy saving of 4 dB one time when BER =10^{-3} is in AWGN.

IV. CONCLUSION

Throught studying the system of MIMO-OFDM and both discrete wavelet transformation (DWT)and convolution coding (CC) We reached the following

- |A periodic prefix greater than the channel propagation delay should be used in order to obtain high reliability in the OFDM system.
- The reliability of OFDM system increases by increasing the number of transmitting antennas (MISO(2x1) or increasing the number of receiving antennas SIMMO(1x2), and this reliability increases further by increasing the number of receiving and transmitting antennas. MIMO(2x2).
- The SIMO(1x2)-OFDM system achieves higher reliability than the MISO(2X1)-OFDM system.
- Using convolution coding with the MIMO-OFDM system improves the BER of this system.
- The utilizing of each convolution coding and DWT with the system of MIMO-OFDM achieves the highest reliability of the system, as the BER reached zero at approximately Eb/No=9 dB for the Rayleigh fading channel and at the value Eb/NO=6 dB for the Rician fading channel and thus We get the best performance of the MIMO-OFDM system. Future work The reliability of the MIMO-OFDM system can be increased further by using more than two antennas at the transmitter or receiver, or by using a coding rate of less than 1/2, or by using both turbo coding with DWT, or by using antenna selection technology with Turbo coding and DWT.

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