Improvement Of BER With The Help Of MIMO –OFDM Using STBC Code Structure

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Abstract-MIMO –OFDM system has been currently recognized as one of the most competitive technology for 4G mobile Communication system In this Paper, a general Space Time Block Code (STBC) structure is proposed for multiple –input multiple output-orthogonal Frequency Division Multiplexing (MIMO-OFDM) systems for 2x2 Antenna configuration. The signal detection technology used in this paper for MIMO-OFDM system is MMSE Equalization (Linear Detection Technique.

In this Paper the Analysis of High level of Modulation (i.e. QPSK) on MIMO –OFDM system is presented. Here AWGN, Rayleigh and Rician channels have been used for analysis purpose and their effect on BER for high data rates have been presented. The proposed MIMO-OFDM system with STBC using 2x2 antenna configurations and 512 FFT length has better performance in terms of BER Vs SNR then the other systems.

Keywords:- MIMO,OFDM, STBC, QPSK etc.

I. INTRODUCTION

During the past decades, wireless communication has benefited from substantial advances and it is considered as the key enabling technique of innovative future consumer products. For the sake of satisfying the requirements of various applications, significant technological achievements are required to ensure that wireless devices have appropriate architectures suitable for supporting a wide range of services delivered to the users. In the foreseeable future, the large-scale deployment of wireless devices and the requirements of high bandwidth and high data rate applications are expected to lead to tremendous new challenges in terms of the efficient exploitation of the achievable spectral resources and constitute a substantial research challenge in the context of the emerging WLANs and other indoor multimedia networks. Due to the physical limits imposed by the mobile radio channel which cause performance degradation and make it very difficult to achieve high bit rates at low error rates over the time dispersive wireless channels. Other detrimental characteristics are co-channel interference (CCI), Doppler Effect, intentional jamming in military communications and Intersymbol interference (ISI) induced by multipath fading; however, there is an irreducible error floor that limit on the maximum attainable transmission rate.

Specifically, the employment of multiple antennas at both the transmitter and the receiver, which is widely referred to as the MIMO technique, constitutes a cost-effective approach to high throughput wireless communications and remote sensing. The concept MIMO for both wired and wireless systems was first introduced by Jack Winters [1]-[3] in 1987 for two basic communication systems. The first was for communication between multiple mobiles and a base station with multiple antennas and the second for communication between two mobiles each with multiple antennas.

Where, he introduced a technique of transmitting data from multiple users over the same frequency/time channel using multiple antennas at both the transmitter and receiver ends. Sparked off by Winters' pioneering work [1], Salz [4] investigated joint transmitter/receiver optimization using the minimum mean square error (MMSE) criterion. Since then, Winters and others [5]–[8] have made further significant advances in the field of MIMOs .

In 1996, Rayleigh and Cioffi [9] and Foschini [2] [10] proposed new approaches for improving the efficiency of MIMO systems, which inspired numerous further contributions [11]–[13] for two suitable architectures for its realisation known as Vertical Bell-Labs Layered Space-me(VBLAST), and Diagonal Bell-Labs Layered Space-Time BLAST (D-BLAST) algorithm has been proposed by Foschini, which is capable of achieving a substantial part of the MIMO capacity.

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

OFDM is a multicarrier transmission technique used in applications catering to both Wired and Wireless Communications. However, in the wired case, the usage of the term Discrete Multi-Tone is more appropriate. The OFDM technique divides the frequency spectrum available into many closely spaced carriers, which are individually modulated by low-rate data streams. In this sense, OFDM is similar to FDMA (The bandwidth is divided into many channels, so that, in a multi-user environment, each channel is allocated to a user). However, the difference lies in the fact that the carriers chosen in OFDM are much more closely spaced than in FDMA (1kHz in OFDM as opposed to about 30kHz in FDMA), thereby increasing its spectral usage efficiency. The orthogonality between the carriers is what facilitates the close spacing of carriers.

2.1 Motivation For Using OFDM

The orthogonality principle essentially implies that each carrier has a null at the center frequency of each of the other carriers in the system while also maintaining an integer number of cycles over a symbol period.

The motivation for using OFDM techniques over TDMA techniques is twofold. First, TDMA limits the total number of users that can be sent efficiently over a channel. In addition, since the symbol rate of each channel is high, problems with multipath delay spread invariably occur. In stark contrast, each carrier in an OFDM signal has a very narrow bandwidth (i.e. 1 kHz); thus the resulting symbol rate is low. This results in the signal having a high degree of tolerance to multipath delay spread, as the delay spread must be very long to cause significant inter-symbol interference (e.g. > 500usec).

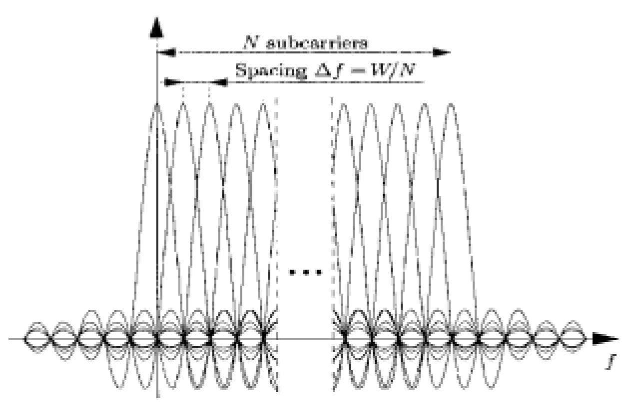

Figure 2.1: Frequency spectrum showing N channels for an OFDM system with N carriersover bandwidth

2.2 OFDM – Basic Principles

Orthogonality

To generate OFDM Signals successfully the relationship between all carriers must be carefully controlled in order to maintain orthogonality. Shown below is the frequency spectrum depicting the various carriers/channels (used interchangeably). Rectangular windowing of transmitted pulses results in a sinc-shaped frequency response for each channel. As can be seen, whenever any particular carrier frequency attains peak amplitude,the remaining carriers have a null point.

2.3 OFDM Generation

The spectrum required is first chosen based on the input data and the modulation scheme used (typically Differential BPSK, QPSK or QAM). Data to be transmitted is assigned to each carrier that is to be produced. Amplitudes and phases of the carriers are calculated based on the chosen scheme of modulation. The required spectrum is then converted back to its time domain signal by employing Inverse Fourier Transform algorithms like the Inverse Fast Fourier Transform.

The next step is that of adding a guard period to the symbol to be transmitted. This ensures robustness against multipath delay spread. This step can be achieved by having a long symbol period, which minimizes intersymbol interference. The level of robustness can be further increased by the addition of a guard period between successive symbols.

2.3.1 Cyclic Prefix

The most popular and effective method of doing this, is the addition of a cyclic prefix. A cyclic prefix is a copy of the last part of the OFDM symbol, which is prepended to the transmitted symbol. This makes the transmitted signal periodic and does not affect the orthogonality of the carriers. Further, this also plays a decisive role in avoiding inter-symbol and inter-carrier interference.

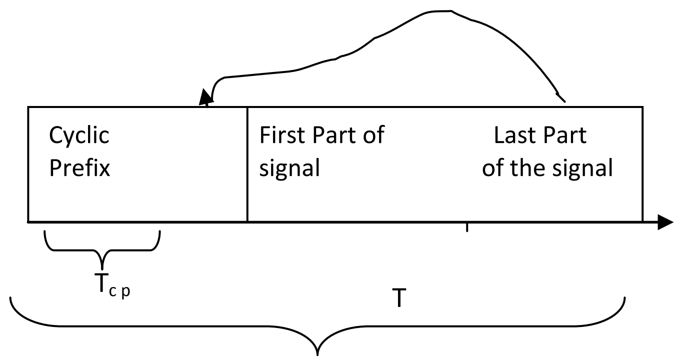

Figure 2.3: The Cyclic Prefix is a copy of the last part of the OFDM signal

A cyclic prefix does however introduce a loss in the signal-to-noise ratio, but this effect is usually negligible as compared to its effect on mitigating interference.

A schematic diagram is shown next and a mathematical model of a base band OFDM system is now developed.

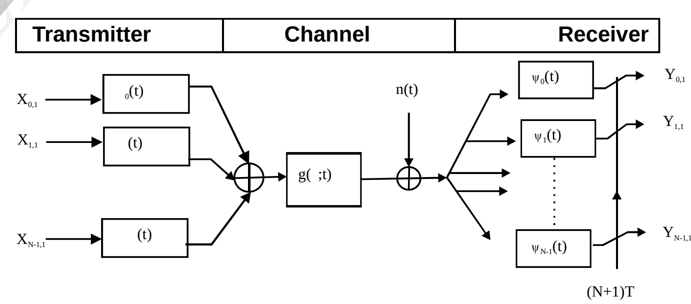

Figure 2.3: Base band OFDM system Model

Since the first OFDM systems did not use digital modulation and demodulation schemes, the continuous-time OFDM model shown above can be considered as the ideal OFDM system. To build the mathematical model, we start with the waveforms used in the transmitter and proceed all the way to the receiver.

2.3.2 Transmitter

We assume an OFDM system with N carriers, a bandwidth of W Hz and a symbol

ISSN: 2278-0181
Vol. 2 Issue 5, May - 2013

length of T seconds, of which T_{cp} seconds is the length of the cyclic prefix. The transmitter uses the following waveforms:

$$\phi_k(t) = \frac{1}{\sqrt{T - T_{cp}}} e^{j2\pi \frac{W}{N} k(t - T_{cp})} \forall t \in [0, T]$$

$$= 0 \qquad \text{otherwise}$$

……….Eqn.1

where $T = (N/W) + T_{cp}$.

A note must also be made of the fact that $\phi_k(t) = \phi_k(t + N/W)$ when t is within the cyclic prefix.

2.3.3 Receiver

A filter bank, matched to the last part $[T_{cp},T]$ of the transmitter waveforms $\Phi_k(t)$, i.e. ,

$$\psi_k(t) = \phi_k^*(T - t) \forall t \in [0, T - T_{cp}]$$

$$=0 \text{ otherwise}$$

........Eqn. 2

This operation effectively removes the cyclic prefix in the receiver stage of the system. All the ISI is contained in the Cyclic Prefix and does not manifest itself in the sampled output obtained at the receiver filter bank.

III. MULTI INPUT MULTI OUTPUT (MIMO) SYSTEMS

Multi antenna systems can be classified into three main categories. Multiple antennas at the transmitter side are usually applicable for beam forming purposes. Transmitter or receiver side multiple antennas for realizing different (frequency, space) diversity schemes.the third class includes systems with multiple transmitter and receiver antennas realizing spatial multiplexing.

In radio communications MIMO means multiple antennas both on transmitter and receiver side of a specific radio link. In case of spatial multiplexing different data symbols are transmitted on the radio link by different antennas on the same frequency within the same time interval. Multipath propogation is assumed in order to ensure the correct operation of spatial multiplexing,since MIMO is performing better in terms of channel capacity in a rich scatter multipath environment than in case of environment with line of sight.

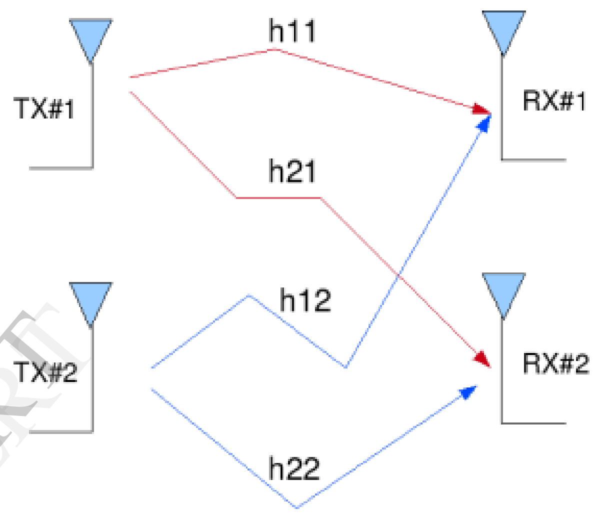

Figure 3.1: Block diagram of a generic MIMO system with 2 transmitters and 2 receivers.

IV. SPACE TIME BLOCK CODE

Space-time block coding is a technique used in wireless communications to transmit multiple copies of a data stream across a number of antennas and to exploit the various received version of the data to improve the reliability of data-transfer. The fact that the transmitted signal must traverse a potentially difficult environment with scattering, reflection, refraction and so on and may then be further corrupted by thermal noise in the receiver means that some of the received copies of data will be better than others. This redundancy results in a higher chance of being able to use one or more of the received copies to correctly decode the received signal.

ISSN: 2278-0181
Vol. 2 Issue 5, May - 2013

An STBC (Space-time block code) is usually represented by a matrix. Each row represents a time slot and each column represents one antenna's transmission over time.

transmit antennas

$$\text{time}-\text{slots}\quad \begin{bmatrix} s_{11} & s_{12} & \cdots & S_1 nT \\ s_{21} & s_{22} & & S_2 nT \\ \vdots & \vdots & & \vdots \\ S_{T1} & S_{T2} & \cdots & S_T nT \end{bmatrix}$$

Here, s_{ij} is the modulated Symbol to be transmitted in time slot I from antenna j. There are to be T time slots and nT transmit antenna as well as Nr receive antennas. This block is usually considered to be 'length' T.

4.1 Orthogonality

STBCs are originally introduced, and as usually studied, are orthogonal. This means that the STBC is designed such that the vector representing any pair of columns taken from the coding matrix is orthogonal. The results of this is simple, linear, optimal decoding at the receiver.

4.2 Design of STBCS

The design of STBCs is based on the so-called diversity criterion derived by Tarokh etal.Orthogonal STBCs can be shown to achieve the maximum diversity allowed by this criterion.

Diversity Criterion

Call a codeword

$C = C_1^1 C_1^2 \ldots\ldots C_1^{Nt}$
$C_2^1 C_2^2 \ldots. C_2^{Nt} \ldots\ldots C_T^1 C_T^2 \ldots.. C_T^{Nt}$

And call an erroneously decoded received codeword

$e = e_1^1 e_1^2 \ldots\ldots e_1^{Nt}$
$e_2^1 e_2^2 \ldots. e_2^{Nt} \ldots\ldots e_T^1 e_T^2 \ldots.. e_T^{Nt}$

Then the matrix

$$B(c,e) = \begin{bmatrix} e_1^1 - c_1^1 & e_2^1 - c_2^1 & \cdots & e_T^1 - c_T^1 \\ e_1^2 - c_1^2 & e_2^2 - c_2^2 & \cdots & e_T^2 - c_T^2 \\ \vdots & \vdots & \ddots & \vdots \\ e_1^{nT} - c_1^{nT} & e_2^{nT} - c_2^{nT} & \cdots & e_T^{nT} - c_T^{nT} \end{bmatrix}$$

has to be full-rank for any pair of distinct codewords **c** and **e** to give the maximum possible order of nTnR. If instead,B (c,e) has minimum rank b over the set of pairs of distinct codeword, then the space-time code offers diversity order bnR. An examiniation of the example STBCs shown below reveals that they all satisfy this criterion for maximum diversity.

4.3 Encoding

4.3.1 Alamouti's code

Alamouti invented the simplest of all the STBCs in 1998. It was designed for a two-transmit antenna system and has the coding matrix:

$$C_2 = \begin{bmatrix} c_1 & c_2 \\ -c_2^* & c_1^* \end{bmatrix}$$

where * denotes complex conjugate

It is readily apperent that this is a rate-1 code. It takes two time slots to transmit two symbols. The significance of Alamouti's proposal that it was the first demonstration of a method of encoding which enables full diversity with liear processing at the receiver. It was the first open-loop transmit diversity technique.

4.3.2 Encoder for Alamouti scheme

The encoder for Alamouti scheme can be seen in figure. This scheme with two transmit antennas and two receive antenna is interpreted here. In Alamouti encoding scheme,during any given transmission period two signals are transmitted simultaneously from two transmit antennas.

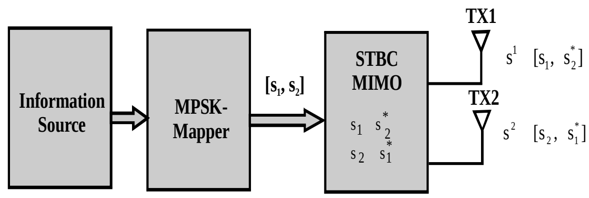

Figure 4.1:Encoder for Alamoutis code

The two-by-two space-time block code is formally written in matrix form as

$$\mathrm{TIME} = \begin{bmatrix} \bar{s}_1 & \bar{s}_0 \\ -\bar{s}_0^* & \bar{s}_0^* \end{bmatrix}$$

Where, the explanation is:

At time t, antenna 1 transmits s_i, and simultaneously, antenna 2 transmits s_0. At time t+T, where T is the symbol duration, signal transmission is switched,with- s_o^*transmitted by antenna 1 and s_i* sim ultaneously transmitted by antenna 2.

V. SIMULATION RESULTS

Let us first see the response of MIMO without OFDM then we will start with the MIMO with OFDM. It is clearly seen from the simulation result of MIMO with MMSE without OFDM that, in increase SNR then Probability of error will get decrease.Now we want to find practically the results of MIMO with MMSE using OFDM how this will change the obtainable error.

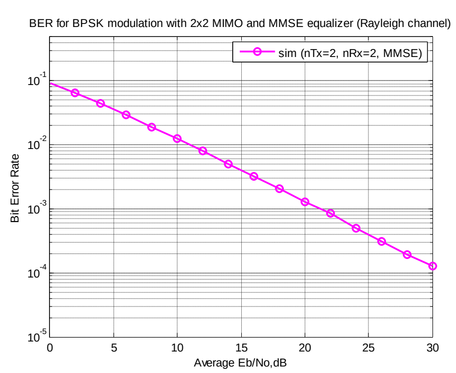

Figure 5.1: BER with MIMO and MMSE without OFDM

Different cases of setting simulation parameters:-

Case I:

Number of Transmitting Antennas = 2

Number of Receiving Antennas = 2

FFT Length = 64

Frame Length = 50

Channel Order L = 5

Cyclic Prefix Length = 16

Here after setting simulation parameters we find that the Minimum Mean Square Error is shown by 0.052 with 0 SNR and after varying SNR we get tremendous decrease in BER.See the following graph of MIMO with MMSE with OFDM:

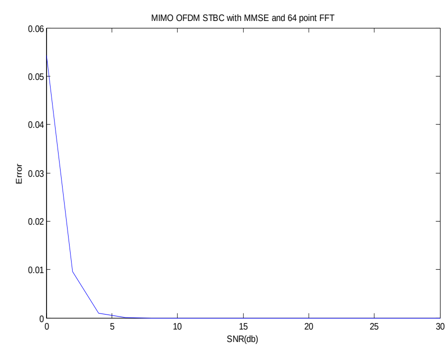

Figure 5.2: MIMO OFDM STBC with MMSE and 64 point FFT

Case II

Number of Transmitting Antennas = 2

Number of Receiving Antennas = 2

FFT Length = 256

Frame Length = 50

Channel Order L = 5

Cyclic Prefix Length = 16

Here after setting simulation parameters as shown above, we find that the Minimum Mean Square Error is shown by 0.042 with 0 SNR and after varying SNR we get tremendous decrease in BER. See the following graph of MIMO with MMSE with OFDM:

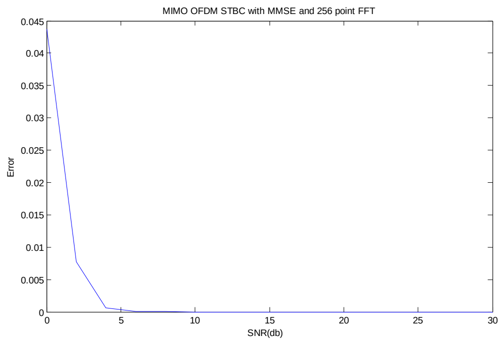

Figure 5.3 : MIMO OFDM STBC with MMSE and 256 point FFT

Case III

Number of Transmitting Antennas = 2

Number of Receiving Antennas = 2

FFT Length = 512

Frame Length = 50

Channel Order L = 5

Cyclic Prefix Length = 16

Here after setting simulation parameters as shown above, we find that the Minimum Mean Square Error is shown by 0.04 with 0 SNR and after varying SNR we get tremendous decrease in BER. See the following graph of MIMO with MMSE with OFDM:

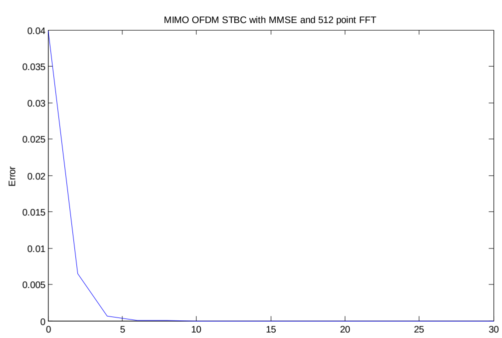

Figure 5.4: MIMO OFDM with MMSE and 512 point FFT

Case IV

Number of Transmitting Antennas = 2

Number of Receiving Antennas = 2

FFT Length = 256

Frame Length = 50

Channel Order L = 10

Cyclic Prefix Length = 16

Here after setting simulation parameters as shown above, we find that the Minimum Mean Square Error is shown by 0.045 with 0 SNR and after varying SNR we get tremendous decrease in BER. . See the following graph of MIMO with MMSE with OFDM:

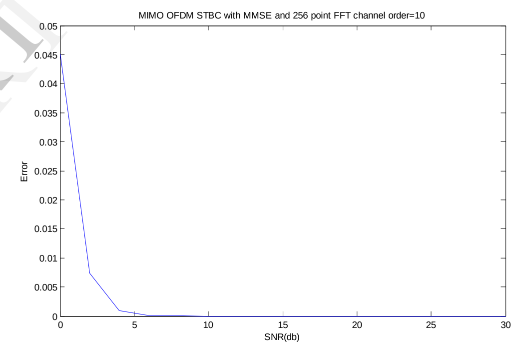

Figure 5.5 :MIMO OFDM STBC with MMSE and 256 point FFT with channel order=10

Case V

Number of Transmitting Antennas = 2

Number of Receiving Antennas = 2

FFT Length = 512

Frame Length = 50

Channel Order L = 10

Cyclic Prefix Length = 16

Here after setting simulation parameters as shown above, we find that the Minimum Mean Square Error is shown by 0.044 with 0 SNR and after varying SNR we get tremendous decrease in BER. . See the following graph of MIMO with MMSE with OFDM:

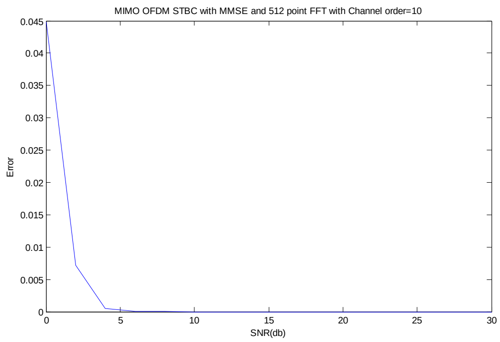

Figure 5.6: MIMO OFDM STBC with MMSE and 512 point FFT with channel order=10

Case VI

Number of Transmitting Antennas = 2

Number of Receiving Antennas = 2

FFT Length = 64

Frame Length = 50

Channel Order L = 5

Cyclic Prefix Length = 32

Here after setting simulation parameters as shown above, we find that the Minimum Mean Square Error is shown by 0.07 with 0 SNR and after varying SNR we get tremendous decrease in BER. See the following graph of MIMO with MMSE with OFDM:

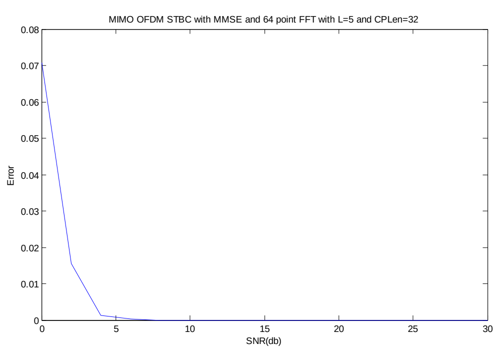

Figure 5.7 : MIMO OFDM STBC with MMSE and 64 point FFT with L=5 and CPLen=32

Case VII

Number of Transmitting Antennas = 2

Number of Receiving Antennas = 2

FFT Length = 64

Frame Length = 50

Channel Order L = 5

Cyclic Prefix Length = 64

Here after setting simulation parameters as shown above, we find that the Minimum Mean Square Error is shown by 0.091 with 0 SNR and after varying SNR we get tremendous decrease in BER. Simulation of the script took 10 minutes. See the following graph of MIMO with MMSE with OFDM:

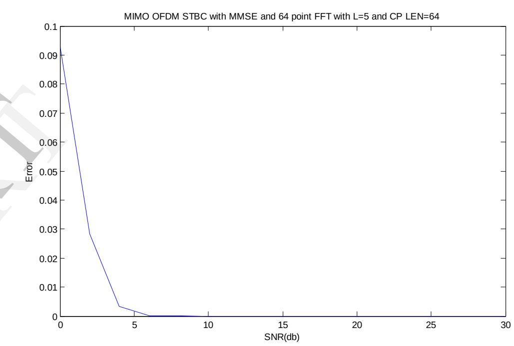

Figure 5.8: MIMO OFDM STBC with MMSE and 64 point FFT with L=5 and CPLen=64

Case VIII

Number of Transmitting Antennas = 2

Number of Receiving Antennas = 2

FFT Length = 64

Frame Length = 100

Channel Order L = 5

Cyclic Prefix Length = 16

Here after setting simulation parameters as shown above, we find that the Minimum Mean Square Error is shown by 0.058 with 0 SNR and after varying SNR we get tremendous decrease in BER. If we compare performance of Frame Length 50 and 100 we find that the errors obtainable are 0.091

and 0.058. See the following graph of MIMO with MMSE with OFDM:

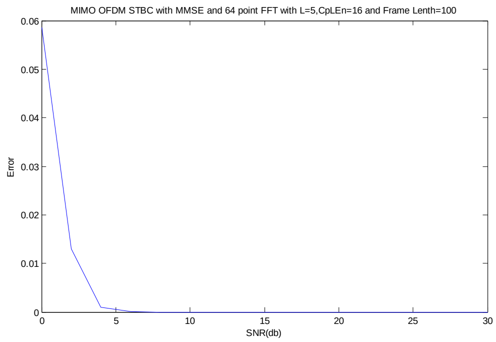

Figure 5.9: Simulation of Ber of Bpsk with 2×2 MIMO and MMSE without OFDM

VI. CONCLUSION

We realized that the MIMO plays very important role in wireless communication now a days With combination of OFDM and MMSE we achieved better response of our considered equalizer. MIMO system are used for enhancement of capacity improvement in SNR at the receiver and to transmit data at higher rate. This paper mainly discuss the effect on the reduction in bit error rate by changing OFDM parameters.

We may improve bit error rate performance by increasing no.of transmit antenna(**T_X**) and no.of receiving antennas(**R_X**). Improvement in OFDM parameter like frame length and FFT length gives a large amont of reduction in BER.frame length and FFT length gives a large amont of reduction in BER.

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