IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Performance Evaluation of BER For MIMO OFDM Systems Using MMSE Equalization with Algorithm with VBLAST

Vivek Trivedi[*1],Praveen Patidar[2],Dr.S.J.Basha[3]

[*1,2,3] Department of ECE, Lakshmi Narain College Of Technology, Indore, India

vivektrivedi12@gmail.com

Abstract

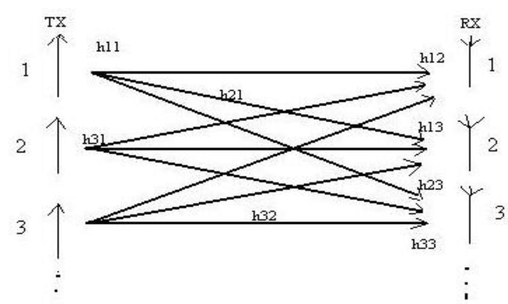
Wireless communication is characterized as the transfer of the information between two points that are not physically connected and the separation between them may vary from meters to kilo-meters. Now a days the wireless communication is changing its scenario due to its ease of availability and reliability and lower costs and small sizes and also due to continue research. Multiple Input Multiple Output (MIMO) is a smart antenna technology in the current wireless communication systems, such as 3G and 4G. MIMO can be combined with Orthogonal Frequency Division Multiplexing (OFDM) to improve communication quality, performance, capacity, and transmission rate. MIMO OFDM system also gives very good Bit Error Rate (BER) performance. Since MIMO uses multiple transmitting and multiple receiving antennas, so complexity is introduced. Basically used detector is MMSE. This paper studies the Vertical Bell Lab Layered Space Time (VBLAST) that is the MIMO system which reduces the complexity and improves gain of the detector. It introduces Successive Interference Cancellation (SIC) algorithm with Minimum Mean Square Error (MMSE) and reduces the detector's complexity. In this paper we are using MIMO OFDM system with VBLAST algorithm with MMSE equalizer is used to achieve minimum BER in multipath fading channel environment. We are using Binary Phase Shift Keying (BPSK) modulation technique.

Keywords: MIMO, OFDM, Equalizer ,VBLAST, MMSE, BER, ISI, Fading

Introduction

Wireless Communication is one of the most important areas in the communication field today. Wireless operations permit services, such as long range communications, that are impossible or impractical to implement with the use of wires. Wireless communication may be via: radio frequency communication, microwave communication, for example long-range line-of-sight via highly directional antennas, or short-range communication infrared (IR), short-range communication.

MIMO is effectively a radio antenna technology as it uses multiple antennas at the transmitter and receiver to enable a variety of signal paths to carry the data, choosing separate paths for each antenna to enable multiple signal paths to be used [4]. MIMO technology offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency or to achieve a diversity gain that improves the link reliability. MIMO is a method of transmitting multiple data beams on multiple transmitters to multiple receivers. The advantage is that the odds of receiving the data are massively increased. Basically, if any one path is faded, there is a high probability that the other paths are not, so the signal still gets through.



In the above fig.1 MIMO system is shown. It is 3X3 MIMO because there are 3 transmitting and 3 receiving antennas.

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation technique. OFDM provides high bandwidth efficiency because the carriers are orthogonal to each other and multiple carriers share the data among themselves. The main

advantage of this transmission technique is their robustness to channel fading in wireless communication environment. The orthogonality between the carriers facilitates the close spacing of carriers. The orthogonality principle 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 [2]. OFDM symbol rate is low since a data stream is divided into several parallel streams before transmission. This make the fading is slow enough for the channel to be considered as constant during one OFDM symbol interval. Cyclic prefix is a crucial feature of OFDM used to combat the inter-symbol interference (ISI) and inter-channel-interference (ICI) introduced by the multipath channel through which the signal is propagated [8].
V-BLAST is a detection algorithm to the receipt MIMO systems. Its principle is quite simple: to make a first detection of the most powerful signal. It regenerates the received signal from this user from this decision. Then, the signal is regenerated subtracted from the received signal and, with this new sign, it proceeds to the detection of the second user's most powerful, since it has already cleared the first and so forth. This process gives a vector containing received less interference. A BLAST scheme is primarily based on the following three steps: i) interference nulling to reduce the effect of the other (interfering) signals on the desired one; ii) ordering to select the sub stream with the largest signal-to-noise ratio (SNR); and iii) successive interference cancellation(SIC), which is a well-known physical layer technique. Briefly SIC is the ability of a receiver to receive two or more signals concurrently (that otherwise cause a collision in today's systems). SIC is possible because the receiver may be able to decode the stronger signal, subtract it from the combined signal, and extract the weaker one from the residue. A large number of low complexity linear MIMO detectors have been developed. Generally these linear detectors are based on minimum mean-square error (MMSE). But the performance of this detector can be poor, especially in MIMO systems that use a small number of receiving antenna branches. To improve performance, a so called V-BLAST algorithm has been introduced. This performs successive interference cancellations in the appropriate order. BLAST system with SIC detector helps to achieve the high spectral efficiency with reasonable decoding complexity, in rich scattering environments through exploiting spatial dimension and also V-BLAST yields higher diversity gains and improves BER performance.

We are combining this system with OFDM. The combination of MIMO and OFDM techniques is a potential candidate for the future wireless networks since they ensure high spectrum efficiency as well as high diversity gain. Combining OFDM with MIMO technique increases spectral efficiency to attain throughput of 1 Gbit/sec and beyond, and improves link reliability. Efficient implementation of MIMO-OFDM system is based on the Fast Fourier Transform (FFT) algorithm and MIMO encoding, such as Alamouti Space Time Block coding (STBC), the Vertical Bell-Labs layered Space Time Block code VBLASTSTBC, and Golden Space-Time Trellis Code (Golden STTC).
We are using here MIMO OFDM system with VBLAST algorithm and MMSE equalizer. So BER performance will be improved to a large extent.

System Model

A.OFDM with MIMO

TRANSMITTER PART

At transmitter first, the data is generated from a random source, consists of a series of ones and zeros. Data input bits are converted into symbol vector using modulation. Modulation scheme used to map the bits to symbols are BPSK, QPSK, 16 PSK, 256 PSK.

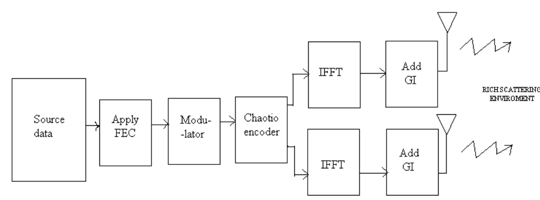


Figure2: Block Diagram of Transmitter of OFDM with MIMO

Since the transmission is done block wise, when forward error correction (FEC) is used, the size of the data generated depends on the block size used, modulation scheme used to map the bits to symbols (BPSK), and whether FEC is used or not. The generated data is passed on to the next stage i.e.to the FEC block.
Forward error correcting codes are applied to normal convolution code sequence and interleaved convolution code sequence. The error correcting codes are used, to avoid long run of zeros or ones, as the data generated is randomized. This results in ease in carrier recovery at the receiver. The randomized data is encoded using tail biting convolution codes (CC) with a coding rate of ½.
The sequence is then fed to the chaotic communication system. The Chaotic communication converts the block of m-binary symbols into two encrypted sequences. Two coupled chaotic communication system is used, hence two sequences

are generated. These sequences are then passed onto the next stage, the IFFT, to convert into time domain

$$S_j(n) = \frac{1}{N}\sum_{n=0}^{N-1} x_j \exp\left(\frac{j2\pi kn}{N}\right) \quad (1)$$

Where, j is the number of transmitting antennas and i is the number of chaotic sequence. Here for two coupled system there are two chaotic sequences.

RECEIVER PART

This is the final part of the communication system and the most important one. In the receiver the signal is received by forming the beam in the desired signal direction, demodulated and then combined by using receiver, and probabilistic symbol estimation is performed.

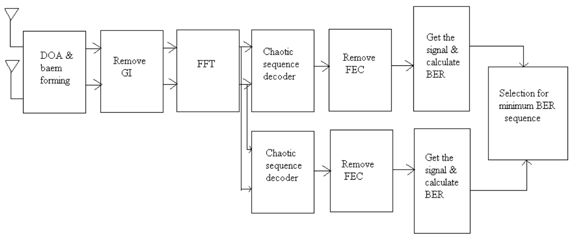


Figure3: Block Diagram of Transmitter of OFDM with MIMO

At receiver first of all the direction of arrival of the multipath signals are determined. Here the assumption is that the multipath components of the signal are strong enough to distinguish them from noise. The LMS and LLMS beam forming algorithms are used to form the beam in the direction of incoming signal.

The OFDM receiver is shown in Fig.3.At the receiver, the signals are received and combined with different path loss and different fading fluctuation. Receiving antennas used at the receiver are 2. The received OFDM symbol before OFDM demodulation can be formulated as:

$$y(n) = FFT[s(n)h(n)] + G(n) \quad (2)$$

Where, G (n) represents an uncorrelated additive white Gaussian noise, h(n) is the communication channel impulse response, and S(n) is the transmitted OFDM symbol in the nth carrier duration.

a) The first thing done at receiver (in simulation) is estimation of angle of reception.
b) Find out the sum of power of all incident signals for each angle from (0º to 180º) of all elements.
c) From the maximum peak in the power spectrum we can estimate the DOA's of the desired signals.
d) Two transmitting and two receiving antennas are used. So at the receiver we get four copies of the received signal.
e) Two copies from chaotic system 1 and two from chaotic system 2.

At the receiver these copies are termed as normal angle reception signals i.e. when the signal from transmitting antenna 1 Tx1, is received by the receiving antenna 1, Rx1 same is the case for Rx2.So,two signals: normal angle reception signal 1and normal angle reception signal 2 are obtained.

Now, when, receiving antenna 1 Rx1, received the signal from transmitting antenna 2 Tx2, termed it as mixed angle reception. Same is the case for Rx2. So, two signals mixed angle reception signal 1 & mixed angle reception signal 2 are obtained.

After estimating the angle of arrival, adaptive beamforming algorithms LMS and LLMS algorithms are used to minimize the interference.

After receiving four copies of the signal, signals are fed to the FFT for frequency domain transformation. For decoding of the signals chaotic decoders are used. Here the signals are decrypted. After decryption signals are added and threshold value can be calculated.

After this FEC is removed from the decoded sequence for normal angle reception signal & mixed angle reception signal.

Now these two sequences are compared to find out which sequence has minimum value of error in bits. For this each sequence is matched with the input sequence to find out which sequence has minimum BER. Finally it gives the result in terms of recovered sequence & recovered mode i.e. recovered sequence is from which mode: normal reception mode or mixed reception mode along with the angle of recovery [1].

B. VBLAST System

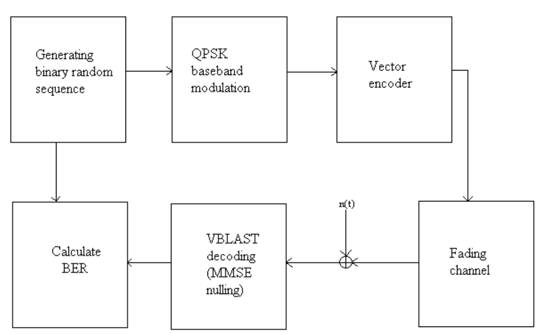


Figure4. Simulation Block Diagram of VBLAST System

Figure4 describes simulation block diagram for V-BLAST scheme. To decode the transmitted symbols of the first layer, the receiver needs to estimate the channel matrix using pilots. In this simulation, the fading channel characteristics are assumed to be known perfectly at the receiver. The transmitter consists of a binary random generator, a QPSK baseband modulator and a vector encoder. The binary random generator generates the transmitted bits. These bits are modulated in the QPSK modulator using the complex envelope form. It is assumed that each symbol has an ideal rectangular pulse shape and may be sampled with a single point per symbol. The vector encoder maps the symbols to each antenna. In the channel block, the transmitted symbols undergo Rayleigh fading and additive noise. Rayleigh fading channel coefficients are generated with two independent Gaussian random variables with unit variance. The phase delay is distributed uniformly between $-\pi$ and$+\pi$. In addition, the channel is assumed to be quasistationary, that is, the channel coefficients do not vary during the given period time. The receiver is made up of decoding processing and an error rate calculation block. At the decoding processing block, we simulate the several types of schemes reviewed briefly in analysis section. The decoding methods are reviewed in the following section. PIC does not need to consider the ordering issue since it cancels out all other paths interference in the same stage. We compares the performance for ordered and non-ordered systems, and the simple ZF and MMSE technique are compared on the basis of PIC and SIC algorithm. For applying the MMSE technique, we need to know the SNR at the receiver. Therefore, knowledge of the SNR is also assumed at the receiver. Finally the SER is calculated by comparing the originally transmitted symbols with received symbols that are estimated at the receiver.

In the V-BLAST the received vector with size *nR* 1 is modeled by

$$R=Ha+n \tag{3}$$

Where *H* represents the channel matrix with dimension *nR* *nT*, whose element hi, j represents the complex fading coefficient for the path from transmit *j* to receive antenna *i*. These fading coefficients are modeled by an independent zero mean complex Gaussian random variable with variance 0.5 per dimension. A denotes the vector of transmitted symbols with dimension *nT* 1, *n* represents a complex vector of independent samples of AWGN over each received antenna with zero mean and varianceσ_n^2. The nulling matrix *G* is described in Eq. (4) and (5) for the ZF and MMSE criteria with the form of pseudo-inverse of the channel matrix *H*:

$$W = (H^*H)^{-1}H^* \tag{4}$$

$$G = (H^*H + \frac{\sigma_n^2}{\sigma_d^2}) \tag{5}$$

Where $\frac{\sigma_n^2}{\sigma_d^2}$ denotes the inverse of signal-to-noise ratio at each receive antenna. *H* represents the conjugate transpose matrix of channel matrix *H.*

C. Equalizers

Equalizer minimizes the error between actual output and desired output by continuous updating its filter coefficients. Equalization is the main area of concern in this paper. Equalization is filtering approach that can be applied in time and frequency domain producing time domain Equalizers (TDEs) and frequency domain equalizers (FDEs). FDEs are preferred over TDEs as they are simpler to use. Equalizers are generally categorized as linear and non-linear depending upon how the output of it is used [6]. Another important concept in equalizer design is number of taps in a filter structure. The maximum time delay spread of the channel limits the number of taps in equalizer design. An equalizer can equalize for delay intervals less than or equal to the maximum delay within the filter structure. The most useful that we are using equalizer algorithm is MMSE.

MMSE Equalizer for 2X2 MIMO:-

MMSE equalizer is a balanced linear equalizer, which does not usually eliminate ISI completely but instead minimizes the total power of the noise and ISI components in the output, therefore preferred in OFDM. We want to solve the problem of ISI therefore the joint operation of OFDM with MMSE.

In the above fig.2 a 2*2 MIMO channel is shown. The MMSE Equalizer for 2*2 MIMO channel will be:-

In the first time slot, the received signal on the first receive antenna is,

$$y_1 = h_{1,1}x_1 + h_{1,2}x_2 + n_2 = [h_{1,1} \quad h_{1,2}]\begin{bmatrix}x_1\\x_2\end{bmatrix} + n_1 \tag{6}$$

The received signal on the second receive antenna is,

$$y_2 = h_{2,1}x_1 + h_{2,2}x_2 + n_2 = [h_{2,1} \; h_{2,2}]\begin{bmatrix}x_1\\x_2\end{bmatrix} + n_2 \tag{7}$$

Where

y_1, y_2 are the received symbol on the first and second antenna respectively,

$h_{1,1}$ is the channel from 1st transmit antenna to 1st receive antenna,

$h_{1,2}$ is the channel from 2nd transmit antenna to 1st receive antenna,

$h_{2,1}$ is the channel from 1st transmit antenna to 2nd receive antenna,

$h_{2,2}$ is the channel from 2nd transmit antenna to 2nd receive antenna,
x_1, x_2 are the transmitted symbols and n_1, n_2 is the noise on 1st,2nd receive antennas.
We assume that the receiver knows $h_{1,1}$ $h_{1,2}, h_{2,1,} h_{2,2}$ and. The receiver also knows and y_1, y_2. For convenience, the above equation can be represented in matrix notation as follows:

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \quad (8)$$

Equivalently,
y = Hx + n
The **MMSE** approach tries to find a coefficient W, which minimizes the criterion,

$$E\left\{[W_{y-x}][W_{y-x}]^H\right\} \quad (9)$$

Solving,

$$W = [H^H H + N_0 I]^{-1} H^H \quad (10)$$

Using the **MMSE** equalization, the receiver can obtain an estimate of the two transmitted symbols x_1, x_2, i.e.

$$\begin{bmatrix} \hat{x}_1 \\ \hat{x}_2 \end{bmatrix} - [H^H H + N_0 I]^{-1} H^H \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} \quad (11)$$

When comparing to the equation in Zero Forcing equalizer, apart from the $N_0 I$ term both the equations are comparable. In fact, when the noise term is zero, the **MMSE** equalizer reduces to Zero Forcing equalizer. The concept of **successive interference cancellation** to the **MMSE equalization** is an important concept [5]. In this paper MMSE equalizer with SIC is used to reduce receiver's complexity. In classical **SIC**, the receiver arbitrarily takes one of the estimated symbols (for example the symbol transmitted in the second spatial dimension, $\hat{x}_2$), and subtract its effect from the received symbol y_1 and y_2.Once the effect of $\hat{x}_2$ is removed, the new channel becomes a one transmit antenna, 2 receive antenna case and can be optimally equalized by **Maximal Ratio Combining (MRC).**
We should subtract the effect of $\hat{x}_1$ first or $\hat{x}_2$ first. To make that decision, let us find out the transmit symbol (after multiplication with the channel) which came at higher power at the receiver. The received power at the both the antennas corresponding to the transmitted symbol x_1 is,

$$p_{x_1} = |h_{1,1}|^2 + |h_{2,1}|^2 \quad (12)$$

The received power at the both the antennas corresponding to the transmitted symbol x_2 is,

$$p_{x_2} = |h_{1,2}|^2 + |h_{2,2}|^2 \quad (13)$$

If $\boldsymbol{p_{x_1} > p_{x_2}}$ then the receiver decides to remove the effect of $\boldsymbol{\hat{x}_1}$ from the received vector $\boldsymbol{y_1}$ and $\boldsymbol{y_2}$ $\boldsymbol{\hat{x}_2}$. Else if $\boldsymbol{p_{x_1} < p_{x_2}}$ the receiver decides to subtract effect of $\boldsymbol{\hat{x}_2}$ from the received vector $\boldsymbol{y_1}$ and $\boldsymbol{y_2}$, and then re-estimate $\boldsymbol{\hat{x}_1}$ **[3].**

Channel Model

In wireless telecommunications, multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. Causes of multipath include atmospheric ducting, ionospheric reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings.
The effects of multipath include constructive and destructive interference, and phase shifting of the signal. This causes Rayleigh fading. The standard statistical model of this gives a distribution known as the Rayleigh distribution.

A. Rayleigh multipath channel model

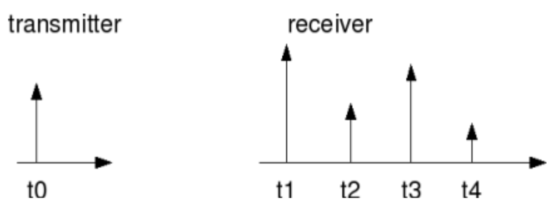


Figure5: Impulse response of a multipath channel

The impulse response is,

$$h(t) = \frac{1}{\sqrt{n}}[h_1(t - t_1) + h_2(t - t_2) + \cdots . + h_n(t - t_n)], \quad (14)$$

Where
$h_1(t - t_1)$is the channel coefficient of the 1st tap,
$h_2(t - t_2)$ is the channel coefficient of the 2nd tap and so on.
The real and imaginary part of each tap is an independent Gaussian random variable with mean 0 and variance 1/2.
The term $\frac{1}{\sqrt{n}}$ is for normalizing the average channel power over multiple channel realizations to 1 [7].

Result

In the graphs given below we can easily see the effect of the MIMO OFDM on the BER performance of the MMSE equalizer. As it is easily seen from the graphs that the MIMO is also helpful in controlling the reliability and data rate of the system.Therefore newer technologies are frequently using MIMO alongwith OFDM to find the lowest errors with high realibility and with higher error correction facilities.
The wireless communication today is very much successful due to easy handling and low power consumption and due to higher correction of transmitted bits. Our approch has produced following:

2X2,2X3,2X4,2X5,3x2,3x3,3x4,3x5,4x2,4x3,4x4,4x5,5x2,5x3,5x4,5x5 MIMO with OFDM 128 FFT size.

TABLE 1: BER Performance for 2X2,2X3,2X4,2X5 MIMOOFDM

SNR	BER(2X2)	BER(2X3)	BER(2X4)	BER(2X5)
0	0.05928	0.05758	0.05479	0.05274
2	0.01337	0.01128	0.01078	0.01053
4	0.0009939	0.0008861	0.0006689	0.0001117
6	5.97e-05	5.93e-05	5.953e-05	3.297e-05
8	3.28e-06	1.719e-06	1.712e-006	1.266e-06
10	1.62e-07	1.60e-07	1.58e-007	1.563e-07

TABLE 2: BER Performance for 3X2,3X3,3X4,3X5 MIMOOFDM

SNR	BER(3X2)	BER(3X3)	BER(3X4)	BER(3X5)
0	0.09368	0.09184	0.08594	0.08533
2	0.02605	0.02585	0.0251	0.02167
4	0.003392	0.003288	0.003195	0.002742
6	0.0003486	0.0002033	0.0002002	0.0001205
8	3.44e-06	3.29e-06	3.21e-06	3.15e-06
10	1.66e-07	1.64e-07	1.623e-07	1.61e-07

TABLE 3: BER Performance for 4X2,4X3,4X4,4X5 MIMO OFDM

SNR	BER(4X2)	BER(4X3)	BER(4X4)	BER(4X5)
0	0.1245	0.1239	0.1209	0.1153
2	0.04155	0.03998	0.03997	0.03793
4	0.007555	0.006422	0.006267	0.005675
6	0.0006033	0.0005814	0.0004314	0.0004252
8	4.844e-06	3.31e-06	3.25e-06	3.19e-06
10	1.69e-07	1.678e-07	1.67e-07	1.63e-07

TABLE 4: BER Performance for 5X2,5X3,5X4,5X5 MIMO OFDM

SNR	BER(5X2)	BER(5X3)	BER(5X4)	BER(5X5)
0	0.15	0.1486	0.1473	0.1469
2	0.05735	0.0549	0.05436	0.05382
4	0.01117	0.01073	0.009742	0.00941
6	0.001128	0.0011	0.001061	0.001041
8	5.80e-05	4.078e-05	2.516e-05	1.891e-05
10	1.72e-07	1.714e-07	1.695e-07	1.643e-07

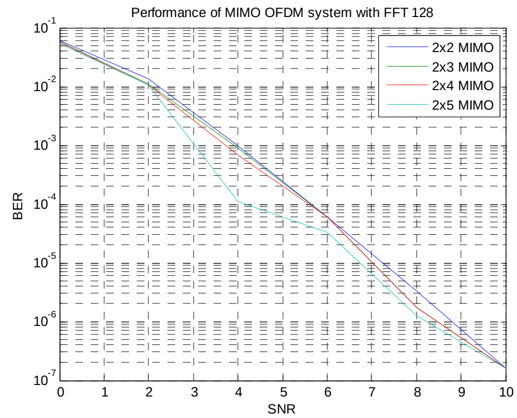


Figure6: BER Performance of 2x2, 3x3, 4x4, 5x5MIMO OFDM 128 FFT

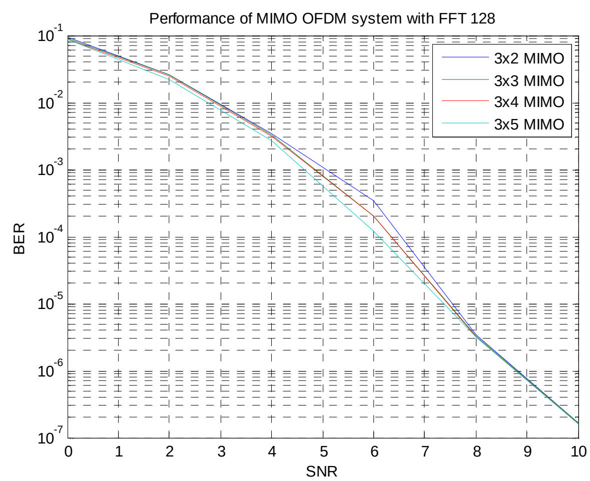


Figure7: BER Performance of 3x2, 3x3, 3x4, 3x5 MIMO OFDM 128 FFT

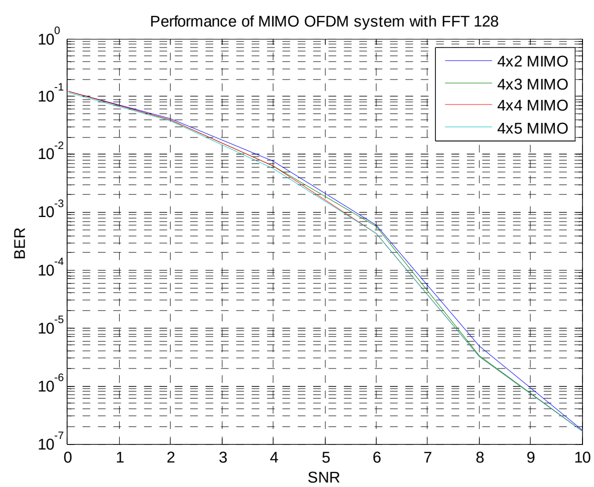


Figure8: BER Performance of 4x2, 4x3, 4x4, 4x5 MIMO OFDM 128 FFT

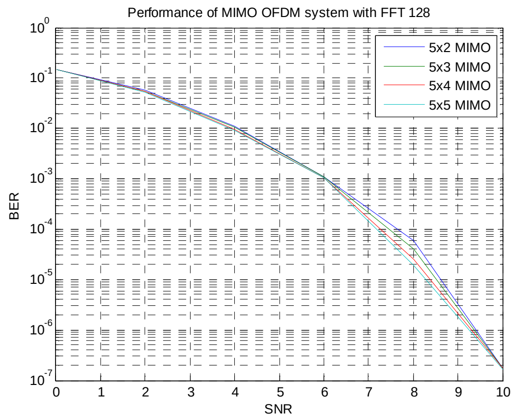


Figure9: BER Performance of 5x2, 5x3, 5x4, 5x5 MIMO OFDM 128 FFT

Conclusion

We have plotted graph between BER vs. SNR for MIMO OFDM systems with VBLAST using MMSE equalizer. From the simulation results we have found out that if we decrease no. of transmitting antennas with fixed receiving antennas, BER performance is improved. We had also noticed that if increasing the no. of transmitting antennas with fixed receiving antennas, BER performance if decreased. It is also seen that if there are minimum transmitting antennas and maximum receiving antennas, we will get minimum BER. We have concluded that BER of 2X5 MIMO at 10 db SNR is 1.563e-007 is the minimum BER in all above combinations.

References

[1] Suchita Varade**,** Kishore Kulat, "BER Comparison of Rayleigh Fading, Rician Fading and AWGN Channel using Chaotic Communication based MIMO-OFDM System", in International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-1, Issue-6, January 2012.

[2] Bhasker Gupta and Davinder S.Saini "BER Performance Improvement in OFDM Systems using Equalization Algorithms "in Proceedings of the 1st International Conference on Parallel, Distributed and Grid Computing (PDGC-2010) 978-1-4244-7674-9/10 ©2010 IEEE .

[3] Vivek Trivedi,Dr. S. J. Basha, "Effect of MMSE And LMMSE Equalizer on The Received Data In Presence of Multipath Fading And MIMO", in International Conference on Science and Information Technology, Dehradun on Jun 3rd 2012 ISSN 978 93 81693 92 6.

[4] Pallavi Bhatnagar, Jaikaran Singh and Mukesh Tiwari, "Performance of MIMO-OFDM System For Rayleigh Fading Channel" in International Journal of Science and Advanced Technology (ISSN 2221-8386) Volume 1 No 3 May 2011.

[5] V.Jagan Naveen, K.Murali Krishna and K.RajaRajeswari "Performance analysis of equalization techniques for MIMO systems in wireless communication" in International Journal of Smart Home Vol.4, No.4, October, 2010

[6] H. Zhang, H. Dai, Q. Zhou, and B. L. Hughes, 2006 On the diversity-multiplexing tradeo for ordered SIC receivers over MIMO channels," IEEE International Conference on Communications (ICC), Istanbul, Turkey.

[7] N.Sathish Kumar and Dr.K.R.Shankar Kumar,2011." Bit Error Rate Performance Analysis of ZF, ML and MMSE Equalizers for MIMO Wireless Communication Receiver", EJSR,Vol.59 No.4 (2011), pp. 522-532.

[8] "Wireledd Communication", 3rd Edition by Upena Dalal page no. 366.