Performance Comparison of Bit Error Rate in SISO and MIMO Using VBLAST-STBC System

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Abstract - *This paper presents a detailed analysis of the working of Vertical Bell Laboratories Layered Space Time (VBLAST) coding technique by the support of SISO and MIMO systems. In this paper we compared the results of Bit Error Rate (BER) values in SISO and MIMO system by the help of Zero Forcing (ZF) equalizer. A single step demodulation and decoding operation may suffer a great downfall in performance of the system. VBLAST space time coding algorithm is used as an iterative way for demodulation and decoding operation so that efficiency of the system can be improved. A mathematical model is also made to represent the working of Zero Forcing detector and receiver model*

Key Words: Multiple Input Multiple Output (MIMO), Single Input Single Output (SISO), VBLAST, Zero Forcing equalizer

2. INTRODUCTION

In the field of radio technology, we use Multiple Input Multiple output (MIMO) as a method of increasing or multiplying the capacity of a system having radio links by using more than one antennas in both transmitter and receiver side so that radio signals can reach to more than one antenna and hence multiple propagation of signal can take place. Since more than one signal can be sent and received by the help of Multiple Input Multiple Output (MIMO) technology, so it has become an important part in the area of wireless communication. Single Input Single Output are having less complexity as compared to MIMO technology. An institute which makes standards for technologies related to multiple antennas are, IEEE 802.11n for Wi Fi and 802.11 ac for (Wi Fi) Wireless Fidelity, High Speed Packet Access (HSPA) and 3rd Generation (3G). Since it has only one antenna in transmitting side and one antenna on receiving side, so interaction between the transmitter and receiver is very low.

Pre-coding is a beam forming technique which uses multiple stream of parallel data. All the processing related to spatial diversity is done at the transmitter end of the system. If the beam forming is single data stream in nature, having a corresponding phase and gain then the signal power will increase at the receiver end of pre-coding Multiple Input Multiple Output (MIMO) system. The main aim of having a beam forming is to increase the gain of a signal. The gain of signal can be increased by adding up all the signals that are being emitted from different antennas and finally this will decrease the fading which causes due to multiple propagation of signal. The propagation which is based on Line Of Sight (LOS), the beam forming results in a one directional pattern over a well synchronized manner. However regular beams do not have a good correlation with the networks related to cellular and mobile and they only depend on multiple signals being propagated over different channels. If we consider that the receiver has more than one antennas then the beam forming of transmitting side cannot increase the level of signal to reach to the individual receiving antennas simultaneously. So here pre-coding plays a vital role which uses more than one streams that enhances the signal level.

If a signal is having high data rate, then in case of spatial multiplexing the high data rate signal is divided into signals with smaller data rates and then it is given as input to the transmitter and multiple antennas in the transmitter side transmits these signals with small data rates over a constant frequency channel. If these signals with smaller data rate reach at the receiver with different signal characteristics then the only way the receiver can separate these signal if the receiver is having Channel State Information (CSI). Spatial multiplexing is a very efficient method to increase the capacity of a channel even if the system works on high Signal to Noise Ratio (SNR).

Diversity coding is a method in which single data stream is being transmitted but the main difference with other techniques is, we apply Space Time Block Code (STBC) over the data stream. Diversity coding increases the fading diversity. Channel knowledge, beam forming and array gain is not present in diversity coding. The main advantage of using Space Time Block Coding (STBC) is it forms multiple versions of receiving signal which increases the reliability of the data. Space Time Block Code (STBC) is orthogonal in nature that means any vector or any representation of any part of the signal will be orthogonal in nature

2. LITERATURE SURVEY

Branka Vucetic [1] et al., the author of this paper has described how the capacity of wireless communication decreases and could not meet the demands of data transmission. The decrease in capacity is due to low data rates, low spectral efficiency and degradation in quality of service. This paper shows how space time coding can be used to avoid fading in wireless communication. Space time codes are highly efficient in context to bandwidth which helps in better signaling within the wireless communication. It uses spatial dimension technique to transmit within the co-related antennas. The author uses various coding techniques such as space time trellis coded modulation technique, space time turbo codes. The drawbacks of using these coding techniques are explained in this paper which describes about the degradation of multipath propagation to achieve a very high spectral efficiency.

D. Gesbert [2] et al., the author of this paper has described about the recent progress in wireless communication using space time coded system. After taking the help of background research the author briefly describes about the algorithms and coding methods that can be used in MIMO so that the capacity of system and quality of communication link using MIMO can be improved

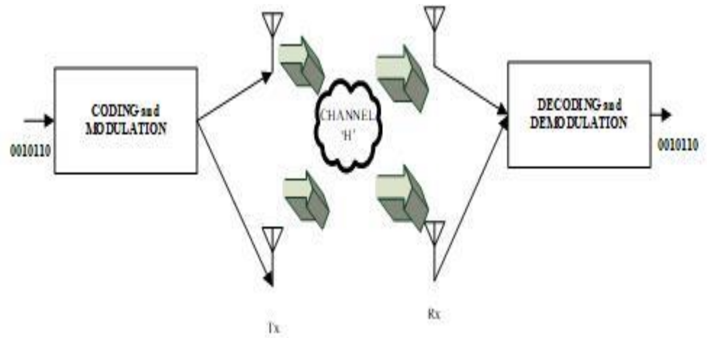

Fig -1: MIMO transmission model

Shreedhar. A. Joshi [3] et al., the author has used VBLAST algorithm in Multiple Input and Multiple Output (MIMO) antenna system for more than one layer in case of detection of symbols in a very high scattering environment over a wireless communication network. Here the author has described how we can use VBLAST coding technique with Zero Forcing, Minimum Mean Square Error, and Maximum Likelihood. Here the author has used these methods by solving last equation first then solving the second last equation and so on. The value of last equation is substituted to the second last and value of second last equation is substituted to the third last and further substitution goes on till the final result evaluated. The author has also used various other techniques like DBLAST in Multiple Input and Multiple Output antennas. VBLAST works on layered structure of space coding and as well as time coding so it has to be connected to the receiver. The author also describes that the entire signal processing is done on the receiver side

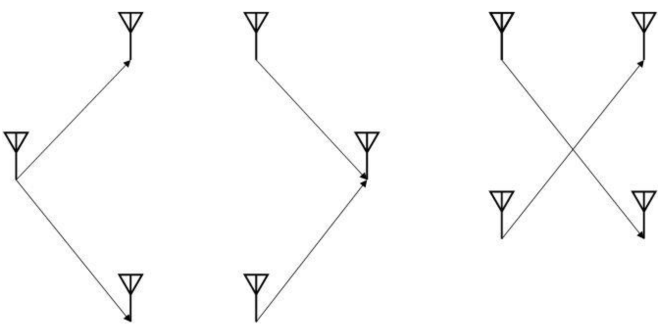

Fig -2: Antenna diversity

Sudhanshu Kumar Chourasia [4] et al., The author of this paper has proposed different mathematical model for different detection techniques that can be used with VBLAST algorithm. Some of the detection methods that author has used are Minimum Mean Square Error, QR decomposition method and Zero Forcing. The signals at the transmitter end and signals at receiver end are both correlative so at the end the author explains by using all these methods and arrangements we can improve the Bit Error rate of. Additionally it has advantages like it is less costly and the spectral efficiency ranges from 20 bits per second per hertz to 40 bits per second per hertz

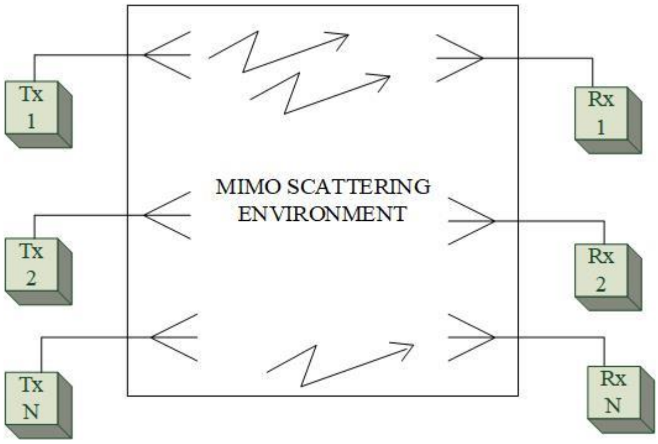

Fig -3: MIMO channel model

Markus Rupp [5] et al., The author explains how space time coding technique can be used to work better with higher diversity. For symmetrical case it has a degree 2^n where 'n' is the number of antennas. This coding technique can also be implemented in detection algorithms like Zero Forcing and Maximum Mean Square Error but there is one condition that it can only work with low complexity. Low complexity can be done by not assuming the inversion in matrices as well as the complexity should also be low in Maximum Likelihood.

3. PERFORMANCE ANALYSIS OF BIT ERROR RATE USING VBLAST ALGORITHM

3.1 VBLAST System Models

Wireless communication theory engage the utilization of numerous antennas at both transmitter and receiver to boost data rates over multiplexing approach. In this paper, we considered the bit error rate (BER) conduct of Vertical Bell Laboratories Layered Space Time Architecture (VBLAST) spatial Multiplexing Technique along with distinct comparison manners like Maximum Likelihood (ML), Zero Forcing (ZF). Also, MIMO systems with large constellations are less efficient compared to small constellation the performance of 1024- PSK under Rician channel is the worst. VBLAST architecture, which uses a self-sufficient or independent coding and decoding, to improve the communication system.

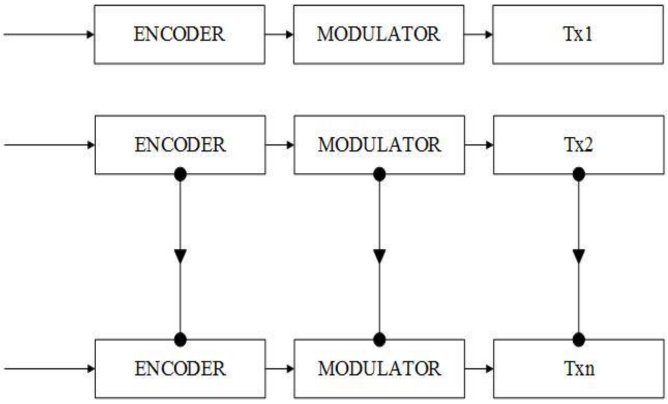

Fig -4: VBLAST transmitter

Figure 4 shows how the transmitter of a VBLAST system works. In a VBLAST system, each symbol is being transmitted by a single antenna and there is no relation between two antennas neither there is any co-relation between the symbols. The coded bits of same code name are being send through different transmitter but after that the symbols which are being allotted with an individual code name will move through a single common channel. The receiving subsistence is applied over a generic VBLAST structure. As each data stream is being individually encoded, so we separate N_t parallel streams which came as an output of transmitter after demodulation and then we decode each parallel data stream using their individual decoders. We apply same decoder and same demodulator for every VBLAST system

Figure 5 shows a simple VBLAST receiver along with collective detection and as we increase the number of data streams the complexity rises exponentially

As an outcome we have to use straightforward detection guidelines which applies flexible information over the decoders of specific data stream which can be further effective in field of exploration. In partnership with subsequent dissolution of data streams, we can carry out the size in case of fast fading in Multiple Input Multiple Output channel. Taking the help of direct scenario, a conclusion can be made that about superior achievement of the VBLAST system when a channel is having Slow Fading

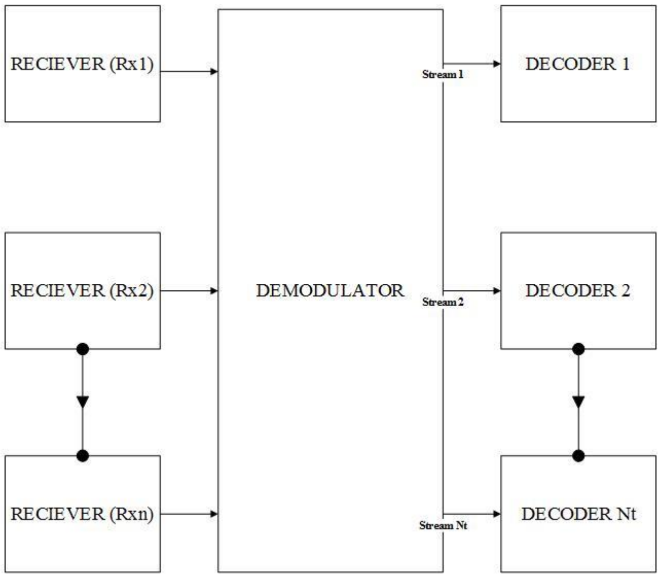

Fig -5: VBLAST receiver

4. ZERO FORCING DETECTOR

If the data which is being transmitted gets noticed by the channel, there is an intelligent model called singular value decomposition that helps the transmitting antenna to deliver synchronized parallel data streams over the Eigen modes of the channel. So we see that the data streams appear orthogonally at the receiver without having any interference among each other. Sometimes a transmitter does not recognize a channel, if that happens then we cannot achieve our goal. Certainly, when individual data stream is passed through MIMO channel, the all reach at the receiver coupled crosswise with each other. It is important for a receiver to separate the data streams with maximum efficiency.

4.1 Projection Method

To apply these notations, we choose the time invariant case first because we have to form a channel matrix. We can create the acknowledged vector given as y[m]

$$y[m] = \sum_{t=1}^{Nt} h_i x_i[m] + w[m]$$

Here h1….. h_{Nt} can be explained as the columns of H, each demonstrates 1×Nr channel directions, and xi[m] is the data flow which we pass on to the i^{th} antenna. Taking the values of k^{th} parallel stream of data, we can update the equation as given below:

$$y[m] = h_k x_k[m] + \sum_{t^1 k}^{Nt} h_i x_i[m] + w$$

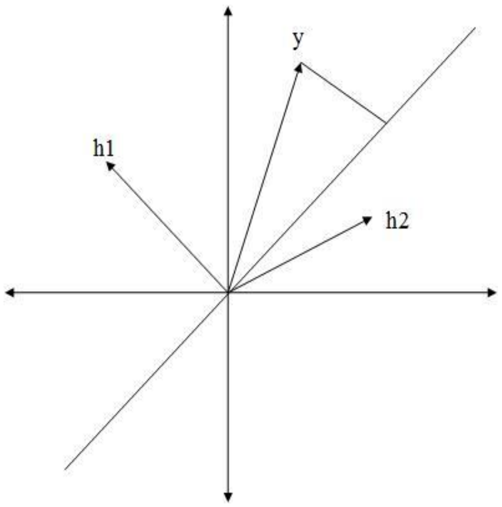

Fig -6: A projection method is being used: y is projected over the subspace which is orthogonal to h1 to demodulate data stream 2

Here we can observe that the data with k^{th} tag suffers interference with other parallel stream of data. To avoid this interference among the data streams, we use countless distinct interpretations within the data streams. We have to use the received data stream 'Y' over the area which is equilateral to the vectors h1……h_{k-1}; h_{k+1}……… h_{Nt} (denoted by V_k). Supposing that the dimension of V_k is d_k.

Protrusion is a continuous procedure and we can mean it by a $d_k \times N_r$ matrix Q_k. The rows of Q_k form an equilateral grounds of Vk, they are complete rectangular to h1………. H_{k-1}; h_{k+1}………. h_{Nt} . The direction Q_{kv} depends on the further extension or updating of V over V_k, but these dependence and extensions are represented in terms of coordinated which is completely related to V_k. We have used a figure to describe the following operation (Figure 6).

If h_k is a continuous sequence of h_1………h_{k-1} and h_{k+1}…… h_{Nt}, the deriving extension of h_k is a vector having zero magnitude. In alternative we have found out that, if there are higher stream of data than the magnitude of the pulse we received (i.e., $N_t > N_r$), then the zeroing application cannot work and cannot be fortunate, even if the rank H is entirely completed. So finally in this case we have to choose such a stream of data which is much higher than N_r. So the only approach we can use is, the use of subsets which we need along the transmitting end of the system. In our further explanation about zero forcing detector, we will assume that Nt should be less than or equal to Nr. Till now we have eliminated the inter symbol interference, so further we will do the projection operation which can be explained by the equation given below:

$$y'[m] = Q_k y[m] = Q_k h_k x_k[m] + w'[m]$$

5. ZERO FORCING DETECTOR WORKING MODEL

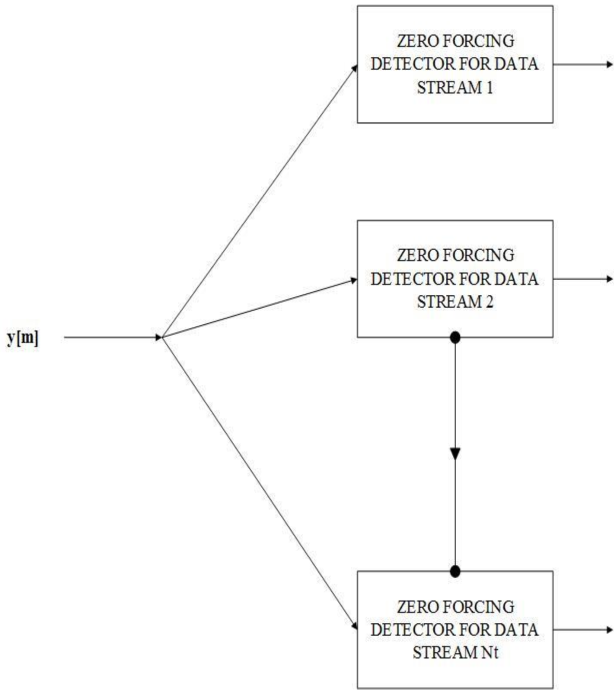

Fig -7: The figure shows a collection of Zero Forcing detectors, each Zero Forcing detector is occupied for each data stream which analyses and computes the data

Straightaway, the inter-stream intervention zeroing is outstanding. Subsequently the projection application is given by the equation which have been explained above:

$$y'[m] = Q_k y[m] = Q_k h_k x_k[m] + w'[m]$$

Where we can explain that w' $[m]$ =Q_kw$[m]$ is a white noise which is introduced after we did the projection operation. We have used matched filter operation to demodulate the k^{th} stream, after matched filtering $Q_k h_k$, the output has SNR

$$P_k \left\| Q_k h_k \right\|^2 / N_0$$

Where P_k is the capability designated to stream k. After the projection operation is being done, we call matched filter as receiver part of Zero Forcing and that is also named as either zeroing of interference or it can be defined as de-correlation. The zeroing of interference is also defined as filter with continuous nature because more than one operation can be done simultaneously that is projection operation and matched filtering operation. Now we take a projection which is h_k over the subspace we name it as v_k, so we can now consider a filter as c^*_k. The equation is given by:

$$c_k^* = (Q_k h_k)^* Q_k$$

6. ZERO FORCING RECEIVER WORKING MODEL

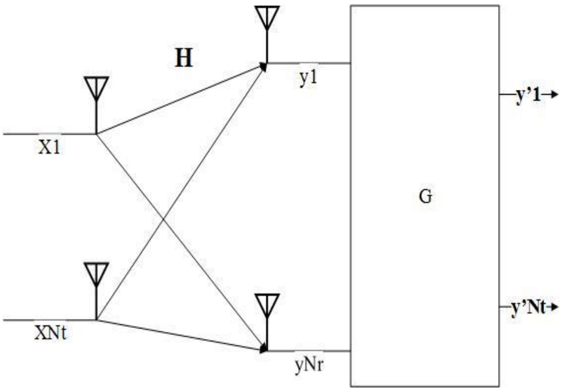

Fig -8: Zero forcing receiver

Here we are using matched filter which decreases the signal to noise ratio in the system, so if we need to improve the signal to noise ratio we use detector part of Zero forcing system which is also linear in nature, but here we face one problem that the filter which we are using zeros out all the constant values from the parallel stream of data. In the previous steps we derived the equations and expressions which depends on k^{th} data stream but now since we are using Zero Forcing detector, we can de-correlate each of the parallel data stream separately as explained in figure 4. Representation of each Zero Forcing detector individually makes the system complex, so we use a kind of representation that applies for a group of Zero Forcing detectors which makes our calculations easy. The Zero forcing detector that we have calculated and derived the matrix for k^{th} data stream is what we describe it as k^{th} column of the pseudo-inverse H*y* of the matrix H which is defined by the channel, is given by:

$$H' = (H * H)^{-1} H *$$

Figure 8 represents a receiver part of Zero Forcing structure in the VBLAST system and we can conclude that matrix G is equal to matrix H*y*. Finally we get the output of zero forcing receiver after applying different mathematical model and derivations. The output expression is given by: $y' = [y'_1 \ldots\ldots y'_{Nt}]^T$ .The white noise subsequent protrusion is $w' = [w'_1 \ldots\ldots w'_{Nt}]$. Thus $y'_1 = x_1 + w'_1$ -------- $y'_{Nt} = x_{Nt} + w'_{Nt}$

Here we do nulling operation in Zero Forcing receiver which effectively simplifies the complex system Nt×Nr to a single input output system which we call it as SISO system (single input single output). In Figure 9 below we developed a channel pattern into a crosswise matrix form. The matrix is represented as Additive White Gaussian Noise (AWGN)

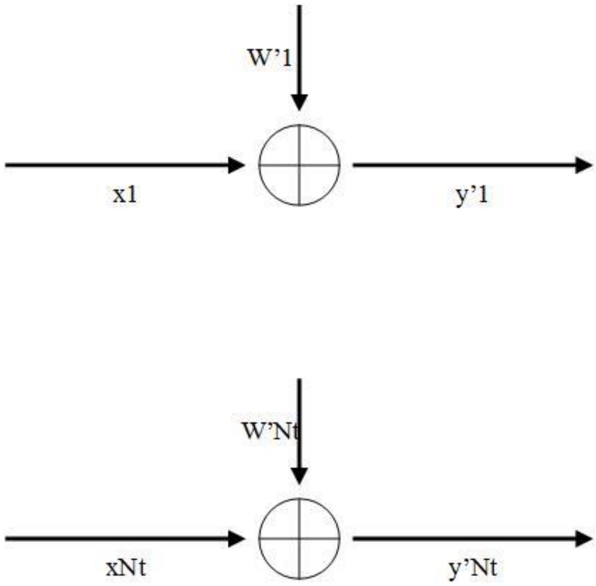

Fig -9: Nt AWGN channels after Zero Forcing nulling operation is being done

7. RESULTS AND SIMULATION

A system has been made using Single Input Single Output (SISO) that is 1×1 and Multiple Input Multiple Output (MIMO) that is 2×2, 3×3, 4×4 till 10×10 to compare the Bit Error Rate (BER) values between these two working systems. Here VBLAST coding algorithm is used to calculate the BER. The basic formula used in VBLAST-STBC is given by

$$Y = HX + N$$

Where Y is represented as receiver matrix that is it contains the elements which are finally evaluated after VBLAST operation, H is the matrix which represents the components of channel, X is the input matrix that is the number of elements in transmitter side and N is the noise matrix associated with each transmitting signal

For making it easier to understand we separated the system showing Bit Error Rate Performance with SISO and odd number of Multiple Input and Multiple Output (MIMO) antennas and another system with only even number of Multiple Input Multiple Output (MIMO) antenna in both transmitter as well as receiver.

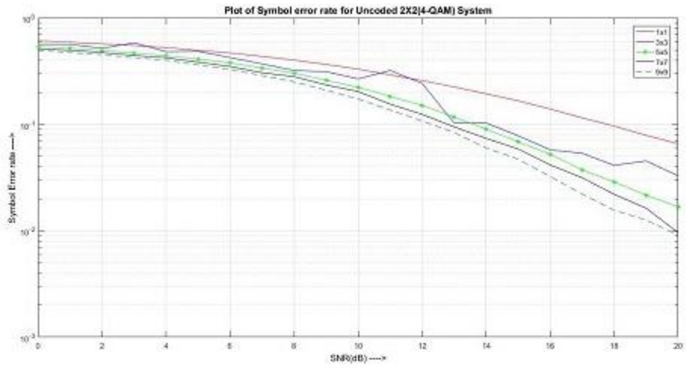

Fig -10: Bit Error Rate (BER) performance plot for 1×1 that is Single Input Single Output (SISO), and odd number of MIMO antennas that is 3×3, 5×5, 7×7 and 9×9 (X-axis SNR in dB and Y-axis Symbol Error Rate)

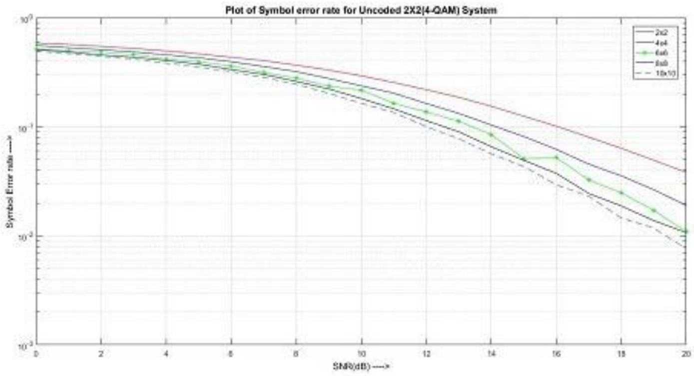

Fig -11: Bit Error Rate (BER) performance plot for even number of MIMO antennas that is 2×2, 4×4, 6×6 8×8 and 10×10 (X-axis SNR in dB and Y-axis Symbol Error Rate)

Combining these two plots we can finally compare the Bit Error Rate (BER) results of Single Input Single Output (SISO) with all other antenna configurations like 2×2, 3×3, 4×4, 5×5, 6×6, 7×7, 8×8, 9×9 and 10×10

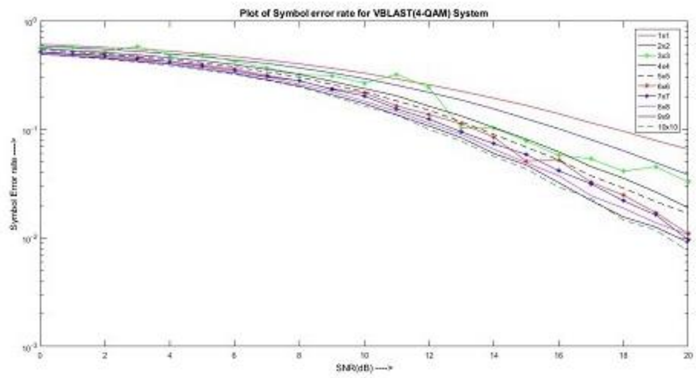

Fig -12: Bit Error Rate (BER) performance plot for Single Input Single Output (SISO) that is 1×1 and Multiple Input Multiple Output (MIMO) antennas that is 2×2, 3×3, 4×4, 5×5, 6×6, 7×7, 8×8, 9×9 and 10×10 (X-axis SNR in dB and Y-axis Symbol Error Rate)

8. CONCLUSION

A set of different Bit Error Rate values was found out using Single Input Single Output (SISO) and Multiple Input and Multiple Output (MIMO) antenna systems. We compared the results and concluded that MIMO system has low Bit Error Rate (BER) than SISO system. If the Bit Error Rate is low, then capacity to transmit data over the channel will increase and hence more efficient transmission can be done. Here in this system 10×10 antenna configuration has the lowest bit error rate. Also separate working models was made by deriving the corresponding projection equations for VBLAST and Zero Forcing (ZF) detector

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