Performance Analysis of V-BLAST Detection Techniques For MIMO Technology

Prof. Shreedhar. A. Joshi [1] ,Ms Anusha J[2], Ms Bhagyalaxmi R H[3],Ms Seema Bhat[4]

[1]Assistant Professor, Department of Electronics, S.D.M College of Engineering and TechnologyDharwad.India.

[2,3,4]Final year students, Department of Electronics, S.D.M College of Engineering and Technology, Dharwad.India.

shreedhar.j@rediffmail.com[1],sai.anu.07@gmail.com[2],bhagya19rh@gmail.com[3],seems091190@gmail.com[4]

Abstract— **The employment of multiple antennas at both transmitter and receiver is referred to as MIMO (Multiple Input Multiple Output) system. The V-BLAST (Vertically - layered Bell Laboratories Layered Space-Time) algorithm is a multilayer symbol detection scheme in rich scattering wireless communication channel. The V-BLAST technique is applied to MIMO (Multiple Input Multiple output) technology. Using various techniques like Zero forcing (ZF), Minimum Mean Square Error (MMSE), Maximum Likelihood (ML), with back substitution methods SIC (Symbol Interference Cancellation) and PIC (Parallel Interference Cancellation) the detection is performed and analysed in this proposed work. The modulation methods adopted are BPSK, QPSK and QAM. The numerical analysis is conducted using MATLAB**.

Keywords—**Minimum Mean Square Error (MMSE), Maximum Likely hood (ML), Zero Forcing (ZF), Bit Error Rates (BER).**

I. INTRODUCTION

The multiple antenna system provides very promising gain in capacity without increasing the use of spectrum, reliability, throughput, power consumption and less sensitivity to fading. They have given a linear increase in system capacity and spectral efficiency with respect to the number of transmit antennas as long as the number of receive antennas is greater or equal to the number of transmit antennas[1],[2]. There are many schemes that can be applied to MIMO systems such as space time block codes, space time trellis codes, and the Vertical Bell Labs Space-Time Architecture (V-BLAST).In BLAST (Bell Labs' Layered Space Time) systems, very high spectral efficiency *can* be achieved by employing antenna arrays at both transmit and receive sides[3]. The V-BLAST receiver uses a spatial domain decision feedback equalizer. In the V-BLAST process each symbol is decoded and then fed back to cancel its interference with other symbols. This process repeats until all the symbols are decoded. The benefits are achievable without increasing the transmission bandwidth or power. Based on BER, performance of various receiver schemes indicates that the ordered SIC detector with ML detection most effectively balances the accuracy of symbol detection. the performance of SIC depends on the order in which the data sub-streams are detected[4]. V-BLAST detectors are efficient both in terms of capacity and diversity. Due to decision feedback structure, the V-BLAST system with MIMO technology yields a very good spectral efficiency in a rich scattering environment, without increasing the transmission bandwidth or power.

II. THE SYSTEM MODEL

One of the earliest communication systems that were proposed to take advantage of the promising capacity of MIMO channels is the BLAST architecture. It achieves high spectral efficiencies by spatially multiplexing coded or uncoded symbols over the MIMO fading channel. From the Fig.1as shown , the Symbols are transmitted through M antennas. Each receiver antenna receives a superposition of faded symbols. The ML decoder would select the set of symbols that are closest in Euclidean distance to the received N signals.

The signal arriving at the receiver is

$$y = Hx + v \qquad (1)$$

Where $y = [y_1 \ y_2 \cdots y \ Nr \ ]^T$ received symbol ,H is channel matrix, $x = [x_1 \ x_2 \cdots xNt \ ]^T$ transmitted symbol, and $v = [v_1, v_2 \cdots vNr \ ]^T$ AWGN[5].
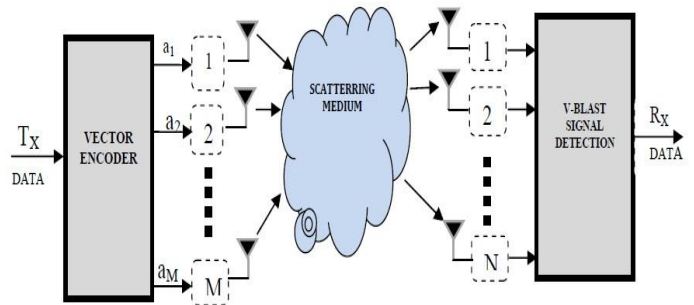

Figure 1. The V-BLAST MIMO Channel Model.

The VBLAST detection technique considers the transmission is of data as follows. Initially data stream is de-multiplexed into M sub-streams termed layers. On the other hand, the layers are arranged horizontally across space and time for V-BLAST and the cycling operation is removed before transmission. At the receiver, the received signals at each receiving antennas is a superposition of M faded symbols plus additive white Gaussian noise (AWGN) .Although the layers

are arranged differently for process for both systems is performed vertically for each received vector. Without loss of generality, assume that the first symbol is to be detected.

III. DIFFERENT RECEIVER DETECTION TECHNIQUES

The V-BLAST detection technique adopted for MIMO are classified as Linear and Non Linear detection schemes. Under Linear technique we have MMSE and ZF. Where as in Non linear we have ML. They are described as follows:

A. Maximum Likelihood (ML): ML, Non Linear detection that compares the received signals with all possible transmitted signal vectors.This is modified by channel matrix H and estimates transmit symbol vector 'x' according to the Maximum Likelihood Principle. The main drawback of ML detector is that, it becomes prohibitively complex because of its complexity which increases exponentially with the transmitter antenna number and the modulation order[6].

$$x_{new} = \arg_{xk \in \{x1, x2...xn\}} \min \|p - Hx_k\|^2 \qquad (2)$$

Where p is the received symbol, x_k is the transmitted symbol at the kth iteration.

B. Zero Forcing (ZF): By employing linear detection technique, at the receiver front-ends to separate the transmitted data streams, and then independently decode each of the streams. Simple linear receiver with low computational complexity and suffers from noise enhancement. It works best with high SNR.

$$x_{new} = ((H^TH)^{-1}H) * x \qquad (3)$$

Where H^T is the transpose of channel matrix H.

*C. Minimum Mean Square Error (MMSE):*The MMSE receiver suppresses both the interference and noise components. This implies that the mean square error between the transmitted symbols and the estimate of the receiver is minimized. The important feature of MMSE detectors are that, they are superior compared to ZF. At Low SNR, MMSE becomes matched filter. Also at high SNR, MMSE becomes Zero-Forcing.

$$x_{new} = D.x = ((1/SNR)I_{Nr} + H^HH))^{-1}.H^Hx \qquad (4)$$

Where D is a channel variable as a function of I_{Nr}. Here I_{Nr} is the information of the symbol 'x' received at the Nth iteration and H^H is the projection of channel matrix H.

D. QR Decomposition: Given a matrix A, its QR decomposition is a matrix decomposition of the form

$$A = Q R \qquad (5)$$

Where R is an upper triangular matrix and R is an orthogonal matrix, i.e., one satisfying

$$Q^T.Q = I \qquad (6)$$

Where Q^T is the transpose of Q and I is the identity matrix.

In V-BLAST, the number of Transmit Antennas should be less than number of receive antennas. The symbols can be transmitted with coding or without coding i.e., modulation. The detection process consists of two main operations:

a). Interference Suppression (Nulling): The suppression operation nulls out interference by projecting the received vector onto the null subspace (perpendicular subspace) of the subspace spanned by the interfering signals. After that, normal detection of the first symbol is performed [7].

b). Interference cancellation (subtraction):

*For SIC:*The contribution of the detected symbol is subtracted from the received vector.

For PIC: This detection process is to retrieve simultaneously after equalization all the interfering symbols based on previous estimations [8].

IV. WORKING ALGORITHMS

The working procedures for V-BLAST detection algorithm for MMSE, ML, ZF and QR with SIC adopting BPSK, QPSK and 16-QAM as follows.
1. Start
2. With the values of SNR (dB), Bandwidth, Number of transmit and receive antennas, Generate channel matrix H.
3. By adding Rayleigh fading conditions, generate output signal vector y.
4. Choosing best signal G and taking (pseudo) inverse of channel matrix H, compute y as y= G * r, where r is nulling rate.
5. Generate data streams as subset [A, a].
6. Generate (pseudo) inverse of channel matrix H, G= inv (HH#).
7. a).For ZF: Assuming ki as zeroing columns, wi as min-norm vector and S as signal vector, compute [wiki ki] = min norm (G, S);
7. b). For MMSE: The nulling weights are:
    w=inv (HH^T *HH+ (1/SNR)*eye (M))*HH^T).
8. Compute y = wiki * r (For ZF) and y=w * r for MMSE.
9. Compute for SIC as received = received – xtemp (ki) – H. Where 'xtemp' as per equations mentioned in (2), (3), (4) respectively.
10. Determine BER from number of iterations.
11. Stop.

Similarly the working procedures for V-BLAST detection algorithm for MMSE, ML, ZF and QR with PIC adopting BPSK, QPSK and 16-QAM as follows:
1). Start
2). Repeat the steps 2 to 6 as above.
3).Without using min-norm function we directly compute xtemp as xtemp=(y>=0)-(y<0)+0.

4). Determine BER from number of iterations.

5). Stop.

V. RESULTS AND DISCUSSIONS

The simulation results for a V-BLAST MIMO system are as shown. The simulations are done for a Rayleigh fading channel using BPSK, QPSK and QAM symbol mapping methods. From the comparison plot shown in Figure 2, we observe the performance of BER with SNR; ML gives lower Bit Error Rate at higher SNR value and thus proving to be the most efficient detection technique for the received symbols. From Figure 3 and Figure 4, we compare MMSE with SIC-PIC and ZF with SIC and PIC respectively and infer that MMSE–SIC and ZF-SIC are better techniques than the PIC. From Figure 5 we conclude that ZF with 16 bit QAM gives better performance than MMSE.
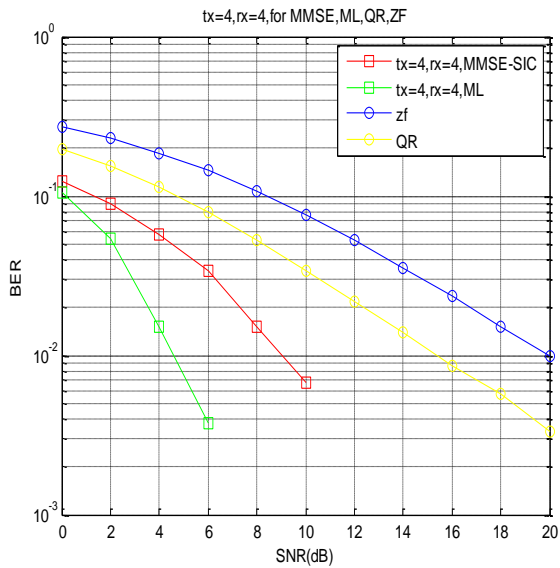

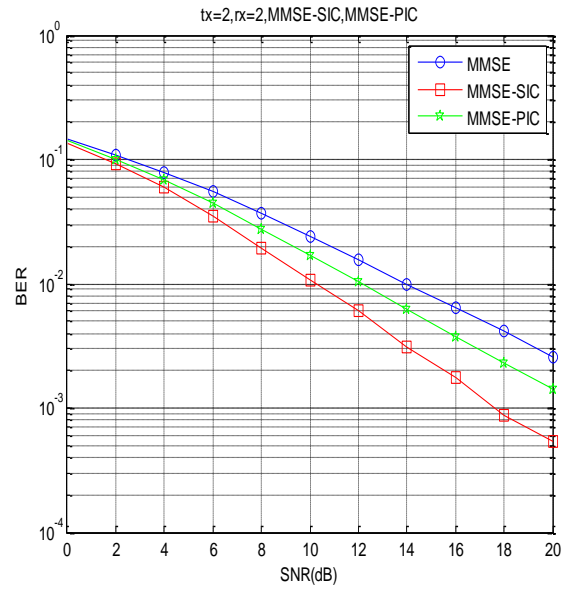Figure 2: V-Blast technique with ML, MMSE-SIC with QPSK. and ZF,QR with BPSK

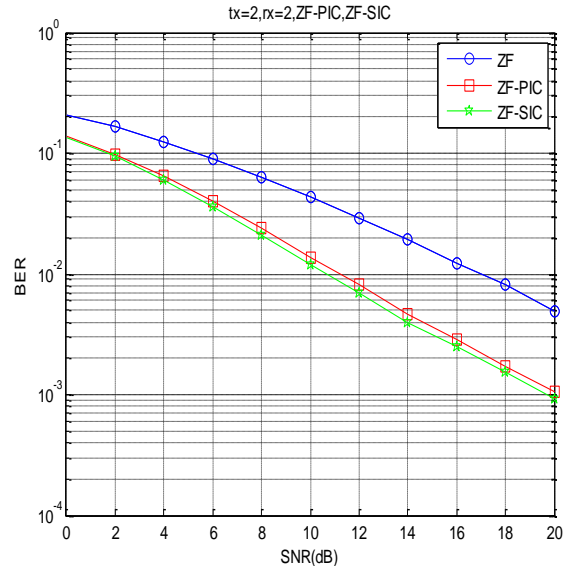Figure 3: V-Blast technique with MMSE,MMSE-SIC,MMSE-PIC with BPSK

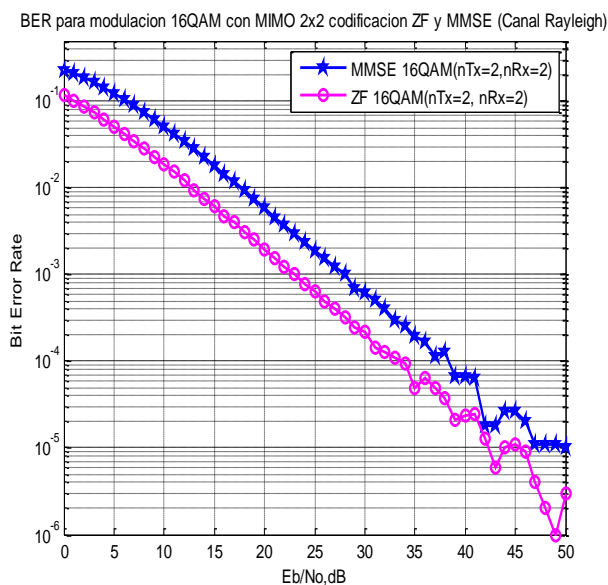Figure 4: V-Blast technique with ZF,ZF-PIC,ZF-SIC with BPSK

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Figure 5: V-Blast technique with MMSE & ZF with 16-bit QAM

VI. CONCLUSION

In this paper, we provide a general multiple antenna system (MIMO) with the V- BLAST technique using several detectors (MMSE, ML, ZF and QR). We conclude that the performance is limited by error propagation. A comparative study of various linear and non linear detectors is made by comparing their outputs with reference to the plots of BER and their corresponding SNR. We show the benefits of ordering strategy over SIC and PIC cancellation methods.

MIMO is an important technology for enabling the wireless industry to deliver a vast potential and promise of wireless broadband. However, the drawback of BLAST algorithms is the propagation of decision errors. Furthermore, due to the interference suppression, early detected symbols at the receiver benefit from lower diversity than later ones. Thus, the algorithm results in unequal diversity advantage for each symbol.

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