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Comparison of Different Modulation Techniques Using V-Blast Mimo System in Rayleigh Channel

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Abstract:- Multiple Input Multiple Output (MIMO) systems have been extensively studied in context of wireless communication system, which promising the both increased capacity and link level reliability. In this paper we will present an analysis of the Vertical Bell Laboratories Layered Space-Time (V-BLAST) system at high signal-to noise ratio (SNR) region using BPSK, QPSK and 16-QAM modulation technique by using various decoding techniques. We will consider a point-to-point MIMO communications over an independent, identically distributed (i.i.d) Rayleigh flat fading channel with 'N' transmitting antennas and 'M' (M≥N) receiving antennas. We will analyze the zero-forcing V-BLAST (ZF-V-BLAST), minimum mean-squared-error (MMSE-V-BLAST), zero-forcing + Ordered Serial Interference Cancellation V-BLAST (ZF+OSIC V-BLAST), minimum mean-squared-error + Ordered Serial Interference Cancellation V-BLAST (MMSE+OSIC V-BLAST) and Maximum Likelihood V-BLAST (ML-V-BLAST) decoding techniques with respect to their BER performances. V-BLAST system is compared with different modulation technique and system gets better result in BPSK modulation. Finally we will conclude that ML-VBLAST decoding technique gives the better performance than other decoding techniques using BPSK modulation. Further simulation results for BPSK modulation with only ML decoding technique using various antennas at input and output. In this we got more optimal result for 4 x 4 antennas for V-BLAST system.

Keywords:- Multiple input multiple output (MIMO), Vertical Bell Laboratories Layered Space-Time (V-BLAST), zero-forcing V-BLAST (ZF--BLAST), minimum mean-squared-error (MMSE-V-BLAST), Maximum Likelihood (ML) Ordered Serial Interference Cancellation (OSIC).

I. INTRODUCTION

Wireless communication system with multi-antenna arrays has been a field of intensive research on the last years. The use of multiple antennas at both the transmitter and the receiver sides can drastically improve the channel capacity and data rate. The study of the performance limits of MIMO system [1] becomes very important since it will give lot ideas in understanding and designing the practical MIMO systems [1]. 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 system (V-BLAST). In this paper, we study the general V-BLAST system with Maximum Likelihood (ML), Zero Forcing (ZF) and Minimum Mean Squared Error (MMSE) detectors in fading channels by using various modulation techniques such as BPSK, QPSK and 16-QAM.

Space Time Layered Architecture offers a big increase in capacity and data rate, promising a linear growth with the size of antenna array under some circumstances [3]. First Bell Laboratories Layered Space-Time Architecture now widely known as D-BLAST [2] is one of the approaches to increase the data rate and capacity of the system. D-BLAST has a computational complexity.

To mitigate the computational complexity of D-BLAST [2], we will use a simplified version of BLAST known as Vertical-Bell Laboratories Layered Space-Time (V-BLAST) [3]. In V-BLAST at the transmitter de-multiplexes the input data streams into 'n' independent sub-streams, which are transmitted in parallel over the 'n' transmitting antennas. At the receiver end, antennas receive the sub-streams, which are mixed and superimposed by noise. Detection of sub-streams at receiver of V-BLAST [2] is done by applying Order determination, Sequential interference nulling and Signal Cancellation [3]. Although V-BLAST is known equivalent to a Decision Feedback Equalizer (DFE) [9] and is optimal in terms of achieving the channel capacity [4]. In an i.i.d Rayleigh Flat fading channel with 'N' transmitting antennas and 'M' receiving antennas (M≥N), the first detected sub-stream has a diversity gain of only M-N+1.The first sub stream is the bottleneck which limits the overall performance of the scheme. One can apply the optimal ordering technique to mitigate this bottleneck effect [3]. At each detection step the receiver should detect the data sub-stream with the largest post processing Signal to Noise Ratio (SNR). However, it is shown in [5] optimal ordering does not improve the diversity gain when there are two transmitting antennas (N=2) but diversity gain remains unknown if we applying optimal ordering and help to improve in general cases [6].

II. MIMO SYSTEM MODEL

We consider single user MIMO communication system [2] with 2 antennas at the transmitter and 2 antennas at the receiver. Consider that we have a transmission sequence is $\{x_1, x_2, \ldots\ldots\ldots, x_n\}$. In normal transmission, we send x_1 in the first time slot, x_2 in the second time slot and x_n in the n^{th} time slot. Now we have two transmit antennas, we may groups the symbols into groups of two. In the first time slot, send x_1 and x_2 from the first and second antenna. In the second time slot, send x_3 and x_4 from the first and second antenna and in next time slot x_5 and x_6 and so on. Let us consider for 2 x 2 MIMO System

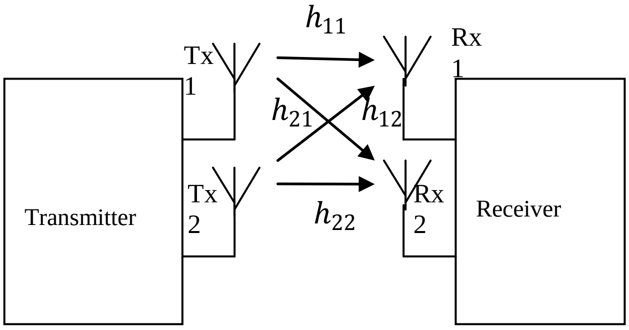

Fig.1. 2 x 2 MIMO system model

The received signal on the first receive antenna is

$$\mathrm{r}_1 = \mathrm{h}_{11}\mathrm{s}_1 + \mathrm{h}_{12}\mathrm{s}_2 + \mathrm{n}_1 \tag{1}$$

The received signal on the second receive antenna is

$$\mathrm{r}_2 = \mathrm{h}_{21}\mathrm{s}_1 + \mathrm{h}_{22}\mathrm{s}_2 + \mathrm{n}_2 \tag{2}$$

where, y_1 *and* y_2 are the received symbol on the first and second antenna respectively, h_{11} is the channel from 1^{st} transmit antenna to 1^{st} receive antenna, h_{12} is the channel from 2^{nd} transmit antenna to 2^{nd} receive antenna, h_{21} is the channel from 1^{st} transmit antenna to 2^{nd} receive antenna, h_{22} is the channel from 2^{nd} transmit antenna to 2^{nd} receive antenna, $s_1 and\ s_2$ are the transmitted symbols and $n_1 and\ n_2$ is the noise on $1^{st}\ and\ 2^{nd}$ receive antennas respectively.

Eq^n (1) and Eq^n (2) can be represented in matrix form

$$\begin{bmatrix}\mathrm{y}_1\\ \mathrm{y}_2\end{bmatrix} = \begin{bmatrix}\mathrm{h}_{11} & \mathrm{h}_{12}\\ \mathrm{h}_{21} & \mathrm{h}_{22}\end{bmatrix}\begin{bmatrix}\mathrm{s}_1\\ \mathrm{s}_2\end{bmatrix} + \begin{bmatrix}\mathrm{n}_1\\ \mathrm{n}_2\end{bmatrix} \tag{3}$$

The sampled baseband representation of signal is given by

$$\mathrm{y} = \mathrm{Hx} + \mathrm{n} \tag{4}$$

And the complex baseband representation of signal [15] is given by

$$y = \sqrt{\frac{P}{M}}Hx + n \tag{5}$$

where $y \in C^{N\times1}$ is the received signal vector, $x \in C^{M\times1}$ is the transmitted signal vector with zero mean and unit variance, P is the total transmit power, $H \in C^{N\times M}$ is the channel response matrix with possibly correlated fading coefficients. In order to access the performance of V-BLAST in correlated channel, we adopted a correlation-based channel model which is expressed as

$$H{\sim}R_{Rx}^{\frac{1}{2}}H_w\left(R_{Tx}^{1\backslash2}\right)^T \tag{6}$$

where x ~ y denotes that x and y are identical in distribution, R_{Rx} and T_{Tx} are the normal correlation distribution matrices at the Rx and transmitter (Tx) respectively, and $H_W \in C^{N\times M}$ contains i.i.d complex Gaussian entries with zero mean and unit variance.

For a system with M_T transmit antennas and M_R receive antennas, the MIMO channel at a given time instant may be represented as a $M_R \times M_T$ matrix

$$\mathrm{H} = \begin{bmatrix}\mathrm{H}_{1,1} & \mathrm{H}_{1,2} & \cdots & \mathrm{H}_{1,\mathrm{M_T}}\\ \mathrm{H}_{2,1} & \mathrm{H}_{2,2} & \ldots & \mathrm{H}_{2,\mathrm{M_T}}\\ \vdots & \vdots & \ddots & \vdots\\ \mathrm{H}_{\mathrm{M_R},1} & \mathrm{H}_{\mathrm{M_R},2} & \cdots & \mathrm{H}_{\mathrm{M_R},\mathrm{M_T}}\end{bmatrix} \tag{7}$$

III. SYSTEM MODEL OF V-BLAST SYSTEM

The V-BLAST system [3] is simplified version of D-BLAST [5] that tries to reduce its computational complexity. But in doing so transmit diversity is loss. A high-level block diagram of a V-BLAST system is shown in Fig.1

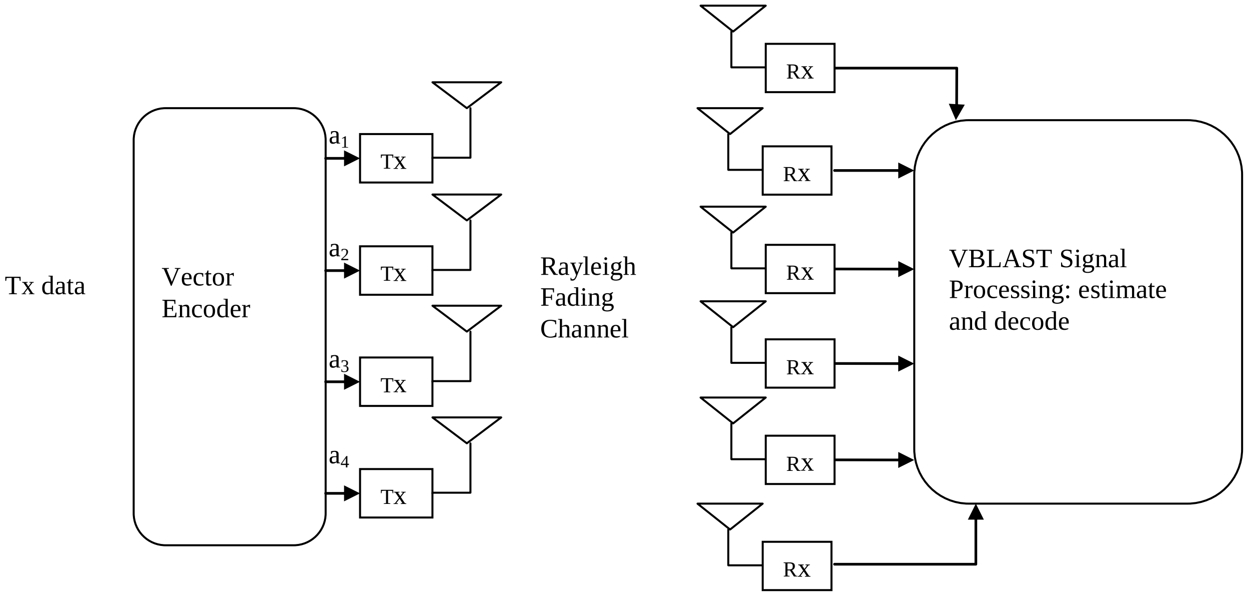

Fig.2 V-BLAST MIMO System Model

3.1 Encoder

A single data stream is de-multiplexed into m sub-streams, and each sub-stream is then encoded into symbols and fed to its respective transmitter. Transmitters 1-m operate co-channel at symbol rate 1/T symbols/sec, with synchronized symbol timing. The power launched by each transmitter is proportional to 1/m so that the total radiated power is constant and independent of 'm'. At a certain symbol instant, the output of the transmission antenna array is a vector [11]

$$a = [a_1, a_2, a_3 \ldots\ldots a_m]^T \tag{8}$$

3.2 Decoder

The decoder needs to demodulate the symbols on the received vector. If channel encoding is used, then the demodulated symbols need to be buffered until the whole block can be decoded. Otherwise, the demodulation can be done immediately. Several decoders are possible for this architecture and these decoders are explained bellow one by one.

IV. DECODING ALGORITHM FOR V-BLAST SYSTEM

One approach to a lower complexity design of the receiver is to use a "divide-and-conquer" strategy instead of decoding all symbols jointly. First, the algorithm decodes the strongest symbol. Then, canceling the effects of this strongest symbol from all received signals, the algorithm detects the next strongest symbol. The algorithm continues by canceling the effects of the detected symbol and the decoding of the next strongest symbol until all symbols are detected. The optimal detection order is from the strongest symbol to the weakest one. This is the original decoding algorithm [9] of V-BLAST preset. It only works if the number of receive antennas is more than the number of transmit antennas, that is M x N. Decoding Algorithm of V-BLAST is shown in Figure.3

The algorithm includes three steps:

- ordering;
- interference cancellation;
- Interference nulling.

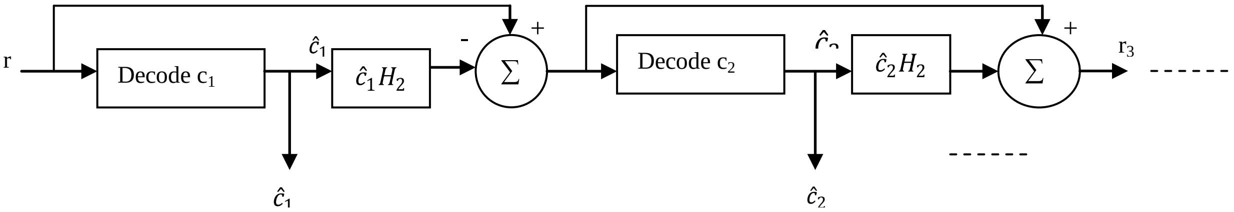

Fig.3 VBLAST Decoder block diagram

3.3 Optimal Ordering

One approach to a lower complexity design of the receiver is to use a “divide-and-conquer” strategy instead of decoding all symbols jointly. First, the algorithm decodes the strongest symbol. Then, canceling the effects of this strongest symbol from all received signals, the algorithm detects the next strongest symbol [12]. The algorithm continues by canceling the effects of the detected symbol and the decoding of the next strongest symbol until all symbols are detected. The optimal detection order is from the strongest symbol to the weakest one. This is the original decoding algorithm of V-BLAST preset [3]. It only works if the number of receive antennas is more than the number of transmit antennas, that is M ≥ N.

In decoding the first symbol, the interference from all other symbols is considered as noise. After finding the best candidate for the first symbol, the effects of this symbol in all of the receiver equations are canceled. Then, the second symbol is detected from the new sets of equations. The effects of the second detected symbol are canceled next to derive a new set of equations. The process continues until all symbols are detected. Of course, the order in which the symbols are detected will impact the final solution.

3.4 Interference Cancellation

At stage n of the algorithm, when c_n is being detected, symbols $c_1, c_2, \ldots, c_{n-1}$ have been already detected. Let us assume a perfect decoder, that is the decoded symbols $\widehat{c_1}, \widehat{c_2}, \ldots\ldots, \hat{c}_{n-1}$ are the same as the transmitted symbols $c_1, c_2, \ldots, c_{n-1}$.

One can subtract $\sum_{i=1}^{n-1} c_i H_i$ from the received vector r to derive an equation that relates remaining undetected symbols to the received vector:

$$r_n = r - \sum_{i=1}^{n-1} c_i H_i + N, \tag{9}$$

$$r_n = \sum_{i=n}^{N} c_i H_i + N, \qquad n = 1,2 \ldots. N-1 \tag{10}$$

In fact, by using induction in addition to the convention $r_1 = r$,one can show that

$$r_{n+1} = r_n - c_n H_n, \qquad n = 1,2,3 \ldots.. N-1 \tag{11}$$

Therefore, at the n^{th} stage of the algorithm after detecting the nth symbol as $\hat{c}_n$, its effect is canceled from the equations by

$$r_{n+1} = r_n + \hat{c}_n H_n \tag{12}$$

This interference cancelation is conceptually similar to DFE [9].

3.5 Interference nulling

Interference nulling is the process of detecting c_n from r_n by first removing the effects of undetected symbols. Basically, in this step the nth symbol is detected by nulling the interference caused by symbols $c_{n+1}, c_{n+2}, \ldots, c_N$. Like any other interference suppression problem, there are many different methods to detect a symbol in the presence of interference [8]

3.5.1 Zero Forcing Interference Nulling

Using zero-forcing [15] for interference nulling is common in practice. First, let us assume perfect detection of symbols as in eq^n (12) We would like to separate the term $c_n H_n$ from r_n.This can be done through multiplying r_n by an M × 1 vector W_n that is orthogonal to interference vectors $H_{n+1}, H_{n+2}, \ldots. H_N$ but not orthogonal to H_n .In other words, W_n should be such that

$$H_i . W_n = 0, \qquad i = n+1, n+2 \ldots\ldots. N \tag{13}$$

$$H_n . W_n = 1 \tag{14}$$

W_n= Zero-Forcing Nulling vector with minimum norm.

Such a vector is uniquely calculated from the channel matrix H. To calculate W_n from H, for M ≥ N first we should replace the rows 1, 2...., n − 1of H by zero.

Let us denote the resulting matrix by Z. Then, W_n is the nth column of Z^+ the Moore–Penrose generalized inverse [13], pseudo-inverse, of Z [10]

Using the error-free detection formula for r^n in (12) and w^n in (14), we have

$$r_n W_n = c_n + N W_n \tag{15}$$

The noise in (15) is still Gaussian and the symbol c_n can be easily decoded. The decoded symbol $\hat{c}_n$ is the closest constellation point to $r_n . W_n$. The noise enhancing factor is

$$E[(N.W_n)^H . N.W_n] = W_n^H . E[N^H . N] W_n \tag{16}$$

$$= N_0 \| W_n \|^2 \tag{17}$$

We know that zero forcing is given by

$$W_{ZF} = (H^* H) H \tag{18}$$

Comparing (17) with (18) demonstrates why adding an interference cancelation step improves the performance. Using the combination of canceling and nulling in a ZF-DFE [8] structure enhances the noise by a factor of $||Wn||^2$. Vector W_n is orthogonal to N − n rows of the channel matrix H. On the other hand, using a pure interference nulling method like ZF, the corresponding vector that detects the nth symbol, the n^{th} column of the pseudo-inverse, is orthogonal to N − 1 rows of the channel matrix H. Using the Cauchy–Schwartz inequality [10], it can be shown that the norm of a vector is larger if it has to be orthogonal to a greater number of rows. Therefore, the enhancing factor for the case of nulling alone, ZF, is more than that of the canceling and nulling, ZF-DFE [9]

3.5.2 MMSE-Interference Nulling

Another approach for interference nulling is MMSE [7]. Let us assume that the trans-mitted vector is a zero-mean random vector that is uncorrelated to the noise. Considering the received vector r in (19) as a noisy observation of the input C, the linear least-mean-squares estimator of C is

$$M = H^{H}.\left(\frac{I^{N}}{\gamma} + H.H^{H}\right)^{-1} \tag{19}$$

Note that in the nth stage of the algorithm, the effects of $c_1, c_2, \dots, c_{n-1}$ have been canceled. Therefore, similar to the ZF nulling, to calculate c_n , first we should replace the rows $1, 2, \dots, n\ - 1$ of H by zero. Let us denote the resulting matrix by Z as we did in the ZF case. Now, to find the best estimate of the nth symbol, that is $\hat{c}_n$, we replace H with Z in (20) to calculate the best linear MMSE estimator at stage n as

$$M = Z^{H}.\left(\frac{I^{N}}{\gamma} + Z.Z^{H}\right)^{-1} \tag{20}$$

Then, the nth column of M, denoted by M_n is utilized as the MMSE nulling vector for the n^{th} symbol. In other words, the decoded symbol $\hat{c}_n$ is the closest constellation point to $r_n.M_n$

V. V-BLAST SYSTEM DECODERS

3.6 Maximum Likelihood Decoder

The ML receiver [7] performs optimum vector decoding and is optimal in the sense of minimizing the error probability. ML receiver is a method that compares the received signals with all possible transmitted signal vectors which is modified by channel matrix H and estimates transmit symbol vector $\hat{\mathrm{C}}$ according to the Maximum Likelihood principle, which is shown as:

$$\hat{\mathrm{C}} = \underset{\hat{\mathrm{C}}}{\operatorname{argmin}} \llbracket \mathrm{r} - \mathrm{C}'\mathrm{H} \rrbracket_{\mathrm{F}}^{2} \tag{21}$$

where $_{\mathrm{F}}$ is the Frobenius norm. Expanding the cost function using Frobenius norm given by

$$\hat{\mathrm{C}}\ = \underset{\hat{\mathrm{C}}}{\operatorname{argmin}} \left[\mathrm{Tr}\left[\left(\mathrm{r} - \mathrm{C}'\mathrm{H}\right)^{\mathrm{H}}.\left(\mathrm{r00} - \mathrm{C}'\mathrm{H}\right)\right]\right] \tag{22}$$

$$\hat{\mathrm{C}}\ = \underset{\hat{\mathrm{C}}}{\operatorname{argmin}} \left[\mathrm{Tr}\left[\mathrm{r}^{\mathrm{H}}.\mathrm{r} + \mathrm{H}^{\mathrm{H}}.\mathrm{C}'^{\mathrm{H}}.\mathrm{C}'.\mathrm{H} - \mathrm{H}^{\mathrm{H}}.\mathrm{C}'^{\mathrm{H}}.\mathrm{r} - \mathrm{r}^{\mathrm{H}}.\mathrm{C}'.\mathrm{H}\right]\right] \tag{23}$$

Considering $\mathrm{r}^{\mathrm{H}}.\mathrm{r}$ is independent of the transmitted codeword so can be rewritten as

$$\hat{\mathrm{C}} = \underset{\hat{\mathrm{C}}}{\operatorname{argmin}} \left[\mathrm{Tr}\left[\mathrm{H}^{\mathrm{H}}.\mathrm{C}'^{\mathrm{H}}.\mathrm{C}'.\mathrm{H}\right] - 2.\mathrm{Real}\left(\mathrm{Tr}\left[\mathrm{H}^{\mathrm{H}}.\mathrm{C}'^{\mathrm{H}}.\mathrm{r}\ \right]\right)\right] \tag{24}$$

Equation “(20)” can be rewritten for multiple receivers as shown in

$$\hat{\mathrm{C}} = \underset{\hat{\mathrm{C}}}{\operatorname{argmin}} \left[\sum_{\mathrm{m}=1}^{\mathrm{M_R}} \left[\mathrm{H}_{\mathrm{m}}^{\mathrm{H}}.\mathrm{C}'^{\mathrm{H}}.\mathrm{C}'.\mathrm{H}_{\mathrm{m}} - 2.\mathrm{Real}\left(\mathrm{H}_{\mathrm{m}}^{\mathrm{H}}.\mathrm{C}'.\mathrm{r}_{\mathrm{m}}\right)\right]\right] \tag{25}$$

where $.^{\mathrm{H}}$ is a Hermition operator [13]. We can write the cost function for only one receiving antenna and then added up to achieve for $\mathrm{M_R}$ receiving antenna.

$$\left[\mathrm{H}_{\mathrm{m}}^{\mathrm{H}}.\mathrm{C}'^{\mathrm{H}}.\mathrm{C}'.\mathrm{H}_{\mathrm{m}}\ - 2.\mathrm{Real}\left(\mathrm{H}_{\mathrm{m}}^{\mathrm{H}}.\mathrm{C}'.\mathrm{r}_{\mathrm{m}}\right)\right]\right] \tag{26}$$

where the minimization is performed over all possible transmit estimated vector symbols. Although ML detection offers optimal error performance, it suffers from complexity issues.

3.7 V-BLAST Zero Forcing Decoder

Zero Forcing is the linear MIMO technique. The processing takes place at the receiver where, under the assumption that the channel matrix H is invertible, H is inverted and the transmitted MIMO vector ‘s’ is estimated by

$$s_{est} = H^{-1}x \tag{27}$$

The solution of ZF is given by:

For Zero Forcing, nulling of the “interferers” can be performed by choosing 1 x N dimensional weight vectors w^{i} (with i=1, 2……..M), referred to as nulling vectors, such that

$$w^{i}h_{p} = \begin{Bmatrix} 0\ , p \neq i \\ 1\ , p = i \end{Bmatrix} \tag{28}$$

where h denotes the p-the column of channel matrix H. Let w^{i} be the i-th row of the matrix W, then it follows that

$$W = HI_{N} \tag{29}$$

Where W is the matrix that represents the linear processing of in the receiver. So, by forcing the “interferers” to zero, each desired element of s can be estimated.

If H is not square, W equals the pseudo-inverse of H [9] denoted by H^{+}

$$W = H^{+} = (H^{H}H)^{-1}H^{H} \tag{30}$$

If elements of H are assumed to be i.i.d [10], the pseudo-inverse [9] exists, when M≥N. For M≤N, $H^H H$ is singular and its inverse does not exists [9]. When the pseudo-inverse exits, the estimates of s (given by S_{est}) can be given by

$$s_{est} = Wx = \mathrm{H}^{+} = (H^H H)^{-1} H^H \mathrm{x} \tag{31}$$

$$s_{est} = \mathrm{s} + (H^H H)^{-1} H^H \mathrm{n} \tag{32}$$

The disadvantage of Zero Forcing [13] is that it suffers from noise enhancement. This can readily observed from above equation.

This leads to estimation error and given by following equation

$$\epsilon = s_{est} - \mathrm{s} = (H^H H)^{-1} H^H \mathrm{n} \tag{33}$$

The ZF receiver converts the joint decoding problem into M single stream decoding problems thereby significantly reducing receiver complexity. This complexity reduction comes, however at the expense of noise enhancement which results in a significant performance degradation.

3.8 V-BLAST Minimum Mean Square Error (MMSE)

The MMSE [15] receiver suppresses both the interference and noise components, whereas, ZF receiver removes only the interference components. This implies that the mean square error between the transmitted symbols and the estimate of the receiver is minimized. Hence MMSE is superior to ZF in the presence of noise. At low SNR, MMSE becomes matched filter and at high SNR, MMSE becomes Zero Forcing (ZF). For MMSE-V-BLAST [10], the nulling vector for the i-th layer is

$$w^i = \left[H_i H_i^* + \frac{1}{snr} I\right]^{-1} h_i, \quad i = 1,2 \dots\dots N \tag{34}$$

Where $H_i = C^{M \times i}$ consists of the first I columns of H. Then the post-processing SNR of the i-th layer is

$$\rho_i^{MMSE} = \frac{|h_i^*|^2}{w_i^*\left(H_{i-1} H_{i-1}^* + snr^{-1} I\right) w_i} \tag{35}$$

Inserting (18) into (19), we can simplify via some straight forward calculations that are

$$\rho_i^{MMSE} = h_i^* C_i^{-1} h_i \qquad \mathrm{i} = 1,2 \dots\dots.. \mathrm{N} \tag{36}$$

where, $C_i^{-1} = H_{i-1} H_{i-1}^* + snr^{-1} I$, applying the matrix inversion, we obtain

$$C_i^{-1} = snr[\mathrm{I} - H_{i-1} H_{i-1}^* + snr^{-1} I]^{-1} \mathrm{H}_{\mathrm{i-1}}^* \tag{37}$$

Inserting (21) into (20) we get

$$\rho_i^{MMSE} = snr\hbar_i^* P \frac{1}{H_{i-1}} \hbar_i + snr_i^* H_{i-1}[(H_{i-1} H_{i-1}^*)^{-1} - (H_{i-1} H_{i-1}^* + snr^{-1} I)^{-1}] \mathrm{H}_{\mathrm{i-1}}^* \mathrm{h_i} \tag{38}$$

$$\rho_i^{MMSE} = \rho_{\mathrm{i}}^{\mathrm{ZF}} + snr h_i^* H_{i-1}[(H_{i-1} H_{i-1}^*)^{-1} - (H_{i-1} H_{i-1}^* + snr^{-1} I)^{-1}] \mathrm{H}_{\mathrm{i-1}}^* \mathrm{h_i} \tag{39}$$

Hence, MMSE receiver approaches the ZF receiver and therefore realizes (N-M+1)th order diversity [5] for each data stream.

3.9 V-BLAST Zero Forcing with OSIC

OSIC is basically based on subtraction of interference of already detected elements of s from the receiver vector x. This results in a modified receiver vector in which effectively fewer interferers are present. Decoding algorithm consists of basically three steps which are summarizing

1) Compute H^+, find the minimum squared length row of H^+, say it is the p-th and permute it to be last row. Permute columns of H accordingly.

2) From the estimate of the corresponding elements of s. In case of ZF:

$$(s_{est})_p = W^n x$$

Where the weight vector W^n equals row N_t of the permuted H^+

3) While M-1>0 go back to step 1, but now with:

$$H \longrightarrow H^{(M-1)} = (h_1 \dots\dots h_{M-1})$$

So we can see here with respect to ZF, the ZF with OSIC algorithm introduces extra complexity.

3.10 V-BLAST Minimum Mean Square Error (MMSE) with OSIC

In order to do OSIC with MMSE, then the algorithm resulting as follows

Covariance matrix can be written as

$$\left[(s - s_{est})(s - s_{est})^H\right] = \sigma_n^2 \left(\alpha I + H^H H\right)^{-1} \equiv \sigma_n^2 P$$

Covariance matrix of the estimation error $(s - s_{est})$ will be used to determine good ordering for detection.

1) Compute W (P is obtained while determining W). Find the smallest diagonal entry of P and suppose this is the pth entry. Permute the pth column of H to be last column and permute the rows of W accordingly.

2) From the estimate of the corresponding elements of s. In case of MMSE:

$$(s_{est})_p = W^M x$$

Where the weight vector W^M equals row M (number of transmitting antennas) of the permuted W

3) While M-1>0 go back to step 1, but now with:

$$H \longrightarrow H^{(M-1)} = (h_1 .... h_{M-1})$$

So here we can see that we get optimal ordering by using MMSE with OSIC

VI. FADING

Fading is used to describe the rapid fluctuations of the amplitudes, phases or multipath delays of a radio signal over a short period of time or travel distance, so that large scale path loss effect may be ignored [5]. Fading, or equivalently small-scale fading, is caused by interference between two or more versions of the transmitted signal which arrive at the receiver at slightly different times. These signals, called multipath waves, combine at the receiver antenna and the corresponding matched filter and provide an effective combined signal. This resulting signal can vary widely in amplitude and phase. The rapid fluctuation of the amplitude of a radio signal over a short period of time, equivalently a short travel distance, is such that the large-scale path loss effects may be ignored. Multipath in the radio channel creates small-scale fading effects. The three most important effects are:

- Rapid changes in signal strength over a small travel distance or time interval
- Random frequency modulation due to varying Doppler shifts on different multipath signals
- Time dispersion caused by multipath propagation delays

In built up urban areas, fading occurs because the height of mobile antennas are well below the height of surrounding structures, so there is no single line of sight (LOS) the base station [5]. The signal received by mobile at any point in space may consist of large number of waves having randomly distributed amplitudes, phases and angles of arrival. These multipath components combine vectorially at the receiver antenna, and because the signal received by mobile is fade [12]. Due to relative motion between the mobile and the base station, each multipath wave experiences an apparent shift in frequency. The shift in received signal frequency due to motion is called Doppler shift, and is directly proportional to the velocity and direction of motion of the mobile with respect to the direction of arrival of the received multipath wave. If the signal bandwidth is wider than the coherence bandwidth then different frequencies undergo independent fading and the result is inter-symbol-interference (ISI).

VII. RAYLEIGH FADING CHANNEL

The fading effect is usually described statistically using the Rayleigh distribution [7]. The amplitude of two quadrature Gaussian signals follows the Rayleigh distribution whereas the phase follows a uniform distribution. The probability distribution function (PDF) of a Rayleigh distribution is given by [12]

$$p(r) = \begin{Bmatrix} \frac{r}{\sigma^2} exp\left(\frac{-r^2}{2\sigma^2}\right) & (0 \le r \le \infty \\ 0 & (r < 0) \end{Bmatrix} \tag{1.16}$$

where σ is the RMS (amplitude) value of the received signal and σ^2 is the average power.

VIII. SIMULATION AND RESULTS

In this paper, we used MATLAB 7.0 software for simulation for the Bit Error Rate (BER) Performance of the VBLAST System [13]. We simulated the BER performance of VBLAST MIMO System Rayleigh flat fading channel [5] by using the different modulation techniques like BPSK, QPSK and 16-QAM

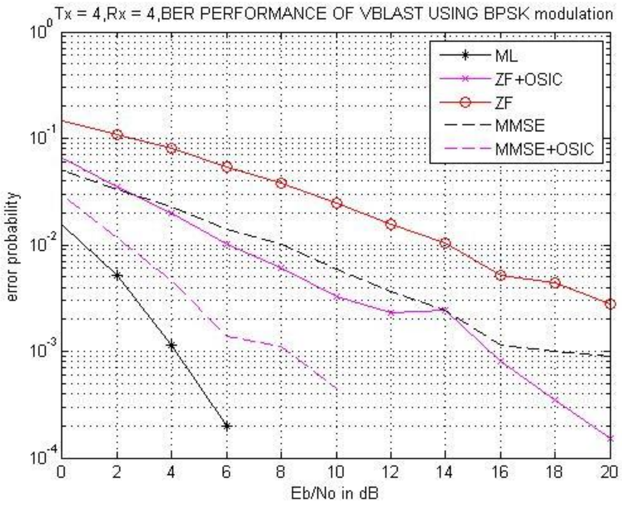

Fig.4: BER for VBLAST using BPSK modulation

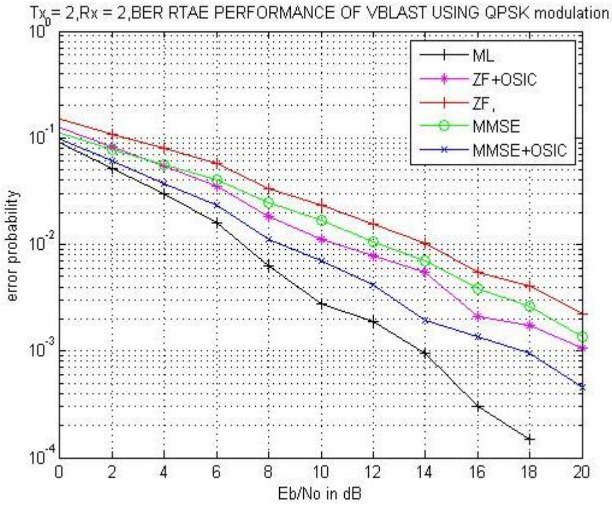

Fig.5: BER for VBLAST using QPSK modulation

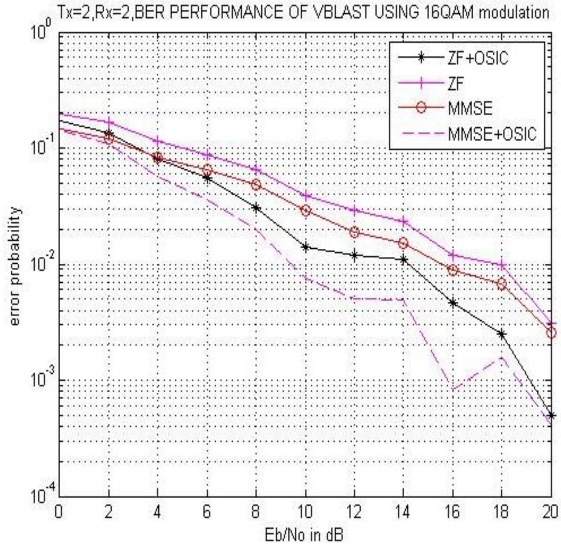

Fig.6: BER for VBLAST using 16QAM modulation

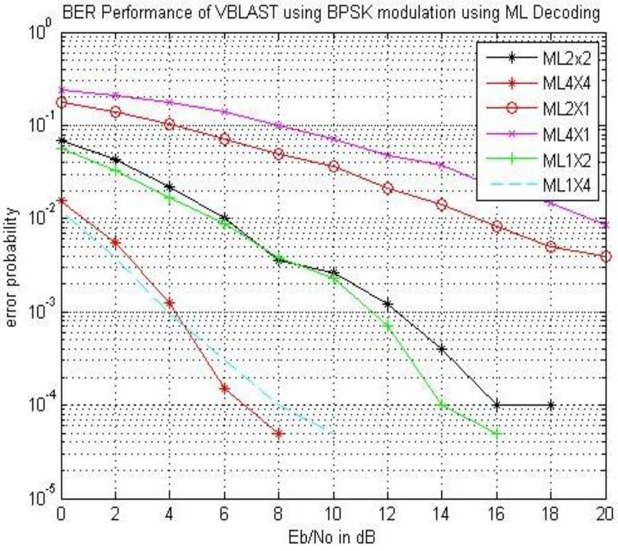

Fig.7: BER using VBLAST using BPSK modulation using ML decoding modulation

Fig.4. shows all the simulation results for BPSK modulation with ML, MMSE, ZF, ZF-OSIC and MMSE-OSIC detectors for 2x2 (Rayleigh Channel). At a certain Bit Error Rate Point, BER=0.001, there is approximately 1.6 db SNR difference between MMSE and MMSE+OSIC detector. The difference is smaller than that we expected and SNR difference between ZF and ZF+OSIC is approx 4db. We can see here that performance curve of these two systems are close to each other when SNR is low, but gap gets larger when SNR gets higher. When the SNR is large, the post detection of SNR may effected by channel matrix H. When BER=0.001, we need SNR=3db in VBLAST system and we need SNR=4.6 Db in ordering system. There is difference of only 1.6db, thus we can use OSIC ordering system instead of simple VBLAST system since these two schemes perform similarly.

Fig.5. shows all the simulation results for QPSK modulation with ML, MMSE, ZF, ZF-OSIC and MMSE-OSIC detectors for 2x2 (Rayleigh Channel). At a certain Bit Error Rate Point, BER=0.001, there is approximately 4 db SNR difference between MMSE and MMSE+OSIC detector and SNR difference between ZF and ZF+OSIC is approx 3db. The difference between ML and MMSE+OSIC is about 2db and difference is smaller than as we expected. We can see here that performance curve of these two systems are close to each other when SNR is low, but gap gets larger when SNR gets higher. When SNR is less that means noise is large, post detection SNR is affected by noise. When the SNR is large, the post detection of SNR may effected by channel matrix H. When BER=0.001, we need SNR=3db in VBLAST system and we need SNR=4.6 Db in ordering system.

Fig.6. shows all the simulation results for QAM-16 modulation with MMSE, ZF, ZF-OSIC and MMSE-OSIC detectors for 2x2 (Rayleigh Channel). For 16QAM ML decoding technique is too complex so we do not do ML decoding for higher modulation. At a certain Bit Error Rate Point, BER=0.001, there is approximately 3 db SNR difference between MMSE and MMSE+OSIC detector and SNR difference between ZF and ZF+OSIC is approx 3db.. We can see here that

performance curve of these two systems are close to each other when SNR is low, but gap does not gets larger when SNR gets higher as we expected.

IX. CONCLUSION

In this paper, we studied MIMO V-BLAST system performance under i.i.d Rayleigh channel. Further this system is compared with different modulation technique and system gets better result in BPSK modulation ***.Fig.7*** shows the simulation results for BPSK modulation with only ML decoding technique using various antennas at input and output. In this we will more optimal result for 4 x 4 antennas for V-BLAST system.

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