

BER ANALYSIS OF V-BLAST MIMO SYSTEMS UNDER VARIOUS CHANNEL MODULATION TECHNIQUES IN MOBILE RADIO CHANNELS

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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' ($M \geq N$) 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 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).

1. 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 becomes very important since it will give lot ideas in understanding and designing the practical MIMO systems. 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 [1]. 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.

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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 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) 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 ($M \geq N$), 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].

2. System Model of V-BLAST

The V-BLAST system [3] is simplified version of D-BLAST [2] 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

2.1. 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.

2.2. 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.

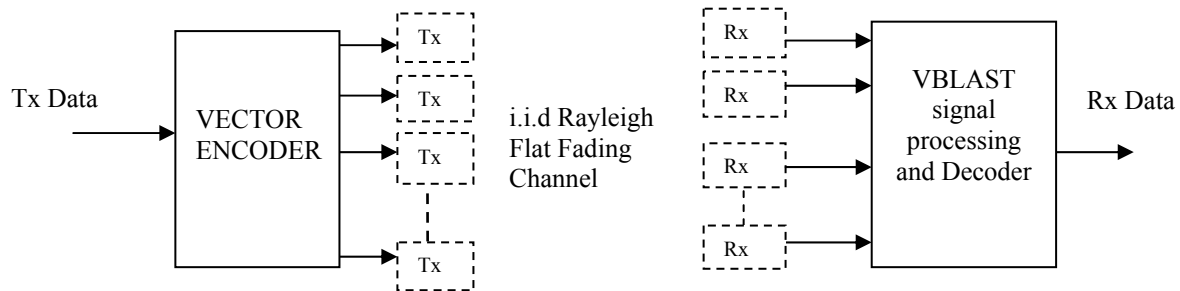


Fig.1 VBLAST Transceiver system

2.2.1. Maximum Likelihood Decoder

The ML receiver 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{C} according to the Maximum Likelihood principle, which is shown as:

$$\hat{C} = \underset{\hat{C}}{\operatorname{argmin}} \left[\|r - C'H\|_F^2 \right]$$

Where, $_F$ is the Frobenius norm.

2.2.2. V-BLAST Zero Forcing (ZF)

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

$$s_{est} = H^{-1}x$$

The solution of ZF is given by:

$$s_{est} = Wx = H^+ x = (H^H H)^{-1} H^H x$$

Where $()^+$ represents the pseudo-inverse.

2.2.3. V-BLAST Minimum Mean Square Error (MMSE)

The MMSE 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, the nulling vector for the i^{th} layer is

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

Where $H_i = C^{M \times i}$ consists of the first i columns of H .

2.2.4. Zero Forcing with Ordered Serial Interference Cancellation (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_i of the permuted H^+

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

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

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

2.2.5. MMSE with Ordered Serial Interference Cancellation (OSIC)

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

Covariance matrix can be written as

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

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 p^{th} entry. Permute the p^{th} 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 of the permuted W and M is the number of transmitting antennas

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

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

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

3. Simulations and Result

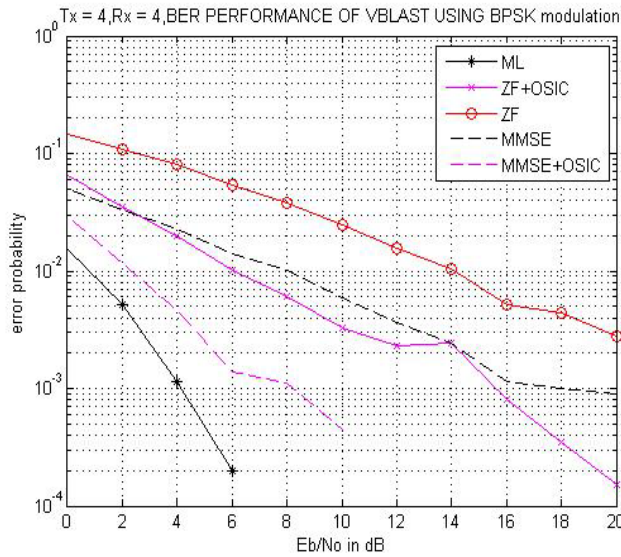


Fig.2: BER for VBLAST using BPSK modulation

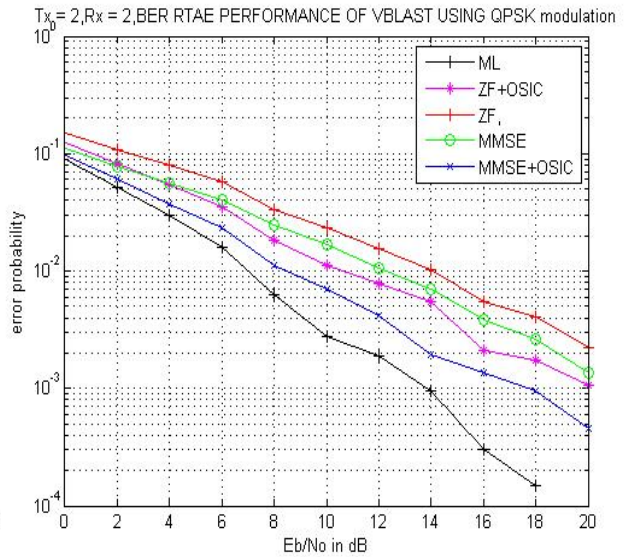


Fig.3: BER for VBLAST using QPSK modulation

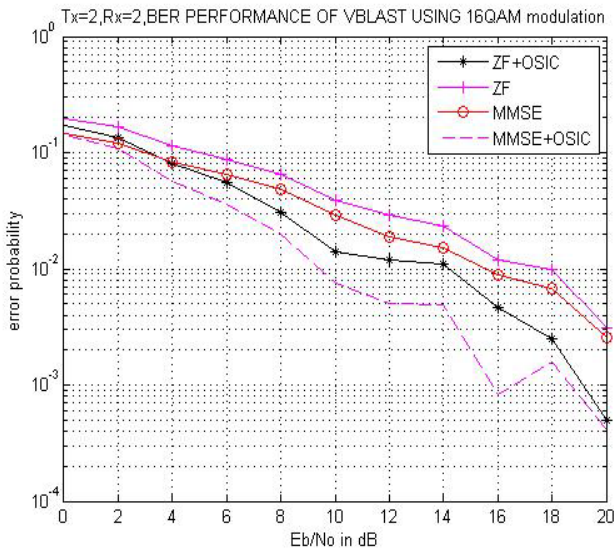


Fig.4: BER for VBLAST using 16QAM modulation

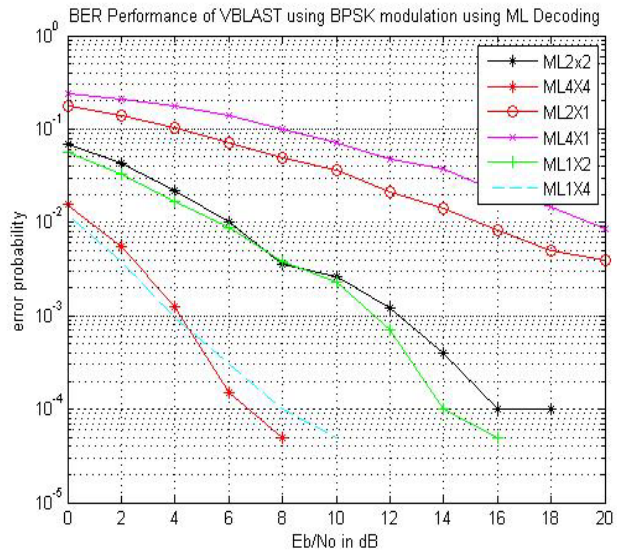


Fig.5: BER using VBLAST using BPSK modulation using ML decoding

Fig.2. 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.3. 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.4. shows all the simulation results for QAM-16 modulation with MMSE, ZF, ZF-OSIC and MMSE-OSIC detectors for 2x2 (Rayleigh C hannel). 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.

4. 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.5 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.

5. References

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