

A Brief Survey on V-BLAST MIMO-OFDM System with ZF and MMSE Techniques

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Abstract - Wireless communication system with multi-antenna arrays has been a field of intensive research on the last years. The application of multiple Transmitting antennas and Receiving Antennas both sides can significantly enhance the channel capacity and data rate. The review of the performance limitations of MIMO system becomes very important since it will give lot ideas in understanding and designing the real life MIMO systems. Vertical Bell Laboratories Layered Space Time (V-BLAST). The idea behind Multiple Input and Multiple Output system is that the signals on the transmitter antennas at one end and the receiver antennas at the other end are correlated in such a way that the performance (Bit Error Rate or BER) or the data rate (bits/sec) of the wireless communication system for each MIMO subscriber will be improved.

Keywords: V-Blast, MIMO-OFDM, Zero Forcing, Minimum Mean Square Error.

I. INTRODUCTION

Wireless communication using MIMO has recently emerged as one of the most significant technical breakthroughs in modern communications technology. MIMO systems establish an arbitrary wireless communication a link for which the transmitting end as well as the receiving end is equipped with multiple antenna elements as illustrated in Fig. 1.

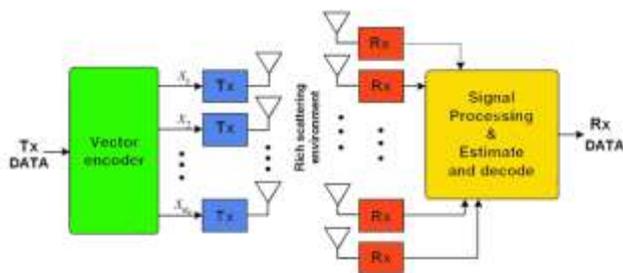


Fig. 1 A Model of V-Blast System

The idea behind MIMO is that the signals on the transmit (TX) antennas at one end and the receive (RX) antennas at the other end are "combined" in such a way that the quality

(Bit Error Rate or BER) or the data rate (bits/sec) of the communication for each MIMO user will be improved. Such an advantage can be used to increase both the network's quality of service and the operator's revenues significantly. Ultimate goals of the future generation wireless communication system are high data rate, high-performance and optimum utilization of the bandwidth. MIMO wireless systems help to achieve that goal.

The achievable capacity and performance depend on the channel conditions and on the structure of the transmit signal. In order to achieve the goal the design MIMO system architecture influences the complexity of the transmitter and, particularly the receiver. The MIMO coding techniques can be split into three groups such as: space-time coding (STC), space division multiplexing (SDM) and beam forming. A large number of low complexity linear MIMO detectors have been studied so far, generally these linear detectors are based on minimum mean-square error (MMSE), based on zero-forcing (ZF) and QR Decomposition. But the performance of this detector can be poor, especially in MIMO systems that use a less number of receiving antenna branches and equal to transmitting antennas. To improve performance, a so called vertical Bell laboratories layered space-time (V-BLAST) algorithm has been introduced; this performs successive interference cancellations in the appropriate order. VBLAST system with Successive Interference Cancellation (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 bit error-rate (BER) performance.

In Section II, the system model is described. The V-BLAST detection techniques based on MIMO systems. In Section IV, the functionality of the proposed detectors has been described with ZF, MMSE and QR in AWGN channel. The simulation results and conclusion are provided in Section III and Section IV, respectively.

The V-BLAST MIMO channel model is as shown in Fig. 1. The transmitters and receivers are assumed to be BPSK modulators operating with co-channels as the case with the transmitters/receivers. The channel is assumed to be AWGN and the channel time variation is considered negligible over L symbol periods which comprise a data streams. The signal arriving at the receiver is

$$r = Ha + n \tag{1}$$

Where H is the matrix channel, a is the transmitted symbol vector, and n is the channel noise. The V-BLAST detection process involves the computing of nulling vectors w_{ki} , where

$$S = \{ k1, k2, k3 \dots kMt \} \tag{2}$$

and S is a set of permutation of the integers 1,2 ... Mt by which orders of the components of a are extracted. The k_i -th nulling vector is defined as the unique minimum norm vector satisfying the condition

$$w_{ki}^T \cdot (H)_{kj} = \begin{cases} 0 & \text{for } j \geq 1 \\ 1 & \text{for } j = 1 \end{cases} = \begin{cases} 0 & \text{for } j \geq 1 \\ 1 & \text{for } j = 1 \end{cases} \tag{3}$$

The output bit stream of a V-BLAST MIMO can be expressed in the min-norm vectors with a and n. The symbol cancellation and linear nulling techniques are used to perform detection. After a transmitted signal vector a is received, interferences are cancelled out using symbol cancellation so the received vector has fewer interferers. The decision statistic at the receiver is

$$y_{k1} = w_{k1}^T \times r \tag{4}$$

Where w_{k1} is the nulling vector. Quantization of y_{k1} is done to obtain a component. With assumption that a_{k1} is cancelled from the received vector R.

$$R = r - a_{k1} (H)_{k1} \tag{5}$$

Where $(H)_{k1}$ is the k_1 -th column of the matrix channel H. This Cancellation is repeated for components $k_2 \dots k_{MT}$ for the all received vectors.

The complete detection algorithm can be summarized as recursive as follows:

II. V-BLAST MIMO DETECTION TECHNIQUE

The V-BLAST system being a Multiple-Input Multiple Output (MIMO) system that includes multiple transmitting

and receiving antennas, the data being transmitted from the multiple transmitting antennas simultaneously as multiple data layers, each data layer being derived from same signal constellation, the data received at a receiver being in the form of a vector.

The classification of MIMO detection techniques adopted for V-BLAST is shown in Fig.2. The V-BLAST MIMO detection method comprising the following steps:

- Calculating a matrix on the basis of channel matrix of the V-BLAST system post-detection Signal to Noise Ratio (SNR);
- Updating the channel matrix by deleting a column that corresponds to a maximum diagonal entry of the matrix, the maximum diagonal entry corresponding to a minimum
- Calculating y with updated received vectors for a data layer, the data layer corresponding to the maximum diagonal entry, y being the size of the signal constellation, the updated received vectors being calculated for all possible constellation points of the signal constellation of the data layer, the data layer corresponding to the maximum diagonal entry corresponds to the minimum post-detection SNR.
- vi. Obtaining a set of reduced possible solution vectors from the SIC iterations; and F. Detecting a solution vector nearest to the received vector from the set of the reduced possible solution vectors.

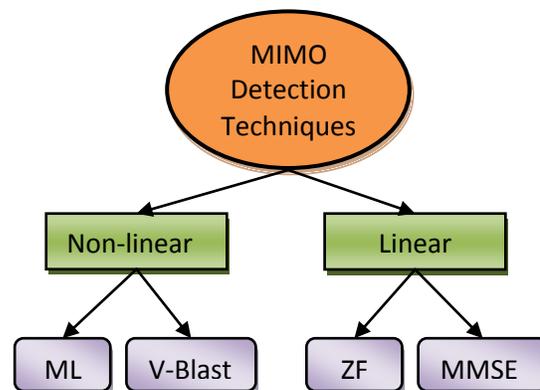


Fig.2. Classification of MIMO Detection techniques.

A. Zero Forcing (ZF):

This is a Simple linear receiver detection technique with low computational complexity and suffers from noise

enhancement. It works best with high SNR. The solution of the ZF is given by

$$S = HH^* X$$

$$\& \quad H^* = (H^* H) - I H^* \quad (7)$$

where H^* represents the pseudo-inverse of H .

B. Minimum Mean Square Error (MMSE):

The MMSE receiver suppresses both the interference and noise components, whereas the 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.

$$S = H^* (H H^* + R_n)^{-1} X \quad (8)$$

Where R_n represents noise / interference covariance.

C. Q-R Decomposition:

The effective way of solving matrix inversion problem is using QR decomposition. Let Q is unitary matrix and R is upper triangular matrix, Then $V = QR$, where Q is unitary matrix and R is an upper triangular matrix. The QR decomposition is given by

$$V^{-1} = (QR)^{-1} = R^{-1} Q^{-1} = R^{-1} QH \quad (9)$$

Where H is Hermitian Transpose.

Matched Filter:

The matched filter is the optimal linear filter for maximizing the signal to noise ratio (SNR) in the presence of additive stochastic noise. Matched filters are commonly used in radar, in which a signal is sent out, and we measure the reflected signals, looking for something similar to what was sent out. Two-dimensional matched filters are commonly used in image processing, e.g., to improve SNR for X-ray pictures. A general representation for a matched filter is illustrated in Figure below.

The filter input $x(t)$ consists of a pulse signal $g(t)$ corrupted by additive channel noise $w(t)$, as shown by

$$x(t) = g(t) + w(t), \quad 0 \leq t \leq T$$

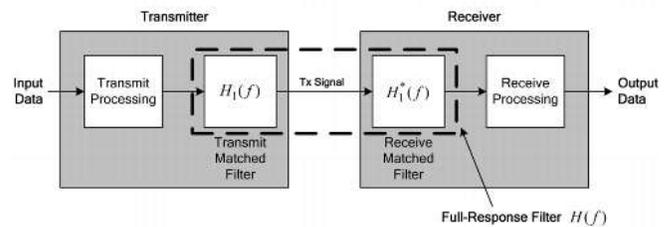


Fig.3. Matched Filter

where T is an arbitrary observation interval. The pulse signal $g(t)$ may represent a binary symbol I or 0 in a digital communication system. The $w(t)$ is the sample function of a white noise process of zero mean and power spectral density $N_0/2$. The source of uncertainty lies in the noise $w(t)$. The function of the receiver is to detect the pulse signal $g(t)$ in an optimum manner, given the received signal $x(t)$. To satisfy this requirement, we have to optimize the design of the filter so as to minimize the effects of noise at the filter output in some statistical sense, and thereby enhance the detection of the pulse signal $g(t)$.

III. RELATED WORK

In 2007 Jiming Chen, Shan Jin, and Yonggang Wang presented their work “Reduced Complexity Mmse-Sic Detector in V-Blast Systems” [3] in 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'07) in which they have used V-Blast MIMO System with MMSE-SIC detection technique with 4-QAM modulation in Fading Channel and theoretical and experimental studies have shown that layered space-time architectures like the Vertical Bell labs Layered Space-Time (V-BLAST) system can exploit the capacity advantage of multiple antenna systems in rich-scattering environments. The simulation result shown the value of BER which was found between 10^{-1} at 6dB SNR and $10^{-3.75}$ at 20dB SNR.

In 2008 Wu Nian Wang Zhongpeng, Zhang Shaozhong presented their work “Performance Comparison of Sub-optimal Algorithms Based on MIMO-OFDM Systems” [4] in 11th IEEE conference on communication Technology proceedings in which they have used V-Blast MIMO System with ZF, MMSE and QR detection technique in Frequency Selective Fading Channel with IFFT modulation. In this paper, several detection algorithms based on MIMO-OFDM systems are briefly introduced, and their performances are evaluated by computer simulation. The simulation results indicate that performance of these algorithms for MIMO-OFDM system is similar to the performance for flat MIMO

system. The value of BER which was found between 10^{-1} at 0dB SNR and $10^{-3.7}$ at 20dB.

In 2009 Kai Wu, Lin Sang, He Wang, Cong Xiong, Dacheng Yang, *Member, IEEE*, Xin Zhang, *Member, IEEE* presented their work "Detection Algorithm for V-BLAST Systems with Novel Interference Cancellation Technique"[4] in IEEE conference on communication Technology proceedings in which they have used V-Blast MIMO System with ZF-OSIC, MMSE-OSIC technique in Flat Rayleigh Fading Channel with QPSK & 16-QAM modulation and evaluated the value of BER which is between 10^{-1} at 0dB SNR and $10^{-3.75}$ at 20dB.

In 2010 Shreedhar. A. Joshi, Dr. Rukmini T S, Dr.Mahesh H M presented their work "Performance Analysis of MIMO Technology using V-BLAST Technique for Different Linear Detectors in a Slow Fading Channel"[6] in Proceedings of 2010 International Conference on Signal Processing, Communication, Computing and Networking Technologies (ICSCCN 2010) in which they have used V-Blast MIMO

System with ZF-OSIC, MMSE-OSIC technique in Rayleigh Fading Channel with BPSK and QPSK modulation and evaluated the value of BER which is between 10^{-1} at 0dB SNR and $10^{-3.5}$ at 13dB.

In 2012 Samundiswary, P.; Kuriakose, S., "BER analysis of MIMO-OFDM using V-BLAST system for different modulation schemes,"[7] Wireless communication systems at high data rates and low power consumptions are currently in high demand. Power efficiency becomes a critical issue for technology that will be used in 3G and 4G technologies. Orthogonal frequency-division multiplexing (OFDM) is a technique using discrete multi-tone modulation with each subcarrier modulating in a conventional modulation scheme. On the other hand, Multiple- Input Multiple-Output (MIMO) systems have become the attention of wireless academic community and industry because of their promising ability to increase capacity and performance with acceptable Bit Error Rate (BER) proportionally with the increased number of antennas.

Table 1: Summary of Literature Review

Year	Author	Title	Methodology	Outcomes
2007	Jiming Chen, Shan Jin, and Yonggang Wang	Reduced Complexity Mmse-Sic Detector in V-Blast Systems	V-Blast MIMO System with ZF, MMSE and QR detection	BER between 10^{-1} at 6dB SNR and $10^{-3.75}$ at 20dB SNR
2008	Wu Nian Wang Zhongpeng, Zhang Shaozhong	Performance Comparison of Sub-optimal Algorithms Based on MIMO-OFDM Systems	V-Blast MIMO System with ZF, MMSE and QR detection with IFFT modulation	BER between 10^{-1} at 0dB SNR and $10^{-3.7}$ at 20dB
2009	Kai Wu, Lin Sang, He Wang, Cong Xiong, Dacheng Yang	Detection Algorithm for V-BLAST Systems with Novel Interference Cancellation Technique	V-Blast MIMO System with ZF-OSIC, MMSE-OSIC	BER between 10^{-1} at 0dB SNR and $10^{-3.75}$ at 20dB
2010	Shreedhar. A. Joshi, Dr. Rukmini T S, Dr.Mahesh H M	Performance Analysis of MIMO Technology using V-BLAST Technique for Different Linear Detectors in a Slow Fading Channel	-Blast MIMO System with ZF-OSIC, MMSE-OSIC with BPSK and QPSK modulation	BER Between 10^{-1} at 0dB SNR and $10^{-3.5}$ at 13dB
2012	Samundiswary, P.; Kuriakose, S.	BER analysis of MIMO-OFDM using V-BLAST system for different modulation schemes	MIMO-OFDM with V-BLAST	Bit Error Rate (BER) proportionally with the increased number of antennas
2012	Kamdar, B.; Shah, D.; Sorathia, S.; Rao, Y. S.	Design and hardware implementation of a low complexity MIMO OFDM system	2x2 MIMO V-BLAST	Low complexity
2013	Iqbal, A.; Kabir, M.H.; Kyung Sup Kwak	Enhanced Zero Forcing Ordered Successive Interference Cancellation scheme for MIMO system	V-Blast with ZF-OSIC, with Low SNR Values	The issue of propagation errors from the previous layers is solved in certain limit

In 2012 Kamdar, B.; Shah, D.; Sorathia, S.; Rao, Y. S., "Design and hardware implementation of a low complexity MIMO OFDM system,"[8], They describes a design and implementation of a baseband Orthogonal Frequency Division Multiplexing (OFDM) transceiver utilizing Multiple Input Multiple Output (MIMO) signal processing for increased data rate. MIMO OFDM has many promising features which allow wireless devices to communicate at a higher data rate with reduced errors and hardware complexity. The system is composed of a 2×2 MIMO utilizing Vertical-Bell Laboratories Layered Space-Time (V-BLAST) detection algorithm. Alternate designs for modulator-demodulator, convolutional encoder - decoder and sync circuit are considered to get optimum resource utilization and low complexity.

In 2013 Iqbal, A.; Kabir, M.H.; Kyung Sup Kwak, "Enhanced Zero Forcing Ordered Successive Interference Cancellation scheme for MIMO system,"[9] Detection for the receivers in Multiple Input Multiple Output (MIMO) system is a challenge. Various detection schemes are considered to improve performance as well as reduce complexity. Maximum Likelihood (ML) is the best among other detection schemes in terms of performance, while facing huge complexity issue. Vertical Bell Lab Space Time (V-BLAST) improves performance with a less complexity compare to ML. In this study we modified Zero Forcing-Ordered Successive Interference Cancellation (ZF-OSIC) scheme to improve its performance. The idea is to assign top layers to ZF-OSIC while last two layers who has lower SNR values to ML for detection.

IV. CONCLUSIONS AND FUTURE SCOPE

In the previous work which was discussed in the literature review shows that there is need of improvement in the system in terms of Multipath Fading and Proper exploitation of the Rich Scattering. The recent advancement have improved the bit error rate to some extent but the system they analyzed is for equal number of transmitter and receiver antennas which makes system costly in terms of number of antennas. In this paper, we have studied the V-BLAST MIMO-OFDM scheme at high SNR region. Both the ZF -V-BLAST, MMSE-V -BLAST and QR-V-BLAST are analyzed with respect to their SNR and BER performances. In V-BLAST MIMO algorithm with MMSE-

IC is proposed for the V-BLAST System which can be achieved by the Matched Filter. As we have seen in the study

the complexity as well as bit error rate will reduce by the use of our approach in MIMO configuration. Moreover we can achieve different tradeoff between Relay fading environment, in frequency selective Relay Fading environment, in fading Diversity and fading diversity environment using Moving Average Filter.

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