# Performance analysis of MIMO-OFDM using V-BLAST Detector for High Data Rate SDR

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*Abstract*— The main goal in developing new wireless communication systems are increasing the transmission capacity and improving the spectrum efficiency. Space-time codes and spatial multiplexing codes exploit the richly scattered wireless channel by using multiple transmit and receive antennas in order to improve the reliability of data transfer and greatly increase the data transmission rates without additional radio resource requirements. Significant performance gain is achieved by varying some transmit and receive parameters. Multiple-input multiple-output (MIMO) is an existing technique that can significantly increase throughput of the system by employing multiple antennas at the transmitter and the receiver. Realizing maximum benefit from this technique requires computationally intensive detectors which poses significant challenges to receiver design. Furthermore, a multiple detectors are needed to handle different configurations. . One such receiver is the V-BLAST (Vertical Bell-Laboratories Layered Space-Time) which utilizes a layered architecture and applies successive cancellation by splitting the channel vertically, and at every stage the stream with the highest signal to noise ratio (SNR) is decoded.

***Key words:*** SNR, MIMO, V-BLAST

## I. INTRODUCTION

The demand for higher data rate communications for multimedia-based bandwidth-intensive applications is on increase. Multi-input-multi-output (MIMO)-based systems have shown promise to meet these challenges. Efficient exploitation of spatial diversity available in the MIMO channel enables higher system capacity. Orthogonal frequency division multiplexing (OFDM) employed in conjunction with MIMO architecture constitutes an attractive solution for modern wireless communication systems as it has the ability to deal with multipath propagation.

At the receiver, the received signal consist of combination of multiple data stream, so higher complexity detector is required to recover it. We are using here the V-BLAST detection technique, it is the detection algorithm to the receipt of multi-antenna MIMO systems. By using V-BLAST algorithm , we show the performance of the MIMO-OFDM and analyze the quality of high data rate SDR based on SNR vs. BER graph. V-BLAST is a detection algorithm to the receipt of multi-antenna MIMO systems.

Previous studies have shown that, the comparative study presents various MIMO VBLAST detection algorithms with respect to signal to noise ratio (SNR) and bit error rate (BER) performance. As the comparison results show, Minimum Mean Square Error (MMSE) algorithm is the best solution for 2X2 MIMO system targeting at Giga-bit wireless transmission. So we are implementing this detection technique, which is utilized by the high data rate Software Defined Radio (SDR). The term software radio implies radio functionalities defined by software. SDR enables a single terminal to handle various kinds of wireless systems through a simple software change and it reconfigures the terminal function.

## II. MULTIPLE INPUT MULTIPLE OUTPUT (MIMO)

MIMO systems are an extension of smart antennas systems. Traditional smart antenna systems employ multiple antennas at the receiver, whereas in a general MIMO system multiple antennas are employed both at the transmitter and the receiver. The addition of multiple antennas at the transmitter combined with advanced signal processing algorithms at the transmitter and the receiver yields significant advantage over traditional smart antenna systems - both in terms of capacity and diversity advantage. A MIMO channel is a wireless link between M transmits and N receive antennas. It consists of MN elements that represent the MIMO channel coefficients. The multiple transmit and receive antennas could belong to a single user modem or it could be distributed among different users. The later configuration is called distributed MIMO and cooperative communications. Statistical MIMO channel models offer flexibility in selecting the channel parameters, temporal and spatial correlations.

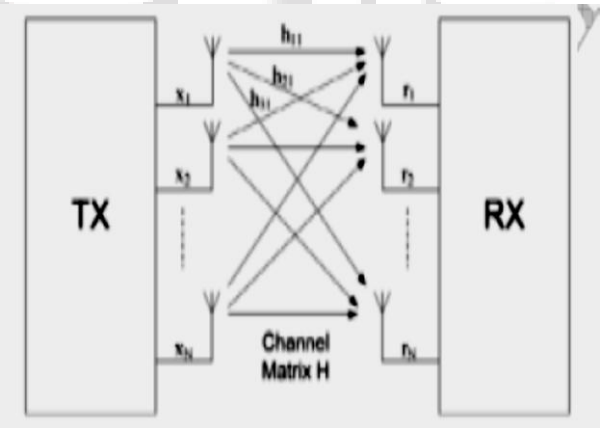


Fig. 1: MIMO Channel

They transmit independent data (say x1, x2, …,xM) on different transmit antennas simultaneously and in the same frequency band. At the receiver, a MIMO decoder users M>N or M=N antennas. Assuming N receive antennas, and representing the signal received by each antenna as r1 ,r2, ....rN

### *A. Mimo System Channel Capacity*

Channel capacity is the maximum information rate that can be transmitted and received with arbitrarily low probability of error at the receiver. A common representation of the channel capacity is within a unit bandwidth of the channel

 

and can be expressed in bps/Hz. MIMO channel capacity depends heavily on the statistical properties and antenna element correlations of the channel.

C = B log_(1 + SNR) (1)

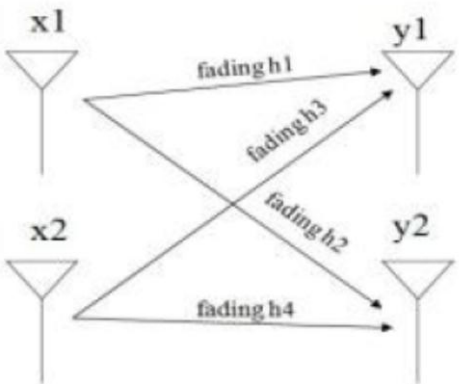


Fig. 2: MIMO system channel capacity

When multiple antennas are used, channel faces multiple input and output, and its capacity in determined by extended Shannon's capacity. Antenna with Nt input from transmitter and Nr output in a receiver channel is expressed as Nt ∗ Nr matrix of channel H. The capacity of a MIMO channel can be estimated by the following equation:

$$C = \log_2\left(1 + \frac{1}{\sigma_n^2} H R_x H^H\right) \quad (2)$$

Where H is Nt ∗ Nr channel matrix, Rx is covariance of input signal x, H^h is transpose conjugate of H matrix and $\sigma_n^2$ is the variance of the uncorrelated and Gaussian noise.

In a basic communication system, the data are modulated onto a single carrier frequency. The available bandwidth is then totally occupied by each symbol. This kind of system can lead to inter symbol-interference (ISI) in case of frequency selective channel. The basic idea of OFDM is to divide the available spectrum into several orthogonal sub channels so that each narrowband sub channels experiences almost flat fading. OFDM is becoming the chosen modulation technique for wireless communications. OFDM can provide large data rates with sufficient robustness to radio channel impairments.

## III. VERTICAL BELL-LABORATORIES LAYERED SPACE-TIME (V-BLAST):

The V-BLAST is an ordered successive cancellation method applied to receiver and at every stage the stream with the highest SNR is decoded.

The transmission is described as follows. A data stream is demultiplexed into M sub-streams termed layers. For D-BLAST at each transmission time, the layers circularly shift across the M transmit antennas resulting in a diagonal structure across space and time. On the other hand, the layers are arranged horizontally across space and time for VBLAST and the cycling operation is removed before transmission is shown in Fig.3. At the receiver, as mentioned previously, the received signals at each receive antenna is a superposition of M faded symbols plus additive white Gaussian noise (AWGN). Although the layers are arranged differently for the two BLAST systems across space and time, the detection process for both systems is performed vertically for each received vector. Without loss of generality, assume that the first symbol is to be detected.

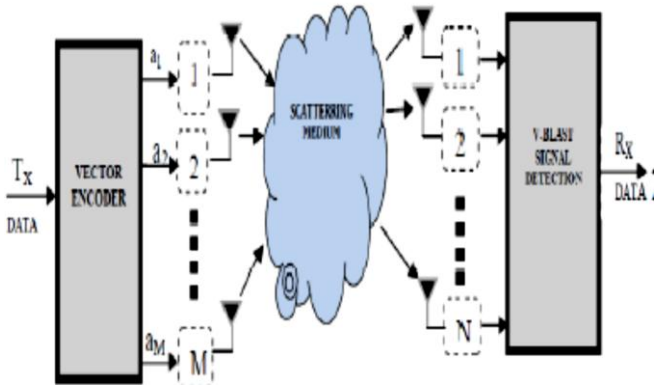


Fig. 3: V-BLAST System Model

The detection process consists of two main operations:

*1) 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.

*2) Interference cancellation (subtraction):*

The contribution of the detected symbol is subtracted from the received vector.

*A. Performance analysis of MIMO technology using V-BLAST Techniques:*

*1) Maximum Likelihood*

ML is a non-linear detection technique. The BER/SNR results of ML are better than MMSE detector but at the cost of additional complexity. So ML is used in applications where high efficiency is requires. Now if we apply V-BLAST algorithm on ML, the performance will be better than ML detector.

*2) Zero Forcing*

Zero Forcing is a linear detection technique. The pseudo inverse of the signal is applied to the received signal in order to make a decision about one user. So the equation for filter matrix G for zero forcing will be,

$$G = (H^H H)^{-1} H^H$$

In this way the received signal is detected by zero forcing detectors. If V-BLAST algorithm is applied on ZF detector, equation 11 will be applied on ZF filter matrix. ZF with V-BLAST shows better performance in comparison to normal ZF in terms of BER/SNR.

*3) Minimum Mean Square Error (MMSE)*

MMSE is also a linear detection technique but more reliable than ZF in case of noisy channel. MMSE does not apply pseudo inverse of signal to make decision about one user, instead it attenuates them to noise level thereby reducing the diversity order. From the filter matrix for MMSE is,

$$G = \left(H^H H + \frac{N_t}{SNR} I_{N_r}\right)^{-1} H^H$$

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.

As the comparison results show, MMSE (Minimum Mean Square Error) algorithm is the best solution for 2X2 MIMO system targeting at Giga-bit wireless transmission. So we are implementing this detection technique, which is utilized by the high data rate Software Defined Radio (SDR).

This technique targets to enhance the performance of V-Blast detector by improving the SNR, which in run utilize by high data rate Software Defined Radio.

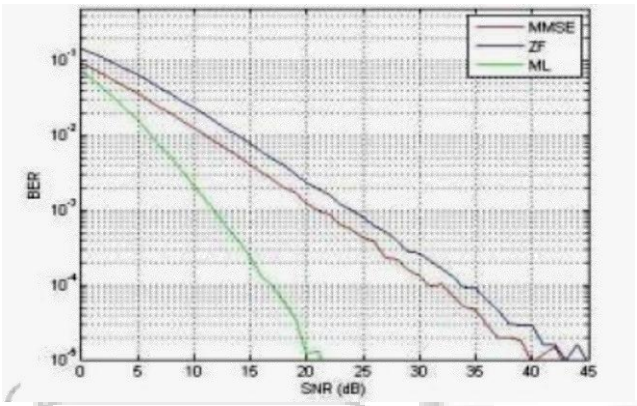


Fig. 4: Performance of VBLAST

*4) Software Defined Radio (SDR):*

Nowadays interests of MIMO researchers are shifting from theoretical analysis to experimental verification of developed algorithms & systems. Equipment for experiment are desired to be flexible to implement a variety of MIMO system, e.g. spatial multiplexing & space time coding, open loop & closed loop, single user & multiuser. One of the solution for such an equipment is software defined radio (SDR) technology.

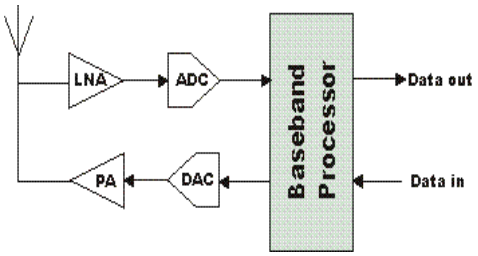


Fig. 5: SDR Model

Software Defined Radio (SDR) technology makes use of highly flexible radios i.e. SDR changes its function by rewriting software on reconfigurable devices such as FPGA and DSP. This technology is extremely valuable to the research community, since an SDR platform can be used for experiments on multiple communication schemes inexpensively compared to traditional approaches.

The demand for mobile communication systems with global coverage, interfacing with various standards and protocols, high data rates and improved link quality for a variety of applications has dramatically increased in recent years. The Software-Defined Radio (SDR) is the recent proposal to achieve these. In SDR, new concepts and methods, which can optimally exploit the limited resources, are necessary. Smart antenna system is one of those, which combats the co-channel interference and maximizes the user capacity of mobile communication system

## IV. CONCLUSION:

This paper proposes the analysis and performance of general MIMO-OFDM system using V-BLAST architecture with Minimum Mean- Square Error (MMSE) techniques. A MIMO OFDM architecture that will significantly increases the achievable bit rate of the system as well as decreases co-channel interference.

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