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Analysis of V-BLAST Techniques for MIMO Wireless Channels

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ABSTRACT

Multiple Input Multiple Output (MIMO) systems have recently emerged as a key technology in wireless communication systems for increasing both data rates and system performance. 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 (VBLAST). This paper proposes MIMO detectors to enhance the performance in MIMO channels. , we study the general MIMO system, the general V-BLAST architecture with Maximum Likelihood (ML), Zero-Forcing (ZF), Minimum Mean-Square Error (MMSE), and Ordered Successive Interference Cancellation (SIC) detectors and simulate this structure in Rayleigh fading channel. Based on frame error rates and bit error rates, we compare the performance and the computational complexity of these schemes with other existence model. Simulations shown that VBLAST implements a detection technique i.e. SIC receiver, based on ZF or MMSE combined with symbol cancellation and optimal ordering to improve the performance with lower complexity.

Keywords: SISO, MIMO, V-BLAST, ZF, MMSE and SIC.

I. INTRODUCTION

MIMO system has proved to achieve high capacity compared to SISO MISO and SIMO systems. For this reason, many algorithms have been proposed to reduce the interference in the received signals caused by other transmitters in the system. Also, they aim achieve closer values to the Shannon capacity limit. D-BLAST (Diagonal Bell Labs Layered Space Time) and V-BLAST (Vertical Bell Labs Layered Space Time) are such schemes used for detection and suppression the interference in MIMO systems. D-Blast, which was proposed by Gerard J. Foschini, applies a diagonal space time coding on the data. By applying this algorithm, it could achieve 90% of Shannon capacity rates as well as high spectral efficiency. However, due to complexity of implementing the algorithm, V-Blast algorithm was proposed. It was established in 1996 at Bell Labs. It demultiplexes the transmitted signal and then maps bit to symbol independently for each substream. A key part of the system is the receiver (Rx)signal processing algorithm.

The first proposed algorithms were the Diagonal Bell Laboratories Layered Space-Time (D-BLAST) and VBLAST. While the D-BLAST achieves the full MIMO capacity, it is more complex as compared to the VBLAST, which, despite its simplicity, achieves a significant portion of the full MIMO capacity. VBLAST is a detection algorithm to the receipt ofmulti-antenna MIMO systems.

V-BLAST (Vertical-Bell Laboratories Layered Space-Time) is a detection algorithm to the receipt of multiantenna MIMO systems. Its principle is quite simple, first it detects the most powerful signal (Highest SNR), and then it regenerates the received signal from this user from available decision. Then, the signal regenerated is subtracted from the received signal and with this new sign; it proceeds to the detection of the second user's most powerful signal, since it has already cleared the first signal and so forth. This gives less interference to a vector received. In V-BLAST, however, the vector encoding process is simply a demultiplex operation followed by independent bit-to-symbol mapping of each sub stream. V-BLAST utilizes a combination of old and new detection techniques to separate the signals in an efficient manner, permitting operation at significant fractions of the Shannon capacity and achieving large spectral efficiencies in the process. To detect symbols in multiple antenna systems, we previously estimate channel coefficients from the received signal. In procedure of detection, it is generally assumed that the channel matrix estimate has no estimation error. However, in the real system, there exist the channel estimation errors, and they cause the degradation of system performance. As in other detection algorithms, channel estimation errors could bring the significant performance degradation.

II. METHODS AND MATERIAL

A. MIMO System Model

Multiple antennas are used on the transmitting or receiving end. Multiple antenna systems of this sort are known as MIMO systems. Along with more robust transmission, MIMO also attempts to increase the data rate using what's known as spatial multiplexing. In actual practice, depending on the condition of the radio channel, both spatial diversity and spatial multiplexing (or a combination of these two techniques) is used.

A MIMO system consists of m transmit antennas and n receive antennas Since the same channel is used, each antenna receives the direct component intended for it as well as the indirect components for the other antennas. Picture a narrowband channel with independent timing. The direct connection from antenna 1 to 1 is characterized by h11 and so forth, while the indirect connection from antenna 1 to 2 is characterized by cross component h21 and so forth.

The conventional case with one transmit antenna and one receive antenna is known as single-input single-output (SISO) in MIMO terminology. If, in the case of spatial multiplexing, an increase in the data rate benefits a single receiver, this is known as single-user MIMO (SU-MIMO). If the individual transmit paths are allocated to different users, this is known as multi-user MIMO (MU-MIMO). This technique is most practical on the uplink, since the use of a single transmit antenna can minimize the complexity required in the mobile station. MU-MIMO is also known as collaborative MIMO.

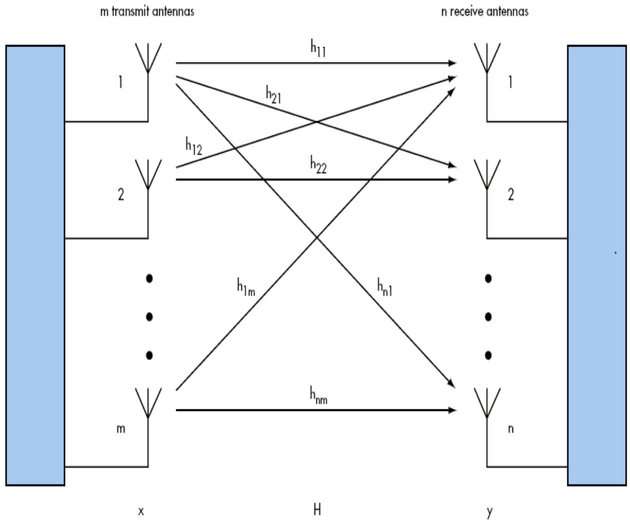

Figure 1. MIMO System Model

B. V-Blast Theory

V-Blast is a single user scheme which has multiple transmitters. It divides the data stream into substreams and transmits them through multiple transmitters at the same time and frequency. This results in receiving the data at the receiver at the same time and frequency. By implementing V-BLAST algorithm, the diversity gain is increased and the bit error rate (BER) performance is improved. The MIMO system is assumed to undergoes flat fading channel.

The detection process consists of three operations: interference suppression (nulling), interference cancellation (subtraction) and optimal ordering. The interference nulling process is carried out by projecting the received signal into the null subspace spanned by the interfering signals. This process is done by using Gramm-Schmidt orthogonalization procedure that converts a set of linearly independent vectors into orthogonal set of vectors. Then, the symbol is detected. The interference cancellation process is done by subtracting the detected symbol from the received signal. The optimal ordering, which is last process, ensures that the detected symbol has the highest signal to noise ratio (SNR). So, V-BLAST algorithm integrates both, linear and nonlinear algorithms presented in interference nulling and interference cancellation respectively. Figure 2 shows the architecture of the successive interference cancellation while Figure 3 shows the perpendicular and parallel components of the received signal with subspace. However, there are two disadvantages in V-BLAST algorithms. The first one is that the error propagates during symbol detection. The other one is that the number of receive antennas must be greater than or equal to the number of transmit antennas to satisfy the interference nulling process.

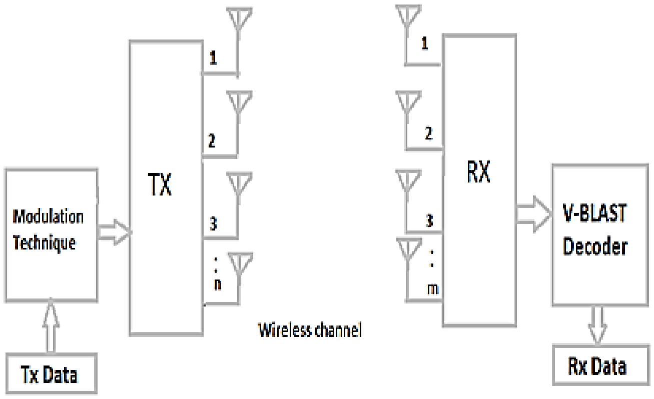

Figure 2. VBLAST System model

Main Steps for V-BLAST detection:
1. Ordering: choosing the best channel.
2. Nulling: using ZF, MMSE, ML.
3. Slicing: making a symbol decision
4. Canceling: subtracting the detected symbol
5. Iteration: going to the first step to detect the next symbol.

III. RESULT AND DISCUSSION

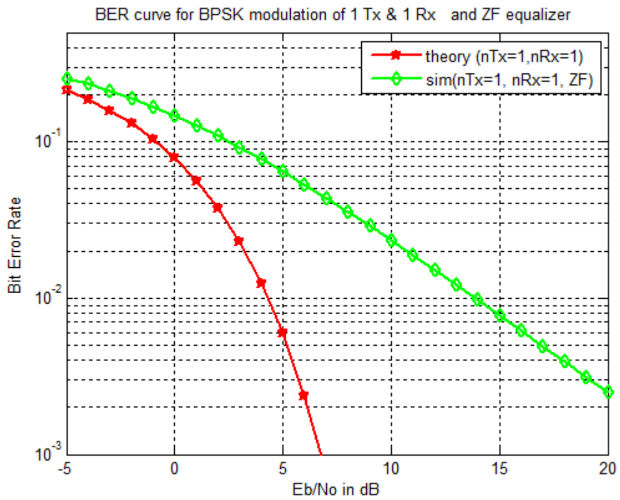

Figure 3. BER performance of SISO(with ZF)

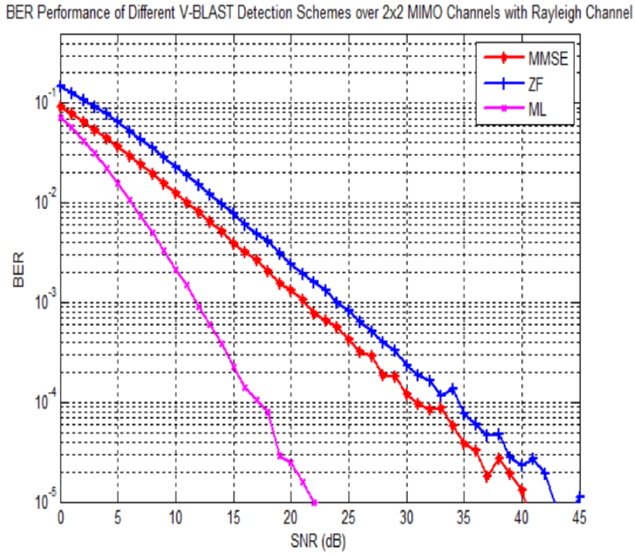

Figure 4. BER performance of MIMO V-BLAST 2X2 system

At a BER of 10-4, the SNRs of ML, MMSE and ZF are 16 dB, 31 dB and 33 dB respectively. We see a huge improvement in using ML detection over MMSE and ZF detections by 15 dB. The performance of MMSE detection is better than ZF detection by 2- 3 dB.

IV. CONCLUSION

For SISO system, ZF receiver produces noise amplification effect. Therefore ZF receiver is not suitable for such system. The MMSE V-BLAST detection algorithm will gives the better SNR and BER performances with 2X2 MIMO system that can be used for high data rate. And which will appear to be a better solution for MIMO system targeting at GHz wireless transmission. However, the system can be used in the area where there is need of high data rate transfer.

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