Survey of Performance Analysis of Data Symbol Detection Techniques in Multiple Antenna System

1Ms. SnehaJojare  
(ME, Student)  
1Department of Electronics and Telecom. Engineering,  
VESIT’s college of Engg., Chembur. Mumbai University  
ojare.sneha@gmail.com

2Prof. Naveeta Kant  
(Professor)  
2Department of Electronics Engineering,  
VESIT’s college of Engg., Chembur. Mumbai University  
naveeta.kant@ves.ac.in

Abstract: Multiple input multiple output (MIMO) configuration can be used to overcome the detrimental effects of multi-path and fading when trying to achieve high data throughput in limited-bandwidth channels. Orthogonal frequency division multiplexing (OFDM) is a multi-carrier modulation scheme along with its inherent capability to reduce inter-symbol interference (ISI). OFDM-MIMO system provides very promising gain in capacity without increasing the use of spectrum, throughput, and power consumption. This system utilizes the spatial diversity property of the multi-channel system. The reliable transmission requires symbols to be effectively recovered at the receiving end. Vertical-Bell Laboratories Layered Space-Time (V-BLAST)detection algorithm is employed for this purpose. This paper proposes the brief overview of OFDM modulation scheme, MIMO system, general V-BLAST architecture, and analysis of V-BLAST algorithm with different signal detection methods like Maximum Likelihood (ML), Zero-Forcing (ZF), Minimum Mean-Square Error (MMSE), Successive Interference Cancellation (SIC), Sphere Decoder (SD).

Keywords: MIMO, OFDM, V-BLAST, ML, MMSE, ZF, SIC, SD.

I. INTRODUCTION

A promising answer for critical increment of the transmission capacity proficiency and execution under clamor is the misuse of the spatial measurement. Various info multiple input multiple output (MIMO) abuses spatial assorted qualities by having a few transmit and get receiving wires. OFDM is balance technique known for its ability to alleviate multipath. In OFDM the fast information stream is separated into narrowband information streams, relating to the subcarriers or sub channels. Thus the image term is a few times longer than in a solitary transporter framework with the same image rate. The image term is made considerably more by adding a cyclic prefix to every image. For whatever length of time that the cyclic prefix is longer than the channel delay spread OFDM offers inter-symbol interference (ISI) free transmission. Another key point of interest of OFDM is that it significantly lessens adjustment multifaceted nature by empowering balance in the recurrence area. OFDM [7], executed with IFFT at the transmitter and FFT at the beneficiary, changes over the wideband sign, influenced by recurrence particular blurring, into narrowband level blurring flags hence the evening out can be performed in the recurrence area. A key part of the framework is the receiver (Rx) signal handling calculation. The initially proposed calculations were the Diagonal Bell research centers layered space-time (D-BLAST) and VBLAST. While the D-BLAST accomplishes the full MIMO capacity[9], it is more mind boggling when contrasted with the VBLAST, which, regardless of its effortlessness, accomplishes a significant part of the full MIMO limit. There are distinctive strategies, for example, Zero forcing (ZF), Minimum Mean Square Estimation (MMSE), Successive Interference Cancellation (SIC), Sphere Decoder (SD), V-BLAST/ZF, V-BLAST/MMSE and Maximum Likelihood (ML). The paper clarifies the V-BLAST discovery calculation with different recognition systems in subtle element.

II. PRINCIPLE OF OFDM

OFDM is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method[7]. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth. The OFDM scheme differs from traditional FDM in the following interrelated ways [6]:

- Multiple carriers (called subcarriers) carry the information stream.
- The subcarriers are orthogonal to each other
- Cyclic prefix mitigates the effects of link fading and inter symbol interference, increases the bandwidth.

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III. MULTIPLE INPUT MULTIPLE OUTPUT (MIMO)

MIMO is viably a radio receiving wire innovation as it uses different reception apparatuses at the transmitter and recipient to empower an assortment of sign ways to convey the information, picking separate ways for every radio wire to empower various sign ways to be utilized. The two primary configurations for MIMO are given underneath [9]:

- **Spatial diversity**:
  Spatial differing qualities utilized as a part of this smaller sense frequently alludes to transmit and get assorted qualities. These two techniques are utilized to give enhancements in the sign to clamor proportion and they are portrayed by enhancing the dependability of the framework as for the different types of blurring.

- **Spatial multiplexing**:
  This form of MIMO is used to provide additional data capacity by utilising the different paths to carry additional traffic, i.e. increasing the data throughput capability.

IV. VERTICAL-BELL LABORATORIES LAYERED SPACE-TIME (V-BLAST)

V-BLAST (Vertical-Bell Laboratories Layered Space-Time) is a detection algorithm to the reception of multi antenna MIMO system[4].

![V-BLAST System](image)

The maximum channel capacity of a MIMO system, the channel capacity can be estimated as a function of N spatial streams [13]. A basic approximation of MIMO channel capacity is a function of spatial streams, bandwidth, and signal-to-noise ratio (SNR) and is given by[14] : Capacity = N BW log2(1 + SNR)

V. V-BLAST DETECTION ALGORITHM

First it detects the most powerful signal with the 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 [9].

![MIMO Antenna System](image)
VI. DETECTION TECHNIQUES FOR VBLAST-MIMO

1. **Zero Forcing**:
A zero-forcing equalizer uses an inverse filter compensation for the channel response function. At the output of the equalizer, it has an overall response function equal to one for the symbol that is being detected and a zero response for other symbols. This results in the removal of the interference from all other symbols in the absence of the noise [1]. Zero forcing is a linear equalization method that does not consider the effects of noise. In fact, the noise may be enhanced in the process of eliminating the interference [11].

2. **Minimum Mean Square Error (MMSE)**:
If the mean square error between the transmitted symbols and the outputs of the detected symbols, or equivalently, the received SNR is taken as the performance criteria, the MMSE detector is the optimal detection that seeks to balance between cancelation of the interference and reduction of noise [1]. When the noise term is zero, the MMSE equalizer reduces to Zero Forcing equalizer at high SNR [12].

3. **Maximum Likelihood (ML)**:
Linear detection method and SIC detection methods have lower complexity than the optimal ML detection, but their performance is significantly not good as the ML detection. Maximum likelihood detection calculates the Euclidean distance between received signal vector and the product of all possible transmitted signal vectors with the given channel, and chooses the one with minimum distance [2].

4. **Successive Interference Cancellation (SIC)**
When signals are detected successively, the outputs of previous detectors can be used to detect forthcoming signals. Such algorithms are termed as decision directed detection algorithms which include successive interference cancellation (SIC), Parallel Interference cancelation (PIC) and multistage detection. SIC approach can be combined with ZF after optimal ordering and with MMSE after equal power allocation. In SIC, first symbol is detected by the decor relator and its output is used to cancel the interference from the received signal vector assuming that first symbol is detected correctly [2].

5. **Sphere Decoder (SD)**:
The main idea behind sphere decoding is to limit the number of possible code words by considering only those code words that are within a sphere centered at the received signal vector [11]. Sphere decoding method intends to find the transmitted signal vector with minimum ML metric [2].

VII. LITERATURE SURVEY

**Performance Analysis of ZF and MMSE Equalizers for MIMO Systems, 2012** [1]. This paper presents an in-depth analysis of the zero forcing (ZF) and minimum mean squared error (MMSE) equalizers applied to wireless multi-input multi-output (MIMO) systems with no fewer receive than transmit Antennas. Three kinds of equalizers, designed based on blindly estimated channel zeros, have been analyzed for SISO channels and MIMO channels. It is shown that the use of channel zero information enables one to analyze equalizers in an efficient manner. Not surprisingly, the zero base-designed ZF equalizer enhances the noise in the channel while the MMSE equalizer provides better noise immunity. It is also
BER Performance Improvement in MIMO Systems Using Various Equalization Techniques, 2012[2]. In this paper, Bit error rate (BER) performance improvements of MIMO systems using various equalization techniques like Zero-forcing (ZF), Minimum mean square error (MMSE), ZF-Successive interference cancellation (ZF-SIC), MMSE-SIC, Maximum likelihood (ML) and Sphere decoder (SD) are shown and compared. ISI which due to multipath fading is effectively mitigated using various equalization algorithms. BER analysis is done using various equalizers in different MIMO channels like Rayleigh frequency flat, Rayleigh frequency selective and Rician frequency flat channels. We find that BER performance is better in Rayleigh flat channels as compared to other channel models. Among equalizers we get best BER performance with low complexity in SD equalizers[11].

A Comparative Analysis in Equalization, 2013[3]. This article focuses on the comparison of equalization techniques for Rician Flat fading and Rayleigh frequency selective fading channel. The performance of these channels based on BER has been considered and it has been found that Rician Flat Fading Channel is the best an Frequency Selective Channel is the worst. It has also been observed that the MMSE and ZF give the worst performance in Rayleigh frequency selective channel as compared to Rician Flat Fading Channel and Rayleigh Flat fading Channel. By analyzing equalization techniques in terms of BER, It has been observed that the successive interference methods outperform the ZF and MMSE however their complexity is higher due to iterative nature of the algorithms. ML provides the best performance in comparison to others. Sphere decoder provides the best performance in SD equalizers with FPGA implementation using output signal clustering.

Ber Performance Improvement in MIMO Systems Using Various Equalization Techniques, 2012[2]. In this paper, Bit error rate (BER) performance improvements of MIMO systems using various equalization techniques like Zero-forcing (ZF), Minimum mean square error (MMSE), ZF-Successive interference cancellation (ZF-SIC), MMSE-SIC, Maximum likelihood (ML) and Sphere decoder (SD) are shown and compared. ISI which due to multipath fading is effectively mitigated using various equalization algorithms. BER analysis is done using various equalizers in different MIMO channels like Rayleigh frequency flat, Rayleigh frequency selective and Rician frequency flat channels. We find that BER performance is better in Rayleigh flat channels as compared to other channel models. Among equalizers we get best BER performance with low complexity in SD equalizers[11].

Enhanced MIMO Detection with Parallel V-BLAST, 2011[8]. This paper concentrates on a parallel V-BLAST calculation, which is called as F-BLAST and FR-BLAST i.e. F-impact with decreased parallelism, as of late proposed by Fouladi Fard, Alimohammad, and Cockburn. This F-BLAST offers the execution that methodology that of ideal ML at the expense of performing V-BLAST in parallel for all M conceivable estimations of the image in the layer with the weakest anticipated that flag would clamor proportion. Here they return to the execution of F-BLAST and show how the level of parallelism can be lessened while keeping up execution that extraordinarily surpasses that of V-BLAST. The actual comparison computational complexity between MMSE, ML, ZF, V-BLAST, F-BLAST and FR-BLAST is shown in Table 1.

Table 1: Computational Complexity for various detection techniques in 4 × 4 MIMO Detectors[8]

They considered the detection of 64QAM symbols in 4 × 4 system the performance is calculated for each M i.e. constellation size (16, 64, 256) and depending on the window size W. The number of real-valued additions, multiplications and reciprocal operations per detected signal rises by factors of 13.7, 12.9 and 50 respectively, when changing the hard decision detector from MMSE to FR(W2, 16)BLAST, and the result is a reduction in the SER by a factor of roughly 40 for SNRs exceeding 30 dB.

VIII CONCLUSION

In this paper, the review on different data symbol detection techniques like ZF, MMSE, ML, SIC, SD is explained on the
basis of study of various literatures. The decoding complexity of the ML Receiver can be reduced significantly by employing linear receiver front-ends to separate the transmitted data streams, and then independently decode each of the streams. Simple linear receiver with low computational complexity and suffers from noise enhancement. It works best with high SNR. 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. Some of the important characteristics of MMSE detector are simple linear receiver, superior performance to ZF and at Low SNR, MMSE becomes matched filter. Also at high SNR, MMSE becomes ZF. Among equalizers we get best BER performance with low complexity in SD equalizers. Also performance obtained by using ML estimate is good but it has a fault. The computational complexity is very high and it increases with the increase in number of transmitting and receiving antennas and the constellation size. For the ZF-SIC, since the interference is already nulled, the significance of SIC is to reduce the noise amplification. For MMSE-SIC, the significance of SIC is not only to minimize the amplification of noise but also to cancel the interference from other antennas. Along with V-BLAST the idea of F-BLAST and its performance is also explained here.

IX. REFERENCES


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