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

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***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.*

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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 modulationmethod[7]. A large number of closely spaced orthogonalsub-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.

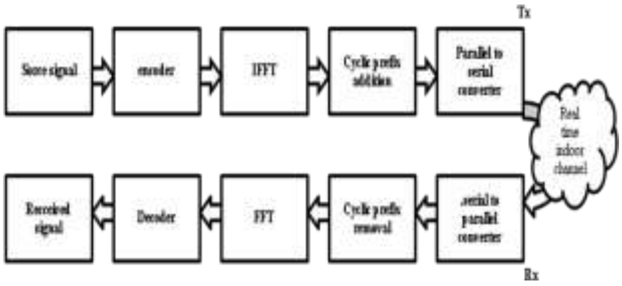

Figure 1: Block Diagram For OFDM

III. MULTIPLE INPUT MULTIPLE OUTPUT (MIMO)

MIMO is viably a radio recieving 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.

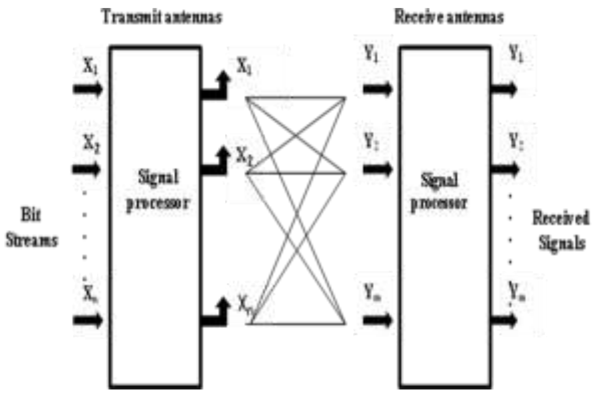

Figure 2: MIMO Antenna System

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)

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].

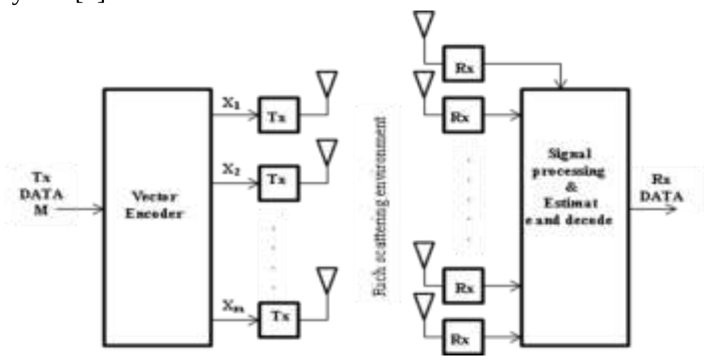

Figure 3: V-BLAST System

Figure 3 demonstrates V-BLAST framework engineering. Vector encoder takes DE multiplexes single stream into M sub-streams with M is the quantity of transmitter receiving wires. Every sub-stream is encoded into images and encouraged to a different transmitter. The tweak technique in these frameworks for the most part is M Quadrature Amplitude Modulation (MQAM). QAM joins stage regulation with sufficiency balance, making it a productive strategy for transmitting information over a restricted data transfer capacity channel. VBLAST's beneficiaries work co-channel, each getting the signs radiating from all M of the transmitting radio wires. For straightforwardness, it is likewise expected that the channel-time variety is insignificant over the L image periods in a burst [10].

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].

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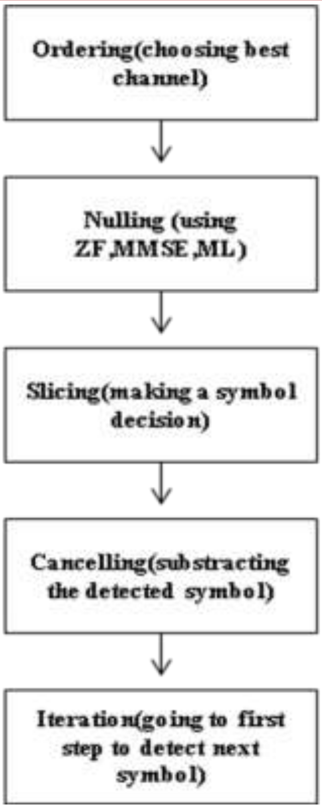

Figure 4: Flowchart For V-BLAST Detection Algoritm

VI. DETECTION TECHNIQUES FOR VBLAST-MIMO

1. Zero Forcing :

A zero-forcing equalizer uses an inverse filter compensatefor 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 andthe 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 reducesto 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 givenchannel, and chooses the one with minimum distance[2].

4. Sucessive 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 forMIMO 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 noted here that the performance of equalizers can be improved with FPGA implementation using output signal clustering, although this need more complicated training algorithms.

BER Performance Improvement in MIMO SystemsUsing Various Equalization Techniques,2012[2].In this paper, Bit error rate (BER) performanceimprovements of MIMO systems using various equalizationtechniques 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.lSI 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 fmd 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 compare to Rician Flat Fading Channel and Rayleigh Flat fading Channe.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 thealgorithms.ML provides the better performance in comparison to others. Sphere decoder provides the best performance and the highest decoding complexity as compare to ML and it is the best suited method to remove lSI in Frequency selective fading channel in MIMO systems.

Performance Analysis of V-Blast Based MIMO-OFDM System with Various Detection Techniques, 2011[5].This paper presents the performance analysis of V-BLAST based multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) system with respect to bit error rate per signal to noise ratio (BER/SNR) for various detection techniques viz zero forcing (ZF), minimum mean square error (MMSE) and maximum likelihood (ML*).*They have analyzed the performance of usingV-BLAST with various detection techniques and compared them on the basis of BER/SNR and hence obtained better performance without additional complexity is obtained.

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.

4 × 4 MIMO Detector	M	Real Multiplications	Real Additions	Real Reciprocals	Fully Parallel Time in Cycles
ML	16	4,718,592	6881312	0	25
	64	1,207,959,553	1,761,607,7729,	0	33
	256	309,237,645,313	450,971,566,145	0	41
MMSE	16	1,304	1,138	2	39
	64	1,496	1,730	2	41
	256	2,264	4,050	2	43
V-BLAST	16	2,080 (1.6)	1,518 (1.3)	4 (2)	128
	64	2,464 (1.7)	2,120 (1.2)	4 (2)	136
	256	4,000 (1.8)	4,440 (1.1)	4 (2)	144
F-BLAST	16	9,784 (7.5)	11,708 (10)	50 (25)	109
	64	54,712 (37)	72,636 (42)	194 (97)	117
	256	510,904 (226)	733,360 (181)	770 (335)	126
FR-BLAST $W=8$	64	7,767 (5.2)	9,846 (5.7)	50 (25)	117
	256	16,888 (7.5)	23,770 (5.9)	50 (25)	126
FR-BLAST $W=16$	64	14,392 (9.6)	18,816 (11)	98 (49)	117
	256	32,824 (15)	46,660 (12)	98 (49)	126

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 detections 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 ZFreceiver 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.

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