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Study & Analysis Of MIMO-OFDM Linear & Non-Linear Detection Strategies

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ABSTRACT: This The Multiple Input Multiple Output (MIMO) - Orthogonal Frequency Division Multiplexing (OFDM) technique has potential to significantly reduce Inter Symbol Interference (ISI) and enhance system capacity for future wireless communication systems. The MIMO-OFDM technology improves the throughput, reliability and predictability of wireless Local Area Networks (LAN). This paper introduces the basic concepts of several MIMO detection (linear and non linear) techniques. The comparative analysis of these techniques is done using MATLAB depending upon their performance for different modulation techniques and for different antenna configurations of MIMO system.

Keywords: MIMO, OFDM, MIMO detectors

1 INTRODUCTION

In recent years, signal detection for MIMO systems has become one of the major issues in research field. There are numerous detection techniques which include linear detectors such as Zero Forcing (ZF) and Vertical Bell Labs Layered Space-Time (V-BLAST) and non-linear detectors such as Maximum Likelihood (ML) detector, Sphere Decoder (SD) with norm 2 and SD with norm ∞ methods. This paper briefly describes the linear detectors for MIMO-OFDM system. The ML detector is optimum in the sense that it minimizes the overall error probability and provide good performance for system with few transmit antennas and smaller constellations. However, the major disadvantage of the ML is its increased computational complexity (due to exhaustive search process) which makes it impractical for systems with large transmit antennas and larger constellations. The theoretical inspection of the ML decoding can be used to predict performance prediction of suboptimal detection strategies. The MIMO detection techniques which include ML, ZF, V-BLAST and SD are presented below.

2 ML DETECTOR

It is an optimum non-linear detector. It searches throughout the lattice points, compares the received signals with all possible transmitted signal vectors s and determines the transmit symbol vector $\hat{s}$ according to the ML Principle. The complexity of ML detector increases exponentially with the no. of transmit antennas and the modulation order. There are several variations of ML detector like SD which determines the optimum signal with reduced complexity [3].

3 ZF DETECTOR

It is one of the simplest detector which acts as an equalizer. It uses an algorithm which apply inverse of the channel frequency response to the received signal, to restore the signal after the channel. The basic idea behind this detector is that if H(s) is channel response of a channel and then input signal is multiplied by the reciprocal of it. This is meant to remove ISI (effect of the channel) from the received signal. For noise free environment, ZF algorithm is very good as it brings ISI down to zero and works best with high SNR. But for noisy channel, it amplifies the noise along with signal which is further detected at the receiver side. At some frequencies the received signal may be weak. To compensate, the magnitude of the zero-forcing filter ("gain") grows very large. As a consequence, any noise added after the channel gets boosted by a large factor and destroys the overall signal-to-noise ratio. This problem can be overcome by using linear Minimum Mean-Square Error (MMSE) equalizer which does not eliminate ISI completely but instead minimizes the total power of the noise and ISI components in the output [1].

4 V-BLASTS DETECTOR

V-BLAST is a type of linear detector that provides better performance than ZF but with small increase in complexity. The V-BLAST strategy is based on successive interference cancellation. The notion behind this strategy is to use an suitable (space-time) encoding scheme at the transmitter, by using the Ordered Successive Interference cancellation (OSIC) [2] or simply the Successive Interference cancellation (SIC) detector, in order to attain good performance at the receiver. V-BLAST detection process involves two main operations namely (a) nulling (interference suppression) and (b) sorting (or layer ordering) and cancelling which involves ordering of the received signals in decreasing amplitudes and then finally cancelling the received signal with the largest amplitude first. The contribution of the detected signal is subtracted from the received vector in this way. This process is repeated until when the received signal with the least amplitude is detected [1].

5 SD

The SD algorithm searches, within the sphere of chosen radius, for the closest lattice point to the received signal, where each lattice point within a lattice field represents a codeword. However SD considers only a small set of lattice points within chosen sphere rather than considering all

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lattice points as in case of ML. Because of this reason, computation complexity of SD is less than ML detector. Sphere Decoder increases/decreases the radius depending upon whether there exists no vector /multiple vectors within a sphere. SD uses l2 norm to conduct the algorithm. The overall hardware complexity of SD is given by (i) the computational (i.e., algorithmic) complexity in terms of the number of nodes visited during algorithm until the ML solution vector is found, plus (ii) the circuit complexity in terms of the length of the critical path in the circuit and the required silicon area. In [4], it is observed that l^{∞} norm can be used for SD, which reduces the hardware complexity of SD but incurs small amount of loss in performance [5].

6 SIMULATION RESULTS & DISCUSSION

The performance of MIMO detectors ZF, V-BLAST, ML, SD with l2 norm, SD with l^{∞} norm is evaluated for modulation M-QAM (M=4,8,16) and for different MIMO antenna configurations. All simulations are performed in MATLAB 2014a software.

6.1 Performance evaluation of ZF & V-BLAST for modulation M-QAM.

For 16×16 MIMO, performance evaluation of ZF for modulation M-QAM, is shown in fig.1.

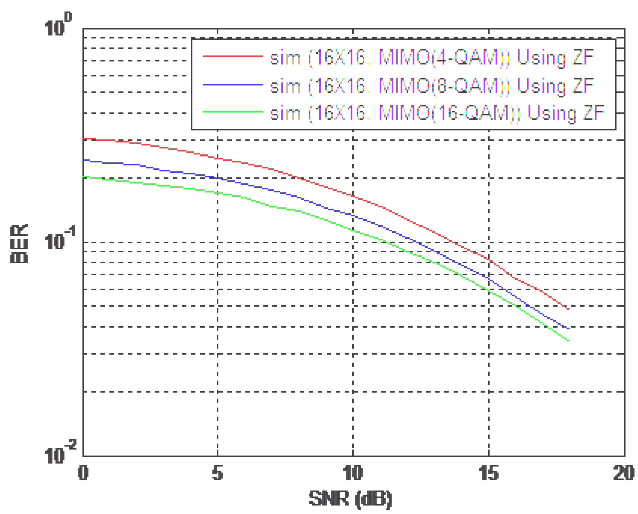

Fig.1 *Performance evaluation of 16×16 MIMO ZF system for different modulations*

It is clear from table 1 that for 16×16 MIMO-ZF, 16-QAM provides better performance results as compared to both 8-QAM and 4-QAM modulations.

Table 1

Relation between SNR and BER for different modulations in case of MIMO-ZF system

BER =	SNR(dB)		
	4-QAM	**8-QAM**	**16-QAM**
0.1	13.5	12.5	11

For 16×16 MIMO, performance evaluation of V-BLAST for modulation M-QAM, (M=4, 8, 16) is shown in fig.2.

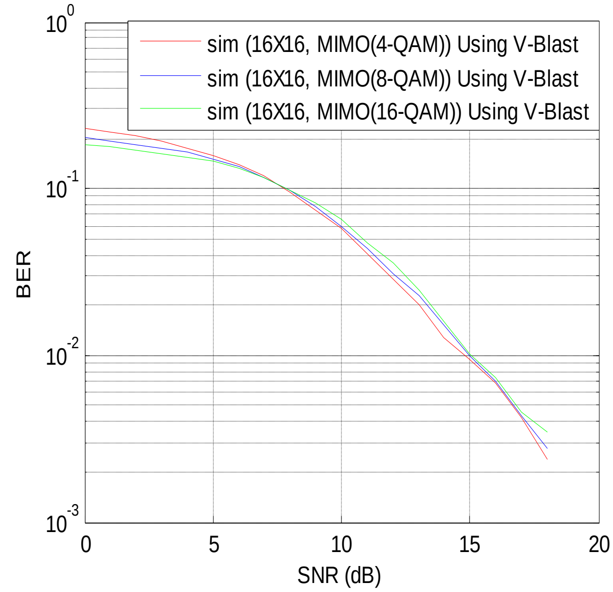

Fig.2 *Performance evaluation of 16×16 MIMO V-BLAST system for different modulations*

It is clear from fig.2, for 16×16 MIMO-ZF, for SNR = 0-6dB, 16-QAM provide good system performance; for SNR > 8.5dB, 4-QAM provide good system performance as compared to other modulations.

6.2 Performance comparison of ZF and V-BLAST for different modulations

The performance of ZF and V-BLAST is compared in terms of BER and SNR in fig.3. The results are obtained using different M-QAM modulations for 16×16 antenna configuration of MIMO system.

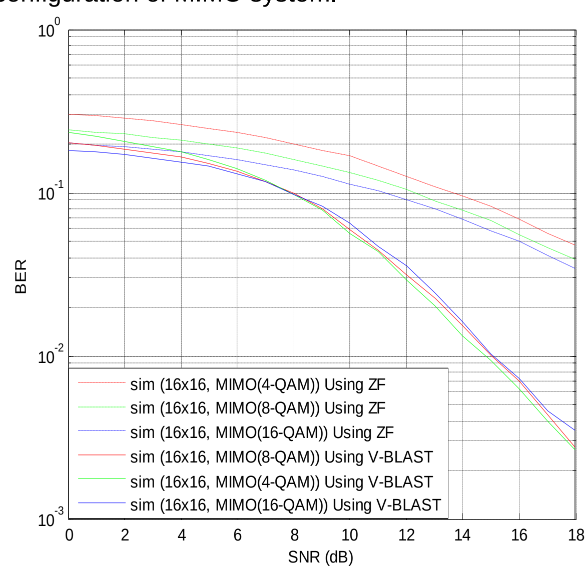

Fig.3 *Performance comparison of ZF and V-BLAST for 16×16 MIMO system using Different M-QAM modulations*

It is clear from fig.3 that with BER = 0.1, the value of SNR is 14 dB, 12.5 dB and 11 dB for MIMO-ZF system in case of

4-QAM, 8-QAM and 16-QAM respectively and SNR for V-BLAST is 8 dB for M-QAM modulations. The SNR values for ZF and V-BLAST at BER=0.1 are shown in table 2.

Table 2
Table showing SNR values for V-BLAST and ZF with different modulation schemes

Modulation Scheme	SNR(dB)	
	V-BLAST	ZF
4-QAM	8	14
8-QAM	8	12.5
16-QAM	8	11

From results in table 2, it is shown that V-BLAST shows good BER performance as compared to ZF for all M-QAM modulations. For BER < 0.1, system with V-BLAST shows good performance for 4-QAM modulation as compared to other modulations. ZF provides more good performance as order of modulation (M) increases in M-QAM for fix antenna configuration 16×16.

6.3 Performance comparison of ZF and V-BLAST for different antenna configurations (4×4, 8×8, 16×16) of MIMO system.
The performance of ZF and V-BLAST is compared in terms of BER and SNR in fig.4. The results are obtained for different antenna configurations of MIMO system using 4-QAM modulation.

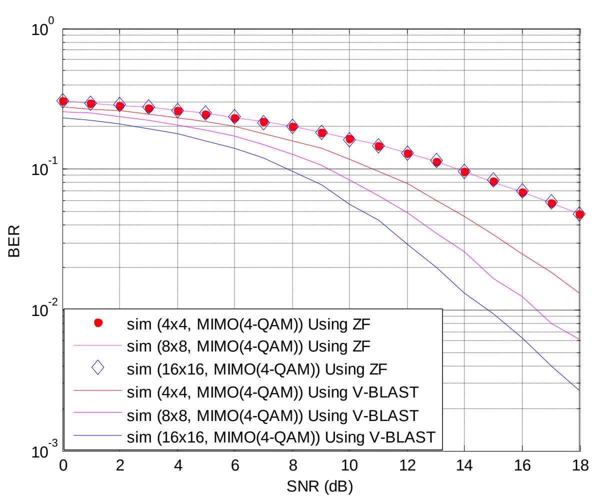

***Fig.4** Performance comparison of ZF and V-BLAST for different antenna configurations using modulation 4-QAM*

It is clear from fig.4 that with BER = 0.1, the value of SNR is 11 dB, 9.2 dB and 8 dB for MIMO V-BLAST system with 4×4, 8×8 and 16×16 antenna configurations respectively and SNR for ZF is 8 dB for all antenna configurations. The SNR values for ZF and V-BLAST at BER=0.1 are shown in table 3.

Table 3
Table showing SNR values for V-BLAST and ZF with different modulation schemes for 16×16 MIMO system

Antenna Configuration	SNR(dB)	
	V-BLAST	ZF
4×4	11	14
8×8	9.2	14
16×16	8	14

From results in table 3, it is shown that V-BLAST shows good BER performance as compared to ZF for all antenna configurations of MIMO system. As size of antenna configuration increases, V-BLAST shows more good performance and ZF shows same performance for all antenna configurations of MIMO system using same modulation 4-QAM.

6.4 Performance comparison of ML, SD with norm 2, SD with inf norm, ZF and V-BLAST for different modulations
The performance of ML, SD with norm 2, SD with norm ∞, ZF and V-BLAST is compared in terms of BER and SNR in fig.5. The results are obtained for 4×4 antenna configuration using 4-QAM modulation. ML detector shows the best performance in comparison to all other detectors. The ZF, V-BLAST and SD with inf norm shows same performance.

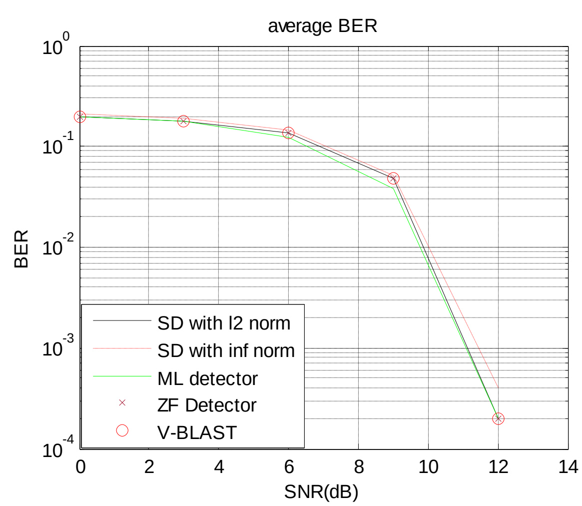

***Fig.5** Performance comparison of ML, SD with norm 2, SD with inf norm, ZF and V-BLAST for 4×4 MIMO system using 4-QAM modulation*

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The performance of ML, SD with norm 2, SD with norm ∞, ZF and V-BLAST is compared in terms of BER and SNR in fig.6. The results are obtained for 4×4 antenna configuration using 16-QAM modulation. For BER = 0.1, the value of SNR is 10.1 dB, 11 dB and 12.5 dB in case of ML, SD with inf norm, SD with l2 norm/V-BLAST/ZF respectively. This shows that ML detector shows the best performance in comparison to all other detectors. The SD with l2 norm shows better performance in comparison to SD with l2 norm/V-BLAST/ZF. The ZF, V-BLAST and SD with l2 norm show same performance.

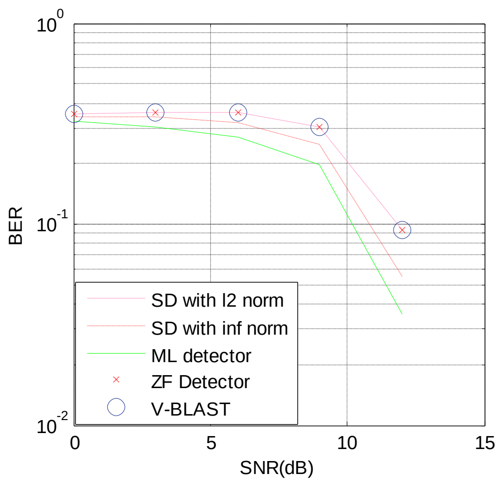

Fig.6 *Performance comparison of ML, SD with norm 2, SD with inf norm, ZF and V-BLAST for 4×4 MIMO system using 16-QAM modulation*

7. CONCLUSION

In this paper, the several MIMO detection techniques are presented. The performance of various MIMO detectors is analyzed and compared for different modulations and different antenna configurations of MIMO system in presence of AWGN. From the obtained results, it is concluded that in case of linear detectors, V-BLAST always show better performance than ZF for M-QAM (M = 4,8,16) modulations and different antenna configurations (4×4, 8×8, 16×16) of MIMO system. In case of non-linear detectors, ML shows better performance than SD for all modulations using 4×4 MIMO system. Among all detectors, ML shows the best performance for all modulations and antenna configurations.

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