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PERFORMANCE ANALYSIS OF MIMO DETECTION ALGORITHMS USING STBCs AND SIMD TECHNIQUES

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ABSTRACT

Multiple Input and Multiple Output (MIMO) is a wireless communication technology that enhances the system capacity using multiple transmitting and receiving antennas. In this system, fading and interference creates due to multipath propagation, Bit Error Rate (BER) increases and the reliability decreases. To decrease the BER and to improve the reliability, detection process is used at the receiver end to recover the original message. The main aim of this paper is to reduce the BER and to improve the reliability of MIMO system by implementing Zero Forcing (ZF) and Minimum Mean Square Error (MMSE) algorithms using MATLAB. However, the reliability of ZF and MMSE algorithm will be more through Space Time Block Codes (STBCs). At first the ZF and MMSE algorithms are implemented by using STBCs and the BER is calculated with respect to the Signal to Noise Ratio (SNR). From BER computation it is found that MMSE algorithm offers less BER than ZF algorithm in STBCs. Beyond that Single Instruction Multiple Data (SIMD) is another technique to improve the reliability. Again, ZF and MMSE algorithms are implemented in SIMD vector processor and the BER on the basis of SNR is also computed. After counting the BER it is found that MMSE algorithm offers less BER than ZF algorithm in SIMD vector processor. Moreover, performance comparison of the STBCs and SIMD vector processor is also analyzed in this research. To compare that at first ZF algorithm is implemented through both the STBCs and SIMD vector processor and the BER is computed to find out the technique which offers lower BER. From this analysis, it is found that SIMD vector processorshows less BER than STBCs. Furthermore, the MMSE algorithm is accomplished by both STBCs and SIMD vector processor and again the BER is calculated and compared to find the technique which delivers lower BER. From this comparison, it is obtained that SIMD vector processor grants higher reliability (less BER) for MMSE algorithm. So, from the above analysis it can be clearly observed that the BER is reduced and the reliability is increased through accomplishing MMSE algorithm in SIMD vector processor of MIMO system.

Keywords: BER,MIMO,MMSE, SIMD, STBCs, ZF

INTRODUCTION

Multiple-input and multiple-output (MIMO) is a method for multiplying the capacity of a radio link using multiple transmitting and receiving antennas to exploit multipath propagation. Now it has become an essential element of wireless communication standards including IEEE 802.11n (Wi-Fi), IEE 802.11ac (Wi-Fi), HSPA+ (3G), WiMAX (4G) etc. MIMO is based on Orthogonal Frequency Division Multiple Access (OFDM). The main advantages of this system are low implementation complexity, high spectral efficiency and good tolerance for inter-symbol interference (ISI) induced my multipath. But one of the

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major drawbacks of MIMO system is that it produces high BER during detection. Many research activities have already been done to recover the detection problem of this system. For example, when multiple antennas are used both at the transmitter and receiver, it provides higher data rates than single antenna systems (Nagarani and Seshaiah2011, Tarokh and Naguibandetal1999). Moreover, the AntMIMO algorithm has been optimized for the detection of MIMO systems using a 4-QAM constellation. The local search algorithm are incorporated within AntMIMO (Jaber2009). On the other hand, the detection method is done by considering a flat fading Rayleigh channel and BPSK modulation scheme. BER analysis is presented using different algorithms and then optimum equalization method is suggested but only in one environment (Malik and Batra2012,RamaKrishna and SrinivasaRao2013).However, only the performances of STBCs are analyzedin (Shah*et.al.* 2003).Furthermore, Symbol Error Rate (SER) and BER are calculated using 16-QAM, 4-PSK and 8-PSK modulation scheme by varying number of transmitting and receiving antenna(Tarokh*et.al.* 2002). So, from the above research activities, it is seen that no researcher does not give a concrete suggestion about MIMO detection algorithm that produces best result for BER reduction and improve reliability in a particular environment.
Therefore, the main aim of this thesis is to reduce the complications of MIMO systems by comparing the MIMO detection algorithms through counting the BER and suggest an environment in which the algorithms show best effectuations.

MATERIALS AND METHOD

MIMO Detection is a technique of baseband signal processing at the receiver. The detectors take received signal and estimates channel matrix as input and generates the original signal as output. At first the input signal or message is encoded and modulated. Then the modulated signal is transmitted through the antenna. Wireless channel is used as a transmission medium. The signals that are received by the receiving antenna are passed to the demodulator through the detector. The same channel matrix is used both at the transmitter and the receiver.

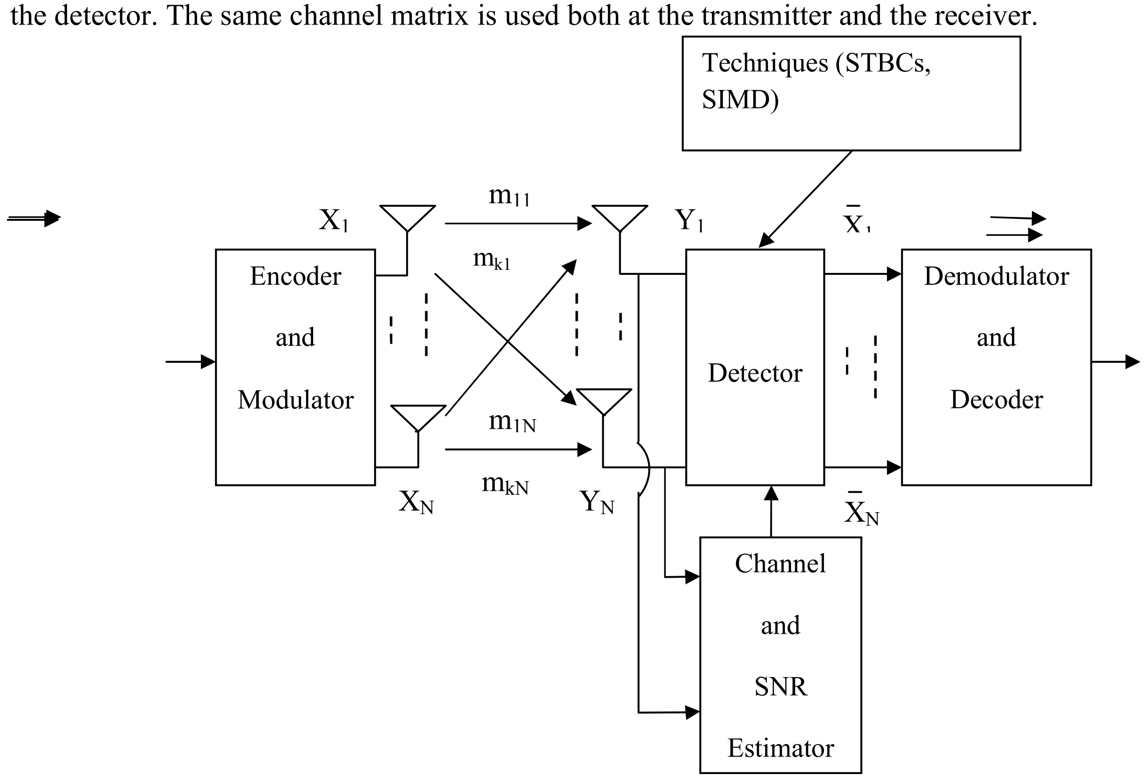

Figure 1. MIMO Detection Model

Above Figure shows the N transmit and K receive antennas. The channel matrix M is expressed as K*N orders.

$$M = \begin{bmatrix} M_{1,1} & M_{1,2} & --- & M_{1,N} \\ M_{2,1} & M_{2,2} & --- & M_{2,N} \\ - & - & ---- & - \\ M_{K,1} & M_{K,2} & --- & M_{K,N} \end{bmatrix}$$

For each subcarrier, the K×1received symbol vector yis given by

$$Y = Mx + n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Wherexis the N × 1 transmitted symbol vectorandnis the K×1additive whiteGaussiannoise vector.

1) MIMO Detection Algorithms

Several algorithms are used for MIMO detection such as Zero Forcing (ZF), Minimum Mean Square Error (MMSE), Maximum Likelihood (ML), Sphere Decoding, Successive Interference Cancellation (SIC), Parallel Interference Cancellation (PIC), Vertical Bell Labs layered space-time (V-BLAST), QR Decomposition algorithm etc. In this thesis the ZF and MMSE algorithms are implemented since they have minimum complexities and linearity.

a) Zero Forcing (ZF) Algorithm

ZF is the simplest algorithm and has the lowest computational complexity. This detector multiplies the received symbol vector by the pseudo-inverse of channel matrix (Waters 2005,Hungand Chung 2010). It removes all Inter-symbol interference but offers low performance. The zero forcing equalization matrixes is represented as follows

$$P_{ZF} = M^{+} = (M^{M}M)^{-1}M^{M} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Here M is the channel matrix and P is the equalization matrix. Since in ZF algorithm, the noise variance is not considered in some frequencies. That's why the received signal may be weak. So, sometimes it offers lower performance. Though the channel impulse response has finite length, the impulse response of the Zero forcing algorithm needs to be infinite long.

b) Minimum Mean Square Error (MMSE) Algorithm

MMSE estimator is an estimation that minimizes the mean square error (MSE). The minimum mean square error equalization matrix is represented as follows

$$P_{MMSE} = (M^{M} + \left(\frac{\sigma_n^2}{\sigma_x^2}\right) I)^{-1}M^{M} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Here σ is the noise variance. Since in MMSE, when the noise variance is declared, it reduces total power of the noise and Inter-symbol interference components in the output and offers high performance. But the computational complexity of MMSE is greater than ZF algorithm.

2) Space Time Block Coding (STBC)

Space-time block coding is a transmission technique that is used in Multiple-Input Multiple-Output (MIMO) communication systems. This channel coding technique is performed in both time and space domain. It allows signals from multiple antennas at different time periods and thus the channel fading reduces. This coding scheme can be performed on a block of symbols and present them as a matrix format at the same time. By space time block coding the MIMO communication system can achieve full data rate. Space-Time Block Codes (STBCs) was invented by Alamouti (Alamouti1998) to address the issue of decoding complexity that their predecessors, the Space-Time Trellis Codes (STTCs), presented (Tarokh *et al.* 1998). It uses linear processing and reduces decoding complexity.

3) Single Instruction Multiple Data Stream (SIMD)

The Single Instruction Multiple Data Stream (SIMD) architecture consists of a control unit (CU) and N identical processing elements (PE) (Figure 2). It is another way to implement MIMO systems. The CU is also called the instruction broadcasting unit. The PE has a memory to store data and the memory may be local or shared. But the PE does not store any instruction. It will always receive the instruction from the CU. To broadcast the instructions the CU has a queue. The queue broadcasts an instruction to all the PEs at the same time. All PEs execute simultaneously the same instruction directed to their individual local data. The CU always waits until all busy PEs are done executing the current instruction before it issues the next instruction in the queue. Thus, synchronization is implicitly performed by the CU at instruction level (Berg and Siegel 1991,Gennaro1998). It is simpler for the user to create and understand programs in SIMD mode because of the implicit synchronization and avoids overhead. Reduction of memory size and cost is possible as only one copy of instructions is stored in the system memory. Cost reduction is further achieved as just one instruction decoder is needed. Only a single program is needed to fully benefit from the potential of an SIMD multiprocessor.

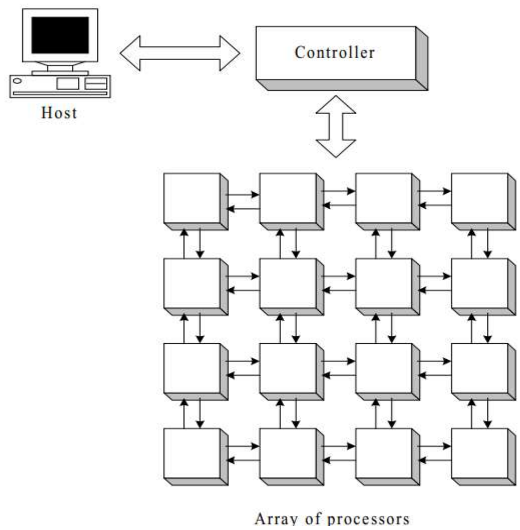

Figure 2. SIMD architecture

4) Bit Error Rate (BER)

One of the most important ways to determine the quality of a digital transmission system is to measure its Bit Error Ratio (BER). It is the percentage of bits that have errors relative to the total number of bits received in a transmission, usually expressed as ten to a negative power. For example, a transmission might have a BER of 10 to the minus 6, meaning that, out of 1,000,000 bits transmitted, one bit was in error. The BER is an indication of how often a packet or other data unit has to be retransmitted because of an error. Too high a BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data since the BER might be reduced, lowering the number of packets that had to be resent.This measured ratio is affected by many factors including: signal to noise, distortion, and jitter. So,

$$BER = \frac{N_{error}}{N_{Bits}} \qquad (4)$$

5) Signal to Noise Ratio (SNR)

In order to determine the strength of a signal it is necessary to calculate the **signal-to-noise-ratio** (SNR). The higher the ratio, the easier to detect a true signal or extract useful information from the raw signal. Thus, it is defined as the ratio of the power (P) of a signal to the power (P) of the background noise.

$$SNR = \frac{P_{Signal}}{P_{Noise}} \qquad (5)$$

The knowledge of this ratio has many important applications in applied mathematics, analytical chemistry, electronics, and the geosciences. In electronics, signal and noise are measured in **decibels**, a measure of volume.

IMPLEMENTATION AND PERFORMANCE ANALAYSIS

In this work we simulate MIMO detection process using MATLAB simulating software. MATLAB stands for matrix laboratory. It is a high-performancelanguage as well as an environment for numerical computation and visualization. It is used to solve many technical computing problems, especially those with matrix and vector formulations.The system which was used for simulation consisted of two antennas for transmitting and two antennas for receiving. The BER was measured for ZF and MMSE algorithm by using both STBCs and SIMD vector processor. The number of sending data packets was 1000 and the SNR was assumed from 15 dB to 20 dB.

Table 1. Simulation parameters

Parameters	Values
Number of Transmitting antenna	2
Number of Receiving antenna	2
OFDM CP	Normal
Channel	Additive White Gaussian Noise
Detection algorithms	ZF, MMSE
Number of symbols	1000
Modulation scheme	4 QAM
SNR	15to 20(dB)

The above parameters are used for BER analysis of STBCs, SIMD vector processor, ZF and MMSE algorithms. To analyze the performance of STBC technique, BER is calculated for MMSE and ZF which is shown in Figure 3.

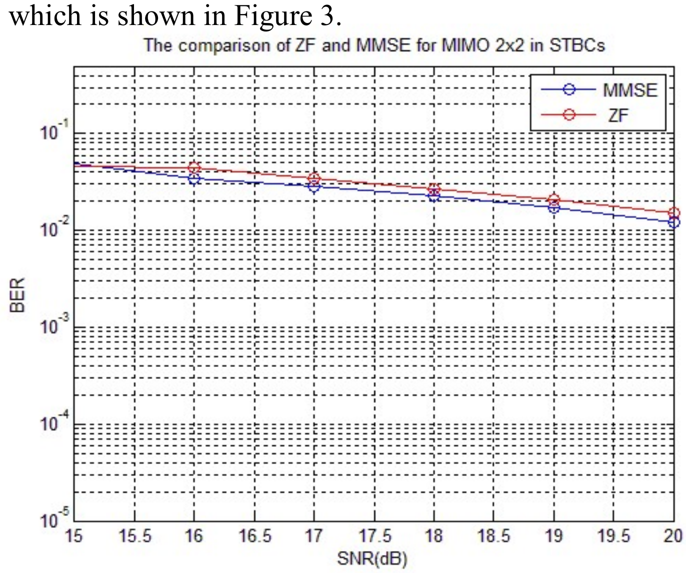

Figure 3. BER vs. SNR of ZF and MMSE algorithms for STBCs

From Figure 3 it can be seen that when the SNR is 16dB, the BER for ZF and MMSE are $10^{-1.45}$ and $10^{-1.5}$ respectively. Similarly, when the SNR is increased to 20dB the BER also reduces significantly for both ZF and MMSE algorithm. However, form the above analysis, it can be also seen that MMSE algorithm reduces the BER more efficiently than the ZF algorithm. Thus, MIMO detection through MMSE algorithmic more accurate in STBCs.The next section discusses the comparison of ZF and MMSE algorithm in SIMD vector processor.

Above figure showsSNR versus BER analysis for ZF and MMSE algorithms in SIMD vector

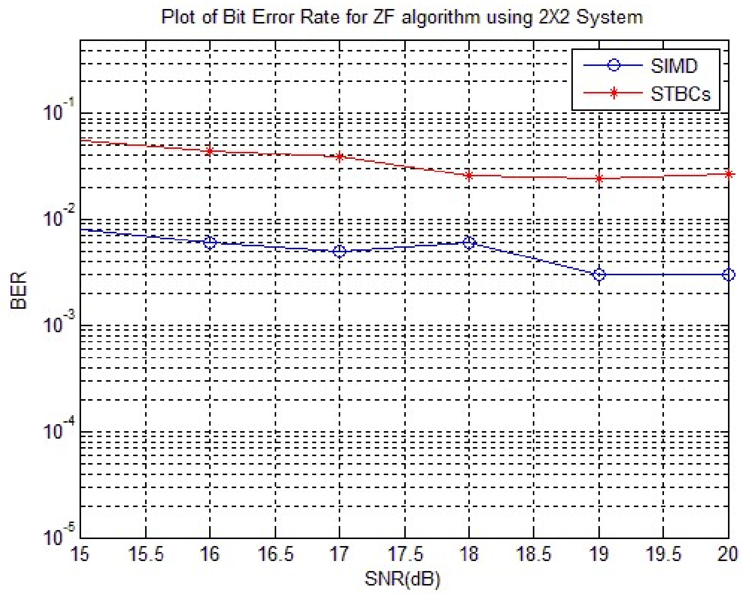

Figure 4. BER analysis of ZF and MMSE algorithms in SIMD Vector Processor

processor. From the above analysis it can be observed that at 16 dB SNR, the BER is approximately $10^{-2.2}$ and $10^{-2.5}$ respectively for ZF and MMSE algorithm. Similarly, if the SNR is increased the BER decreases for both ZF and MMSE algorithm.So, form the above figure, it can be observed that MMSE algorithm reduces BER more significantly than ZF in case of SIMD vector processor. Thus MIMO detection through MMSE is more efficient in SIMD vector processor. Now, it should be identified that which technique produces better result among STBCs and SIMD vector processor for reliability analysis. That's why in the next section, BER is analyzed and compared forSTBCs and SIMD vector processor.

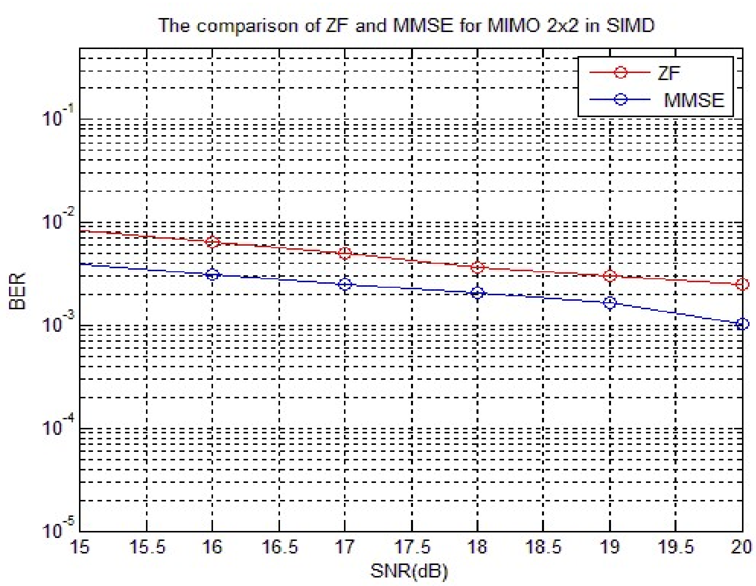

Figure 5. BER computation of ZF algorithm for STBCs and SIMD Vector processor

Figure5 shows Comparison of STBCs and SIMD Vector processor in terms of BER Calculation for ZF algorithm. From this figure, it can be seen that the BER of STBCs at 17dB is about $10^{-1.4}$and $10^{-1.7}$ at 19 dB. On the other hand, in SIMD vector processor the BER is near to $10^{-2.3}$ at 17dB and $10^{-2.5}$ at 19 dB. So, it can be concluded that the BER in SIMD is lower than STBCs. That's why SIMD vector processor has better performance and preferable environment than STMCs for MIMO Detection. The next section describes and compares the performance of SIMD vector processor and STBC's for MMSE algorithm.

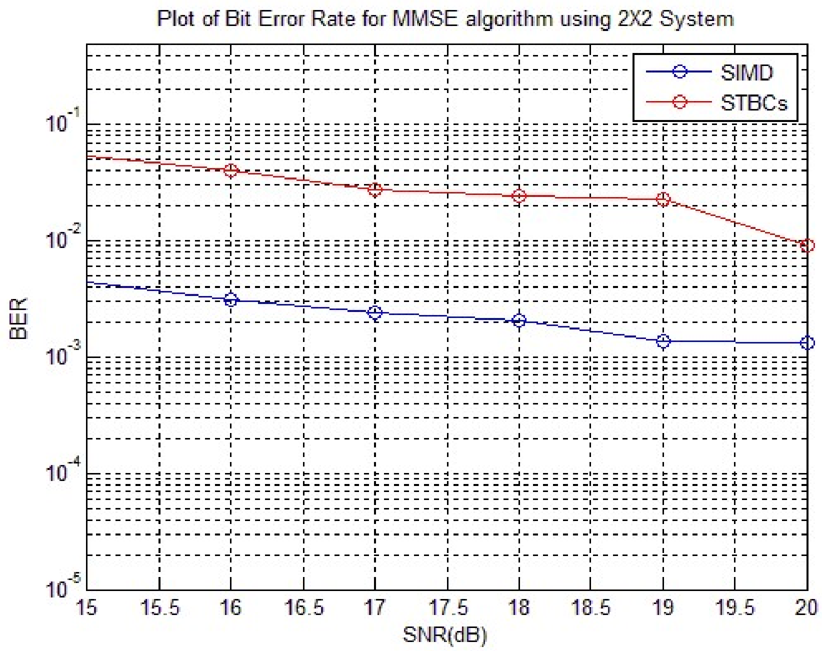

Figure 6. Performance measurement of MMSE algorithm for STBCs and SIMD Vector processor

Figure 6 compares between STBCs and SIMD vector processor by computing the BER for MMSE algorithm. From this figure it can be seen that when the SNR is increased the BER reduces gradually for both SIMD vector processor and STBC's. When SNR is 16dB, the BER for STBC and SIMD vector processor are $10^{-1.3}$ and $10^{-2.5}$ respectively. Thus, from this analysis it can be seen that SIMD vector processor has low BER then STBCs for MMSE algorithm. So MIMO Detection process was more appropriate through SIMD vector processor.

CONCLUSIONS

This paperimplements and computes the BER for ZF as well asMMSE algorithmthrough both STBCs and SIMD vector processor. From the simulation results, it can be concluded that MMSE algorithm reduces BER more efficiently than ZF algorithm for both STBCs and SIMD vector processor. On the other hand, the BER with respect to SNR is also analyzed and compared in order to find out which technique betweenSTBCs and SIMD Vector processor produces better result for BER reduction in case of ZF and MMSE algorithm. From this analysis it can be observed that SIMD vector processor produces best result for BER reduction both for ZF and MMSE algorithm. Finally, it can beconcluded that MIMO detection through MMSE algorithm in SIMD vector processor is more accurate and reliable.

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