Simulative Investigations on Three Different Multi Input Multi Output Signal Detection Techniques

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***Abstract*—**Now a days, the demand for wireless communication is increasing dramatically across the world. but as the radio spectrum is limited hence the only solutionis to increase the data rates to accommodate more users. These data rates can be achieved only by designing more efficient signaling techniques.Multiple Input Multiple Output (MIMO) technology is one of the most promising wireless technologies that can efficiently boost the data transmission rate, improve system coverage, and enhance link reliability. Higher data rate can be achieved by designing more efficient signaling techniques. MIMO techniques enable a new dimension called the spatial dimension (SM-MIMO). Inter Symbol Interference (ISI) is the major problem in MIMO system. Various MIMO detection algorithms have been proposed in literature to exploit the gains provided by MIMO. By employing multiple antennas at transmitter and receiver sides, MIMO techniques enable a new dimension called the spatial dimension that can be utilized in different ways to combat the impairments of wireless channels, but Inter Symbol Interference (ISI) is the main problem. To reduce ISI there are different detection techniques used. Detection is a well known technique for combating inter symbol interferenceThis paper will focus three different types of detection techniques like Zero forcing (ZF), Fixed Zero forcing (Fixed ZF), Lattice reduction (LR). These detectors are compared and analyzed for different Signal Error Rate (SER) v/s Signal to Noise Ratio (SNR) in spatial multiplexing domain. A simulation results shows that Lattice reduction detectors have better performance in terms of BERand SER.

Keywords*-Inter symbol Interference (ISI), Multiple Input Multiple Output (MIMO), Spatial Multiplexing, Signal Detection, Lattice Reduction (LR), and Zero Forcing (ZF)*

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I. INTRODUCTION

Using MIMO technology either the data rate can be increased or SER can be reduced. If we want to increase the data rates spatial multiplexing technique should be used. If different propagation paths can be resolved by multiple antennas then independent data can be transferred through each propagation path at same frequency, and the data rate can be increased. In this technique, different information signals are sent by different transmitters. To reduce the SER, diversity technique is used in which the same information signal is sent from all the transmitters. Demands for capacity in wireless communications, driven by Cellular mobile, Internet and Multimedia services have been rapidly increasing worldwide. On the other hand available radio spectrum is limited and the communication capacity needs cannot be met without a significant increase in communication spectral efficiency. Advances in coding, such as Turbo codes, Low density parity check codes and Space time codes [1], [2] made it feasible to approach the Shannon capacity limit in system with a single antenna link. Significant further advances in spectral efficiency are available though increasing the number of antennas at both transmitter and the receiver which is as MIMO technology. It being one of new forms of smart antenna technology.MIMO,now a day considered in newwirelesstechnology,as it offers high increase in data andlink range without extra bandwidth or transmit power. It is achieved by higher spectral efficiency (more bits per second per hertz of bandwidth) and link reliability or diversity (reduced fading) [3]. Because of these properties, MIMO is an important part of modern wireless communication system. Spatially distributed channels can be supported simultaneously in the same frequency band by using multiple antennas at both the transmitter and the receiver, and by transmitting data in parallel through these channels the data rate can be increased [4]. Such systems are capable of greatly increasing the spectral efficiency over traditional single channel systems by deployed in a rich scattering environment. The capacity of the flat MIMO Rayleigh fading channel associated with a system with N transmit antennas and M ≥Nreceive antennas is given as

$$C = \log_2(\det[I_M + \rho HH])\text{bit/sec/Hz}(1)$$

Where I_M is the $M \times N$ identity matrix,His the $M \times N$ matrix whose elements $\{h_{mn}\}$ represent the channel gains between pairs of transmit and receive antennas, and ρ is SNR. The achievable data rate depends on the rank of H. For large SNR and large N and M, the capacity tends to the value $r \log_2 \rho$, where $r = \text{rank}(H)$. When the elements ofHare identically distributed and independent, the rank $r = H$. Hence, in this ideal scenario of independent fading, the data rate grows linearly with the number of transmit antennas. Ideally, the Mreceive antennas can provide M_{th} order diversity reception for each of the N transmitted signals in addition to whatever implicit diversity the channel has to offer. Since there is no orthogonal structure imposed on the signals by the transmitter and the received signals contain inter channel interference. The receiver must therefore be able to separate the N signals and at the same time take advantage of the inherent signal diversity. The rule of thumb is that in order to ensure independent fading, the antennas have to be separated by at least half a wavelength at the receiver and as much as several wavelengths at an elevated transmitting base station. In this paper, we will discuss the performance of three detectors named as ZF, Fixed ZF and Lattic reduction detection method. We would focus our discussion to the experimental results carried out to MIMO systems and then try to analyze which of the detectors have a better performance in terms of SER for a given SNR.

II. *MIMO SYSTEM MODELS*

A. ZF Signal Detection techniques

In communication system, ZF Equalizer is a linear equalization algorithm, which inverts the frequency response of channel, and it was proposed by Robert Lucky. For restore the signal before the channel, ZF Equalizer uses the inverse of channel to the received signal. This algorithm is named as Zero Forcing, because it achieves zero ISI. This algorithm is widely used in such cases in which ISI is more predominant as compare to noise [5]. Frequency response of ZF is represented as

$$C(f) = 1/F(f) \quad (2)$$

Let Consider a 2×2 MIMO channel, and Pseudo inverse for a general$m \times n$ matrix and is represented as

$$H^H H = \begin{bmatrix} h_{1,1}^* & h_{2,1}^* \\ h_{1,2}^* & h_{2,2}^* \end{bmatrix} \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix} \quad (3)$$

ZF technique nullifies the interference by the following weight matrix

$$W_{ZF} = (H^H H)^{-1} H^H \quad (4)$$

In ZF algorithm, the error performance is directly connected to the power of $(\bar{z}_{ZF})$, which is represented by Frobenius Norms of channel. Similarly the post detection noise power can be evaluated by using the concept of Singular Value Decomposition (SVD) such as

$$\begin{aligned} \|\bar{Z}_{ZF}\|_2^2 &= \|(H^H H)^{-1} H^H z\|^2 \\ &= \|(V \in^2 V^H)^{-1} V \in U^H z\|^2 \\ &= \|(V \in^{-2} V^H) V \in U^H z\|^2 \quad (5) \end{aligned}$$

The final result of ZF is represented by using following expression as

$$E\{\|\bar{Z}_{ZF}\|_2^2\} = \sum_{i=1}^{N_T} \frac{\sigma_Z^2}{\sigma_i^2} \quad (6)$$

B. Fixed ZF Detection technique

Before applying LLL reduction or fixed ZF detection technique, it is necessary to transform QR decomposition of channel matrix, which can be obtained by Gram-Schmidt orthogonalization by using following equation (7):

$$H = \tilde{Q}\tilde{R} \quad (7)$$

Where $\tilde{Q} \in R^{K\times N}$ is a unitary matrix and$\tilde{R} \in R^{N\times N}$ is an upper triangular matrix.

In order to obtain more orthogonal basis of channel matrix, we can also further transform the upper triangular matrix by satisfying the below two conditions:

$$|\tilde{R}_{k,l}| \le 1/2 \, |\tilde{R}_{l,l}| \quad (8)$$

$$\delta \, |\tilde{R}_{k-1,k-1}|^2 \le |\tilde{R}_{k,l}|^2 + |\tilde{R}_{k-1,k}|^2 \quad (9)$$

In above equation (9) δ is a basic parameter. By reducing or maximization of diagonal matrix, these equations can also be used to reduce the lower triangular matrix.

Above algorithms repeats all the above conditions until satisfying the equation (9).

C. LR detection technique

LR detector has recently emerged as a low-complexity strategy for performing hard output detection for MIMO channels with QAM inputs. The basic idea behind LR detectors is to perform detection using a reduced lattice basis instead of the original lattice basis. Due to a better conditioned channel matrix, such detection technique has better performance$\tilde{H}$. It is also noted that by applying LR, the MIMO detection equation becomes,

$$\hat{x} = \arg\min \|\tilde{z} - \tilde{R}x\|^2 \quad (10)$$

The idea behind, is to reduce their correlation and make the decision regions closer to that of the ideal regions of the ML detector, LR uses the orthogonal zing of the basis vectors of the estimated channel matrix. In figure, basis vectors and decision regions before and after LR reduction are shown for a 2×2 case.

It is concluded that, the decision regions generated by the orthogonal basis vectors are more noise resist as compare to those decision regions which is generated by non-orthogonal basis vectors. It is also important to note that the process of LR detector does not affect the transmitter side in any way. LR is essentially a re-interpretation of the transmitted signal (x instead of s) which is based on the new lattice-reduced channel matrix on the receiver end.

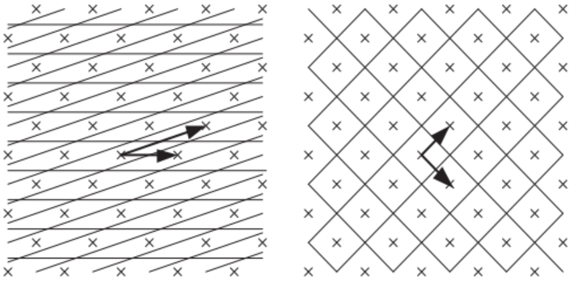

Figure 1: Generated Decision Regions (a) before LR and (b) after LR

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Through more orthogonal basis vectors, LR matrix is used to improve detection quality. However, the detected symbol is x, and by re-transforming it into s (by multiplying it by T), the re-interpretation made earlier is cancelled out. This process is shown in figure 2.

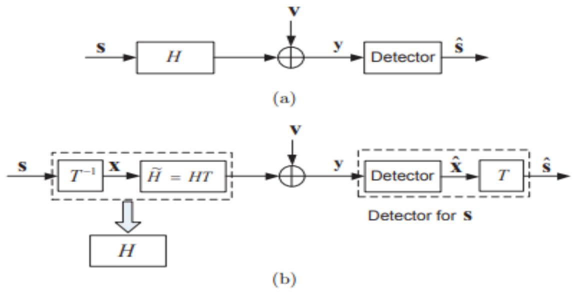

Figure 2: MIMO System Model (a) without LR, (b) with LR

III. SIMULATION RESULTS

In this paper, 4×4, 8×8, 12×12, 16×16 and 20×20,MIMO system are analyzed and compared under AWGN and flat fading Rayleigh channel. It is concluded that large value of SER indicates low quality communication while large value of SNR indicates better communication. Table 1.shows simulation parameters for the required system.

A. SIMULATION SETUP FOR MIMODETECTOR

TABLE 1

SIMULATION PARAMETERS

Number of transmit antennas (N_{TX})	4,8,12,16,20
Number of receive antennas(N_{RX})	4,8,12,16,20
Noise	Gaussian Noise
Channel	AWGN channel and Rayleigh fading channel
Signal to Noise Ratio(SNR)dB	0-40
Modulation	Binary phase-shift keying (BPSK)
Detectors	ZF, LR and Fixed ZF

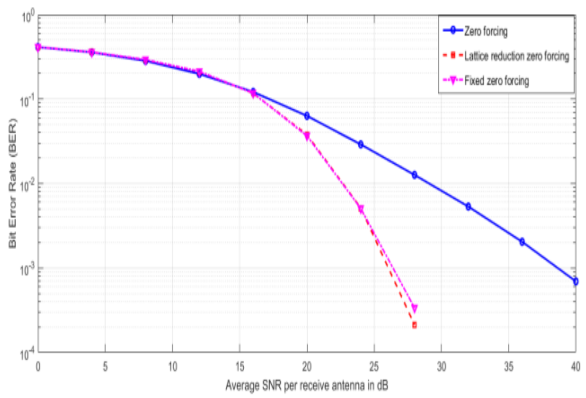

Figure 3: Comparison of various MIMO detectors in 4×4 MIMO system with BPSK modulation

B. RESULTS

Figure 3 shows the comparison of SNR and SER of various MIMO detectors in4×4 MIMO system with 4 transmitting and 4 receiving antennaand shows that ZF achieve better SER i.e. 0.0006938 at higher value of SER i.e. 40.

Figure 4.shows the comparison of SNR and SER of various MIMO detectors in 8×8 MIMO system with 8 transmitting and 8 receiving antenna and concluded that ZF achieve better SER i.e. 0.004359 at higher value of SER i.e. 40.

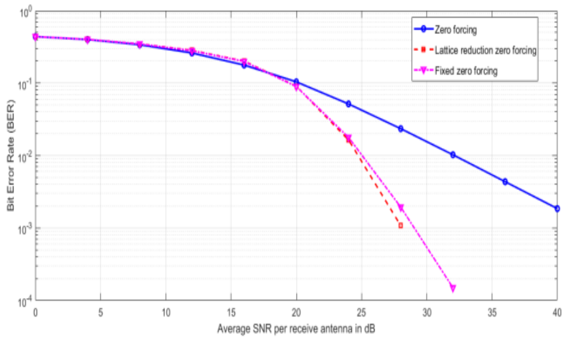

Figure 4: Comparison of various MIMO detectors in 8×8 MIMO system with BPSK modulation

Figure 5 shows the comparison of SNR and SER of various MIMO detectors in 12×12 MIMO system with 12 transmitting and 8 receiving antenna and concluded that ZF achieve better SER i.e. 0.002729 at higher value of SER i.e. 40.

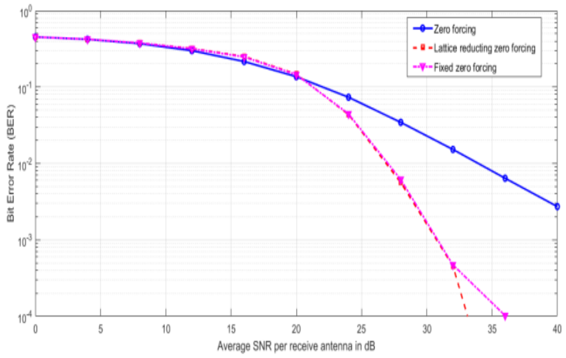

Figure 5: Comparison of various MIMO detectors in 12×12 MIMO system with BPSK modulation

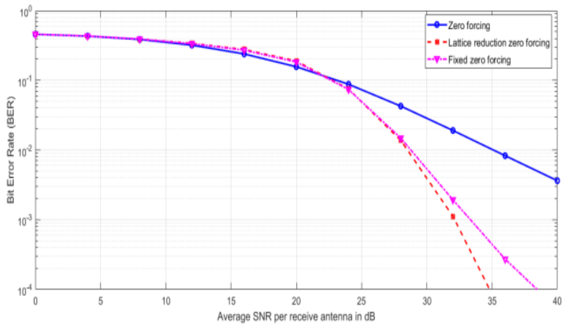

Figure 6:Comparison of various MIMO detectors in 16×16 MIMO system with BPSK modulation

Figure 6 shows the comparison of SNR and SER of various MIMO detectors in 16×16 MIMO system with 16 transmitting and 16 receiving antenna and shows that FixedZF achieved better SER i.e. 0.00418 at higher value of SER i.e. 40.

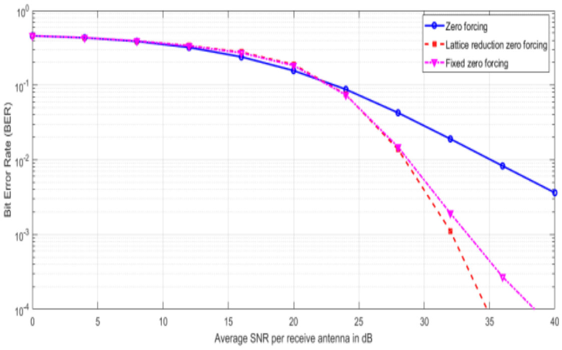

Figure 7:Comparison of various MIMO detectors in 8×8 MIMO system with BPSK modulation

Figure 7 shows the comparison of SNR and SER of various MIMO detectors in 20×20 MIMO system with 20 transmitting and 20 receiving antenna.shows the comparison of various signal detectors with aspects of SNR and SER and shows that Fixed ZF achieved better SER i.e. 0.00418 at higher value of SER i.e. 40.

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IV. CONCLUSION

Since increasing the bandwidth of a communication system is rarely an option due to physical or legal constraints, future communication systems must use the available spectrum more efficiently in order to increase throughput. In wireless communications spectral efficiency can be increased by using multiple transmit and receive antennas. However, while the capacity of these MIMO channels increases linearly with the number of antennas, the complexity of detection increases exponentially. The practical implication of this is that receivers require vastly more computational power in MIMO systems. Suboptimal detectors can be used to reduce the complexity of the receiver, but they perform worse since they require more transmit power to successfully communicate than the optimal detector. In this thesis, we have proposed MIMO detection strategies and algorithms that can be used to manage the performance complexity trade-off for MIMO channels.In this paper,three detectors named as ZF, Fixed ZF and LR detector are compared and analyzed for different SER v/s SNR in SM. In this thesis, $4 \times 4, 8 \times 8, 12 \times 12, 16 \times 16, 20 \times 20$ MIMO system analyzed with different detection schemes under AWGN and flat fading. Simulation results shows that LR detectors have better performance in terms of BER and SER.

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