



MIMO CONFIGURATION SCHEME WITH SPATIAL MULTIPLEXING AND QPSK MODULATION

Yasir Bilal¹, Asif Tyagi², Javed Ashraf³

¹Research Scholar, ²Assistant Professor, ³Associate Professor,
Department of Electronics & Communication Engineering,
Al-Falah School of Engineering and Technology, Faridabad, (India)

ABSTRACT

Multiple Input Multiple Output is an emerging technology that can greatly increase the capacity of a channel without supplementary spectral resources. The only challenge is to get the output of transmitted signal with low complexity and high performance and it can be achieved using optimal designing of detecting algorithm. In this paper, Several MIMO Spatial Multiplexing detectors have been introduced and analyzed the result in terms of bit error rate. There are several schemes that can be applied to MIMO such as Space Time Trellis Codes, Space Time Block Codes, Vertical Bell Labs Space - Time architecture (VBLAST) and Spatial Multiplexing technique. The main aim of this paper is to propose a signal detector scheme called MIMO detectors in order to increase the MIMO channel performance. We investigate the MIMO system, spatial multiplexing scheme with Maximum Likelihood (ML) Detection, Zero Forcing (ZF) Detection and Minimum Mean Square Error (MMSE) detection and imitate this structure in Rayleigh Fading Channel. We also compare the performance of different MIMO systems with QPSK Modulation in fading channels. Different characteristics and aspects have been discussed and considered in this evaluation like signal to noise ratio (SNR), bit error rate (BER) and the number of transmit and receive antennas. We compare the performances of SISO with MIMO and as well as compare the performance among different MIMO sizes and graphs have been generated using MATLAB. It has been found that ML receiver seems to have the optimum BER performance, Spatial Multiplexing achieves bit error rates close to the ML scheme while retaining the low-complexity. Also we analyzed from the simulation that spatial multiplexing performs in a similar way as Bell Labs Space - Time (BLAST) algorithm.

Keywords: MIMO, Spatial Multiplexing, ML, MMSE and ZF.

I. INTRODUCTION

It is well known that wireless communication networks can dramatically improve their throughput and robustness by using MIMO at both the transmitter and receiver side in order to meet rapidly growing requirement for broadband such as high quality audio and video. The existing wireless communication technologies cannot support broadband data rates in an efficient way because of their sensitivity to fading. MIMO wireless systems are motivated by two ultimate goals of wireless communication- viz high data rate and high performance [1], [2]. MIMO systems are illustrated in figure 1.

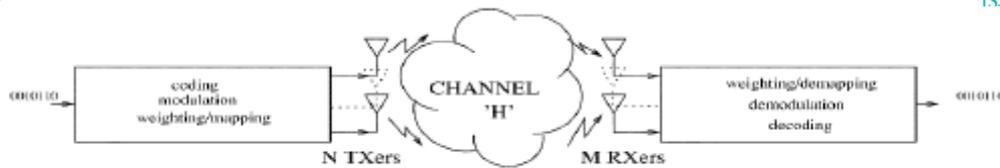


Figure1: Diagram of MIMO Wireless Transmission System.

Transmitter and Receiver are Equipped with Multiple Antennas

There are three categories of MIMO techniques. The first one aims to enhance the reliability of a system by decreasing fading effect through multiple spatial paths. Such techniques include STBC and STTC. The second class aims to enhance the capacity by using layered approach. The example of this system suggested by Foschini et al [3] is V- BLAST. Finally the third one probes the knowledge of the channel at transmitter. It decomposes the channel coefficient matrix using SVD and uses these decomposed unitary matrices as pre- and post-filters at the transmitter and the receiver to achieve near capacity [4]. Among them V-BLAST is mostly widely adopted as it has low complexity and high spectral efficiency [5]. When maximum likelihood detector is utilised, V-BLAST system experience receive diversity but the decoding complexity is enhanced by the number of transmit antennas. However, some near-ML schemes like Sphere-coding (SC) and semi -definite programming (SDP) can be used to minimize the decoding complexity at low signal to noise ratio. When a large number of antennas are introduced or high signal constellations are used, complexity of near -ML scheme might be still high. Some suboptimal detectors have been elaborated, e.g., successive interference cancellations (SIC), decision feedback equalizer (DFE), which are unable to collect receive diversity [6]. To further reduce the complexity, one can use linear detectors like zero forcing, minimum mean square Error and maximum likelihood equalizers.

II. SPATIAL MULTIPLEXING

The Spatial Multiplexing can be understood by the concept of MIMO antenna configuration. In this process, we divide the high data rate signal into multiple low data rate streams and each stream is transmitted from a different transmitting antenna. These signals arrive at receiver antenna array with different spatial signatures. The receiver then separates these streams into a parallel channel, thus improving the capacity. Thus we can say that Spatial Multiplexing is a very strong technique for increasing channel capacity at higher SNR values.

The maximum number of spatial streams can be limited by the lesser number of antennas at the transmitter or receiver side. Spatial multiplexing can be used with or without transmit channel knowledge. The concept of spatial multiplexing has been described in figure 2

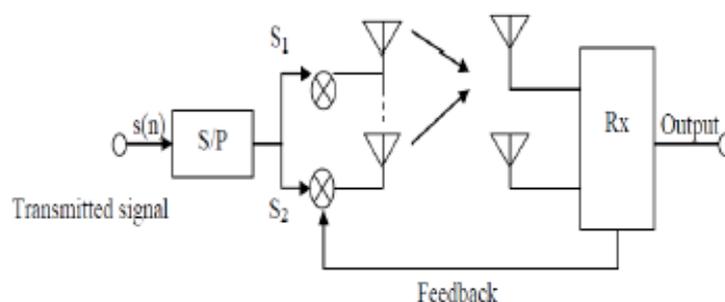


Figure 2: Spatial Multiplexing Concept

Channel can be defined as a transmission medium between transmitter and receiver. It can be wired or wireless. In wired transmission we use some medium like coaxial cable, twisted pair cable or optical fiber and transmission is smooth as compared with wireless transmission because received signal is not directly coming from transmitter but the combination of reflected, diffracted, and scattered copies of the transmitted signal. These signals are called multipath components. Rayleigh fading channel can be taken into consideration for the analysis.

3.1 Rayleigh Fading Channel

Rayleigh Fading is an acceptable model if there are so many objects in the air that scatter the radio signal before it arrives at the receiver. For sufficiently much scattered case, the central limit theorem expresses that the channel impulse response will be well-modelled as a Gaussian process irrespective of the distribution of individual components. If there will be no dominant component to the scatter, then such a process will have zero mean and evenly distributed phase between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed. Calling this Random Variable R, the density function will have

$$P_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}, r \geq 0$$

Where $\Omega = E(R^2)$.

The gain and phase elements of channel's distortion are often conveniently represented as a complex number. Rayleigh fading is displayed by an assumption that the real and imaginary parts of the response are modeled by independent and identically distributed zero-mean Gaussian processes so that the amplitude of the response is the sum of two such processes.

IV. MODULATION TECHNIQUE

Modulation may be defined as the process of mapping the digital information into analog information in order to transmit it over the channel. In Modulation, a binary signal changes binary bits into analog waveform.

Modulation can be done either by changing the amplitude, phase or frequency of sinusoidal carrier. Every digital communication system has its unique modulator that is responsible for this task. There are several digital modulation techniques used for data transmission.

4.1 Quadrature Phase Shift Keying

The most widely used modulation technique in Wireless Communication is QPSK that use four points in constellation diagram equispaced around a circle. With four phases, QPSK can encode two bits per symbol as shown in figure 3 with gray coding to minimize BER.

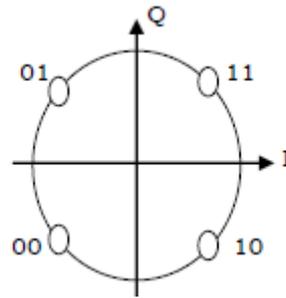


Figure 3: QPSK Constellation Diagram

Quadrature phase shift keying is actually a form of PSK in which simultaneously two bits are modulated by selecting one of four possible carrier phase shifts (0, $\pi/2$, π , and $3\pi/2$). QPSK perform by changing the phase of the In-phase (I) carrier from 0° to 180° and the Quadrature-phase (Q) carrier between 90° and 270° . This is used to indicate the four states of a 2-bit binary code. Each state of these carriers is referred to as a Symbol. As it has four states so it is a more bandwidth-efficient type of modulation than BPSK, possibly twice as efficient.

V. DETECTION SCHEMES

There are several detection schemes present with combination of linear and nonlinear detectors. The most common techniques are ZF, MMSE and ML detection techniques. The generalized block diagram for MIMO Detection techniques is shown in figure 4.

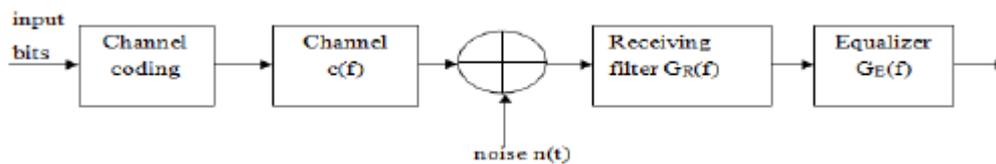


Figure 4: Block Diagram of System with Equalizer

5.1 Zero Forcing (ZF) Detection

Zero forcing refers to a form of linear equalization algorithm used in the communication system. It inverts the frequency response of the received signal, this inverse is taken for the restoration of signal after the channel. Robert lucky proposed the concept of zero forcing equalizer. The estimation of strongest transmitted signal is obtained by nulling out the weaker transmit signal. The strongest signal has been subtracted from received signal and proceeds to decode strong signal from the remaining transmitted signal. ZF Detector ignores the additive noise and may outstandingly amplify noise for the channel. It has many applications. For example it is being studied for 802.11n (MIMO). The ZF equalizer is given by

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

Where W_{ZF} is the equalization matrix and H is the channel matrix. Assuming $M_R \geq M_T$ and H has full rank, the result of ZF equalization before quantization is written

$$Y_{ZF} = (H^H H)^{-1} H^H y$$

5.2 Minimum Mean Square Error (MMSE) Detection

Minimum mean square error equalizer minimizes the mean –square error between the output of the equalizer and the transmitted symbol, which is a stochastic gradient algorithm with low complexity. The MMS Equalization is

$$W_{MMSE} = \arg \min_{G} E_{x,n} [\|x - \hat{x}\|^2]$$

Where W_{MMSE} is equalization matrix, H channel correlated matrix and n is channel noise

$$Y_{MMSE} = H^H (HH^H + n_o I_n)^{-1} y$$

5.3 Maximum Likelihood (ML) Detection

The idea is to assume a particular model with unknown parameters; we can then define the probability of observing a given event conditional on a particular set of parameters. We have observed a set of outcomes in the real world. It is then possible to choose a set of parameters which are most likely to have produced the observed results. This is maximum likelihood. In most cases it is both consistent and efficient. It provides a standard to compare other estimation techniques.

Consider a sample (X_1, \dots, X_n) which is drawn from a probability distribution $P(X|A)$ where A are parameters. If the X s are independent with probability density function $P(X_i|A)$ the joint probability of the whole set is

$$P(X_1, \dots, X_n | A) = \prod_{i=1}^n P(X_i | A)$$

This may be maximised with respect to A to give the maximum likelihood estimates.

VI. COMPARISON OF RESULTS

6.1 SISO with QPSK

If we analyse the performance of single input with single output antenna scheme with ZF, MMSE and ML, it is crystal clear that all detectors perform in the same way therefore the resources of the receiver are completely utilized or consumed by all the cast of high power and with high complexity. To better understand the cocept let us look at the figure 5.

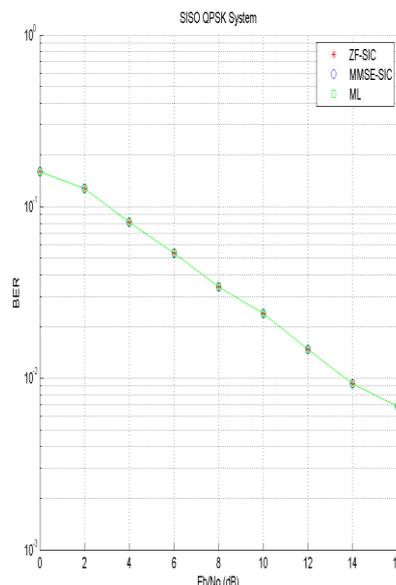


Figure 5: SISO with QPSK

6.2 MIMO with QPSK

The improvement can be seen in the above result if we consider the 2x2, 3x3 and 4x4 MIMO scheme with QPSK. Here MLSE performs better in comparison with the other considered approaches as shown in figure 6, 7 and 8.

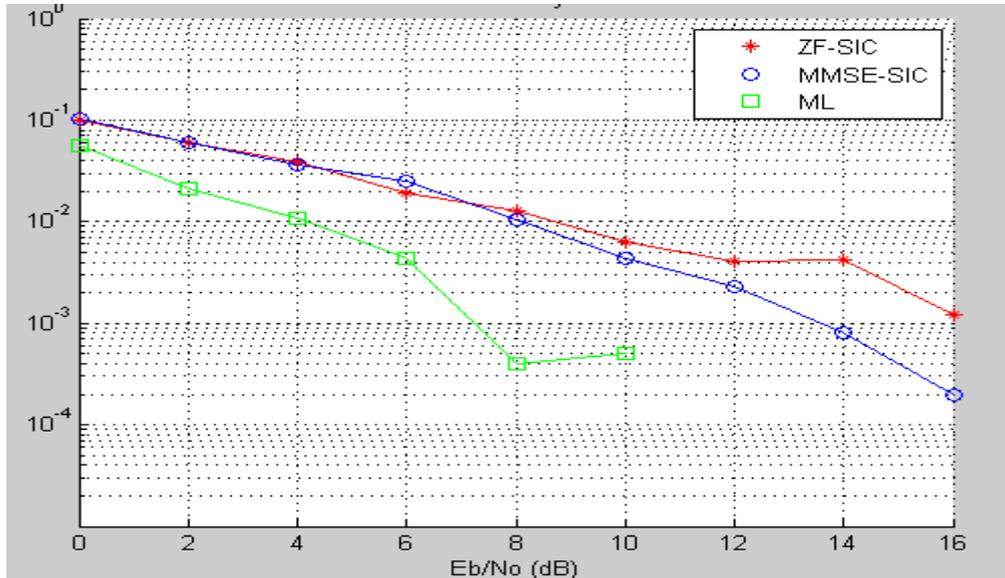


Figure 6: 2x2 MISO with ZF, MMSE, and ML with QPSK.

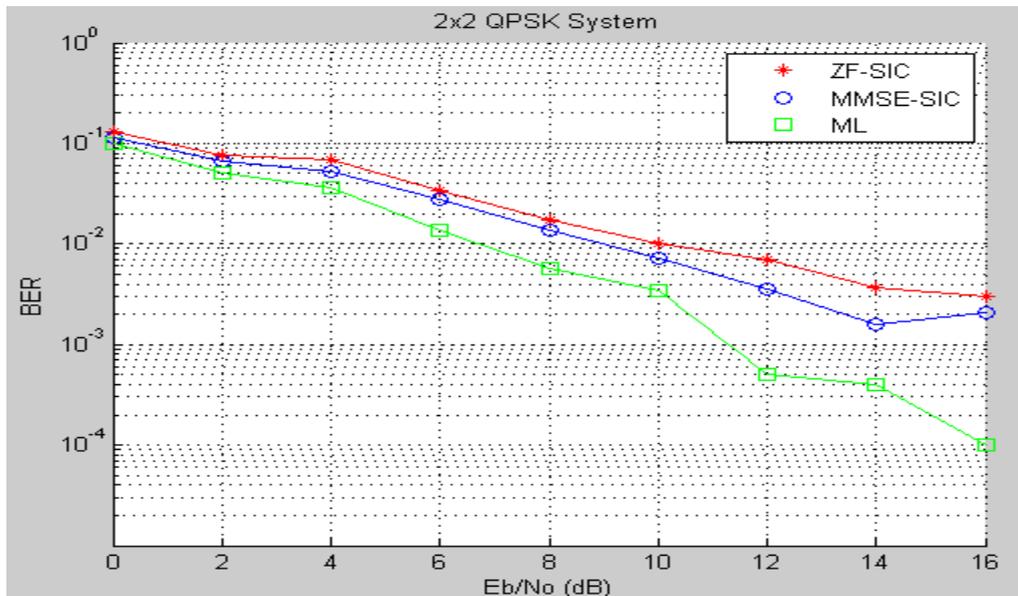


Figure 7: 3x3 MIMO with ZF, MMSE and ML with QPSK

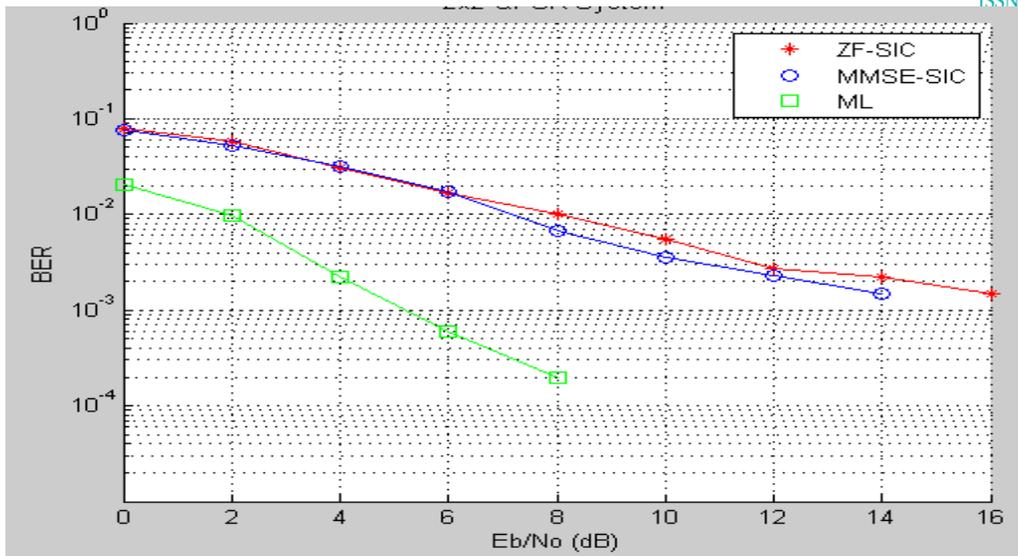


Figure 8: 4x4 MIMO with ZF, MMSE and ML with QPSK

VII. DISCUSSION ON RESULTS

Let us look at the capacity of the multiple inputs and multiple output antennas considered in transmitters and receivers. If we increase the size of MIMO like 2x2, 3x3, 4x4 etc. then the capacity of the MIMO is increased with the size as shown in figure 9. No doubt that performance is also increased dramatically as we increase the number MIMO size but when we see the simulation result, we find that capacity of 4x4 MIMO is high but at the same time it needs a high simulation time and it has got more complexity, more power consumptions than 2x2 and 3x3 MIMO. Therefore we prefer such BER combination that has got less simulation time, less complexity and less power consumptions. Based on this fact, we select the suitable combination to recover and equalizer our data.

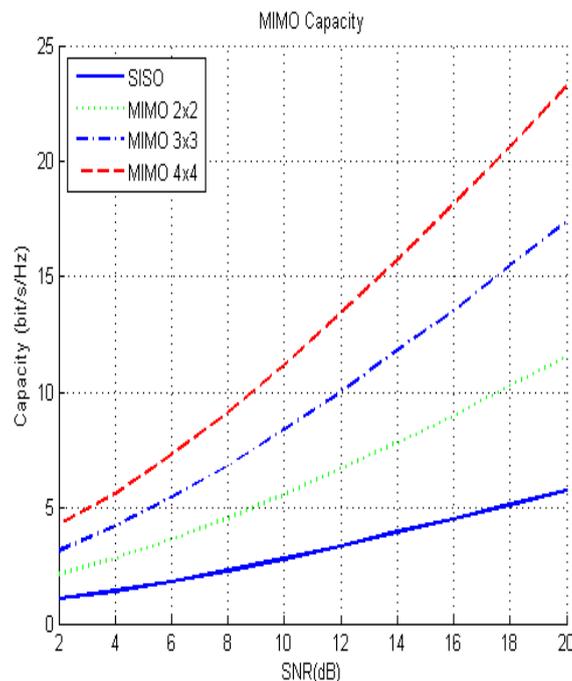


Figure 9: capacity of SISO and Different MIMO Sizes

VIII. CONCLUSION

We analyzed the performance of linear detectors for MIMO Spatial Multiplexing systems in Rayleigh fading channel and AWGN channel for QPSK modulation, which exhibited the best trade-off between performance and complexity among Spatial Multiplexing techniques. We show that conventional linear equalizers can only collect diversity $N_r - N_t + 1$ for MIMO systems though they have very low complexity. By investigating and simulating each receiver concepts, if Spatial Multiplexing implements a detection technique, i.e. MMSE receiver and optimal ordering to improve the performance, although ML receiver appears to have the best BER performance.

IX. FUTURE SCOPE

The MIMO principle is based on a Rayleigh multipath environment. So finally we proposed that ML detector for MIMO-Spatial fading model with QPSK modulation is the ultimate optimization technique in the next generation broadband communication system.

REFERENCES

- [1] G. J. Foschini and M. J. Gans, "On limits of wireless communications in fading environment when using multiple antennas," *Wireless Personal Commun.* vol. 6, pp.311-335, Mar. 1998.
- [2] V. Tarokh, N. Seshadri, and A. R. Calderbank, "Space-time codes for high data rate wireless Communication: Performance criterion and code construction," *IEEE Trans. Inf. Theory*, vol. 44, no. 2, pp. 744-765, Mar. 1998
- [3] P. W. Wolniansky, G. J. Foschini, G. D. Golden and R. A. Valenzuela, "V-BLAST: an architecture for realizing very high data rates over the rich-scattering wireless channel," *In Proceeding of International symposium on Signals, Systems Electronics*, pp. 259-300, October 1998.
- [4] J. Ha, A. N. Mody, J. H. Sung, J. Barry, S. McLaughlin and G. L. Stuber, "LDPC coded OFDM with Alamouti/SVD diversity technique," *IEEE Journal on Wireless Personal Communication*, Vol. 23 ,Issue 1, pp. 183-194, Oct. 2002.
- [5] G. D. Golden, G. J. Foschini, R. A. Valenzuela, and P. W. Wolniansky, "Detection algorithm and initial laboratory results using V-BLAST spacetime communication architecture," *Electron. Lett.* vol. 35, no. 1, pp. 14-16, Jan. 7, 1999.
- [6] D. Tse and P. Viswanath, *Fundamentals of Wireless Communications*. Cambridge, 2005.