

# BER Analysis of MIMO System Detection Using Rayleigh Channel

Swetamadhab Mahanta, Sakshi Tiwari, Ramesh Bharti

**Abstract**— MIMO plays an important role in today's 4G wireless system. MIMO has opened the doors to a diversity of new applications and facilitated more cost effective implementation of existing applications by magically multiplying spectral efficiency. This dissertation gives an analytical examining of signal detection by the use of SIC (Successive Interference Canceller) with Zero Forcing (ZF), ML, MMSE, and QR decomposition for 64-QAM modulation schemes with the help of Rayleigh fading channel with the various combinations of transmitting and receiving antennas. Here, it is concluded that for 64-QAM scheme, ML is the best detection scheme as it is giving low value of Bit Error Rate (BER) for different values of Signal to Noise Ratio (SNR). Apart from that, as the no of antenna is increasing at the receiver end, i.e. for receive diversity, the Bit Error Rate (BER) is reducing drastically. Here, the numerical analysis is done by using MATLAB R2010a.

**Index Terms** — MIMO systems, SIC, ZF, MMSE, QR Decomposition, QAM.

## I. INTRODUCTION

Multiple input-multiple outputs (MIMO) work as a multiple antenna system. The MIMO technology stands out to be excellent in utilizing multiple signals which are received from the wireless medium. This has effectively improvised wireless channel operation. As MIMO transmission employs numerous antennas at both ends of the communication link; it fallouts to be a tremendously spectrum-efficient technology.

In 1896, Guglielmo Marconi [1] was the first one who illustrated non-line-of-sight (NLOS) wireless communication system. Since then many technicians examined multipath signals [2-3] as a solemn hurdle in attaining greater and finer operations. Many researchers have been conducted to overcome such downsides as mentioned above. The very first paper brought up analysing MIMO's capability was published in Global Communications Conference Proceedings in 1996. There spurts up incessant expedition for escalating capability and enhanced quality in wireless mobile radio communication. The consistent transmission entails ciphers to be successfully detected at the receiving edge. For MIMO

system, the best soft decoder used for the minimization of the BER is usually the maximum-likelihood (ML) detector [5-6]. On the contrary, the foremost shortcoming spurts up in the detection process is that it sometimes turn out to be extremely complicated because of its complex design. This leads to an enhance increment with escalate number of transmitting antennas at the transmitter and also directly proportional to its order. In [7] and [8], the detection scheme has been upgraded through some data probability estimation. In [9], many reduced-complexity actualizations of the detector schemes are followed back so that by taking the help of only one matrix inverse, we can able to estimate each transmitted symbols. Therefore, this detection scheme can act as a propitious candidate in practical case. The rest of the paper is being organized in the following way. In Section 2, the MIMO system model is being explained. The different detection scheme which is based on MIMO systems under appropriate channel estimation is explained in Section 3. In Section 4, we have the explanation of QAM scheme. Finally the simulation results and conclusion are given in Section 5 and Section 6, respectively.

## II. MIMO MODEL ANALYSIS

The MIMO model considered for this proposed work is shown in Figure.1. Here, we consider  $T_t$  no. of transmit antennas and  $R_r$  no of receive antennas. The overall

channel can be represented as a  $r \times t$  complex matrix  $H$  with the entries of  $[H]_{r \times t} \approx h_{r \times t}$  where  $h_{r \times t}$  is the flat fading Rayleigh coefficient of the channel from the  $t$  th transmit antenna to the  $r$  th receive antenna.

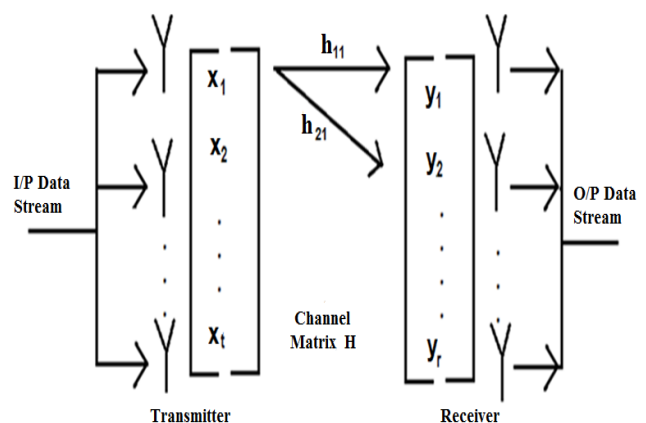


Figure 1. Block diagram of MIMO system

Manuscript received May 04, 2014

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III. DIFFERENT DETECTION SCHEMES

3.1 Maximum Likelihood(ML)

Maximum Detection (ML) symbol detection method is one of the optimum methods of detecting the transmitted symbols at the receiving part, which are being transmitted from the transmitting part. This detection scheme is non linear in nature. According to this principle, the estimated symbol can be estimated as:

$$X = \arg \min |x - H_s^2| \tag{1}$$

Where,  $H_s$  is the estimated symbol vector from  $H$ .

1.2 Zero Forcing(ZF)

Zero Forcing (ZF) is the one of the widely used detection method having low computational complexity. The Zero Forcing detection scheme is linear in nature but it suffers from sudden noise enhancement. At some high value of SNR, it gives optimum result. Now, the estimated result is given by.

$$\hat{X} = (H^{\#}H)^{-1} H^{\#} \bar{y} \tag{2}$$

Where,  $H^{\#}$  represents the pseudo-inverse of  $H$ .

1.3 Minimum Mean Square Error(MMSE)

The MMSE detector holds back both interference as well as noise components, but in comparison with ZF detector, it only removes the interference or the noise. From this we can come to a conclusion that the mean square error (MSE) is minimized. To overcome the drawback of sudden noise enhancement of ZF, the concept of MMSE is introduced for detection. So, we can say that, MMSE is pretentious to ZF in the presence of noise and interference. Hence, the Linear Minimum Mean Square Estimator for the MIMO System is.

$$\hat{X} = P_d H^{\#} (H H^{\#} + \sigma_n^2)^{-1} \bar{y}. \tag{3}$$

Where,

$P_d$  = Power of each diagonal element.

$\sigma_n^2$  = Power of noise component.

1.4 QR Decomposition

The QR Decomposition is an effective technique of solving matrix inversion problem. Hence, for a given matrix  $A$ , we can find out its QR Decomposition as

$$A = QR \tag{4}$$

where,  $R$  is the upper triangular matrix and  $Q$  is the orthogonal matrix, satisfying  $Q^T . Q = I$

where,

$I$  = Identity Matrix.

IV. QUARDATURE AMPLITUDE MODULATION

Quadrature amplitude modulation (QAM) is a modulation scheme in which two sinusoidal carriers, one exactly 90 degrees out of phase with respect to the other, are used to transmit data over a channel. Because the orthogonal carriers occupy the same frequency band and differ by a 90 degree phase shift, each can be modulated independently, transmitted over the same frequency band, and separated by demodulation at the receiver. For a given available bandwidth, QAM enables data transmission at twice the rate of standard pulse amplitude modulation (PAM) without any degradation in the bit error rate (BER). QAM and its derivatives are used in both mobile radio and satellite communication systems.

QAM is a signal in which the resultant output consists of both amplitude and phase variations. Digital formats of QAM are often referred to as "Quantised QAM" and they are being increasingly used for data communications often within radio communications systems. Radio communications systems ranging from cellular technology through wireless systems including WiMAX, and Wi-Fi 802.11 use a variety of forms of QAM, and the use of QAM will only increase within the field of radio communications. 16- QAM uses 4 levels in the I direction and 4 levels in the Q direction for a total of 16 symbols. 32-QAM uses a total of 32 symbols in the constellation. The general representation of QAM can be defined by the transmitted signal as

$$s_i(t) = \sqrt{2E_o/T} a_i \cos(2\pi f_c t) + \sqrt{2E_o/T} b_i \sin(2\pi f_c t)$$

Where, E is the energy of the signal with lowest aaplitude and T is the symbol duration.

V. SIMULATION RESULTS

In this section, we have illustrated the 64-QAM scheme for different detection techniques. The simulations are done for a Rayleigh fading channel. Here, the simulation is done on MATLAB as per the standards of IEEE802.11a.

Fig. 2 shows the BER performance comparison for a MIMO system with fixed transmitting and receiving antenna i.e. Tx=2 and Rx=2 for ZF, MMSE, QR, MMSE-SIC, ZF-SIC and ML detection scheme for Rayleigh channel. From the curves shown, it can be concluded that the value of BER for ML detection is low compared to the other detection techniques.

Fig. 4: BER analysis for Tx=2, Rx=6 for 64-QAM

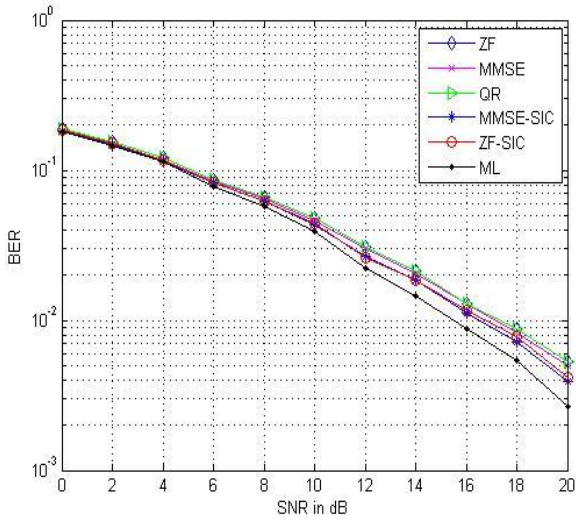


Fig. 2: BER analysis for Tx=2, Rx=2 for 64-QAM

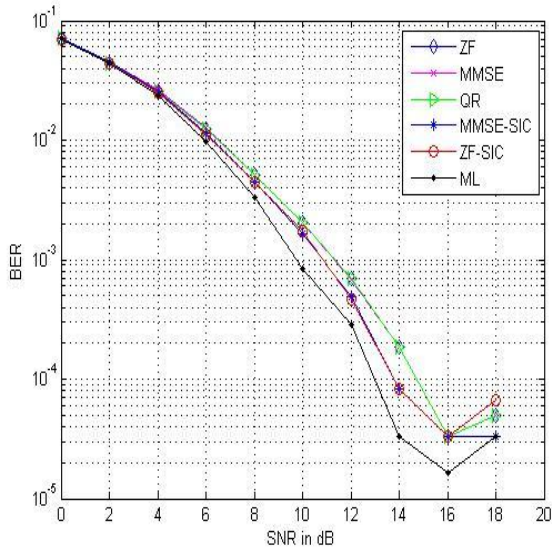


Fig. 3: BER analysis for Tx=2, Rx=4 for 64-QAM

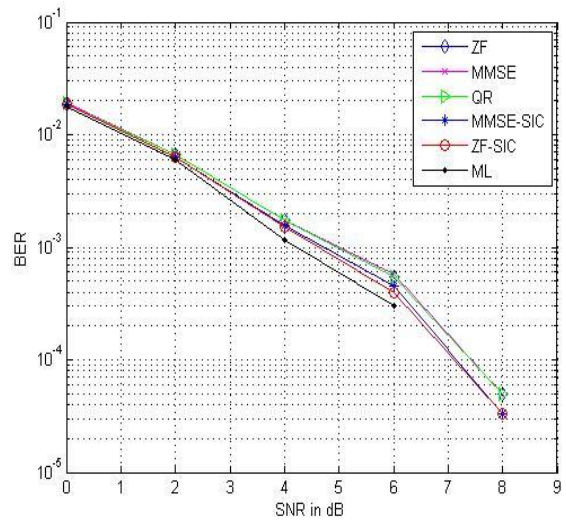
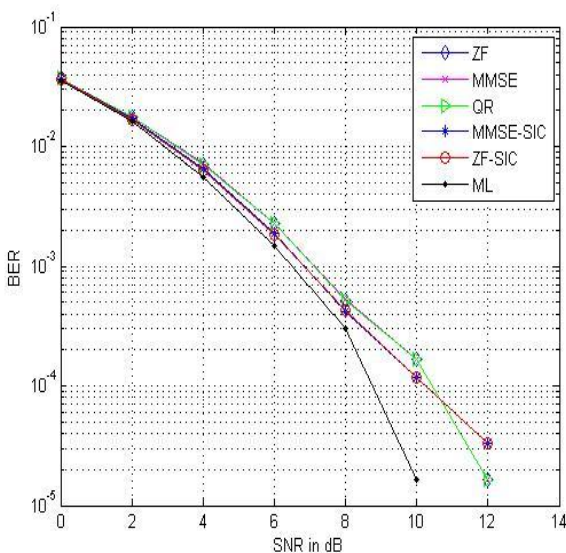


Fig. 5: BER analysis for Tx=2, Rx=8 for 64-QAM

Similarly, Fig.3, Fig.4 & Fig.5 shows the BER performance comparison for a MIMO system with fixed transmitting and receiving antenna i.e. (2\*4), (2\*6) & (2\*8) for ZF, MMSE, QR, MMSE-SIC, ZF-SIC and ML detection scheme for Rayleigh channel resp. From the curves shown, it can be concluded that the value of BER for ML Detection is low compared to the other detection techniques.

## VI. CONCLUSION

Through this paper, we provide a special multiple antenna system (MIMO) with the SIC technique using several detection schemes. The work proposed here puts forward an analytical view through which analysis is done for signal detection by making use of SIC (Successive Interference Canceller) in addition with Zero Forcing (ZF), Minimum Mean Square Error (MMSE), Maximum Likelihood Detection and QR decomposition. Here the use of these techniques is utilized for 64-QAM Schemes for various combinations of transmitting and receiving antennas by the aid of Rayleigh fading channel. This stands out to be a proficient way for errorless signal. Keeping an account on the analysis made above it can be derived out from the research that for 64-QAM scheme, ML Detection is the best detection technique as it is giving low value of Bit Error Rate (BER) for different values of Signal to Noise Ratio (SNR). Apart from that, as the number of antenna is increasing at the receiver end, the Bit Error Rate (BER) is reducing drastically for the ML detection technique which makes it even more error free and proficient. By keeping the transmitting antenna (Tx) fixed and varying the receiving antenna (Rx) i.e. for receive diversity condition, the error probability (BER) reduces drastically to as low as possible. In addition to this there is scope of examining and analyzing both Rayleigh fading channel and Rician fading channel. Observing, the outcomes of performances shown by the two fading mechanisms i.e.

Rayleigh and Rician fading, it can be further measure up against various parameters employing QAM Scheme. In future, there is also a scope of analyzing the work by using some other modulation techniques like MSK, M-Array PSK etc with various combinations of antenna.

### ACKNOWLEDGEMENT

The authors would like to thank the Management, Principal, Director and HOD of Electronics and Communication department of Suresh Gyan Vihar University Jaipur, India for encouraging us for this research work.

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