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# Evaluation of MIMO Detection Schemes in Relaying Network

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## ABSTRACT

In multiple input and multiple output wireless systems MIMO coded information signal detection is an important function of the destination node. In MIMO fading channel the detection is more challenging because fading and spatial interference among multiple antennas at the destination cause due to the simultaneous signal transmission by multiple antenna elements. Therefore it is required to have a modern signal processing algorithm for MIMO detection. In this work various MIMO) detection schemes are evaluated with relaying transmission perspective that will to design an efficient detection scheme to implement in real scenarios.
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**Keywords:** *MIMO, Relaying, Signal Processing, Detection, Dual-hop*

## 1. INTRODUCTION

The function of detection schemes in MIMO system is to obtain an estimate of the transmit vector given knowledge of the received vector and the channel matrix of the MIMO Channel. In available literature several well-known detection schemes are designed for MIMO single user and multiuser systems are presented. The detection schemes for MIMO systems are categorized as linear and nonlinear detection schemes. Famous detector algorithms are matched filter , zero-forcing and minimum mean squared error detections , whereas non-linear detection schemes are reported as zero-forcing and suppressed interference cancellation (ZF-SIC) and minimum mean squared suppressed interference cancellation (MMSE-SIC) [1] the nonlinear techniques are complex but are effective schemes. The commonly used deletion schemes in MIMO systems are illustrated in next sections.

## 2. SYSTEM MODEL

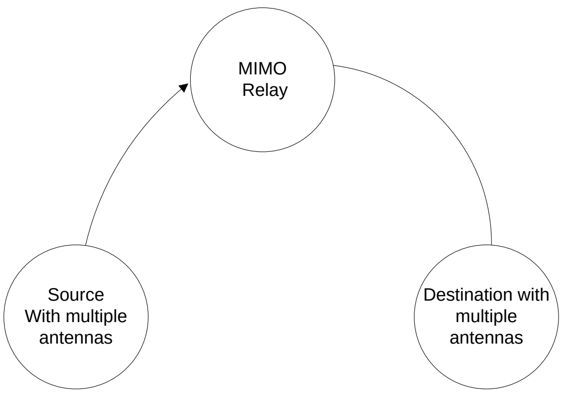


**Figure.1 MIMO network with three terminals**

The system model of the relay based MIMO three terminal network is shown in Fig.1. It comprises of one source, one relay node and one destination. Multiple antennas are employed at all the points of presence of the network.

Table.1 List of symbols

| Symbol | Description |
|---|---|
| $y_d$ | Signal received at the destination |
| *H* | is MIMO channel Matrix |
| $n_d$ | is the noise as destination |
| *s* | is the signal transmitted by the source |
| Q | is the unitary matrix |
| *R* | is the upper triangular mar |
| *W* | Detection at the receiver |

## 3. MIMO DETECTION METHODS

In this section, various well known MIMO linear detection approaches are presented which are:

### *3.1 Maximum Likelihood Detection (ML)*

In a MIMO system with M transmit and N receive antennas, the signal s is transmitted by MIMO source and $y_d$ being the signal received at the destination through MIMO channel denoted by H matrix, G is the channel between source to relay point in the network that is given as;

$$y_d = Hs + n_d \quad (1)$$

Here, $n_d$ is noise at the destination, therefore

$$H = [h_1, h_2 \ldots h_M] \quad (2)$$

$$G = [g_1, g_2 \ldots g_M] \quad (3)$$

Where, $h_m$ is the $m^{th}$ column vector of channel matrix H. The ML process the candidate vectors are selected with maximum likely with possibly lowest error probability [2].

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Linear detections schemes are considered for MIMO detection due to the low complexity. In signal $y_d$ (the received signal) is filtered separately each data symbol is detected.

### *3.2 Zero Forcing (ZF) MIMO Detection*

The ZF detection scheme is applied to suppress interference among multiple data streams. This is done by performing pseudo inverse of the channel matrix H. The ZF detection us expressed as [2].

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

and

$$\hat{s}_{zf} = W_{ZF}^H y_d \quad (5)$$

$$\hat{s}_{zf} = H^H (H^H H)^{-1} y_d \quad (6)$$

$$\hat{s}_{zf} = s + H^H (H^H H)^{-1} n_d \quad (7)$$

When the channel matrix H is close to singular, the noise term of Equation (6) is enhanced. In this situation with an enhanced noise vector good performance cannot be assured. The benefit of this MIMO detection scheme is to eliminates interference completely [2].

### *3.3 MMSE based MIMO receiver design*

This problem of noise enhancement due to zero forcing detectors can be alleviated by using MMSE criterion based MIMO detection. It takes the receiver noise and interference process [3]. The MIMO receiver using this type design minimizes the average estimation error on the transmitted symbols [4]. Thus, at the low SNR it performs better than the ZF based receiver. Using the channel knowledge at receiver, the MMSE component $W_{MMSE}$ is calculated to optimize the criterion [5]. It is given as;

$$E\big[[W_{MMSE} y_d - s][W_{MMSE} y_d - s]^H\big] \quad (8)$$

Solving this MMSE criterion for the typical MIMO channel analytically to find $W_{MMSE}$ gives

$$W_{MMSE} = H^{-1}(H^H H + \sigma I_{N_d}) \quad (9)$$

### *3.4 Successive Interference Cancelation*

Successive interference cancelation (SIC) is nonlinear decoding methods. In SIC detection. The SIC decodes and subtracts each symbol successively from the next symbol with high SINR at each stage. MIMO detection scheme with channel pre-processing enables the resultant scheme. When, QR decomposition is applied to the channel the search complexity is reduced considerably when the QRD is used with other available detection schemes too. Furthermore, with use of QRD with SIC reduces error propagation in the receiver and makes it an efficient and optimum detection method [4, 6].

### *3.5 QRD Based Signal Detection*

The ZF and MMSE are linear detection schemes and perform well in complexity in dissimilarity to the ML technique. The enactment of the linear schemes is corrupted because of noise enlargements in linear processes. The SIC is implemented with many linear schemes to achieve the better results [4, 6]. The channel matrix is decomposed into two unitary matrix *Q* and an upper triangular matrix R by using QRD operation on the channel matrix in MIMO detection. The QRD reduces complexity by avoiding matrix inversion. The SIC based schemes were developed to get trade-off between computational load and outcomes.

In MIMO relaying systems, the QR decomposition (QRD) is used at the receiver. The QRD of the equivalent channel $G_{sd}$ of dual-hop network is given as [7];
The QRD operation gives two output matrices namely Q and R, which are the $m \times n$ unitary and upper right triangular matrix respectively having form

$$Q = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \quad (10)$$

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ 0 & r_{22} & r_{23} \\ 0 & 0 & r_{33} \end{bmatrix} \quad (11)$$

The receiver filter based on QRD [7] is given as;

$$W = (Q_{sd})^H \quad (12)$$

In literature various MIMO detection schemes are proposed to attain near ML detection performance [8]. The based QRD and sphere decoding are the best capable methods [9]. In [9-12] it is presented that QR decomposition based MIMO detection is effective to attain the MLD performance with significant reduction in complexity.

Detectors based on interference cancelation belong to the class of non-linear detectors which perform interference estimation and removal in multiple stages. Popular interference cancelation techniques include successive interference cancelation (SIC) and parallel interference cancelation (PIC). SIC is known for its simplicity. The steps involved in SIC based detection can be summarized as follows [8].

1. Initially, the symbol transmitted in a data stream (preferably in the strongest data stream) is detected using a detector (e.g., using any of the MF, ZF, MMSE detectors). SIC is referred to as MF-SIC, ZF-SIC, and MMSE-SIC if the component detector used is MF, ZF, and MMSE, respectively. With ZF-SIC, the data streams can be ordered based on their

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received SNRs, or, equivalently, based on the norm of k, k = 1, . . . , nt.

2. Using the detected data symbol and knowledge of the channel matrix, an estimate of the interference contributed by it is estimated. 3. The estimated interference is canceled from the expected signal. 4. The interference canceled signal output is utilized in detecting the symbol in the succeeding strongest data. This stream's interference contribution is then estimated and canceled. This procedure is continued till the last (weakest) data stream is detected [1].

## 4. SIMULATION RESULTS AND DISCUSSION

For the analytical results, MATLAB is used as the simulation tool. In this a analysis different MIMO detection schemes are compared to study the performance in relay assisted MIMO system. Here, the three terminal MIMO network is considered, with single source, one relay and one destination. Three antennas are configured at each node on the network. The channel is assumed at IID Raleigh channel with AWGN.

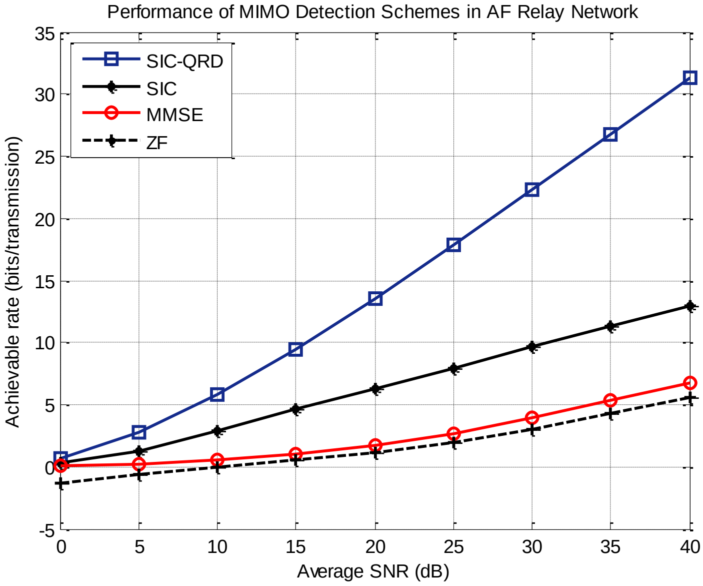


**Figure.1. Performance comparison of the various MIMO detection schemes in MIMO relay assisted system**

The above figure represents the performance of the well-known detection scheme for relay assisted MIMO network. The Maximum likelihood (ML), this scheme provides best BER performance at the cost of computational complexity and is very difficult to implement in the real systems. ZF detection for MIMO is an effective in recovering multiple data streams and is very simple technique. It provides low computational load and ML scheme. The ZF detection requires knowledge of the channel that is very difficult to get practically. The worst BER performance is archived with ZF because it enhances the noise.

MMSE detection algorithm has Low complexity as compared ML scheme for the MIMO systems. It provides better results in multiuser MIMO systems and considered as the tradeoff between matched filter and ZF based detections. Successive interference cancellation (SIC) is much advantageous in decoding large number of overlapping information signals. SIC performance depends on the strength of the signal received and that best fits in the relay assisted MIMO systems, where the relay nodes aids the strength to the signals. The Fig.1 represents the obvious results of the QRD-SIC detection scheme for the relay assisted MIMO systems.

## 5. CONCLUSION

In this paper, a variety of MIMO signal detection schemes have been studied, then we proposed an ordered QRD-SIC scheme for relay aided MIMO system. Simulation results show that the performance of the ordered QRD-SIC scheme of system is very applicable.

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