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A mathematical analysis of M-MIMO using ML based signal detection algorithms

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Abstract

The advanced radio communication is being rapidly deploying in the world. Multiple Inputs and Multiple Outputs (MIMO) is limited to 8 Antennas at the base station already utilized in fourth generation(4G). Massive-MIMO (M-MIMO) has been gaining and anormal popularities for its characteristics and utilisation in 5G. The throughput of the system is significantly increased by utilizing maximum number of antennas at the BS. However, the detection of the original signal is considered a complex task in massive MIMO. Hence, in this article we introduce a novel QRM-MLD method with an aim to enhance the throughput with a low intricacy. Further we compared a proposed Machine learning (ML) based QRM-MLD with existing detection scheme the experimental result revealed that the QRM-MLD acquired a gain of 2DB as compound with conventional QRM-MLD.

Subject Classification: *68T45.*

Keywords: *Massive MIMO, ML, Detection methods.*

1. Introduction

In the present situation the 5G framework is partly deployed in the entire globe. The advanced technology has been integrated with 5G to enhance the performance of wireless standards. Among several technologies explained is [1], Massive MIMO is of the most superior method combined with the 5G infrastructure. The use of huge data traffic will give a massive requirement of new spectrum band. The use of MM-Wave in 5G is seen as initial state to overcome the spectrum scarcity issue which need a small dimension antenna. The small dimension of antenna will boost the efficiency of MIMO framework. In the present scenario, the MIMO is integrated with 4G, where 8*8 antennas are implemented. In 5G, it is proposed to implement 256 antennas at base station and upper 32 antennas as the user gadgets. This Concept of utilizing large number of arrays in 5G will enhance the coverage area, the throughput. It also overcome the frequency lose by introducing the beam foaming. However, M-MIMO also introduces a complex issue such as Interference [2], High Implementation Cost, Design of small dimension antenna and Signal detection and so on. One of the drawbacks of MIMO is to abdication of performance for adequate detection of signals. It is seen that there are several algorithms are implemented which are good for different dimension of MIMO framework. Hence, the design of detection algorithm with an optional detection and performance is considered as one of the complex problems. There are several hard and soft detection schemes are implemented. It is observed that the conventional algorithm gave an efficient output with high intricacy. In [1] the authors projected QRM-MLD for 5G framework. Outcome of the work reveal that the proposed QRM-MLD outperform the conventional algorithms. The aim of the [2] is to reduce the intricacy of the QRM-MLD algorithm for MIMO structure. The study reveal that the proposed algorithm enhances the throughput with low intricacy. In [3], the author introduced a QRM-MLD and Beam Forming (BF) integrated hybrid algorithm for NOMA structure. It is seen that the optimal latency is obtained with enhanced throughput is compared with existing algorithms. The authors in [4] designed an intelligent detections algorithm for 5G waveform. The conventional algorithms are comprehensively studied and its advanced methods are implemented based on the drawbacks of the conventional schemes. It is concluded that the projected an intelligent algorithm gave an optimal performance with trivial intricacy.

2. ML-based QRM-MLD Algorithms

The MIMO channel is modelled is [5]:

$$Z = hx + n \tag{1}$$

Where z is the received signal,
x is the transmitted signal,
h is the response of channel and n is the distortion in received signals.
The equation (1) in two dimensions (R=2R and T=2T):

$$z = Hx + N \tag{2}$$

The signal detections are classified into soft and hard detection. The ZF obtained an optimal signal detection in double shape. In 2FE, the pseudo inverse and quantization method are applied to generate interference free symbols. The ZFE can be express as [6]:

$$ZFE = \left(\frac{1}{N^T H}\right) H^T \tag{3}$$

Match Filtering is considered as one of the simplest detection algorithms which do not apply an inverse method. The detection is obtained simply by multiplexing the received signal by H^T [7]. The structure of M-MIMO is given in Figure 1

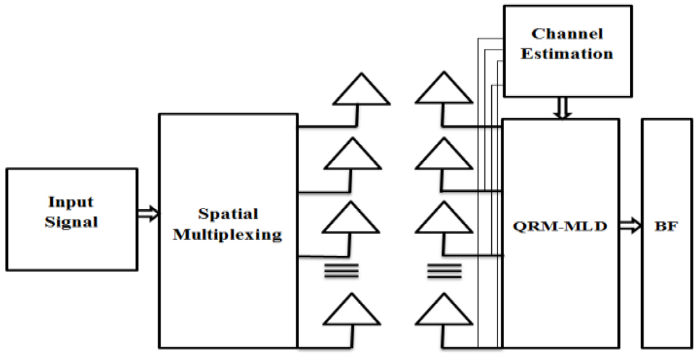

Figure 1

Proposed model

Let us consider M-MIMO signal with transmitted signal ($Y(l)$), channel response (H) and noise n) represented as [8]:

$$Y(l) = H(0)s(l) + H(1)s(l-1) + ... + H(l-1)y(l-L+1) + n(l) \tag{3}$$

The equation (3) can be represented as:

$$Y(0) = H(0)S(o) \tag{4}$$

$$Y(1) = H(1)S(1) \tag{5}$$

In general, the above signalcan be written as:

$$Y(l) = H(l)S(l) + n \tag{6}$$

The channel characteristic is defined as:

$$h = \begin{bmatrix} H_{00} + \ldots + H_{N-1}, \\ \vdots \quad \vdots\vdots \\ H_{0,N-1} + \ldots + H_{N-1} \end{bmatrix} \begin{bmatrix} s\hat{}_1(l) \\ s\hat{}_2(l) \\ \vdots \\ s\hat{}_N(l) \end{bmatrix} + N \tag{7}$$

The channel rank (r) is given by:

$$r = \begin{bmatrix} h_1 r(N) & \cdots & H_1 r(0) \\ \vdots & \ddots & \vdots \\ h_N rank(N) & \cdots & H_N r(0) \end{bmatrix} \tag{8}$$

Further, the $Y(l)$ can be written as:

$$Y \wedge (l) = h(k)s \wedge (l) + n(l) \tag{9}$$

The QRM is applied on equation (9) written as:

$$H(l) = U(l) * b_m(l) \tag{10}$$

The signal detection is given as:

$$\overline{S} = \| y^{\wedge}(l) - b_m(l) y^{\wedge}(l) \|^2 \tag{11}$$

3. Simulation Results

In this work, MATLAB 2022 is utilized to study the characteristics of conventional and proposed detection algorithms. Table 1. indicate the comparative analysis of detection methods. We have used 16*16, 32*32 and 64*64 antennas, spectrum of 80 MHz and 64 QAM transmission. In Figure 2, the throughput of the 64*64 MIMO structure is evaluated for detection algorithm. The novel QRM-MLD obtained a BER of 10^{-3} at the SNR of 2.4 dB. The novel QRM-MLD obtained a gain of 2.8 dB, 3.6 dB and 4.9 dB as compared with conventional QRM-MLD, ZFE and MF. Hence, it is concluded that the projected QRM-MLD outperform the conventional algorithms. Figure 3 show a 32*32 MIMO framework for different algorithms. The BER of 10^{-3} is obtained at the SNR of 4 dB (hybrid), 7.1 dB (Conventional QRM-MLD), 8 dB (ZFE), and 9.2 dB (MF) It is seen that the projected algorithm outperforms the conventional algorithms. For 16*16 MIMO signal detection, the algorithms are evaluated in Figure 4. The simulated curve reveals that the protected QRM-MLD give a better performance as compared with existing algorithms. The spectrum performance of M-MIMO is evaluated by simulating its bandwidth leakage

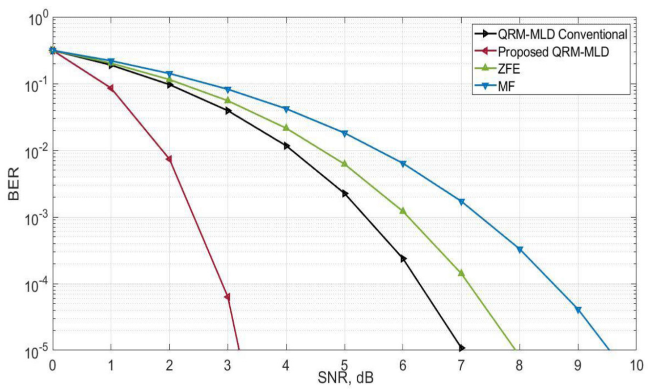

Figure 2

64x64 MIMO Detection

characteristics in Figure 5. The spectrum leakage is -20 dB (64*64), -41 dB (32*32) and -81.2 dB (16*16). Hence, an efficient spectrum enhancement is obtained for M-MIMO structure.

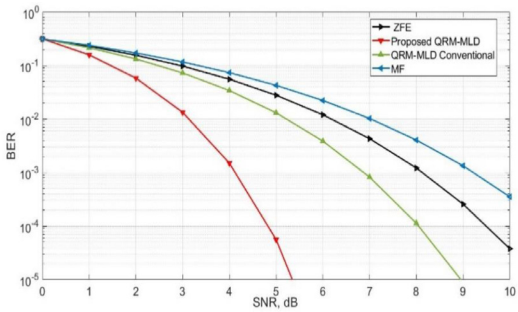

Figure 3

64x64 MIMO Detection

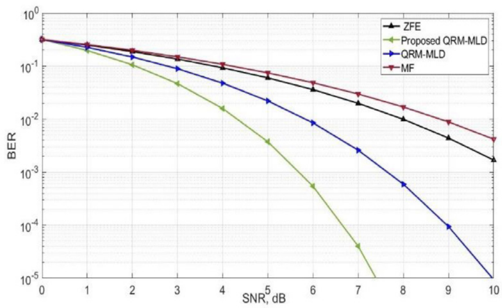

Figure 4

16x16 MIMO Detection

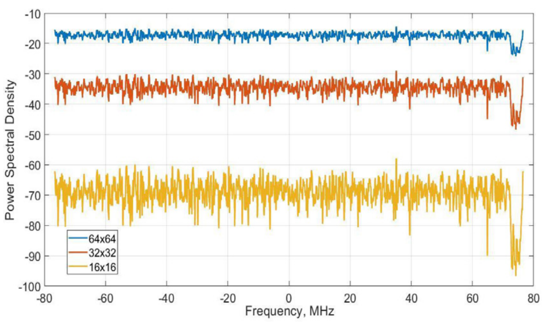

Figure 5

PSD of M-MIMO

Table 1

Analysis of Detection Frame

<table>
<tr><td rowspan="4">QRM-MLD</td><td>Advantages</td><td>Disadvantages</td></tr>
<tr><td>The intricacy is low.</td><td rowspan="3">The proposed QRM-MLD give low intricacy with 2FE and MF but still the complexity is existed.</td></tr>
<tr><td>The throughput performance is good in handling environment.</td></tr>
<tr><td>The high efficiency is obtained at high diversity gain.</td></tr>
<tr><td rowspan="2">MF</td><td>The intricacy is low</td><td rowspan="2">The performance is limited in fading</td></tr>
<tr><td>The efficiency is optimal if column of the transmitting matrix is orthogonal.</td></tr>
<tr><td rowspan="3">ZFE</td><td>The intricacy is low</td><td>The throughput of the 2FE is low for improper channel matrix.</td></tr>
<tr><td>The performance is satisfactory in pending scenario.</td><td>It gives limited performance for higher diversity gain.</td></tr>
<tr><td>It is seen that the exactment of 2FE is better than MF.</td><td></td></tr>
</table>

4. Conclusion

In this article, is presented the novel QRM-MLD procedure. After an efficient M-MIMO signal recognition. The performance of project QRM-MLD, conventional MLD, MF and 2FE algorithms are investigated for different MIMO structure (16*16, 32*32, and 64* 64). The MATLAB simulation is used to verified the throughput and spectrum performance of the MIMO system. From the simulated curve, it is concluded that the projected QRM-MLD gave a best performance than the existing methods of signal detection. It is noted that the spectrum leakage can be minimized in M-MIMO structures. Finally, it is concluded that high BER can be obtained at low SNR for large MIMO structure.

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