

BER Performance Comparison of Large Scale MIMO Receiver Using Q-ary APSK

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Abstract: A Large Scale Multiple-Input Multiple-Output (LS-MIMO) receiver is presented in this paper which utilizes two proposed detectors at the receiver. Spatial Modulation (SM) at the transmitter uses Q-ary Amplitude and Phase Shift Keying (APSK) constellation in which the indexes of the user terminal antennas encode the input information and convey the modulated information through the indexes of the transmit antenna. The Modified-Near Maximum Likelihood (MNML) detection and Hybrid Detection (HD) methods are used at the LS-MIMO receiver. Simulation results show that the Bit Error Rate (BER) performance of the MNML and HD detectors are near to the Maximum Likelihood (ML) detection and superior than the Multiple Stage (MS) detection.

Key words: Bit Error Rate (BER) • MS detection • Maximum Likelihood (ML) detection • Multiple-Input Multiple-Output (MIMO) • Q-ary Amplitude and Phase-Shift Keying (APSK)

INTRODUCTION

In future generation, the data transmission rates and quality of service are guaranteed in wireless communication. This provides the properties of the wireless medium and the received signal strength may be caused due to the different propagation paths [1]. Fading degrades the performance of Multiple-Input Multiple-Output (MIMO) system. MIMO system increases the spatial multiplexing since it uses the rich scattering environment [2]. Spatial Modulation (SM) in MIMO communication transmits the encoded information through the indexes of the antennas separately and independently [3, 4]. SM increases the spectral efficiency and low complexity since only one antenna will be active at each time in the transmission and other antennas have zero power. Due to this Inter channel Interference (ICI) may be reduced at the receiver [5]. Generalized spatial modulation (GSM) uses the multiple transmitting antennas and Radio Frequency (RF) chain [6]. The complexity of Maximum Likelihood (ML) detector increases since the number of antennas and the constellation size increases. Different detectors have been proposed to achieve the near optimum ML performance [7]. Maximum Ratio

Combiner (MRC) combines the signals from each antenna and the signals are rotated and weighted based on the strength and phase of the channel. Then the signals from all antennas are combined together to produce the maximum gain. Modified MRC (MMRC) detection is presented for conventional channels. MS detector achieves low computational complexity and better performance by splitting the detection in two stages. A Pseudo Random Phase Precoded SM (PRPP-SM) is introduced in [8]. The active antenna of the transmitter is randomly determined by modulation bits. If the active antenna transmits errors the channel, the system performance may be degraded. In [9], SM is independent of constellation size. The computational complexity of the hard limiting ML detector is independent of the modulation order. The proposed method is applied to square Quadrature Amplitude Modulation (QAM) and rectangular QAM. A Distance Based ordered Detection (DBD) method was proposed for coded SM MIMO system [10]. In [11], a low complexity ML detection method was introduced by using spatial modulation with M-ary Phase Shift Keying (PSK) modulation, which provides optimum ML performance. In [12], the transmitted symbol values are directly found based on

ML detection. In this case, ML space is independent of constellation size of the signal. A star QAM aided SM MIMO system performs better than the conventional modulation schemes such as PSK and QAM. QAM and PSK are not suitable for the non linear channels since high Peak-to-Average Power Ratio (PAPR). In QAM, for high data rates and modulation size increases PAPR may be high. Due to this, Amplitude and Phase Shift Keying (APSK) was introduced in [13] to achieve low power level. APSK provides high spectral efficiency and used for various communication like space, 5G and satellite. The different low complexity receivers were studied in [14].

In this paper, MNML Detector and HD detectors are used at the LS-MIMO receiver which uses SM with Q-ary APSK constellation. The paper is organized as follows. The system model is discussed in section 2. In section 3 illustrates the constellation diagram of Q-ary APSK modulation. The existing and proposed detectors are derived in section 4. The simulation results are analyzed and BER performance of the proposed and existing detectors is compared in section 5. Conclusion in section 6 infers that the proposed detectors provide near ML performance.

System Model: Consider a LS-MIMO system. SM which has ' S_t ' transmit antennas and ' S_r ' receive antennas. The input information at the transmitter composed of two blocks; the active antenna index ' i ' is selected by the $\log_2(S_t N)$ bits from the constellation W and $\log_2(N)$ bits are mapped to the modulated symbol ' M_d ' obtained from the constellation set ' M '.

$$W=1,2,\dots, S_t \quad (1)$$

At the transmitter, the transmitted signal vector x is,

$$x = (0, \dots, 0, M_d, 0, \dots, 0)^T \in C^{S_t} \quad (2)$$

In equation (2), ' M_d ' indicates i^{th} position. At the receiver side, $S_r N$ is obtained by using the received signal to detect the antenna index ' i ' and modulated symbol M_d . Equation (2) represents the modulated Q-ary APSK signal. ' M_d ' is the transmitted signal of the active antenna. The received signal is represented by,

$$y = Hx + n = h_i M_d + n \quad (3)$$

where, H is the Channel matrix, h_i represents the i^{th} column of H . n is the zero mean Gaussian vector having variance of $E[n n^H] = \sigma^2 I_{S_r \times S_r}$.

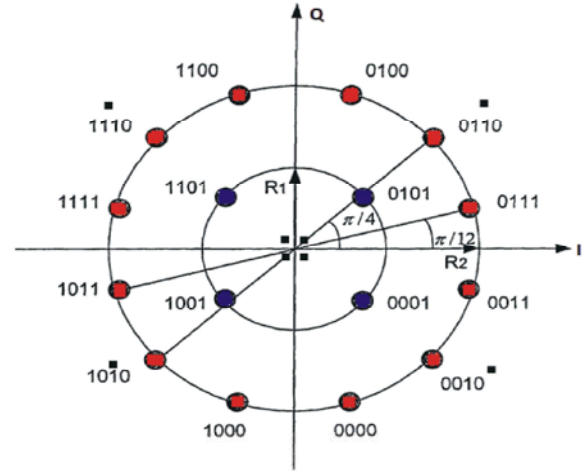


Fig. 1: 16-ary APSK constellation diagram

Q-Ary APSK Constellation: The constellation of Q-ary APSK consists of r rings and the constellation of the signal is given as,

$$M = \begin{cases} \gamma_1 \exp \left(j \left(\frac{2\pi}{L_1} t + \Phi_1 \right) \right), t = 0, \dots, L_1 - 1 \\ \gamma_2 \exp \left(j \left(\frac{2\pi}{L_2} t + \Phi_2 \right) \right), t = 0, \dots, L_2 - 1 \\ \vdots \\ \gamma_L \exp \left(j \left(\frac{2\pi}{L_r} t + \Phi_r \right) \right), t = 0, \dots, L_r - 1 \end{cases} \quad (4)$$

where, L represents the number of points, γ denotes the number of radius and Φ is the initial phase shift of the r^{th} ring. The constellation size for $Q = 16$ with $r=2$ rings and $Q=32$ with $r=3$ rings respectively. The three steps of Q-ary APSK constellation are select r and L_r , the radius γ and Φ .

The constellation diagram of 16-ary APSK modulation scheme is shown in Fig. 1. It consists of two rings. For the inner ring (indicated in blue dots) $L_1=4$ and $\Phi_1=\pi/4$ and for the outer ring (indicated in red dots) $L_2=12$ and $\Phi_2=\pi/12$ respectively. The signal point of 16-ary APSK is generally represented by,

$$M = \gamma \exp \left(j \left(\frac{2\pi}{L} t + \Phi \right) \right), t = 0, \dots, L - 1 \quad (5)$$

From the Fig. 1, it is observed that the inner ring produces the new set of points which are close to the

origin and the computation of third power of the signal points of outer ring produces the four points which are centered at $(+1,+1)$, $(+1,-1)$, $(-1,+1)$, $(-1,-1)$. The signal points at origin of Fig. 1 are indicated as color dots (blue and red) and signal power of them as black squares. The p^{th} power of the signal points is calculated based on r rings, where $p=r+1$. If the signal points belong to the outer ring $\gamma=\gamma_2$, $L=L_2$ and $\Phi=\Phi_2$. Otherwise $\gamma=\gamma_1$, $L=L_1$ and $\Phi=\Phi_1$.

Existing and Proposed Detections

MS Detector: In MS detection, initially the active antenna index is estimated based on MMRC detection as,

$$g = \underset{t=W}{\operatorname{argmax}} |u_i| \quad (6)$$

where,

$$u_i = \frac{h_i^H}{\|h_i\|_F} y \quad (7)$$

Next, ML detection is applied to the transmitted signal is given by,

$$(i_{ML}, S_{ML}) = \arg \min_{t=g, M_d=M} \left(\|h_i M_d\|_F^2 - 2R(y^H h_i M_d) \right) \quad (8)$$

ML Detector: The ML detection is applied at the signal received at the receiver is as follows,

$$\begin{aligned} (i_{ML}, S_{ML}) &= \arg \min_{t=W, M_d=M} \|y - h_i M_d\|_F^2 \\ &= \arg \min_{t=W, M_d=M} \left(\|h_i M_d\|_F^2 - 2R(y^H h_i M_d) \right) \end{aligned} \quad (9)$$

where,

i_{ML} - Estimated antenna index

S_{ML} - Estimated modulated symbol

R - Real part of Complex values number

MNML Detector: The MNML detection consists of two steps. The first step finds the most probable ring of the Q-ary APSK constellation in which the received belongs. In second step, antenna index and the ring are to be obtained. For equation (3), the signal z_i is defined as,

$$z_i = \frac{h_i^H y}{\|h_i\|_F^2} \quad (10)$$

Then the p^{th} power of z_i as follows,

$$V_i = z_i^p \quad (11)$$

The radius of each ring can be estimated as,

$$\gamma_k = \left[\gamma_k \exp \left(j \left(\frac{2\pi}{L_k} t + \Phi_t \right) \right) \right]^p = \gamma_k^p \quad (12)$$

where, λ_k is the threshold of the ring for $k=1,2,\dots,r-1$.

λ_k is defined as,

$$\lambda_k = \frac{\gamma_k L_{k+1} + \gamma_{k+1} L_k}{L_k + L_{k+1}} \quad (13)$$

Hence, the ring of the received symbol can be estimated as follows.

- if $\lambda_{k-1} < \lambda_i < \lambda_k$ for $i=1,2,\dots$ St, then $\Delta = k$
- if, $\lambda_k < \lambda_i < \lambda_{k+1}$ then $\Delta = k + 1$

where, Δ represents the estimated ring.

Next, the estimated symbol can be obtained as,

$$S_{\Delta,t} = \gamma_k \exp \left(j \left(\frac{2\pi}{L_{\Delta}} t + \Phi_t \right) \right) \quad (14)$$

Finally, the antenna index can be obtained as,

$$i = \arg \min_{t \in W} \|y - h_i S_{\Delta,t}\|_F^2 \quad (15)$$

HD Detector: The HD detection involves two steps to detect the transmitted symbols. MS detection is applied to detect the active antenna in the first step then the MNML detection applied to reduce the search space in the index of the active antenna.

Simulation Results: The analysis of BER performance of LS-MIMO receiver is discussed in this section. The simulation is carried out using MATLAB communication toolbox. The simulated results and comparisons are discussed as follows. The MNML, HD, ML and MS detectors performance are analyzed using Rayleigh fading channels with 16-APSK and 32-APSK constellation. The BER performance LS-MIMO system is plotted at an average of SNR in db. Fig. 2 shows the BER performance of MNML, HD, ML and MS detectors using 16-APSK modulation with $S_r=8$, $S_t=8$. Fig. 3 shows the BER performance of MNML, HD, ML and MS detectors using 16-APSK modulation with $S_r=32$, $S_t=64$.

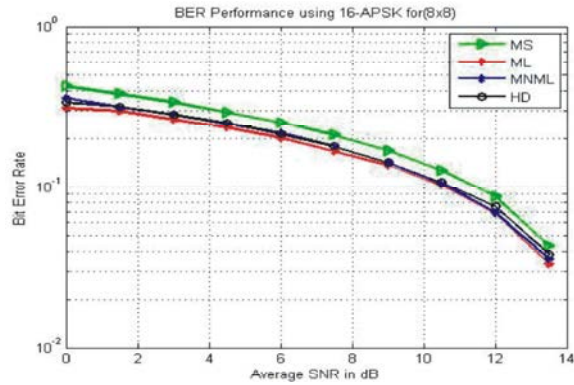


Fig. 2: Comparison of BER Performance using 16-APSK with $S_t=8$, $S_r=8$

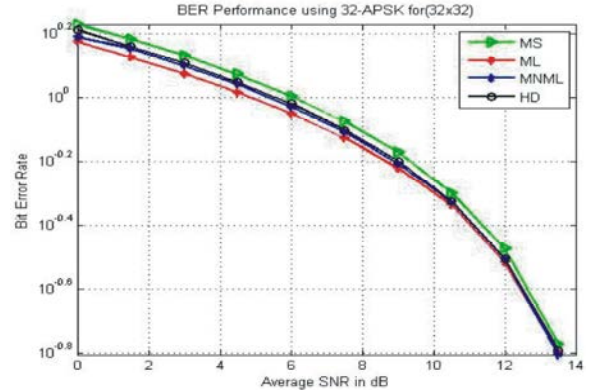


Fig. 5: Comparison of BER Performance using 32-APSK with $S_t=32$, $S_r=32$

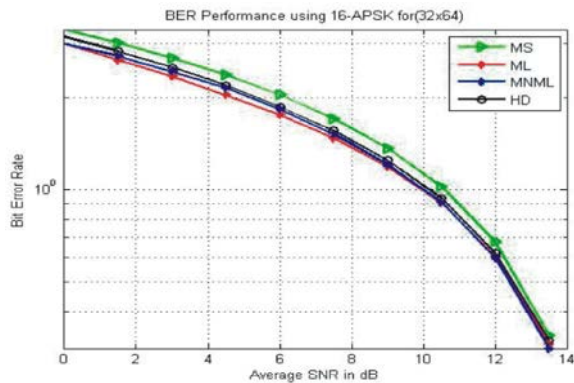


Fig. 3: Comparison of BER Performance using 16-APSK with $S_t=32$, $S_r=64$

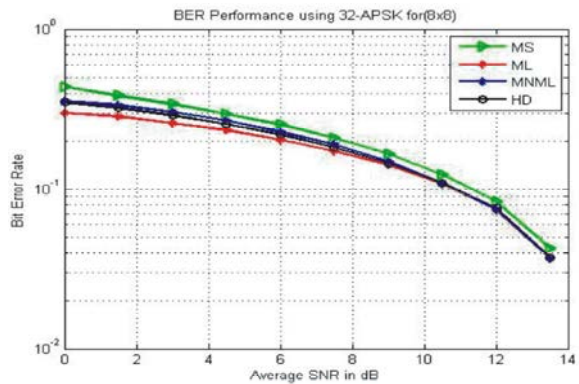


Fig. 4: Comparison of BER Performance using 32-APSK with $S_t=8$, $S_r=8$

Fig. 4 shows the BER performance of MNML, HD, ML and MS detectors using 32-APSK modulation with $S_t=8$, $S_r=8$. Fig. 5 shows the BER performance of MNML, HD, ML and MS detectors using 32-APSK modulation with $S_t=32$, $S_r=32$. From the simulation results, it is observed that the BER performance at average SNR of (9-12) dB, both MNML and HD detectors are near to

the ML detection performance and provide better BER performance than the MS detection for higher order modulation. It may be observed that both MNML and HD detectors are depending on the number of rings and independent of the constellation size.

CONCLUSION

The MNML and HD detectors are proposed in this paper for LS-MIMO receiver using SM with Q-ary APSK modulation. SM in which the input information is encoded and conveyed through the indexes of the transmit antennas. The proposed detectors depend only on the number of rings and independent on the constellation size. Simulation results show that the BER performance of proposed detectors provides near ML performance and provide better performance than the MS detector.

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