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Hybrid Low Complex near Optimal Detector for Spatial Modulation

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ABSTRACT

In our previous work maximum throughput in multi stream MIMO is analyzed by overcoming the inter antenna interference. To mitigate the Inter antenna interference spatial modulation can be used. Spatial Modulation (SM) aided MIMO systems are the emerging MIMO systems which are low complex and energy efficient. These systems additionally use spatial dimensions for transmitting information. In this paper a low complex detector based on matched filter is proposed for spatial modulation to achieve near maximum likelihood performance while avoiding exhaustive ML search since MF based detector exhibits a considerable reduced complexity since activated transmitting antenna and modulated amplitude phase modulation constellation are estimated separately. Simulation results show the performance of the proposed method with optimal ML detector, MRC and conventional matched filter methods.

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1. INTRODUCTION

The performance of the wireless communication systems can be enhanced by using multiple antennas at the transmitter, receiver, or both, this signal processing technique is known as Multiple Input Multiple Output (MIMO) [1], [2]. This signal processing technique can be used to overcome the multipath scattering effect. MIMO uses random fading and multipath propagation to increase the transmission rate and can achieve capacity gain or diversity gain. In [3], [4] transmission techniques in MIMO can be extended to time-domain, frequency domain or combination of both time-domain and frequency domain. To achieve the freedom offered by MIMO channels, a transmission technique as to be designed to achieve the diverse range of real time requirements and to overcome the tradeoff among computational complexity and the achievable bit error rate (BER) and maximum transmission rate [5].

Recently proposed single RF chain [6], spatial modulation (SM) is a promising among the MIMO techniques. Spatial Modulated MIMO uses the indices of the transmitting antennas (TAs) for transmitting information, apart from traditional Amplitude and Phase Modulation (APM) [7]. Potentiality of SM-MIMO is higher when compared to that of space-time coding at a given SNR [8]. SM-MIMO uses only single TA at any instant which is the most prominent benefit. Since only single TA is active SM can overcome the multiple radio frequency chain so that Inter-Antenna synchronization and the inter antenna interference can be mitigated, which has a great effect in traditional MIMO techniques [9]. The additional benefit of SM is, as it is using only single RF chain total power consumption can be reduced [10], [11]. In fact, only a single power amplifier is needed for implementing SM-MIMO systems, which is typically responsible for the vast majority of power dissipation at the transmitter.

In this paper section 2 deals with spatial modulation system model, optimal detector and sub optimal detector for decoding spatial modulated data. In section 3 hybrid low complex near optimal detector is proposed for SM. Section 4 deals with the simulation results and its discussion.

2. SPATIAL MODULATION

2.1. System Model

Consider N_t and N_r are the no of transmitting antennas and the receiving antennas respectively. In case of conventional MIMO systems takes advantage of all transmitting antennas and transmit multiple data streams through them simultaneously.

In case of SM-MIMO bit streams generated by source are divided into, spatial symbols and constellation symbols. No of bits used to represent spatial symbol is given by $\log_2 N_t$ and bits for constellation symbol is given by $\log_2 M$ where M is modulation index. Spatial bits are used to denote the active antenna and the bits in the constellation symbol are used to choose symbol in signal constellation.

In this paper l_t is used to denote the active transmitting antenna where $l_t \in \{1,2, \ldots N_t\}$ and symbol transmitted through l_t is denoted by s_t where $s_t \in \{s_1, s_2, \ldots s_M\}$. The transmitted vector for given l_t and s_t is given by (1)

$$X_{l_t,s_t} = \left[0_{1\times l_t-1}, \ldots, s_t, \ldots 0_{1\times N_t-l_t}\right]^T \tag{1}$$

where $[.]^T$ denotes transpose of the matrix.
The received vector is given by (2)

$$Y = HX_{l_t,s_t} + n \tag{2}$$

where H is the channel matrix and n- 1xNr Additive White Gaussian Noise (AWGN) with zero mean and σ^2 as variance. Equation 2 can be modified as Equation 3.

$$Y = h_{l_t} s_t + n \tag{3}$$

2.2. ML Detector

ML algorithm has an optimal performance for SM system. But the complexity of ML detector is very high with exhaustive search for ‘l’ i.e., active transmitting antenna and‘s’ i.e., modulated APM constellation. Estimated ‘l’ and‘s’ is given as

$$(l, s) = \arg\min_{1\leq l\leq Nt, s_t\in S} ||y - h_l s_t||^2 \tag{4}$$

where ‘l’ is transmitting antenna, Nt number of transmitting antennas, S denotes symbol alphabet.

2.3. MRC Detector

The MRC [12] based sub-optimal SM detector decouples the transmit antenna and symbol estimation processes. The transmit antenna index is estimated first followed by symbol estimation. In general, these two estimation processes are interdependent and their subsequent decoupling during detection leads to reduced performance. In this method the Hermitian transpose of the channel matrix H is multiplied by the received signal Y in order to formulate the decision metric of Z.

$$Z = H^H Y \tag{5}$$

Then, the index q of the activated dispersion matrix is given as

$$q = \text{argmax}_q |Z| \tag{6}$$

Transmit antenna estimate is assumed to be correct and based on this assumption combined symbol is given by

$$x = H^H Y \tag{7}$$

2.4. MF Detector

In this method same like MRC the Hermitian transpose of the channel matrix H is multiplied by the received signal Y in order to formulate the decision metric of Z.

$$Z = H^H Y \tag{8}$$

Then, the index q of the activated dispersion matrix and the transmitted symbol index l are estimated separately, as follows:

$$q = \text{argmax}_q \, |Z| \tag{9}$$

$$l = \text{argmin}_l \, |Z_q - \|h_q\|^2 s_l| \tag{10}$$

3. MODIFIED MATCHED FILTER BASED DETECTOR

In this method each column in channel matrix H is normalized and transformed as shown below

$$\hat{H} = \left[\frac{h1}{\|h1\|}, \frac{h2}{\|h2\|}, \ldots\right] \tag{11}$$

MF detector decision metric is given as

$$Z = \hat{H}^H Y \tag{12}$$

Then a vector by vector exhaustive search is done on the decision metric for the estimation of the active transmitting antenna.

$$(\hat{q}, \hat{l}) = \arg \ \min_{q,l} \|Z - \|h_q\| K_{q,l}\|^2 \tag{13}$$

$$(\hat{q}, \hat{l}) = \arg \ \max_{q,l} [2\|h_q\|\{real(z_q)real(s_l) + imag(z_q)imag(s_l)\} - \|h_q\|^2 |s_l|^2] \tag{14}$$

where real(), imag() represent real and imaginary part respectively. In order to reduce the complexity of the detection relying on above Equation, we introduced the separate detection of q and l. active transmit antenna is given by

$$\hat{q} = \arg \ \max_{q,l} [2\|h_q\|\{real(z_q)real(s_l) + imag(z_q)imag(s_l)\} - \|h_q\|^2 |s_l|^2] \tag{15}$$

By using above detected transmit antenna, symbol index s is detected as

$$l = \text{argmin}_l \, |Z_{\hat{q}} - \|h_{\hat{q}}\|^2 s_l| \tag{16}$$

The complexity of detection of $\hat{q}$ of above modified MF detector can future be reduced as

$$\hat{q} = \arg \ \max_q \left[|real(z_q)| \frac{|real(s_l')|}{|s_l'|} + |imag(z_q)| \frac{|imag(s_l')|}{|s_l'|}\right] \tag{17}$$

For detection of symbol index l, same Equation used in detection of l in modified MF is used.

4. RESULTS AND ANALYSIS

Bit Error Rate (BER) performance of the spatial modulation based MIMO over various detectors is analyzed and compared with the modified matched filter I and II. A 2x2 MIMO configuration with various modulation schemes like 4-QAM, 8-QAM, 16-QAM and 32-QAM is implemented under Rayleigh fading channel, here one bit is used to select the transmitting antenna and remaining bits are transmitted through the selected antenna. BER performance of 2x2 SM based MIMO with maximum likelihood detector is shown in figure, at BER=10^{-3} from the simulation result effect of modulation schemes can be clearly seen. BER performance of the MRC detector is illustrated in Figure 2.

Figure 3 show the BER performance of the system with conventional matched filter based detector over different modulation schemes for a 2x2 SM based MIMO. Figure 4 and 5 show the BER performance of the modified MF detector I and II over different modulation schemes. BER performance of modified MF detector I and modified MF detector II over different modulation schemes is shown in figure 4 and 5. When compared to modified MF I and modified MF II, MF II is less complex than MF I and performance wise MF I is dominant than MF II.

Figure 6 shows the BER performance comparison of the proposed modified MF detector with existing optimal ML detector, sub optimal MRC detector and conventional MF detector. When compared with the existing MRC and conventional MF, performance of modified MF is superior and when compared to optimal ML detector, modified MF achieves near optimal solution.

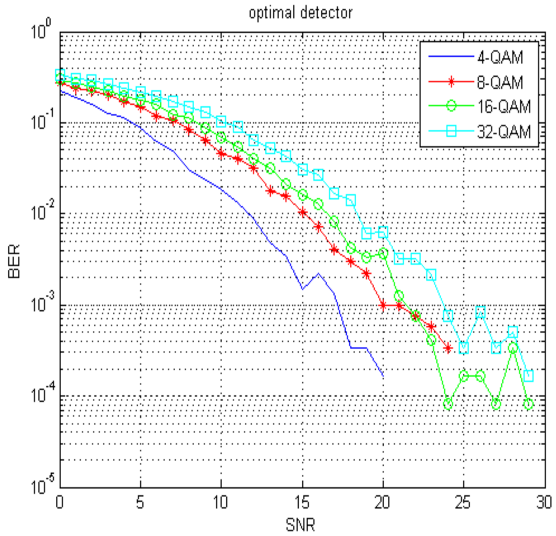

Figure 1. BER performance of 2x2 SM based MIMO with Maximum likelihood detector over Rayleigh fading channel under different modulation schemes

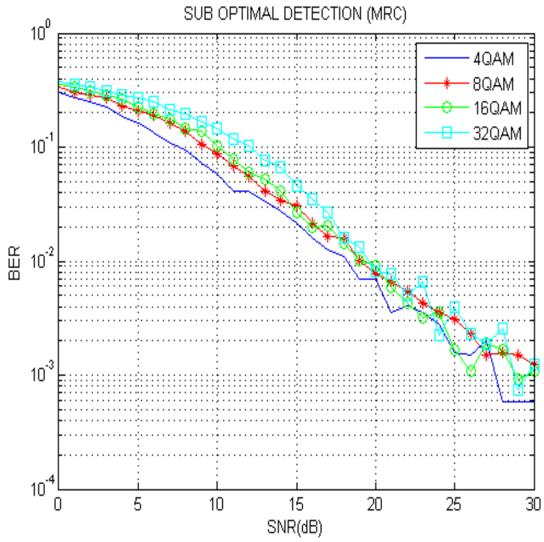

Figure 2. BER performance of 2x2 SM based MIMO with MRC detector over Rayleigh fading channel under different modulation schemes

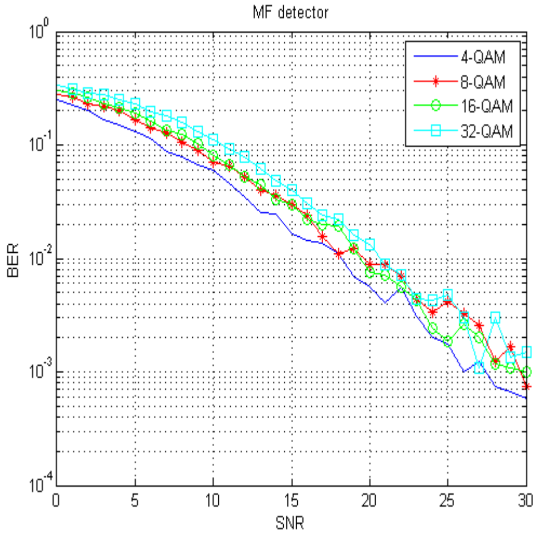

Figure 3. BER performance of 2x2 SM based MIMO with MF detector over Rayleigh fading channel under different modulation schemes

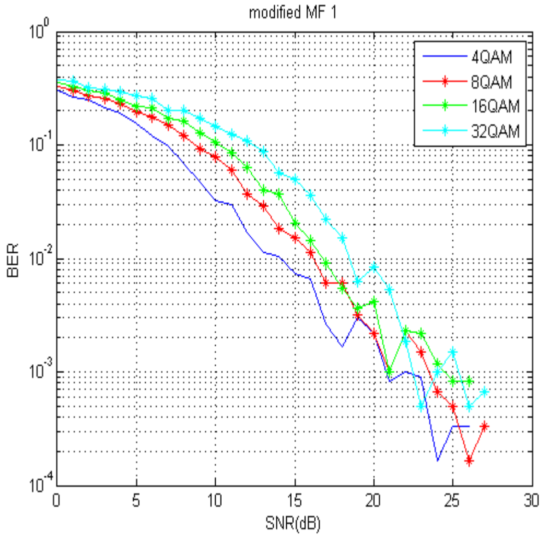

Figure 4. BER performance of 2x2 SM based MIMO with MF I detector over Rayleigh fading channel under different modulation schemes

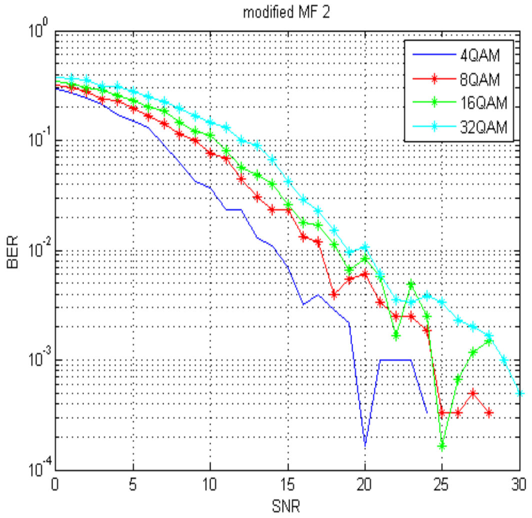

Figure 5. BER performance of 2x2 SM based MIMO with MF II detector over Rayleigh fading channel under different modulation schemes

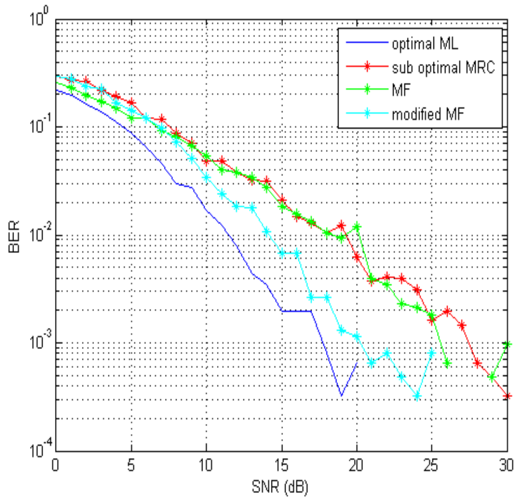

Figure 6. BER performance comparison of ML, MRC, MF and Modified MF I

5. CONCLUSION

From the simulation result we can conclude that the modified version of the matched filter based detector achieves near optimal solution. As the detection of the active antenna element and the transmitted data are estimated separately done in modified MF the complexity of the detector is reduced when compared with the optimal detector. When the two different variants of the MF detectors are compared the performance of the modified MF I is better than the second one were as the complexity of modified MF I is high when compared to MF II.

REFERENCES

[1] P. Rajani Kumari, Dr. K. Chenna Kesava Reddy and Dr. K.S. Ramesh, "Ordered Successive Interference Cancellation for Maximum Throughput in Multi Stream MIMO using Different Modulation Schemes", *Indian Journal of Science and Technology*, Vol 9(9), March 2016.

[2] Kehinde Odeyemi, Erastus Ogunti, "Capacity Enhancement for High Data Rate Wireless Communication System", *International Journal of Electrical and Computer Engineering*, 2014; 4(5), 800-809.

[3] S. Sugiura, S. Chen, and L. Hanzo, "MIMO-aided nearcapacity turbo transceivers: Taxonomy and performance versus complexity", *IEEE Commun. Surveys Tutorials*. 2012; 14(2), 421-442.

[4] S. Sugiura, S. Chen, and L. Hanzo, "A universal space-time architecture for multiple-antenna aided systems", *IEEE Commun. Surveys Tutorials*. 2012; 14(2), 401-420.

[5] J. Mietzner, R. Schober, L. Lampe, W.H. Gerstacker, and P.A. Hoeher, "Multiple-Antenna Techniques for Wireless Communications-A Comprehensive Literature Survey", *IEEE Communications Surveys & Tutorials*, 2009; 11(2), 87- 105.

[6] R.Y. Mesleh, H. Haas, S. Sinanovic, C.W. Ahn, and S. Yun, "Spatial Modulation", *IEEE Trans. Veh. Technol*. 2008; 57(4), 2228-2241.

[7] L. Hanzo, S.X. Ng, T. Keller, and W. Webb, "Quadrature Amplitude Modulation: From Basics to Adaptive Trellis-Coded, Turbo-Equalised and Space-Time Coded OFDM, CDMA and MC-CDMA Systems", *John Wiley and IEEE Press*, 2004.

[8] M. Di Renzo, H. Haas, and P.M. Grant, "Spatial Modulation for Multiple-Antenna Wireless Systems: A Survey", *IEEE Commun. Mag*. 2011; 49(12), 182-191.

[9] M. Di Renzo, H. Haas, A. Ghrayeb, S. Sugiura, and L. Hanzo, *"Spatial Modulation for Generalized MIMO: Challenges, Opportunities and Implementation"*, Proceedings of the IEEE, 2014; 102(1), 56-103.

[10] A. Stavridis, S. Sinanovic, M. Di Renzo, H. Haas, and P.M. Grant, "*An Energy Saving base Station Employing Spatial Modulation"*, IEEE Int. Workshop on Computer-Aided Modeling Analysis and Design of Communication Links and Networks, Barcelona, Spain, Sept. 2012; 1-6.

[11] A. Stavridis, S. Sinanovic, M. Di Renzo, and H. Haas, "*Energy Evaluation of Spatial Modulation at a Multi-Antenna base Station"*, IEEE Veh. Technol. Conf. -Fall, Barcelona, Spain, Sept. 2013, 1-5.

[12] Vaibhav. S. Hendre, M. Murugan, Sneha Kamthe, P"erformance Analysis of Transmit Antenna Selection with MRC in MIMO for Image Transmission in Multipath Fading Channels Using Simulink", *International Journal of Electrical and Computer Engineering*, 2015; 5(1), 119-128.