ISSN 2319 - 6629
Volume 6, No.5, August - September 2017
International Journal of Wireless Communications and Networking Technologies
Available Online at http://warse.org/IJWCNT/static/pdf/file/ijwcnt01652017.pdf

SM-MIMO Detection System by Using MLD, MRC-ZF, ZF Schemes

Kishore Odugu[1], Arun kumar Dannana[2]
[1]Assistant professor, Department of ECE, GMR Institute of Technology, Rajam, Srikakaulum District ,Andhra Pradesh , INDIA, kishore.o@gmrit.org
[2] Associate Engineer, L& T technology services, Mysore, Karnataka, INDIA, arunkumardannana@gmail.com

ABSTRACT

The transmission of information from the transmitter terminals to a base station that is recipient terminals about the condition of definitive foundation, for example, Smart Grid requires high unwavering quality and low dormancy. The mix of spatial modulation (SM) systems and Massive Multiple-Input-Multiple-Output (M-MIMO), alluded to as Massive SM-MIMO systems, has been proposed in communication systems to help these transmissions. Every terminal is furnished with different antennas and encode its transmitted bits by utilizing the Spatial modulation system. With SM, the data bits of every terminal is part into two bits squares. Building up a pragmatic Massive SM-MIMO system is trying because of the multifaceted nature and dormancy of Base Station location plans. In this, develop low complexity, low latency SM-MIMO detection schemes these demonstrate noteworthy out exhibitions in signal interference noise ratio (SINR). The advantage of utilizing Massive SM-MIMO systems to expand the unwavering quality and to decrease delay in transmissions in similar frequency bands.

Key words: Spatial modulation, MIMO, Detection Scheme,

1. INTRODUCTION

Currently, allotted spectrum for operators is dissected into disjoint frequency bands, each of which possesses different radio networks with different propagation characteristics and building penetration losses. This means that base station designs must service many different bands with different cell sites, where each site has multiple base stations (one for each frequency or technology usage e.g. third generation (3G), fourth generation (4G), and Long-Term Evolution - Advanced (LTE-A)). To procure new spectrum, it can take a decade of administration through regulatory bodies such as the International Telecommunication Union (ITU) and the U.S. Federal Communications Commission (FCC). When spectrum is finally licensed, incumbent users must be moved off the spectrum, causing further delays and increasing costs.
Recently, the combination of massive multiple-input-multiple-output (M-MIMO) and spatial modulation (SM) systems, referred to as massive SM-MIMO systems, has been considered as key 5G cellular technologies for increasing the reliability of multiple terminal transmissions. Each terminal is equipped with multiple antennas and encode its transmitted bits by using the SM technique. With SM, the information bits of each terminal is split into two bits blocks. The first block is used to select the transmit antenna while the second block is encoded as a modulated symbol, drawn from a standard constellation diagram such as M-QAM schemes [1]. By splitting the encoding process for the information bits into two blocks, the modulated symbol rate used by the second block can be reduced, leading to an improvement in signal-interference-plus-noise ratio (SINR) due to an increase in the distance between constellation points. Signals transmitted from different terminals are then received simultaneously at base station (BS) antennas, equipped with a large number of antennas. The data detection at the BS for the massive SM-MIMO system is performed by using maximum likelihood detection (MLD) schemes [2], [3]. As a consequence, the computational complexity in detection increase exponentially with the number of antennas which increases the latency of the systems. In [4], a message passing technique is used to reduce the detection complexity, however the scheme requires BS to send an extra information about the number of antennas used to the terminals.
In this paper, we investigate low-complexity detection schemes for massive SM-MIMO system, Sevral SM-MIMO transmitter system used as terminal. Each terminal encodes its information bits by using the SM technique that selects the transmit antenna and modulation symbol. Multiple symbols from each terminal are then transmitted to the BS by using an orthogonal-frequency-division-multiplexing (OFDM) waveform. The massive MIMO receiver at the BS is constructed by synchronizing terminals, each equipped with four antennas, connected with a daisy chain formation . [5]

To reduce the detection complexity in a massive antenna system at the BS, instead of using MLD schemes, we investigate two linear detection methods, referred to as zero forcing (ZF) and maximum-ratio-combining-zero-forcing (MRC-ZF) detection schemes. In the ZF symbol detection scheme, we apply a pseudo-inverse operation to a channel matrix, constructed by using channel state information (CSI) between all terminals and BS antennas. In the MRC-ZF detection scheme, we split the detection processes into two. In the first process, we apply a MRC operation to detect the transmit antenna for each terminal.

We then apply the ZF symbol detection scheme with a channel matrix, constructed only from the CSIs of detected transmit antennas. The matrix reduction leads to a lower detection latency as compared to the ZF detection scheme. Our experimental results indicate that 20 times reduction in detection latency and a significantly closer real-time SINR performance to the MLD schemes (e.g. within 3dB from the theoretical performance) as compared to existing schemes in the literature [2] , [3] and [6] can be achieved. In this paper, developed a low complexity detection schemes for the proposed SM-MIMO systems by using a combination of MRC and ZF schemes to ensure system scalability with an increasing number of BS antennas. [5]

2. SM-MIMO SYSTEM

We contemplate a massive SM-MIMO system where a BS, furnished with T_n antennas, receives symbols from S terminals, furnished with R_n antennas, and SR_n □ T_n . The terminals create an OFDM waveform which is done by transmitting symbols in multiple sub-carriers. The system models are depicted in [5], For each OFDM sub-carrier, we assume each terminal S has p bits to be transmitted, which are collected as a vector P_S . At every terminal S uses SM rules to map P_S to another transmit vector X_s of size T_n that contains only one non-zero element that indicates the chosen transmit antenna $I_s \in (1,2,....T_n)$ given as

$$x_s = \left[Z_{1\times(I_s-1)} \quad x \quad Z_{1\times(T_n - I_s)} \right]^T \tag{1}$$

Where $Z_{1\times q}$ is all zero vector with q column that determined by the choice of antenna I_s in connection to the first $\log_2(T_n)$ bits p .The balance $\log_2 M = p - \log_2(T_n)$ bits are then encoded as transmit symbol x by using a standard modulation symbol such as M-QAM/PSK schemes [7]. encoded by using OFDM modulator (OFDM mod) and transmitted only by the selected antenna.

the wireless channel for each OFDM sub-carrier between R_n BS receive antennas and S terminals, each with T_n transmit antennas, can be written as

$$C_s = \begin{pmatrix} c_{1,1}^s & \cdots & c_{1,T_n}^s \\ \vdots & \ddots & \vdots \\ c_{R_n,1}^s & \cdots & c_{R_n,T_n}^s \end{pmatrix} \tag{2}$$

$c_{v,i}^s$ is channel state response between transmit antenna i of terminal S and receive antenna v at the BS where $s = 1,2......S$, $v = 1,2.....R_n$ and $i = 1,2......T_n$. The received signal after applying OFDM demodulator can then be expressed as

$$y = CX + n \tag{3}$$

Here $y = \left[y_1, y_2.......y_{R_n} \right]^T$, $C = \left[C_1, C_2........C_s \right]$ and $X = \left[x_1 , x_2.......x_k \right]^T$ are $R_n \times ST_n$ and $ST_n \times 1$ matrices. y_v represents the received signal at BS antenna v while $n = \left[n_1, n_2......n_{R_n} \right]^T$ is independent and identically distributed (IID) additive white Gaussian noise (AWGN) vector with zero mean and variance of σ^2 .

3. DETECTION SCHEMES FOR SM-MIMO SYSTEM

3.1 Maximum Likelihood Detector (MLD)

Maximum Likelihood Detector (MLD) is considered as the optimum detector for a MIMO system given by Equation. The transmitted signal could be effectively recovered at the receiver based on the following minimum distance criterion

$$\hat{x} = \underset{x_k \in (x_1, x_2, ...x_N)}{\arg\min} \left\| y - Cx_S \right\| \tag{4}$$

where $\hat{x}$ is the estimated symbol vector using the above criterion, MLD compares the received signal with all possible transmitted signal vector which is modified by channel matrix H and estimates transmit symbol vector x . Although MLD achieves the best performance and diversity order, it requires a brute-force search which has an exponential complexity in the number of transmit antennas and constellation size. [8]–[10].

3.2 MRC-ZF Detection Scheme

To implement the proposed MRC-ZF detection scheme, we first use the Hermitian conjugate of C , C^H as MRC weights and apply them to the received signal at the BS. Hence the detected vector $\tilde{r} = \left[\tilde{r}_{1,1}, \tilde{r}_{2,1}, ...\tilde{r}_{T_n,S} \right]$ for each subcarrier can be written as

$$\tilde{r} = C^H y = C^H CX + \tilde{n} \tag{5}$$

Where $\tilde{r}_{i,s}$ denotes the detected symbol from transmit antenna i of terminal S .The antenna detection for each terminal S is

$$\tilde{I}_s = \underset{i=1,2,......T_n}{\arg\max} \left| \tilde{r}_{i,s} \right| \tag{6}$$

The CSIs of the detected antennas are then used to form a new Reduced C matrix , $C_M = \left[C_{1,\tilde{I}_1}, C_{1,\tilde{I}_2} ....C_{S,\tilde{I}_S} \right]$ where $C_{S,J}$ denotes a vector with CSIs between BS R_n antennas and the transmit antenna $\tilde{I}_S$ of terminal S as its entries . We then apply a pseudo inverse operation

$$D_M = C_M * \left(C_M{}^T C_M{}^* \right)^{-1} \tag{7}$$

Then received signal at BS is then given as

$$\tilde{y}_M = D_M y = X + \tilde{n}_2 \tag{8}$$

Where $\tilde{y}_M = \left[\tilde{y}_M^1, \tilde{y}_M^2 ......\tilde{y}_M^S \right]^T$ denotes the detected symbol vector from S terminal and $\tilde{n}_2$ is the noise element. The transmitted symbols for each terminal can then be estimated by using the received signal that correspond the chosen transmit antenna $\tilde{I}_s$, $s = 1, 2, ...S$ as follows

$$\tilde{x} = Q \left| \tilde{y}_M^S (n) \right| \tag{9}$$

Where $Q(.)$ is the constellation quantization function which

maps the closest signal point from M_{ary} QAM/PSK symbols using Euclidean distance [11]. By using (6) and (9) we can detect the first $\log_2 (T_n)$ bits of p and the remaining bits, respectively. We repeat the above detection process for each OFDM sub-carriers to recover the data transmitted by the terminals.

3.3 Zero Forcing (ZF) Detection Scheme

Implement the ZF detection scheme, we apply a pseudo inverse operation to C which can be expressed as

$$D_{ZF} = C * \left(C^T C^* \right)^{-1} \tag{10}$$

By applying (10) to (3), the detected signal $\tilde{y} = \left[\tilde{y}_{1,1}, \tilde{y}_{2,1} ....\tilde{y}_{T_n,S} \right]$ for each sub-carrier can be written as

$$\tilde{y} = D_{ZF} y = D_{ZF} CX + D_{ZF} n = X + \tilde{n} \tag{11}$$

Where $\tilde{y}_{i,s}$ denotes the detected symbol from transmit antenna i of terminal S , $i = 1, 2, ...T_n$, $s = 1, 2, ...S$, $\tilde{n}$ is the noise element after the ZF detection. The transmit antenna detection for each terminal S is performed by choosing the location of the maximum of the absolute value of $\tilde{y}_{i,s}$, $i = 1, 2, ...T_n$ as follows

$$\tilde{I}_s = \underset{i=1,2,......T_n}{\arg\max} \left| \tilde{y}_{i,s} \right| \tag{12}$$

The transmitted symbols for each terminal can then be estimated by using the received signal that correspond the chosen transmit antenna $\tilde{I}_s$, $s = 1, 2, ...S$ as follows

$$\tilde{x} = Q \left| \tilde{y}_{\tilde{I}_s, S} \right| \tag{13}$$

Where $Q(.)$ is the constellation quantization function which

maps the closest signal point from M_{ary} QAM/PSK symbols using Euclidean distance [11]. By using (12) and (13) we can detect the first $\log_2 (T_n)$ bits of p and the remaining bits, respectively. We repeat the above detection process for each OFDM sub-carriers to recover the data transmitted by the terminals.

4. RESULT ANALYSIS

The performance of each detection schemes for SM-MIMO systems can evaluated using Signal to Interference Noise Ratio (SINR). To calculate the SINR performance of each terminals in the massive SM-MIMO prototype, we will first calculate the Error Vector Magnitude (EV) [12].

$$EV_{RMS}^s = \frac{\frac{1}{N} \sum_{n-1}^{N} \left| x(n) - \tilde{y}_{\tilde{I}_s, S}(n) \right|^2}{\sum_{n-1}^{N} \left| x(n) \right|^2} \tag{14}$$

where N is the number of symbols over which the value of EV is measured, $x(n)$ is the n th non-zero transmitted symbol and $\tilde{y}_{\tilde{I}_s, S}(n)$ is detected n th symbol from transmit antenna $\tilde{I}_s$,the relationship between EV and $SINR_S$ for each terminal,

$$EV_{RMS}^s = \sqrt{\frac{1}{SINR_S}} \tag{15}$$

Performance Evaluation of each detection schemes by calculation $SINR_S$. First calculate SINR for two terminals system with number receive antenna increase at each terminal

In Fig 1, it shows that as number of receive antenna at each Base station (BS) terminal it will increase SINR in DB, in contrast it will also increases complexity of detections systems and delay in the system. It also shows that MLD detection scheme giving highest SINR performance among all other schemes even with less number of receive antennas

In Fig 2, it shows that when increase in Base station (BS) terminals it will increase SINR in DB in MRC schemes, utilizing Zero forcing scheme with other schemes may results better performance but increases complexity of detections systems and delay in the system. It also shows that MLD detection scheme giving highest SINR performance among all other schemes even with less number of receive antennas

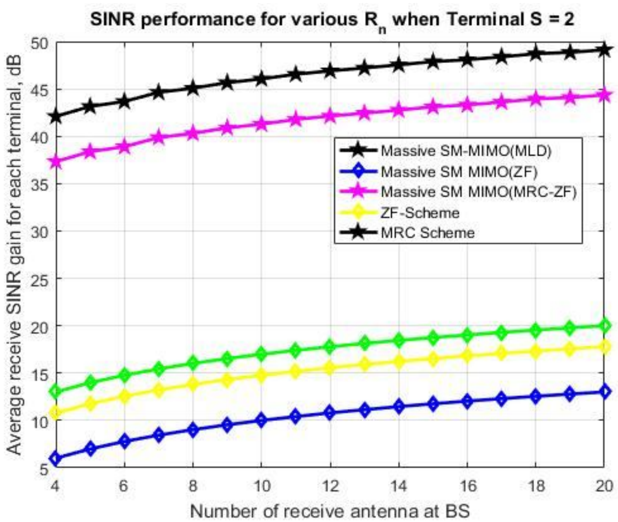

Fig 1: SINR Performance for various R_n when Terminal S = 2

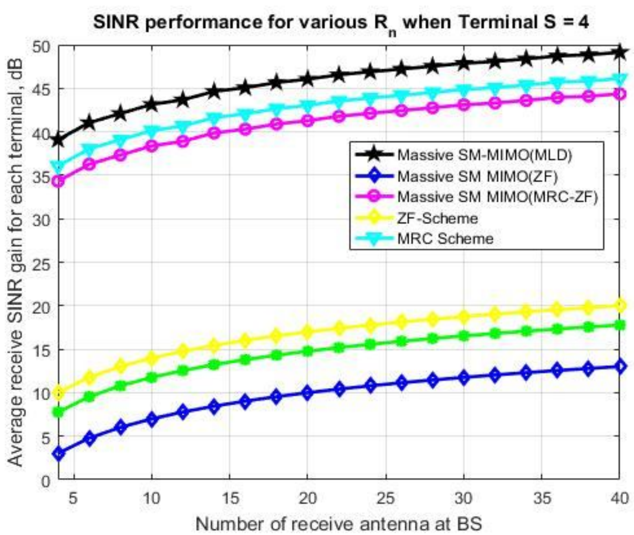

Fig 2: SINR Performance for various R_n when Terminal S = 4

5. CONCLUSION

In this work, A massive SM-MIMO OFDM system serving multiple terminals is considered. The work intends low complexity detection schemes whose performance is insensitive with the increasing number of BS antennas and close to the optimum maximum likelihood detection scheme. To reduce the detection complexity at BS, instead of using MLD schemes, the two linear detection methods with different complexity where both are shown to have the closest real-time SINR performance to the MLD schemes [13].

REFERENCES

1. C. E. Chen, C. H. Li, and Y. H. Huang, “**An improved ordered-block MMSE detector for generalized spatial modulation**,” *IEEE Commun. Lett.*, 2015.
2. Y. Cui and X. Fang, “**Performance Analysis of Massive Spatial Modulation MIMO in High-Speed Railway**,” *IEEE Trans. Veh. Technol.*, vol. 65, no. 11, pp. 8925–8932, 2016.
3. N. Serafimovski and S. Sinanović, “**Multiple access spatial modulation**,” *EURASIP J. Wirel. Commun. Netw.*, pp. 1–20, 2012.
4. S. Wang, Y. Li, M. Zhao, and J. Wang, “**Energy-Efficient and Low-Complexity Uplink Transceiver for Massive Spatial Modulation MIMO**,” *IEEE Trans. Veh. Technol.*, vol. 64, no. 10, pp. 4617–4632, 2015.
5. H. Tang, W. Zhang, W. Hardjawana, and B. Vucetic, “**Improving latency and reliability in 5G Internet-of-Things networks**,” *IEEE Int. Conf. Smart Grid Commun*, 2016, pp. 509–513, 2016.
6. C. Shepard et al., “**Argos: practical many-antenna base stations**,” *Proc. 18th Annu. Int. Conf. Mob. Comput. Netw. - Mobicom ’12* ,ACM 2012, no. i, p. 53–64.
7. M. Di Renzo, H. Haas, A. Ghrayeb, S. Sugiura, and L. Hanzo, “**Spatial modulation for generalized MIMO: Challenges, opportunities, and implementation**,” *Proc. IEEE, vol. 102, no. 1, pp. 56–103, 2014.*
8. X. Zhu and R. D. Murch, “**Performance analysis of maximum likelihood detection in a MIMO antenna system**,” *IEEE Trans. Commun., vol. 50, no. 2, pp. 187–191, 2002.*
9. M. X. Chang and W. Y. Chang, “**Maximum-likelihood detection for MIMO systems based on differential metrics,**” *IEEE Trans. Signal Process., vol. 65, no. 14, pp. 3718–3732, 2017.*
10. B. Hassibi and H. Vikalo, “**On the Sphere-Decoding Algorithm I. Expected Complexity**”, *IEEE Trans. Signal Process., vol. 53, no. 8, pp. 2806–2818, 2005.*
11. R. Y. Mesleh, H. Haas, S. Sinanovic, C. W. A. C. W. Ahn, and S. Y. S. Yun, “**Spatial Modulation**,” *IEEE Trans. Veh. Technol., vol. 57, no. 4, pp. 2228–2241, 2008.*
12. H. A. Mahmoud and H. Arslan, “**Error vector magnitude to SNR conversion for nondata-aided receivers**,” *IEEE Trans. Wirel. Commun., vol. 8, no. 5, pp. 2694–2704, 2009.*
13. K. Gnanishivaram and S. Neeraja, “**FFT / IFFT Processor Design for 5G MIMO OFDM Systems,**” *IJWCNT ,vol. 3, no. 3, pp. 54–60, 2014.*