Selection of Antennas for Multi Stream Transmission

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Abstract - *A significant increase in spectrum efficiency is required to cope with the exponentially increasing traffic loads. These challenges the design of multiple-input multiple-output (MIMO) systems associated with the BS (Base Station). A typical long-term evolution BS consists of radio-frequency (RF) chains, direct current to direct current converters, cooling fans, etc. An adaptive antenna selection method for optimum transmission is proposed here. For multi stream MIMO, it aims to reduce the BER (Bit Error Rate) and average bit error probability (ABEP). It selects the best combination of signal and spatial constellation sizes, which minimizes the ABEP, BER. Results are also compared with the existing techniques.*

***Key Words*: MIMO, Multi stream, MIMO, Antenna selection, Transmit and Receive diversity, Multi user MIMO.**

1. INTRODUCTION

The number of wireless devices has steadily increased since the first mobile phones in the early 1980s. The original function of a mobile phone has changed radically. Now, the mobile devices are everywhere. These wireless devices have changed the way humanity functions. They have become the foundations of a larger, smarter, more technologically advanced society, which aims to be connected, mobile and increasingly energy efficient.

The increase in demand for all types of wireless services (multimedia, data voice, etc) demands the need for higher capacity and data rates. The bandwidth needed for voice calls, data traffic will demand much more bandwidth as new services emerges [1]. So the, emerging technologies that improve wireless systems spectrum efficiency are becoming a necessity, especially in broadband applications.

MIMO is an antenna technology for wireless communications in which multiple antennas are used at both the transmitter and the receiver [2]. It is the one of several forms of smart antenna technology. It is proven that, compared with a single-input single-output (SISO) system with flat Rayleigh fading or narrowband channels, a MIMO system can improve the capacity by a factor of the minimum number of transmit and receive antennas [3]. There are great challenges in the designing of MIMO systems associated with the BS [4]. These drives research on improving the overall performance of BS.

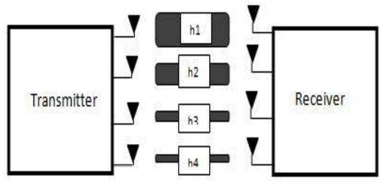

Fig-1: A 4×4 MIMO system set up

Even though all transmit antennas use the same transmit power, the channel environment changes the relative power of the sub-streams at the receiver. In Fig-1 the thickness of the channel denotes the relative power of each sub-stream at the receiver.

SM (Spatial Modulation) is a transmission technique that uses MIMO system. It increases spectral efficiency [5]. In SM only one antenna is active for transmission at a time in contrast to the classical multiple input multiple output techniques like BLAST [6]or space-time coding [7].

The research interest in this field has led to the development of several novel schemes. Inspired by the potential of SM, several authors have used and extended the concept of SM in different communication scenarios [8]. For example, Space Shift Keying is a low complexity and low rate variant of SM [9]. A first real system implementation of SM is reported in [10]. A discussion on the performance of SM under real channel measurements is included in [11], [12]. A complete introduction on SM is provided in [13]. Besides this, a number of techniques such DTX (Discontinuous Transmission & CTX (Continuous Transmission) [14], On-off power amplifiers [15] are developed mainly to reduce the power consumption at the BS and to utilize the spectrum efficiently.

Although improved transmission technologies have reduced the bandwidth needed for voice calls, data traffic will demand much more bandwidth as new services emerges.

An adaptive antenna selection method for optimum transmission for multi user MIMO is proposed. The aim is to produce the better spectrum spectrum efficiency. It selects the best combination of signal and spatial constellation sizes, which minimizes the ABEP, BER. The advantage is that the proposed method needs only very limited feedback.

The remainder of this paper is organized as follows. Section II describes the system model. In section III the block diagram is included. Simulation results are presented in section IV. Finally the paper is concluded in section V.

2. SYSTEM MODEL

The MIMO is based on the idea of using multiple antennas at transmitter side and receiver side [2]. The number of antennas varies from side to side or can be the same. The MIMO system uses diversity techniques to improve the system overall performance, and can achieve lower the BER of the system significantly. There is a simple category of multi-antenna types such as SISO, SIMO, MISO, and MIMO.

2.1 MIMO system

The MIMO System consists of two or more antennas at the transmitter and receiver (transmit and receive diversity) [16], [17]. Diversity is used to improve the quality and reliability of the wireless link [18].This kind of technology has led to a lot of development in wireless communications.

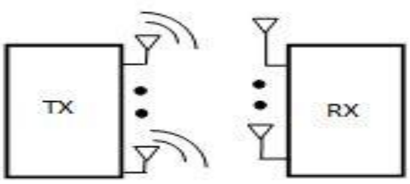

Fig-2: A block diagram of transmit and Receive diversity – MIMO

Features of transmit and receive diversity are the following: i) Higher Bit Rates with Spatial Multiplexing, ii) Smaller Error Rates through Spatial Diversity, iii) Improved Signal-to-Noise Ratios with Smart Antennas.

2.2 Channel Model

Diagram of a MIMO wireless transmission system is shown in Fig-2, the transmitter and receiver are equipped with multiple antenna elements. The transmit stream goes through a matrix channel which consists of multiple receive antennas at the receiver. Then the receiver gets the received signal vectors by the multiple receive antennas and decodes the received signal vectors into the original information.

$$r = Hs + n \qquad (1)$$

Where r is the $M \times 1$ received signal vector as there are M antennas in the receiver, H represented channel matrix, s is the $N \times 1$ transmitted signal vector as there are N antennas in transmitter and n is an $M \times 1$ vector of additive noise term.

3. MULTISTREAM MIMO TRANSMISSION

3.1 Antenna Selection Motivation

Although MIMO can enhance the capacity and reliability of the system, this gain comes with certain trade-off, like the usage of more RF chains. A system with M transmit antennas and N receive antennas requires M complete RF chains in the transmitter and N complete RF chains in the receiver, apart from low-noise amplifiers, down-converters, and analog-to-digital converters. Therefore, the cost of the system increases. Further the correspondingly larger number of channel state parameters increases complexity, e.g., for channel estimation and feedback calculation [9].

3.2 Multi stream MIMO

Figure 3, shows the block diagram of multi-stream MIMO transmission scheme. It includes multiple RF chains. The multi stream input is considered and is transmitted through different RF chains

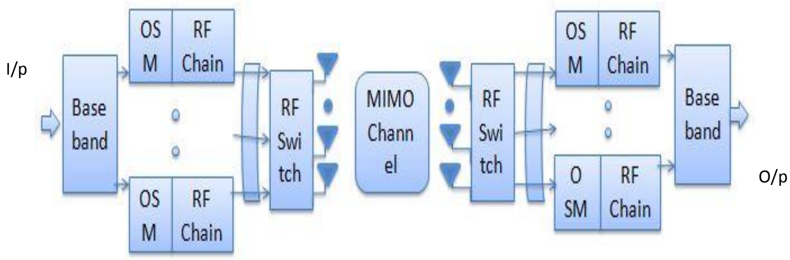

Fig-3: Block diagram of multi stream MIMO.

Each RF chain consists of optimized SM blocks to perform corresponding mapping. For each RF chain assigned to the user, some bit/bits is assigned so that number of bits to be transmitted can be reduced.

The performance over Rayleigh fading channel is considered. The antennas at each end of the communication circuits are combined to minimize errors and optimize data speed. An adaptive antenna selection method for optimum transmission is proposed here. It uses multiple RF chain BS based on optimized SM. Initially it chooses an RF chain then introduces an ABEP upper bound. Then it obtains best combination of signal constellation and number of antennas [20]. For optimization it includes,

1) Introducing an ABEP upper bound for SM. An upper bound can be obtained as in (4) [20].

$$ABEP = \frac{B(M)^{2N_r} + C(2^{\eta_S} - M\log_2(M))}{\eta_S \gamma^{N_r}} \quad (2)$$

$$B = \left(\frac{2}{\Omega}\right)^{N_r} \frac{1}{\pi^{2N_r+1}} \int_0^{\pi} (sin\theta)^{2N_r} d\theta \quad (3)$$

$$C = \frac{4^{N_r-1}\Gamma(N_r+0.5)}{\Omega^{N_r}\sqrt{\pi}\Gamma(N_r+1)} \left(\sum_{k=0}^{+\infty} \frac{\Gamma(2k+1)\rho_{av}^k}{4^k(k!)\Gamma(k+1)}\right) \quad (4)$$

Where η_s is the bit steam length, C is the average degree that the selected antenna array is affected by fading distribution, N_r is the receive antennas, B is a variable obtained while simplifying ABEP expression and is independent of ,M is the constellation size ,M,Ω is the spread controlling parameter of fading distribution.

$$\gamma = \frac{E_m L}{N_0} = \text{SNR} \quad (5)$$

E_m is the average energy per symbol transmission, and L is the path loss without shadowing, N_0 is the noise power.
2) Obtaining optimum (M, N).The optimum no of transmit antennas can be obtained as

$$M_{opt} = \underset{M}{arg\ min}\ B(M)^{2N_r} - CM\log_2(M) \quad (6)$$

Subject to: $1 \le M \le 2^{\eta_S}$

Then the optimum no of receiving antennas can be selected as follows,

$$\log_2(N) = (\eta_S - \log_2(M)) \quad (7)$$

3) Selecting required number of transmit antennas: Using RCP. In Figure 5, an RCP solution is demonstrated for the case of N_t= 32 and N = 8.

3.3 Receiver

The received matrix is given by:

$$Y(t) = \boldsymbol{H}(t) \otimes \boldsymbol{S}(t) + \boldsymbol{N}(t), \quad (8)$$

Where $\boldsymbol{S}(t)$ is a transmit matrix, $\boldsymbol{N}(t)$ is the noise matrix, and ⊗ denotes time convolution. The size of matrix (t) is $M \times n$. Maximal ratio combining is used to detect the transmit antenna number and the transmitted symbol in the frequency domain for each sub channel. Matrix of the channel $\boldsymbol{H}$ is assumed to be known at the receiver and the size is $N \times M$.

$$g(k) = \mathbf{H}(k)\mathbf{Y}(k) \quad (9)$$

When the time and frequency synchronization are done and no noise, $\mathbf{g}(k)$ is the same as $X(k)$.

3.4 M & N Trade off

In general, any number of transmit antennas and any digital modulation scheme can be used. The constellation diagram and the number of transmit antennas determine the total number of bits to be transmitted on each sub channel at each instant. Eg: The combination of BPSK and four transmitting antennas results in a total of three bits of information to be transmitted on each sub channel. While, we can use four modified Quadrature Amplitude Modulation (QAM) and two transmitting antennas to send the same rate of information (3 bits/s), as shown in Table I also shows tradeoff between signal constellation and spatial constellation sizes [13].

3.5 Antenna Selection

The required number of transmit antennas are selected from the antenna array. Since, the correlation coefficient $\rho_{ti,tj}$ is inversely proportional to the distance $d_{ti,tj}$, the aim is to maximize the minimum geometric distance between any pair of the chosen antennas [21].

Figure 4, shows the ideal circle packing (ICP) solution where the antennas are located at the circle centers. A realistic circle packing (RCP) is developed by selecting those antennas closest to the ideal positions. In Figure 5, an RCP solution is demonstrated for the case of N_t= 32 and N = 8.

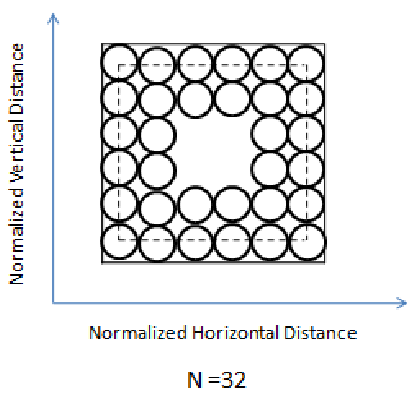

Fig-4: Circle packing

With an increase of N_t, the RCP solution becomes closer to ICP as the antenna array supplies a larger flexibility in positions.

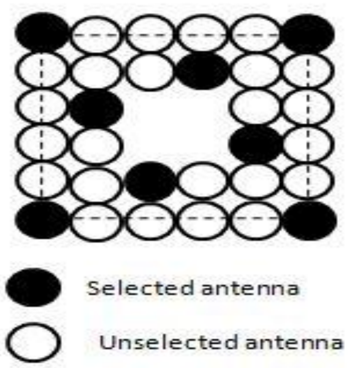

Fig-5: RCP for 8 out of 32 antennas

4. SIMULATION RESULTS

In this section to validate the performance of this scheme Monte Carlo results are presented. Rayleigh fading is considered here because; multi path fading is typically modeled by Rayleigh distribution. The performance of multi stream MIMO transmission method proposed here is compared with some other schemes such as fixed SM schemes, single stream MIMO (TOSM), etc.

4.1 Antenna selection scheme performance

The BER performance of the proposed RCP approach is evaluated against two baseline schemes: a) the exhaustive search (ES); and b) the worst case (the neighboring antennas are selected). Figure 6 shows the BER performance of RCP for η_s = 4. Due to the intractable complexity of ES, results when η_s > 5 is not presented. As shown, the RCP scheme achieves almost the same performance as ES with a gap of very few dB., As the correlation increases the performance of WS becomes much worse.

4.2 Performance of ABEP

In Figure 7, the simplified ABEP results are shown. To present an extensive comparison, several scenarios are considered by varying the shape factor, the number of receive antennas, the spectrum efficiency and *Eb*/*N*0. A unit spread controlling factor is assumed.

The simplified ABEP is an approximation of the ABEP upper bound and expects some deviations especially at high channel correlations. The simplified ABEP for MU-MIMO is showing better performance compared to others.

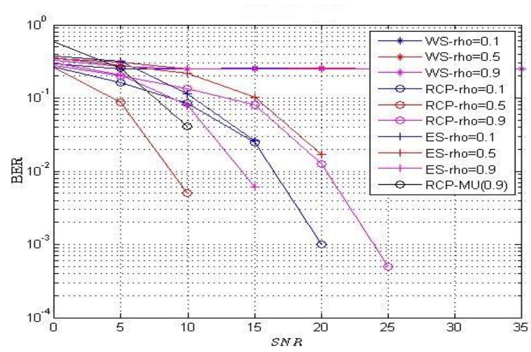

Fig-6: BER performance of RCP

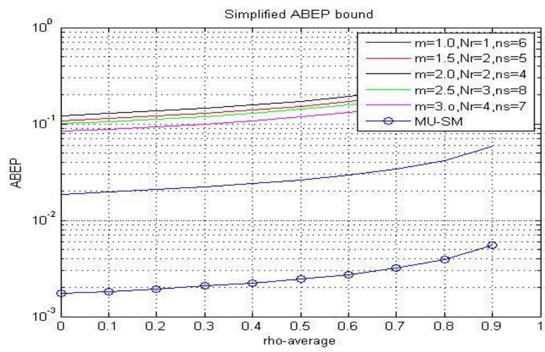

Fig-7: ABEP performance

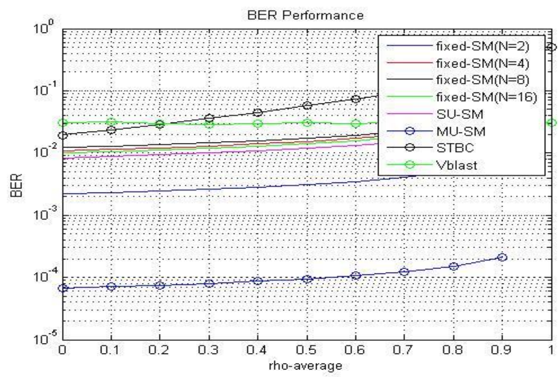

Fig-8: BER Plot

4.3 BER performance

Based on the obtained optimal *N*, the BER performance is evaluated and is shown in figure 8. Assuming *Nr* = 2 and *Eb*/*N*0 = 25 dB, Figure 8, shows the BER results against the channel correlation for η_s = 5. The case of N = 1 is referred to as single-input multiple-output (SIMO). The MU-MIMO employing multiple transmit antennas perform much better than the fixed-SM with a small N. Specifically, it outperforms fixed-SM with N = 2.

5. CONCLUSIONS

In this paper an optimum transmits structure for multi stream MIMO transmission is proposed. For optimization the size of signal and spatial constellations are balanced to reduce the computational complexity and to have better performance. The antenna selection method RCP has employed instead of using ES and WS methods. For each user the first step is chose an RF chain and then to determine optimum number of antennas by minimizing the ABEP bound. Then the antenna selection using RCP is employed. The proposal is considered in Rayleigh fading channel condition. The number of bits to be transmitted can be reduced. Since only an antenna transmits at an instant of time, and others are silent power can be saved. The results show that the method performs very well for both the BER and ABEP. A key challenge of future mobile communications research is to strike an attractive compromise between wireless network's area spectral-efficiency and energy-efficiency. This necessitates a clean slate approach to wireless system design, embracing the rich body of existing knowledge especially on Multiple-Input-Multiple-Output (MIMO) technologies. Further research will extend the optimum transmit structure to be more energy efficient and less complex.

REFERENCES

[1] OFCOM, "The Communications Market 2008," OFCOM, Tech. Rep. 4 Telecoms, August 2009. [Online]. Available: http://www.ofcom.org.uk/research/cm/cmr09/ CMRMain 4.pdf

[2] D. shan Shiu P. J. Smith D. Gesbert, M. Sha_ and A. Naguib. "From Theory to Practice: an Overview of MIMO space-time coded Wireless Systems". IEEE J. Selected Areas Comm., vol. 21, pg. 281{302, 2003.

[3] E. Telatar, "Capacity of Multi-Antenna Gaussian Channels", European Transaction Telecommunication, vol. 10, no. 6, pp. 558{595, Novem- ber/December 1999.

[4] A. Paulraj, R. Nabar, and D. Gore, Introduction to Space-Time Wireless Communications. U.K.: Cambridge University Press, 2003.

[5] R. Mesleh, H. Haas, C. W. Ahn, and S. Yun, "Spatial modulation–a new low complexity spectral efficiency enhancing technique", in Proc. Conf. Commun. Netw. China, Beijing, China, pp. 1-5, Oct. 2006.

[6] P. Wolniansky, G. Foschini, G. Golden, and R. Valenzuela, "V-BLAST: An architecture for realizing very high data rates over the rich-scattering wireless channel," in Proc. ISSSE, Sep. 1998, pp. 295–300.

[7] V. Tarokh, H. Jafarkhani, and A. Calderbank, "Space-time block codes from orthogonal designs," IEEE Trans. Inf. Theory, vol. 45, no. 5, pp. 1456–1467, Jul. 1999.

[8] Athanasios Stavridis, Marco Di Renzo, Harald Haas, "Performance Analysis of Multistream Receive Spatial Modulation in the MIMO Broadcast Channel" IEEE Transactions on Wireless Communications, vol. 15, no. 3, March 2016

[9] M. Di Renzo and H. Haas, "A general framework for performance analysis of Space ShiftKeying (SSK) modulation forMISOcorrelated Nakagami-m fading channels," IEEE Trans. Commun., vol. 58, no. 9, pp. 2590–2603,Sep. 2010.

[10] N. Serafimovski et al., "Practical implementation of spatial modulation", IEEE Trans. Veh. Technol., vol. 62, no. 9, pp. 4511–4523, Nov. 2013.

[11] A. Younis et al., "Performance of spatial modulation using measured realworld channels," in Proc. 78th IEEE Veh. Tech. Conf. (VTC), Las Vegas, NV, USA, Sep. 2–5, 2013, pp. 1–5.

[12] J. Zhang, Y. Wang, L. Ding, and N. Zhang, "Bit error probability of spatial modulation over measured indoor channels," IEEE Trans. Wireless Commun., vol. 13, no. 3, pp. 1380–1387, Mar. 2014.

[13] R. Mesleh, H. Haas, S. Sinanovic, C. W. Ahn, and S. Yun, "Spatial modulation," IEEE Trans. Veh. Technol., vol. 57, no. 4, pp. 2228–2241, Jul. 2008.

[14] P. Frenger, P. Moberg, J. Malmodin, Y. Jading, and I. Godor, "Reducing energy consumption in LTE with cell DTX," in Proc. 73rd IEEE VTC Spring, May 2011, pp. 1–5.

[15] A. Chatzipapas, S. Alouf, and V. Mancuso, " On the minimization of power consumption in base stations using on/off power amplifiers", in Proc. IEEE Online Conf. Green Com, Sep. 2011, pp.18–23.

[16] B. Clerckx and C. Oestges, "MIMO Wireless Networks: Channels, Techniques and Standards for Multi-Antenna, Multi-User and Multi-Cell Systems", Academic Press: Oxford, UK pp.7-9, Jan 2013.

[17] B. Clerckx and C. Oestges, "MIMO Wireless Networks: Channels, Techniques and Standards for Multi-Antenna, Multi-User and Multi-Cell Systems", Academic Press: Oxford, UK pp. 7-9, Jan 2013.

[18] D. G. Brennan, "Linear diversity combining techniques," Proc. IEEE, vol. 91, no. 2, pp. 331-356, Feb. 2003.

[19] Shahab Sanayei, Aria Nosratinia, "Antenna Selection in MIMO Systems". IEEE Communications Magazine, October 2004.

[20] Xiping Wu, Marco Di Renzo, and Harald Haas, "Adaptive Selection of Antennas for Optimum Transmission in Spatial Modulation", IEEE Transactions on Wireless Communications, Vol. 14, no. 7, July 2015

[21] K. Stphenson, Introduction to Circle Packing: The Theory of Discrete Analytic Function. Cambridge, U.K.: Cambridge Univ. Press, 2005.