ELSEVIER

CrossMark

Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 54 (2015) 558 – 565

Procedia Computer Science

Eleventh International Multi-Conference on Information Processing-2015 (IMCIP-2015)

Multiple Transmit Antenna Selection in MIMO-OSTBC System in Nakagami-*m* Fading Channel

Vaibhav Hendre[a,b,*], M. Murugan[c] and Akshay B. Chandgude[a]

[a] *Electronics & Telecommunication Engineering Department at Trinity College of Engineering & Research, Pune*
[b] *Research Scholar of Electronics Engineering Department at Sathyabama University, Chennai, Tamilnadu*
[c] *Electronics & Communication Engineering Department at SRM's Valliammai Engineering College, Chennai, Tamilnadu*

Abstract

Transmit Antenna Selection (TAS) is essential part of future wireless systems to reduce the complexity of multiple antenna techniques and to satisfy the need of higher data rates. In this paper, we present TAS technique based on Maximal Ratio Combining (MRC) scheme with multiple antenna selection. The sub optimal antenna selection is carried out for selecting more than one subset of antenna which minimizes the upper bound of pair wise error probability. The performance analysis of the system is carried out under Nakagami-*m* flat fading channel. The Bit Error Rate (BER) analysis is performed for multiple antenna selection in MIMO-OSTBC system for arbitrary values of '*m*' in Nakagami-*m* fading channel.

Peer-review under responsibility of organizing committee of the Eleventh International Multi-Conference on Information Processing-2015 (IMCIP-2015)

Keywords: Maximal ratio combining (MRC); Multiple input multiple output (MIMO); Nakagami-*m* fading channels; Orthogonal space time block coding (OSTBC); Transmit antenna selection (TAS).

1. Motivation

Multiple Input Multiple Output (MIMO) wireless systems have multiple antenna elements at both transmitter and receiver end. MIMO systems with many antenna elements at both link ends are a proficient outcome for future wireless communications systems because they provide high data rates by making full use of the spatial domain with limited bandwidth and transmit power[1]. Space-Time Block Coding (STBC) is a MIMO transmit action designed to exploit high reliability and transmit diversity[2]. The multiple antenna systems take benefit of space diversity by which transmission of several parallel data streams can be done to increase the capacity of the system. In order to overcome the hardware complexity of MIMO systems, an Antenna Selection (AS) technique which selects less number of antennas based on the channel state information of the system are popular in recent wireless communication systems[3]. Transmit Antenna Selection (TAS) is recommended in uplink and downlink of recent wireless systems.

*Corresponding author. Tel.: +91-9921580670.
E-mail address: hendrevaibhav@gmail.com

Peer-review under responsibility of organizing committee of the Eleventh International Multi-Conference on Information Processing-2015 (IMCIP-2015)
doi:10.1016/j.procs.2015.06.064

2. Background Work

In TAS, one or more antennas are selected at transmitter end based on CSI estimated at receiver end[4]. TAS scheme with Maximal Ratio Combining (MRC) is proposed in[5] for single transmit antenna selection. Here pilot based training sequences estimates the channel at receiver and based on feedback the single antenna is selected for uncoded transmission whereas all the other transmit antennas are inactive during transmission of data[6]. The single antenna takes less power for transmission as shown in equation (1), we can see that the total power required for all antennas is less than or equal to power required for single antenna.

$$\sum_{k=1}^{N} p_k \leq P \tag{1}$$

where N the total number of antenna elements is, p_k is the power allocated through the k^{th} antenna element, and P is the power for a single antenna component[7]. In literature, TAS is proposed with the assumption that the multipath fading environment is approximated to either Rayleigh or Rician distribution. In Rayleigh, there is no line of sight component present between mobile station and base station. The signal gets reflected and scattered from different directions. For simulating high frequency signals propagating in an exospheric channel Rayleigh fading models are used. Though, Rayleigh fading does not fulfil the long distance effects with sufficient accuracy. The Rician fading occurs when there is a mainly stationary signal component present. The TAS/MRC system for Rician fading channel is given in[8].

Nakagami observed this fact first, who then formulated a parametric gamma distribution-based density function to describe the experimental data he obtained[9]. It is well known that Nakagami-m fading covers a wide range of fading scenarios via the m ($m \geq 1/2$) parameter, which includes the Rayleigh fading ($m = 1$) as a its special case[10]. The Nakagami fading model is used for detection of signals for MRC systems in[11]. In[12], transmit selection diversity with MRC is proposed for Nakagami fading models. The BER analysis of TAS/MRC system is presented in[13]. Generalized antenna selection technique is proposed in[14, 15] for Nakagami-m fading model. The performance analysis of transmit antenna selection for MRC system is presented in[16]. However it is restricted to single antenna selection only.

3. Contribution

This paper presents the performance analysis of TAS/MRC systems in independent flat Nakagami-m fading channels for arbitrary values of 'm' for multiple antenna selection. This paper is an extension of the work presented in[16] for multiple antenna selection. The BER performance of Maximal-Ratio Combining system with multiple transmit antenna selection in flat Nakagami-m fading channels is carried out. First the Probability Density Function (PDF) is derived for arbitrary real-values of 'm'. An interesting conclusion is reached that the diversity order is based upon the outcome of three parameters: Nakagami parameter 'm', the number of transmit antennas and number of receive antennas. Simulation results are provided to prove the analysis.

The BER analysis is also carried out for TAS/MRC system for various MIMO configurations such as (4, 1; 4), (4, 2; 4), (4, 3; 4), and 4×4 MIMO systems with and without TAS under the effect of Nakagami-m fading channel. The further part of the paper is structured as follows: Section 2 introduces the system model and channel model. Section 3 presents BER analysis of TAS/MRC scheme for Nakagami-m fading channel. The performance analysis is carried out for MIMO-OSTBC system with and without TAS in Section 4 for TAS/MRC system. Section 5 presents conclusion.

4. System and Channel Model

We consider a MIMO wireless system with TAS along with MRC at receiver under a flat Nakagami-m fading channel. Let 'Lt' number of transmit antennas and 'Lr' number of receive antennas where $(Lt; Lr)$ represents the system without antenna selection.

Figure 1 shows the system block diagram. Let 'H' is the channel matrix with dimensions $L_t \times L_r$ and $h_{i,j}$ are the channel fading coefficients where $1 \leq i \leq L_t$ and $1 \leq j \leq L_r$. These fading coefficients are the samples of

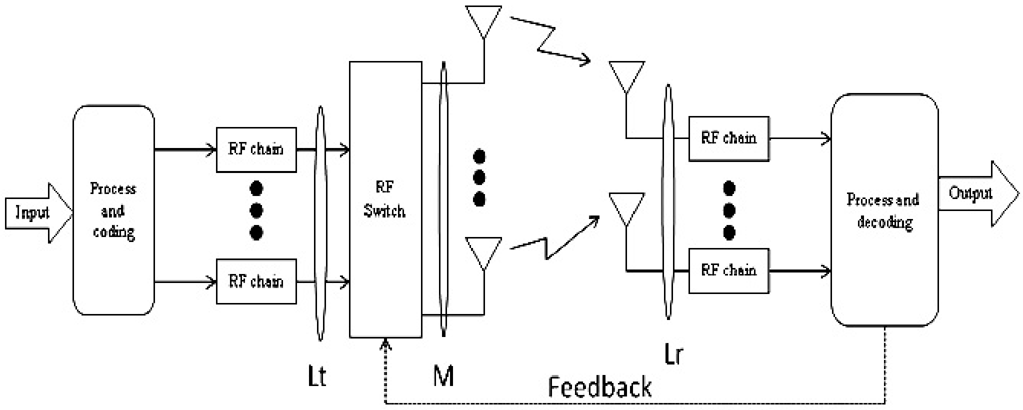

Fig. 1. System block diagram.

Nakagami-m fading function. Then the amplitude $|h_{i,j}|$ follows a Nakagami distribution with fading parameter 'm'. The generalized equation for received signal at the input of receiver is given by

$$y = hx + n \tag{2}$$

where 'y' is received signal vector, 'x' is OSTBC encoded signal vector, 'h' is channel gain matrix and 'n' is noise vector.

Here pilot based training sequence is send from every antenna towards the receiver. At receiver end MRC value for every antenna is calculated. The index of single selected transmit antenna, denoted by I, can be determined by equation as in (3). The single selected transmit antenna, denoted by 'I' which maximizes the total received signal power and is determined by[8]

$$I = \underset{1\le i\le L_t}{\operatorname{argmax}} \left\{ C_i = \sum_{j=1}^{L_r} |h_{i,j}|^2 \right\} \tag{3}$$

We assume that the channel remains constant for a transmission of data and this constant within block varies independently.

Let γ indicate the instantaneous SNR of the MRC output, or instantaneous post-processing SNR. For a $(1, L_r)$ MRC system with a single transmit antenna and L_r receive antennas in Nakagami-m fading channels, so the PDF of γ is given by[15]

$$p_\gamma(\gamma) = \frac{\gamma^{mL_r-1}}{\left(\frac{\bar{\gamma}}{m}\right)^{mL_r} \Gamma(mL_r)} \exp\left(-m\frac{\gamma}{\gamma}\right) \tag{4}$$

where the gamma function is defined as $-\gamma(z) = \int_0^\infty x^{z-1} e^{-x}\, dx$, and the average SNR $\bar{\gamma} = \frac{E_s}{N_0}$, in which E_S is the average energy per symbol at the transmitter and N_0 is the power spectral density of the Additive White Gaussian Noise (AWGN) at each receive antenna. For a random real-valued 'm', the Cumulative Distribution Function (CDF) of γ is calculated as

$$p_\gamma(\gamma) = \frac{\gamma\left(mL_r, m\frac{\gamma}{\gamma}\right)}{\gamma(mL_r)} \tag{5}$$

where $(\alpha, x) = \int_0^x e^{-t} t^{\alpha-1}\, dt$, Re > 0, is the lower incomplete gamma function. We are using equation (4) and (5) for further analysis of BER calculations for Nakagami fading. The single antenna selection case proposed in[16] uses equation (3).

Here we present the multiple antenna selection based on sub optimal selection method. While selecting the subset of antenna we first select antenna which will provide maximum value of MRC as given by equation (3). Further all subsets are arranged in ascending order of MRC. Let us arrange C_i in increasing order of magnitude, and denote them by $C(l)$, where $1 \leq l \leq L_t$, and $C(1) \leq C(2) \leq \cdots \leq C(L_t)$. The instantaneous post-processing SNR of the $(L_t, 1; L_r)$ TAS/MRC system, denoted by $\gamma(L_t)$, can be written as $\gamma(L_t) = C(L_t)\bar{\gamma}$.

Consider the channel matrix $H = [h_i j]$ where $h_{ij} \sim \mathcal{CN}(0,1)$ is the channel gain between the i^{th} transmit and j^{th} receive antenna. $\widetilde{H} \in \mathbb{C}^{L_r \times N}$ consists of the channel gains for the N selected transmit antennas and L_r received antennas which is a sub matrix of the channel matrix $\widetilde{H} \in \mathbb{C}^{L_r \times L_t}$. Let us consider h_j where $(j = 1, 2, \ldots, L_t)$ is the columns of the channel matrix H. Here we can sort these columns as per the increasing order of Norms, $\|h_{i1}\| \geq \|h_{iL_t}\|$ where $i_k \in \{1, 2, \ldots, L_t\}$ and the order of the indexes $i_1, i_2, \ldots, i_{L_t}$ is, in general, different from the order of the indexes $1, 2, \ldots, L_t$. Here we can select the best possible transmit antenna which will try to minimize the BER.

Let $P_r(\mathbf{C}_i \rightarrow \mathbf{C}_j \mid \mathbf{H}_{\{P_1, P_2, \ldots, P_Q\}})$ denote the pair wise error probability when a space-time codeword $\mathbf{C}_i$ is transmitted but $\mathbf{C}_j$ is decoded for the given channel $\mathbf{H}_{\{P_1, P_2, \ldots, P_Q\}}$, $j \neq i$. For an effective channel $\mathbf{H}_{\{P_1, P_2, \ldots, P_Q\}}$ with Q columns of $\mathbf{H}$ chosen, an upper bound for the pair wise error probability for orthogonal STBC (OSTBC) is given as[15]

$$P_r(\mathbf{C}_i \rightarrow \mathbf{C}_j \mid \mathbf{H}_{\{P_1, P_2, \ldots, P_Q\}}) = Q\left(\sqrt{\frac{\rho\|\mathbf{H}_{\{P_1, P_2, \ldots, P_Q\}} E_{i,j}\|_F^2}{2N_T}}\right)$$

$$\leq \exp\left(-\frac{\rho\|\mathbf{H}\{P_1, P_2, \ldots, P_Q\}^{E_{i,j}\|_F^2}}{4N_T}\right) \tag{6}$$

By using this upper bound, we can select Q number of antennas which will minimizes the upper bound given by equation (6) as

$$\{P_1^{\text{opt}}, P_2^{\text{opt}}, \ldots, P_Q^{\text{opt}}\} = \underset{P_1, P_2, \ldots, P_Q \in A_Q}{\text{argmax}} \|\mathbf{H}_{\{P_1, P_2, \ldots, P_Q\}} \mathbf{E}_{i,j}\|_F^2$$

$$= \underset{P_1, P_2, \ldots, P_Q \in A_Q}{\text{arg max}} \mathbf{H}_{\{P_1, P_2, \ldots, P_Q\}} \mathbf{E}_{i,j} \mathbf{E}_{i,j}^H H_{\{P_1, P_2, \ldots, P_Q\}}^H \tag{7}$$

The average SNR on the receiver side with Q selected antennas of $\{P_i\}_{i=1}^Q$ is given as

$$\eta_{\{P_1, P_2, \ldots, P_Q\}} = \frac{\rho}{Q}\|\mathbf{H}_{\{P_1, P_2, \ldots, P_Q\}}\|_F^2 \tag{8}$$

As per equation (7) and (8) we are selecting the subset of antenna which will maximize the received SNR. After the optimal selection of Q number of antennas the average received SNR is given by

$$\frac{\rho}{Q}\|\mathbf{H}\|_F^2 \geq \eta_{\{P_1, P_2, \ldots, P_Q\}} \geq \frac{\rho}{N_T} \tag{9}$$

This shows that we can achieve the diversity order of $N_T \times N_R$ antennas without TAS by using optimal antenna selection in Equation (9). Here we assumed that H follows Nakagami-m distribution.

5. BER Analysis for TAS/MRC System in Nakagami Fading Channel

The BER performance for TAS/MRC system is presented in[16] for single TAS in Nakagami-m fading channel. We are extending the same mathematical formulation further for the case of multiple antenna selection. In order to calculate the exact BER, we have to consider the PDF of instantaneous channel gain. The instantaneous BER for

BPSK can be given as $P_E(\beta) = Q(\sqrt{k\beta\bar{\gamma}})$ where $\beta = \underline{\underline{\gamma}}$ which is channel power gain. The average BER is given as per[16] is

$$P_E = \frac{2^t a \Gamma\left(t + \frac{3}{2}\right)}{\sqrt{\pi}(t+1)}(k\bar{\gamma})^{-(t+1)} + o(\bar{\gamma}^{-(t+1)}) \tag{10}$$

Further for single TAS/MRC system this can be approximated to

$$P_E = \frac{m^{mL_tL_r}\Gamma\left(mL_tL_r + \frac{1}{2}\right)}{2\sqrt{\pi}[\Gamma(mL_r+1)]^{L_t}}(\bar{\gamma})^{-(mL_tL_r)} + x \tag{11}$$

Here we assume that $k = 2$ for BPSK and $x = o(\bar{\gamma}^{-mL_tL_r})$. Now '$m$' and L_r are constant and integers. From this for single antenna selection combination $(L_t, 1; L_r)$ we have the BER equation as

$$P_E = \frac{m^{mL_tL_r}(2mL_tL_r - 1)!}{2^{2mL_tL_r}[(mL_r)!]^{L_t}(2mL_tL_r - 1)!}(\bar{\gamma})^{-(mL_tL_r)} + x \tag{12}$$

This we can be further extended to the case of multiple antenna selection. Let us assume that the case of 4 transmit antenna and we will select 2 antennas out of 4. Now for the combination of $(4, 1; L_r)$ we can find the probability of error as given below

$$P_1 = \frac{m^{4mL_r}(8mL_r - 1)!}{2^{8mL_r}[(mL_r)!]^4(8mL_r - 1)!}(\bar{\gamma})^{-(4mL_r)} + o(\bar{\gamma}^{-4mL_r}) \tag{13}$$

Further we can calculate the P_2 in similar way as mentioned in[15]. Now looking at to equation (7), the optimum value of both P_1 and P_2 can be calculated for the case of two antenna selection. Therefore for the case of $(4, 2; L_r)$ the overall BER can be obtained from equation (7). The sub optimal based selection is done which is based on the pair-wise error probability obtained from equation (7). The best subset is selected in increasing order of MRC value as mentioned in section 4. This subset is selected such that the upper bound of pair wise error probability will be minimized as given in equation (8). It is also possible to carry out the analysis in decreasing order of selection.

6. Performance Analysis

The performance of system is analyzed for Bit Error Rate (BER) for various configurations such as (4, 1; 4), (4, 2; 4), (4, 3; 4), and 4×4 MIMO systems with multiple TAS and without TAS for Nakagami-m fading channel. We first try to show the PDF of Nakagami fading model for various values of 'm'. Figure 2 shows the PDF of Nakagami-m distribution given by equation (4) for arbitrary values of m by keeping the shaping factor constant. From graph we can see that the Nakagami-m fading covers a wide range of fading scenarios via the $m(m \leq 1/2)$ parameter. The Rayleigh fading can be achieved for $(m = 1)$ as a special case of Nakagami fading. The most practical approximation of the channel can be possible for the $m > 2$. The multiple antenna selection case for Alamouti for MIMO-OSTBC system is simulated for BER analysis.

Figure 3 shows the BER analysis comparison for 4×4 MIMO with and without TAS. Here we compare the TAS for single and two antenna selection along with without TAS case. The BER performance improves with (4, 1; 4) MIMO with single antenna selection compare to 4×4 MIMO without TAS for Nakagami-m fading channel. Similarly it can be seen that the system performance improves with two transmit antenna selection for (4, 2; 4) compare to (4, 1; 4) system.

The concept of multiple antenna selection is further extended according to equation (7) for more than one antenna. Figure 4 shows that the BER performance increases as we go on increasing the number of subset of antennas selected. As shown in Fig. 4, The performance improves for (4, 3; 4) compare to (4, 2; 4) and (4, 1; 4) case. This shows that multiple antenna selection gives better performance compare to conventional MIMO configurations.

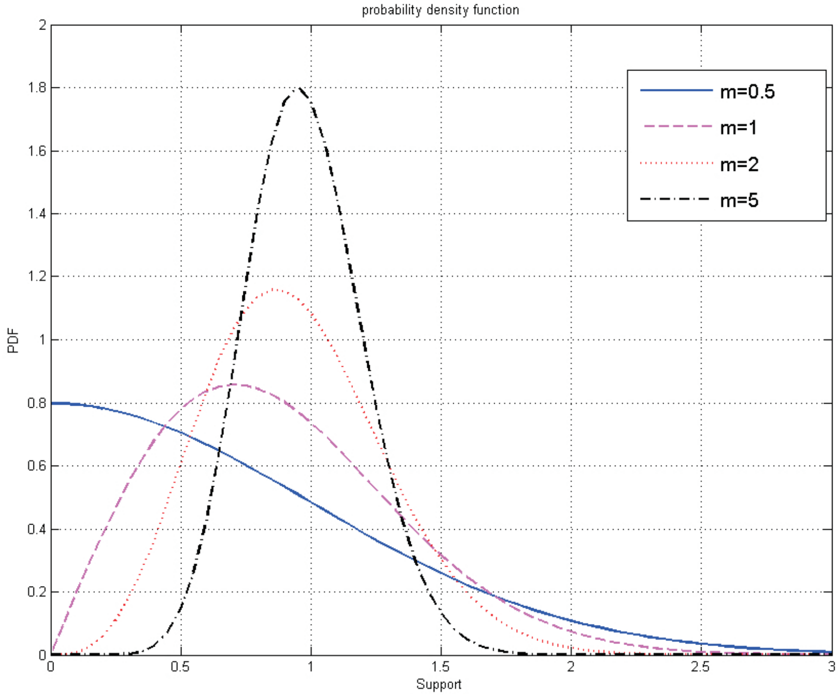

Fig. 2. Nakagami-m PDF for various values of m.

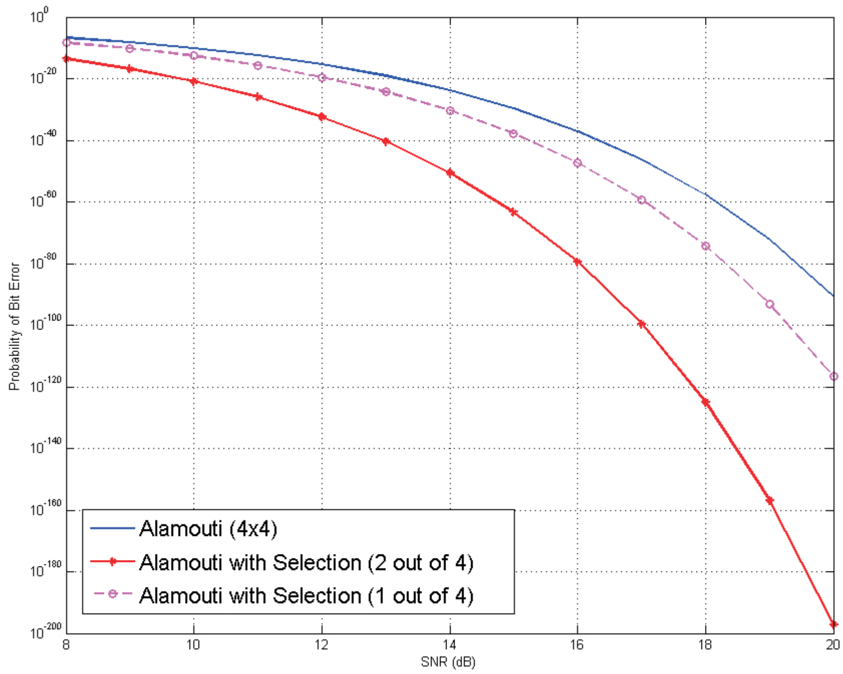

Fig. 3. BER analysis for MIMO-OSTBC system with multiple TAS in Nakagami-m fading channel.

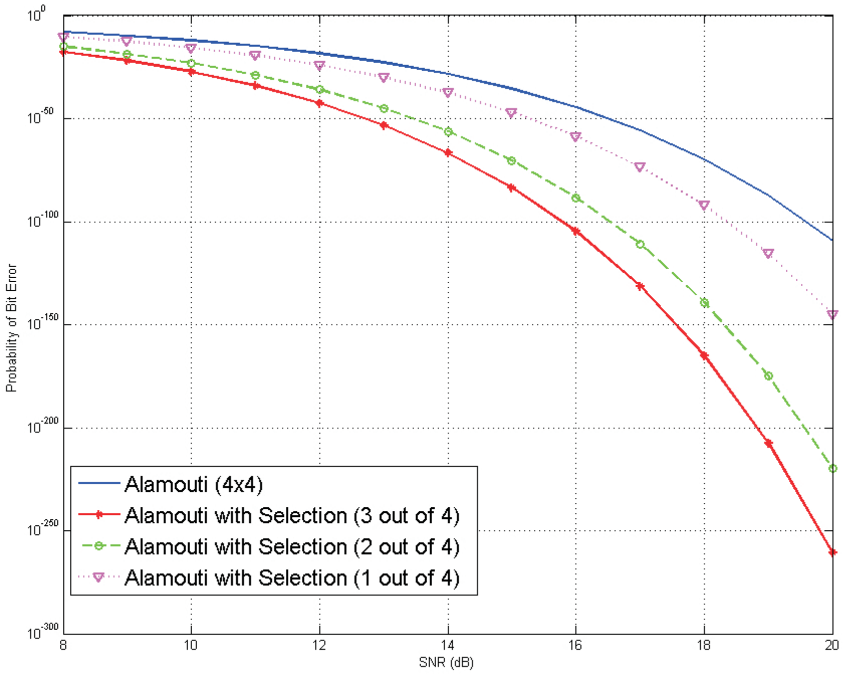

Fig. 4. BER analysis for MIMO-OSTBC system with multiple TAS in Nakagami-*m* fading channel.

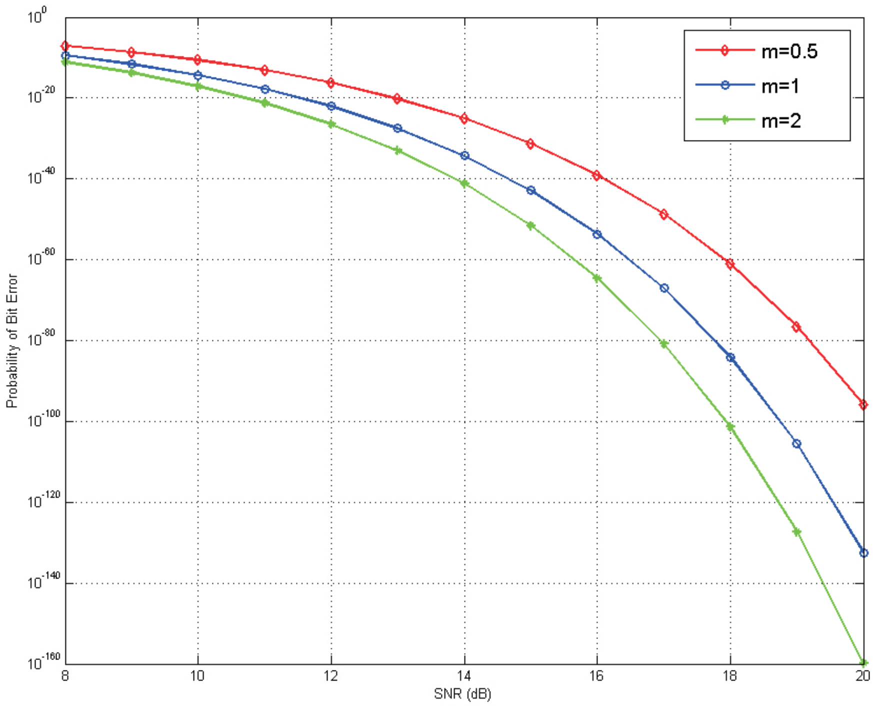

Fig. 5. BER analysis comparison for single TAS for various values of '*m*' in Nakagami-*m* fading channel.

The arbitrary values of 'm' in Nakagami-m fading gives different fading distributions as shown in Fig. 2. Therefore it is necessary to verify the performance of the system with TAS for different fading distributions. Figure 5 shows the BER performance for single TAS system for $m = 0.5$, 1 and 2. The case for $m = 1$ is a Rayleigh distribution. The performance is nearly similar even for $m = 0.5$ case of very large fading distribution.

References

[1] Tsoulos, MIMO System Technology for Wireless Communications, *The Elect. Engg. and Applied Signal Processing Series,* Taylor and Francis Series, CRC Press, (2006).
[2] A. B. Gershman and N. D. Sidiropoulos, Space-Time Processing for MIMO Communications, John Wiley and Sons Ltd., (2005).
[3] A. F. Molisch and M. Z. Win, MIMO Systems with Antenna Selection, *IEEE Microwave Mag.*, vol. 5, pp. 46–56, March (2004).
[4] Shiva Prakash and Ian McLoughlin, Effects of Channel Prediction for Transmit Antenna Selection with Maximal Ratio Combining in Rayleigh Fading, *IEEE Trans. on Veh. Technol.*, vol. 60, no. 6, pp. 2555–2568, July (2011).
[5] Z. Chen, J. Yuan and B. Vucetic, Analysis of Transmit Antenna Selection/Maximal-Ratio Combining in Rayleigh Fading Channels, *IEEE Trans. Veh. Technol.*, vol. 54, no. 4, pp. 1312–1321, July (2005).
[6] S. Thoen, L. Van der Perre, B. Gyselinckx and M. Engels, Performance Analysis of Combined Transmit-SC/Receive-MRC, *IEEE Trans. Commun.*, vol. 49, pp. 5–8, January (2001).
[7] M. Z. Win and J. H. Winters, Virtual Branch Analysis of Symbol Error Probability for Hybrid Selection/Maximal-Ratio Combining in Rayleigh Fading, *IEEE Trans. Commun.*, vol. 49, pp. 1926–1934, November (2001).
[8] V. S. Hendre, M. Murugan and Sneha Kamthe, Transmit Antenna Selection in MIMO for Image Transmission with MRC in Rician fADING channel, *IEEE Global Conf. on Wireless Computing and Networking*, pp. 239–243, December (2014).
[9] Li Tang and Zhu Hongbo, Analysis and Simulation of Nakagami Fading Channel with MATLAB, *IEEE Asia-Pacific Conf. on Environmental Electromagnetics*, pp. 490–494, (2003).
[10] M. Nakagami, The m-Distribution, a General Formula of Intensity Distribution of Rapid Fading, in *Statistical Methods in Radio Wave Propagation*, W. G. Hoffman, ed. Pergamon Press, pp. 3–36, (1960).
[11] E. K. Al-Hussaini and A. A. M. Al-Bassiouni, Performance of MRC Diversity Systems for the Detection of Signals with Nakagami Fading, *IEEE Trans. Commun.*, vol. 33, no. 12, pp. 1315–1319, December (1985).
[12] J. Tang and X. Zhang, Transmit Selection Diversity with Maximal Ratio Combining for Multicarrier DS-CDMA Wireless Networks Over Nakagami-*m* Fading Channels, *IEEE J. Select. Areas Commun.*, vol. 24, no. 1, pp. 104–112, January (2006).
[13] B. Wang, Accurate BER of Transmitter Antenna Selection/Receiver-MRC Over Arbitrarily Correlated Nakagami Fading Channels, In *Proc. IEEE Int. Conf. Acoustic Speech and Signal Processing*, Toulouse, France, vol. 4, pp. 753–756, May (2006).
[14] S. Choi and Y. Ko, Performance of Selection MIMO Systems with Generalized Selection Criterion Over Nakagami-*m* Fading Channels, *IEICE Trans. Commun.*, vol. E89-B, no. 12, pp. 3467–3470, December (2006).
[15] S. R. Meraji, Performance Analysis of Transmit Antenna Selection in Nakagami-*m* Fading Channels, *Wireless Pers. Commun.*, vol. 43, pp. 327–333, October (2007).
[16] Z. Chen, J. Yuan and B. Vucetic, Error Performance of Maximal-Ratio Combining with Transmit Antenna Selection in Flat Nakagami-*m* Fading Channels, *IEEE Trans. Wireless Commun.*, vol. 8, no. 1, pp. 1312–1321, January (2009).