Sub-Optimal Antenna Selection Technique Over Weibull—Gamma Fading Channel for MIMO Communication Systems

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***Abstract*—** The performance of multiple-input multiple-output (MIMO) communication system is assessed in this paper using antenna selection techniques (AST) over Weibull—Gamma fading (WGF) channel. The multipath and shadowing degrades the system performance in wireless communication. To model the multipath and shadowing effects, the composite WGF channel is considered in this paper. The channel state information on the transmitter side (CSIT) can be utilized to improve the system capacity and error rate at the same time with reduced complexity of the hardware. The CSIT in AST is used for orthogonal space time block code (OSTBC) of MIMO system over WGF channel to improve bit-error rate (BER) of the system. In this paper both optimal and suboptimal AST analysis is derived. Despite the fact that the suboptimal AST provides desired capacity improvement with less complexity, the optimal technique is preferred to enhance the system performance at the cost of increased complexity.

***Keywords*— MIMO Communication; antenna selection techniques; Weibull—Gamma fading; channel state information on the transmitter side.**

I. INTRODUCTION

Multiple-input multiple-output (MIMO) is a smart communication technique in wireless communication to deal with the increasing demand for the high data rate. Installing multiple antennas at the transmitter and receiver increases the performance of the wireless communication system with increased spectral efficiency and high quality of service to provide high speed data transmission [1 -7]. The main advantage of MIMO communication system is providing enhanced capacity of the system with already available frequency resources in two different methods: diversity methods and spatial multiplexing. The diversity scheme is used to improve the BER of the communication system utilizing the multipath effects of wireless communication between the transmitter and receiver [1-15]. Diversity gain aids in avoiding all the signals falling into deep fade simultaneously. The later scheme called spatial multiplexing utilizing the rich scattering phenomena present in the wireless environment to descramble signals at the receiver transmitted from multiple antennas simultaneously. The advantage of spatial multiplexing is achieving higher gain by resolving the several parallel spatial paths in the channel. The well known spatial multiplexing scheme is the Bell Labs Space Time (BLAST) architecture. Although the enhancement of capacity and bit error rate (BER) increases with MIMO, there comes complexity in hardware in terms of size and price with increasing number of antennas. Alamouti introduced a space time transmit diversity technique called Space-time block coding (STBC) which aids in transmission of high data rate increasing the capacity of MIMO wireless communication systems. This technique is generalized using orthogonal design for more than two transmit antenna which is called Orthogonal Space-time block coding (OSTBC) [3, 5-8]. The OSTBC converts the MIMO channel into scalar channels independent from each other offering diversity gain employing simpler encoding and decoding process. To overcome the complexity and cost arising due to increasing the number of transmit and receive antennas, antenna selection technique (AST) is proposed in recent past. The fundamental idea in AST is to select best set of subset antennas in the transmitter or receiver so that the number of encoding/decoding reduced at the transmit/receive antenna. The AST mainly focus in terms of diversity performance and capacity enhancement. Antenna selection is employed to decrease the complexity of the MIMO. There are two types of antenna selection technique: transmit antenna selection and another one is receive antenna selection. In this paper transmit antenna selection is employed. In transmit antenna selection the transmit antennas corresponds to columns of the channel matrix. The optimal antenna selection method has exorbitant computational complexity because of exhaustive search among all possible subsets of antennas. In this paper, Norm-based antenna selection procedure is adapted which selects the rows with the highest Euclidean norms of the channel matrix. Due to this in the high SNR region, the capacity loss is more compared to optimal antenna selection method. To achieve the comparable capacity with optimal methods, Gorokhov proposed a decremental selection method [2, 4]. In this method, each time one antenna is removed from the set of available antennas. The process is continued until to get the desired number of antennas present. In [4], based on QR decomposition near optimal antenna selection method with incremental selection proposed ensuring capacity increase. The near optimal method resembles to a Gram-Schimidt orthogonalization method in the high SNR state. Both of the above incremental and decremental methods are called successively selection greedy algorithms. A correlation based antenna selection procedure employed in [ ] to achieve less complexity but with higher capacity loss. In this paper based on norm and correlation, a sub-optimal procedure is implemented.

The 800-900 MHz spectrum is used for cellular mobile communication because of high penetration of signals in this spectrum range. In urban environments to model the land-mobile channel in this frequency range, Weibull fading model is used. To improve the performance of wireless communication systems appreciating the Weibull fading channel is significant. The temperament of wireless communication is multipath and shadow fading. To model the multipath effect Rayleigh distribution, Nakagami distribution and Weibull distribution have been suggested. Similarly, to model the effects of shadowing lognormal or Gamma distribution is proposed. In the environment where multipath and shadowing superimposed several composite distributions proposed like like Rayleigh- and Nakagami-lognormal. In this paper, the composite Weibull—Gamma Fading Channel is considered to analyze the performance of ATS. Nakagami with Gamma/log-normal distributions are used to generate shadow fading models [5, 7, 10]. The benefit of Weibull distribution over Nakagami is its easy tractable. Several composite distributions are derived in [5]. In [1, 10], Weibull process multiplied with a lognormal process is investigated for non-homogeneous scattering beside with shadowing effects. Gamma distribution is more suitable to model shadowing effects mathematically compared to lognormaldistribution.

The paper is organized as follows: In Section II, the MIMO system model is described. In Section III, the sub-optimal antenna selection algorithm is presented. In Section IV, the complexity is compared with the near-optimal algorithm of [7]. In Section V, simulation results and comparison are presented. Simulation result shows that the sub-optimal algorithm has a similar performance to the near-optimal algorithm. At last, Section VI gives the conclusion.

II. STBC System and Channel Model

Consider a MIMO wireless communication system with L_t transmit antennas and L_r receive antennas with the assumption of channel state information (CSI) is available at the transmitter. For OSTBC MIMO communication [3, 5-8] N number of antennas are selected to transmit from the available L_t transmit antennas. The remaining $L_t - N$ antennas are not active. The channel matrix is denoted by $\tilde{\mathbf{H}} \in \mathbb{C}^{L_r \times L_t}$ and the submatrix of the channel matrix is is denoted by $\tilde{\mathbf{H}} \in \mathbb{C}^{L_r \times N}$ where $\mathbf{H} = [h_{ij}]$. The channel gain h_{ij} between the i^{th} transmit antenna and the j^{th} receive antenna is given by $h_{ij} \sim \mathbb{CN}(0,1)$. The channel submatix is given as

$$\tilde{\mathbf{H}} = [h_{\mathrm{i}1}\, h_{\mathrm{i}2}\, \dots\, h_{\mathrm{iN}}] \qquad (1)$$

Where the columns $h_{\mathbf{ij}}$ are sorted according to their norms such that $|h_{i1}| \geq \cdots \geq |h_{iL_t}|$, $i_k \in \{1,2,\dots,L_t\}$. The transmitted symbols are mapped to OSTBC stream into N number of selected antennas is given by $\in \mathbb{C}^{N\times 1}$. The received signal is given as

$$\mathbf{Y} = \sqrt{\frac{E_s}{N}}\tilde{\mathbf{H}}\mathbf{s} + \mathbf{V} \qquad (2)$$

Where, $\mathbf{Y} \in \mathbb{C}^{L_r \times 1}$ is the complex matrix form of the received signal, $\mathbf{s} \in \mathbb{C}^{N\times 1}$ is transmitted signal mapped to OSTBC stream into N number of selected antennas, E_s is the transmitted symbol energy and $\mathbf{V}$ is additive white Gaussian noise (AWGN) with size $L_r \times 1$ and independent and identical distributed.

MIMO communication system is considered to Q (symbols $\{s_1, s_2 \dots, s_Q\}$) independent single input single output (SISO) systems under OSTBC. The average energy of Q symbols chosen from an M -PAM or M -QAM constellations is assumed one. The symbol rate $\mathrm{R_s} = \frac{\mathrm{Q}}{\mathrm{T}}$ which is T symbol periods are needed to transmit Q symbols in OSTBC system. The small scale fading and shadowing effects are modeled as WGF channel matrix .

$$\mathbf{H} = \sqrt{\frac{g}{d^v}}\ddot{\mathbf{H}} \qquad (3)$$

where, d represents the distance between the transmitter and receiver; v represents the path loss exponent with average fading power given by $\Omega = E[x^2]$; the gamma random variable g which is independent and identically distributed (i.i.d) with probability density function (PDF), represented by

$$P(x) = \frac{1}{\Gamma m}\left(\frac{m}{\Omega}\right)^m x^{m-1} e^{\frac{-mx}{\Omega}}, \qquad x, \Omega, m \geq 0. \qquad (4)$$

The Weibull distribution for $\ddot{\mathbf{H}}$ is given by the PDF

$$P(x) = \beta\lambda^{-\beta}x^{\beta-1}e^{-\left(\frac{x}{\lambda}\right)^\beta}, \qquad x, \lambda, \beta \geq 0. \qquad (5)$$

Where β and m are Weibull and gamma fading parameters. The composite PDF of WGF Channel is determined by combining (4) and (5). The WGF approximated to

Weibull distribution for $m \to \infty$ Rayleigh distribution for $\beta = 2,\ m \to \infty$,and additive white Gaussian noise (AWGN) channel for $\beta \to \infty,\ m \to \infty,$. The distribution function WGF is also called as generalized Weibull distribution which is defined for several multipath and shadowing effects by increasing the values of β and m.

III. ANTENNA SELECTION TECHNIQUE

The sub-optimal and optimal antenna selection technique is elaborated in this section for MIMO communication systems. The AST is used to improve the performance of system capacity.

A. Sub-Optimal Antenna Selection Technique

The channel capacity of the submatrix $\tilde{\mathbf{H}}$ for AST is given by

$$C\left(\tilde{\mathbf{H}}\right) = \log_2 det\left(\mathbf{I}_N + \frac{E_s}{N}\tilde{\mathbf{H}}^H\tilde{\mathbf{H}}\right). \quad (6)$$

There are $\binom{L_t}{N}$ selection possibilities of selecting transmit antenna and searching the

optimal subset comprehensively has exorbitant complexity. The AST problem is to find the best subset N^* to maximize the channel capacity. The algorithm to select antenna is given as:

$$\begin{aligned} N^* &= arg\, \max_N \left\{C\left(\tilde{\mathbf{H}}\right)\right\} \\ &= arg\, \max_N \left\{\log_2 det\left(\mathbf{I}_N + \frac{E_s}{N}\tilde{\mathbf{H}}^H\tilde{\mathbf{H}}\right)\right\} \end{aligned} \quad (7)$$

At high SNR the (7) becomes

$$\begin{aligned} N^* &= arg\, \max_N \left\{\log_2 det\left(\frac{E_s}{N}\tilde{\mathbf{H}}^H\tilde{\mathbf{H}}\right)\right\} \\ \Leftrightarrow\ N^* &= arg\, \max_N \left\{\log_2 det\left(\tilde{\mathbf{H}}^H\tilde{\mathbf{H}}\right)\right\} \end{aligned} \quad (8)$$

QR decomposition is applied channel submatrix $\tilde{\mathbf{H}}$.

$$\tilde{\mathbf{H}} = \boldsymbol{QR} \quad (9)$$

Substituting (9) into (8), the (8) becomes

$$\begin{aligned} N^* &= arg\, \max_N \left\{\log_2 \left(\prod_{j=1}^{N} \mathbf{R}_{\mathbf{jj}}\right)^2\right\} \\ \Leftrightarrow N^* &= arg\, \max_N \left\{\left(\prod_{j=1}^{N} \mathbf{R}_{\mathrm{jj}}\right)^2\right\} \end{aligned} \quad (10)$$

The (10) can be modified by using a correlation metric Z_{l_i}, Z_{l_j}

$$N^* = \arg \max_N \left\{\left(\prod_{j=1}^{N} \mathbf{R}_{\mathrm{jj}}\right)^2\right\}$$

$$N^* = arg\, \max_N \left\{\prod_{j=1}^{N}\left(\left|h_{ij}\right|^2\left(1 - \sum_{i=1}^{j-1} ||Z_{l_i} Z_{l_j}||^2\right)\right)\right\} \quad (11)$$

Where h_{ij} is the column verctor of the channel submatrix $\tilde{\mathbf{H}}$

When j is relatively small, the Z_{l_i}, Z_{l_j} is approximated to row correlation which is defined in [4]

$$Z_{l_i}, Z_{l_j} = \rho_{l_i,\ l_j} \quad (12)$$

$$\rho_{l_i,l_j} = v_{l_i}^H v_{l_j} = \frac{h_{ij}^H h_{ij}}{\left|h_{ij}^H\right| * \left|h_{ij}\right|} \quad (13)$$

The $\boldsymbol{R}_{\mathrm{jj}}$ can be rewritten based on the approximation in (12) as

$$\mathbf{R}_{jj} = \left|h_{ij}\right|^2 \left(1 - \sum_{i=1}^{j-1} \left|\rho_{l_i,l_j}\right|^2\right) \quad (14)$$

Based on (14), a sub-optimal antenna selection algorithm is proposed which is based on norm and correlation successivly working. Initially the algorithm starts with an empty set and only one antenna is added each time in this set. $\boldsymbol{R}_{jj}$is to be maximized by selecting appropriate antenna in each stage. By QR decomposition method, a step-by-step antenna selection method is adopted to maximize the system capacity [] . The main idea is to maximize $\boldsymbol{R}_{jj}$which is corresponding to $\boldsymbol{G}^H$in the given below equation

$$\frac{L_t}{\rho}\mathbf{I}_{L_r} + \tilde{\mathbf{H}}\tilde{\mathbf{H}}^H = \mathbf{G}\mathbf{G}^{\mathrm{H}} \quad (15)$$

In (15), if the SNR is high, the following approximation is adopted

$$\tilde{\mathbf{H}}^H = \mathbf{G}^{\mathrm{H}} \quad (16)$$

The antenna selection procedure is made simple and flexible that norm and correlation only needed to for approximation in this suboptimal ATS.

***B.** Optimal Antenna Selection Technique*

From $L_t$transmit antenna$N$antennas chosen in order to increase the system capacity. The system capacity for Ntransmit antenna is given as [3]

$$C\left(\tilde{\mathbf{H}}\right) = \log_2 det\left(\mathbf{I}_{L_r} + \frac{E_s}{N\sigma^2}\tilde{\mathbf{H}}^H\tilde{\mathbf{H}}\right) \quad .(17)$$

The aim is to maximize the system capacity so that the antenna with maximum capacity is selected. In order to maximize the capacity the set of antennas has to be selected from the possible combination of antennas.

IV. BIT-ERROR RATE ANALYSIS FOR OSTBC

To assess the performance of OSTBC system BER is a important measure [3, 8, 14]. In this paper AST is used to reduce the error rate in the system. The upper bound for the error probability is given for Ncolumns of channe submatix $\tilde{\mathbf{H}}$as

$$\mathbf{P}e(di \to dj) = N\left\{\sqrt{\frac{\rho\left\|\varepsilon_{ij}\tilde{\mathbf{H}}\right\|^2}{2\mathrm{L_t}}}\right\} \quad (18)$$

$$\ll exp\left\{-\frac{\rho\left\|\varepsilon_{ij}\tilde{\mathbf{H}}\right\|^2}{4\mathrm{L_t}}\right\}$$

N transmit antennas are selected inorder to minimize the upper bound in (18) and is given by

$$N^* = \underset{N \in A_L}{arg\,max}\left|\tilde{\mathbf{H}}\right|^2 \quad (19)$$

with the selected Nantennas, the received average SNR is given by

$$\gamma_N = \frac{\rho}{N}\left|\tilde{\mathbf{H}}\right|^2 \quad (20)$$

using the AST the range for average received SNR using AS selection is given as $\frac{\rho}{N}|\mathbf{H}|^2 \ \geq \ \gamma_N \ \geq \ \frac{\rho}{L_t}|\mathbf{H}|^2$ (21)

The upper and lower bound of$|\mathbf{H}|^2$ is shown in (21) and the diversity order acheived by the ATS isL_rL_t.

V. SIMULATION RESULTS

In this simulation section, the SNR and channel capacity is presented and analyzed the antenna selection for MIMO communication system. The system performances on changing the number of selected antennas under the different fading channels are compared. The SNR and BER analysis is also discussed for the various fading condition under 16-QAM. The interference between the antennas is eliminated by maintaining the sufficient antenna spacing. The simulation parameters are shown in Table 1.

Table 1: Simulation parameters

Parameter	Value
Number of transmit antennas	4
Number of receive antennas	4
Number of antennas for selection	2,3,4
Multi path fading parameter	2,6
Shadowing parameter m	1,70

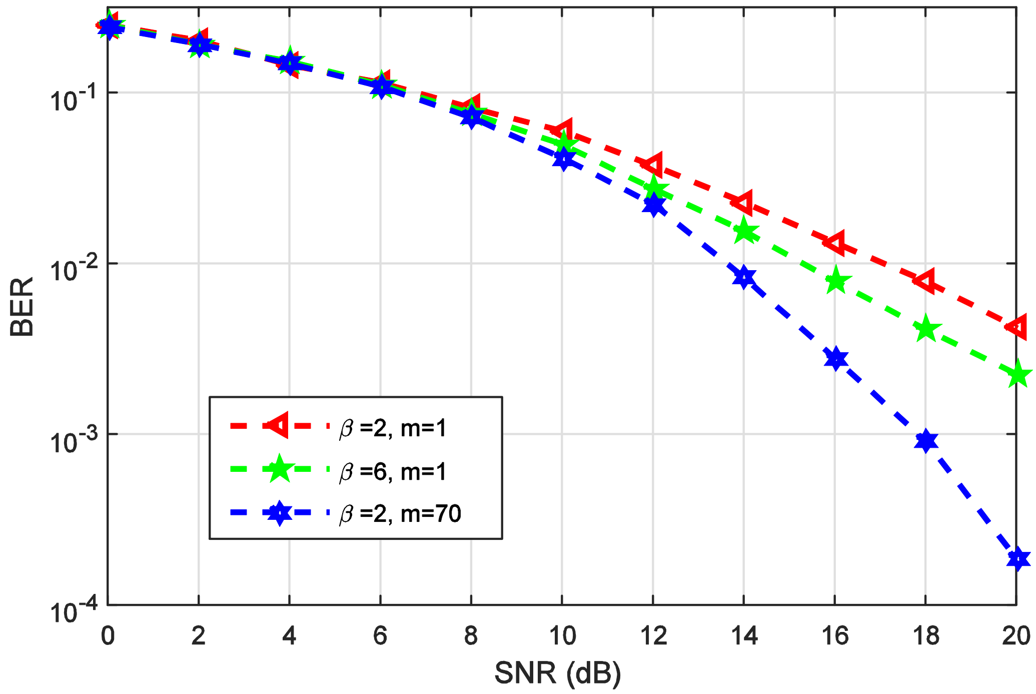

Figure 1: Performance of average data rate versus number of transmit antennas.

In the MIMO communication system the SNR improvement can be achieved by increasing the antenna. The improvement in the SNR is shown in Figure 2, Figure 3 and Figure 4 . The improved SNR means, it is easy to decode the symbols at the receiver with less probability of error. The fading effect of MIMO system is reduced because of the multi antenna system.

In Figure 1, the SNR and BER performance is shown for different fading conditions under 16QAM for OSTBC MIMO communication systems. The BER is analyzed for considering the multi path fading parameter$\beta = 2$ & 6and shadow fading parameter$m = 1 \,\&\, 70$. The low βindicates low multipath fading and higher value indicates the high multipath fading present in the environment. The heavy shadowing effect value is given as m=70 and light shadowing effect value is given by m=1.$\beta = 2$ and $m = 70$Indicates the Rayleigh fading environment.$\beta \rightarrow \infty$ and $m \rightarrow \infty$ indicates the AWGN environment.

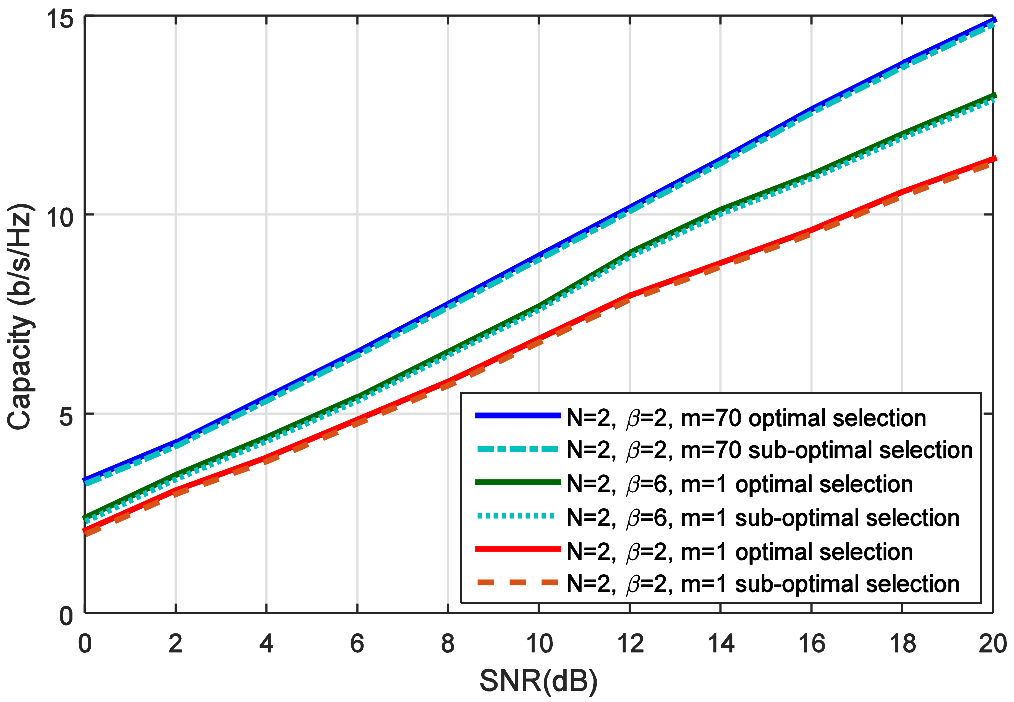

Figure 2: Performance of average data rate versus number of transmit antennas.

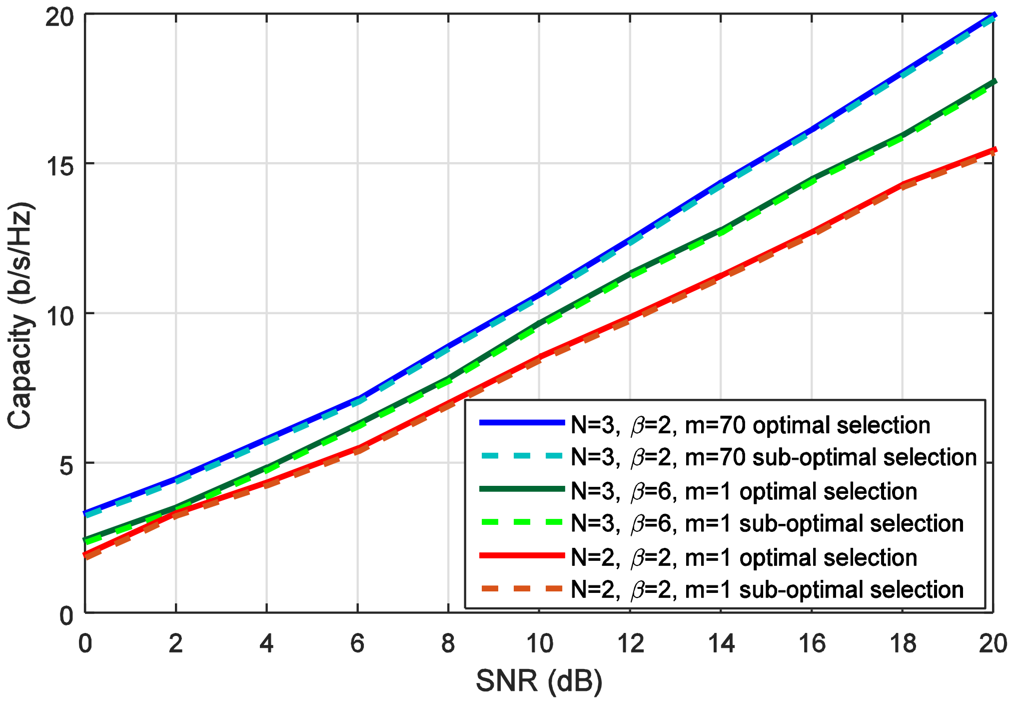

Figure 3: Performance of average data rate versus number of transmit antennas.

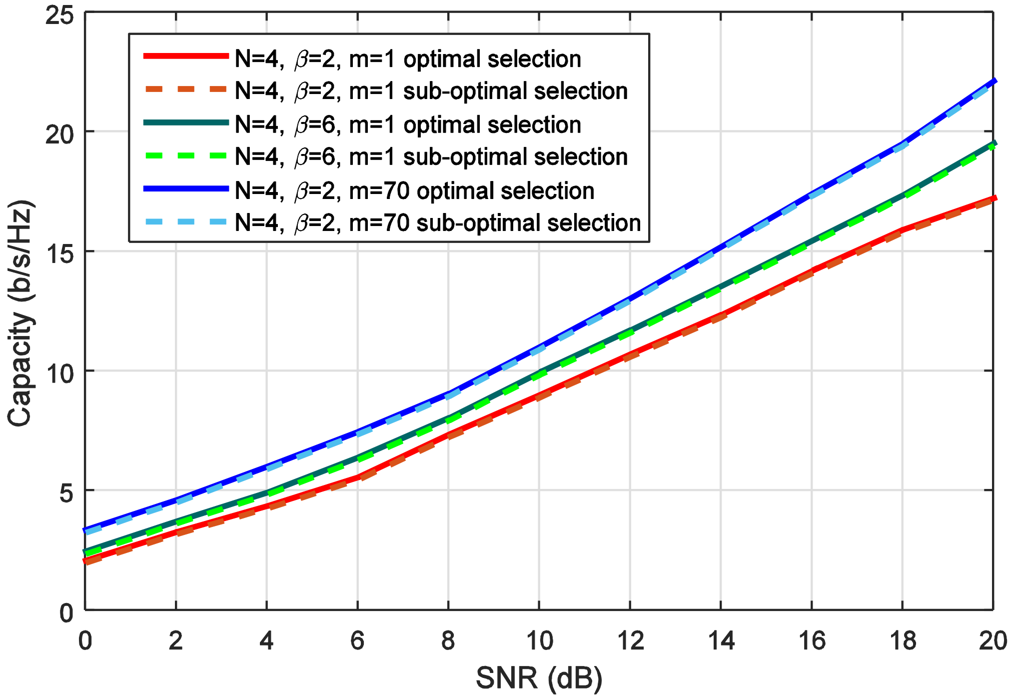

Figure 4: Performance of average data rate versus number of transmit antennas.

The SNR and capacity analysis for different transmit antenna selection for different fading and shadowing environment is analyzed in Figure 2, Figure 3 and Figure 4 for both the optimal and proposed sub-optimal cases. In Figure 2, the number of transmit antenna selected is 2 out of 4 transmit antennas. The performance of proposed sub-optmial method is converging with the optimal method capacity performance. The WGF channel achieves higher capacity compared with other fading models considered for simulation and it is shown in the Figure 2. The Figure 3 and Figure 4 shows the capacity performance of the proposed sub-optimal antenna selection with 3 and 4 transmit antennas. From the Figure 2, Figure 3 and Figure 4, it is inferred that the capacity of the system is increasing with increase in number of transmit antenna selected. Without the addition bandwidth requirement, the MIMO communication system can improve the channel capacity.

VI. Conclusion

The performance of OSTBC MIMO communication systems in terms of capacity analysis is done in this paper for optimal and proposed sub-optimal AST. The improvement in the SNR which is useful in decoding the signals at the receive end with low probability of error is demonstrated while increasing the number of transmit antennas. The simulation results proved the proposed sub-optimal method exhibits a similar performance compared with optimal antenna selection technique with complexity and cost reduced. The channel capacity analysis was done for various multipath and shadow fading environment. The increase in fading parameters which results in the decrease in the effects of fading in wireless systems. The channel capacity also improved while increasing the fading parameters. The simulation exhibits the proposed sub-optimal algorithm performing effectively in high SNR region with less number of antennas selected for transmitting.

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References

[1] K. Tiwari, D. S. Saini, S. V. Bhooshan, On the capacity of MIMO weibull-gamma fading channels in low SNR regime, *Journal of Electrical and Computer Engineering 2016.*

[2] S. Sanaye i, A. Nosratinia, Antenna selection in mimo systems, *IEEE Communications Magazine 42 (10) (2004) 68-73.*

[3] K. Tiwari, D. S. Saini, S. V. Bhooshan, Antenna selection for mimo systems over weibull-gamma fading channel, *Perspectives in Science (2016) 475-478.*

[4] S. Liu, Z . He, W. Wu, X. Chang, Z. Li, E. Schulz, A fast sub-optimal antenna selection algorithm in m imo systems, in: *Wireless Communications and Networking Conference, 2006. WCNC 2006. IEEE, Vol. 2, IEEE, 2006, pp. 734-739.*

[5] K. Tiwari, D. S. Saini , Ser improvisation of mimo-mrc system over weibull-gamma fading channel, *in: Signal processing and communication (ICSC), 2015 international conference on, IEEE, 2015, pp. 70-73.*

[6] A. Bessate, F. El Bouanani, A new performance results of mimo system with orthogonal STBC over independent and identical weibull fading channels, *in: Advanced Communication System s and Information Security (ACOSIS), International Conference on, IEEE, 2016 , pp. 1-7.*

[7] K. Tiwari, D. S. Saini, S. V. Bhooshan, Asep of MIMO system with MMSC_OISC detection over weibul l-gamma fading channel subject to AWGN, *Journal of Computer Networks and Communications 2016 (2016) 4.*

[8] S. Kaviani, C. Tellambura, Closed-form BER analysis for antenna selection using orthogonal space-time block codes, *IEEE communications letters 10 (10) (2006) 704-706.*

[9] M. Lupupa, M. E. Dlodlo, Channel capacity performance of transmit antenna selective mimo system in weibull fading, *in: Proc of the 12th Southern Africa Telecommunication Networks and Applications Conference (SATNAC), 2009.*

[10] P. S. Bithas, G. K. Karagiannidis, N. C. Sagias, P. T. et al, Performance analysis of a class of gsc receivers over nonidentical weibull fading channels, *IEEE Trans on Vehicular Technol ogy 54 (6) (2005) 1963-1970.*

[11] P. Huang, D. Rajan, J. Camp, Weibull and suzuki fading channel generator design to reduce hardware resources, *in: Wireless Communica-tions and Networking Conference (WCNC), 2013 IEEE, IEEE, 2013, pp. 3443-3448.*

[12] J. Pérez, J. Ibánez, L. Vielva, I. Santamaria, Closed-form approximation for the outage capacity of Orthogonal STBC, *IEEE Communications Letters 9 (11) (2005) 961-963.*

[13] C. Zhong, M. Matthai ou, A. Huang, Z. Zhang, On the sum rate of MIMO Nakagami-m fading channels with MMSE receivers, *in: Sensor Array and Multichannel Signa l Processing Workshop (SAM), IEEE, 2012, pp. 49-52.*

[14] M.-C. Lee, W.-H. Chung, T.-S. Lee, BER analysis for spatial modulation in multicast MIMO systems, *IEEE Trans on Communications 64 (7) (2016) 2939-2951.*

[15] I. Trigui, A. Laourine, S., A. Stephenne, On the performance of cascaded generalized fading channels, *in: Proceedings of the 28th IEEE conference on Global telecommunications, IEEE Press, 2009, pp. 5818-5822.*