Performance evaluation of TAS/MRC assisted communication technique based on Fisher- Snedecor *F* fading channels

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Abstract: Cooperative wireless communication has turned into a salient feature in wireless communication because it can diversify the coverage area, reducing transmission power. Multiple-Input-Multiple-Output (MIMO) system also improves the performance as well as the capacity of the wireless system. But MIMO system uses an immense number of antennas, so there is an elevation in the hardware intricacy as well as its price. To overcome this, a MIMO system that operates a single transmit antenna at a time, namely transmit antenna selection (TAS) scheme over Fisher-Snedecor *F* fading channel, is considered in this paper. Maximal Ratio Combining (MRC) is carried out at the receiver over the fading channel. Expressions for outage probability and average bit error rate (ABER) are derived in the light of TAS/MRC MIMO systems. The derived expressions are validated by using Monte-Carlo simulation results.

Keywords: ABER, Cooperative communication, Outage Probability, TAS/MRC.

1. INTRODUCTION

Cooperative transmission is remunerative for lengthening the coverage area of wireless communication [1]. The feasible way to get preferable information-carrying capacity is by using multiple antennas at the transmitter resulting in MIMO system [2]. Due to the baggy range of RF chains involved in the MIMO system, the hurdle in hardware along with the price increases. To overcome this problem, transmit antenna selection (TAS) can be carried out at the transmitter. To intensify the system performance, the MRC diversity technique is imposed on the receiver. In the last few years, dual-hop techniques have shown prodigious interest from the wireless clique as it is one of the most promising technologies in wireless communication. In [3], the channel for the system follows Fisher-Snedecor *F* fading distribution. The Fisher-Snedecor *F* fading distribution has recently been proposed in [4] to model D2D transmission links at 5.8 GHz in both indoor as well as outdoor enclosing's. In [5], the outage probability as well as ABER are investigated for a dual-hop communication system with a non-regenerative relay under α-μ fading conditions. The dual-hop communication performance with variable gain amplify-and-forward (AF) relay is derived in [6], which works in the environment of Fisher-Snedecor *F* fading distribution. A close form statement of the BER for coherent modulation technique using moment generating function (MGF) for the α-μ fading is acquired in [7]. The TAS/MRC scales down the complexities of the system noticeably. In this scheme, the channel state information (CSI) of all links has been sent back to the transmitter and based on CSI information, the excellent transmitting antenna that maximizes the instantaneous SNR at the MRC receiver output is allowed for transmission [8]. In [9], the performance analysis of the TAS/MRC system in independent Weibull channels is presented. In [10], the closed-form approximation of the summation of i.i.d α-μ variates is provided. The expressions are also utilized to obtain the approximation for outage probability and ABER for MRC as well as equal gain combining (EGC). In [11], the closed-form expression for strictly positive secrecy capacity (SPSC) is analysed over Fisher-Snedecor *F* fading channel. Additionally, the Fisher-Snedecor *F* fading distribution can be scaled-down to typical fading distribution like Nakagami-*m*, one-sided Gaussian and Rayleigh distribution [4]. In [12], the authors have studied the performance of a new framework for low outage downlink non-orthogonal multiple access (NOMA) considering both amplify-and-forward and decode-and-forward relaying for a coordinated direct and relay transmission (CDRT) schemes with direct links to both the near-user and far user highlighting the importance of optimal rate selection for maximizing the energy efficiency. Performance analysis of TAS/MRC system subjected to Fisher-Snedecor *F* fading channel is hardly available in the literature.

This paper presents an explanation of outage probability and ABER for some binary modulations considering the arbitrary number of transmit antennas, receiving antennas, fading severity and shadowing parameter. MRC diversity combining technique and TAS at the transmitter is applied in this work.

The other sections are organised as follows: in section 2, the communication setup and the channel are presented. In section 3, outage probability for TAS/MRC is expressed. The representation of ABER is reflected in section 4. The effects of system parameters with deliberation are given in section 5. In section 6, the conclusions drawn are provided.

2. COMMUNICATION SETUP AND CHANNEL

We consider the $L\times R$ MIMO system that contains a source (S) having L transmitting antennas and an MRC receiver (D) with R receiving antennas. The antenna which maximizes the received SNR is selected at the source to transmit the information. The received SNR for MRC combining strategy is identified by $\gamma_t = \sum_{l=1}^{R} \gamma_l$ and γ_l is the instantaneous SNR of the l^{th} input branch. The transmitting antenna that maximizes the SNR at the receiver can be determined by [13]

$$I_{MRC} = \arg\max_{1\le i\le L} \gamma_{L,i} = \sum_{k=1}^{R} \gamma_{k,i} \ . \qquad (1)$$

In (1) the $\gamma_{L,i}$ denotes total received instantaneous SNR when i^{th} transmitting antenna is adopted. I_{MRC} is the antenna index that corresponds to the transmitting antenna. The CDF of MRC input SNR for i.i.d. Fisher-Snedecor *F* variates can be obtained from [14] as

$$F_{\gamma}(\gamma) = \frac{1}{\Gamma(1+mR)} \left(\frac{m}{p\bar{\gamma}}\right)^{mR} \left[\frac{\Gamma(m+p)}{\Gamma(p)}\right]^{R} \gamma^{mR} \, {}_2F_1\left(m+p, mR; 1+mR, -\frac{m\gamma}{p\bar{\gamma}}\right) . \qquad (2)$$

whereby, *m* represents fading severity parameter, *p* represents the shadowing parameter, $\Gamma(.)$ is the gamma function and ${}_2F_1(.)$ represents the Gauss hypergeometric function. In TAS/MRC system, the CDF of output SNR can be given as

$$F_{\gamma_t}(\gamma) = \left[\frac{1}{\Gamma(1+mR)} \left(\frac{m}{p\bar{\gamma}}\right)^{mR} \left[\frac{\Gamma(m+p)}{\Gamma(p)}\right]^{R} \gamma^{mR} \, {}_2F_1\left(m+p, mR; 1+mR, -\frac{m\gamma}{p\bar{\gamma}}\right)\right]^{L} . \qquad (3)$$

3. OUTAGE PROBABILITY

It is the probability that the instantaneous SNR is lower than the required threshold SNR γ_{th}. For the TAS/MRC system, outage probability expression can be obtained by putting $\gamma = \gamma_{th}$ in (3). In terms of normalized average branch SNR, $\bar{\gamma}_N = \frac{\bar{\gamma}}{\gamma_{th}}$, the expression of outage probability can be written as

$$P_O(\gamma_{th}) = \left[\frac{1}{\Gamma(1+mR)}\right]^L \left(\frac{m}{p\bar{\gamma}_N}\right)^{mRL} \left[\frac{\Gamma(m+p)}{\Gamma(p)}\right]^{RL} \left\{ {}_2F_1\left(m+p, mR; 1+mR, -\frac{m}{p\bar{\gamma}_N}\right)\right\}^L . \quad (4)$$

4. AVERAGE BIT ERROR RATE

ABER depends on the fading distribution together with modulation techniques used. The ABER in relation to the CDF of output SNR is expressed as [15]

$$\bar{p}_E = -\int_0^\infty p_E^{/}(\gamma) F_{\gamma_t}(\gamma) d\gamma \ . \quad (5)$$

where $p_E^{/}(\gamma)$ is conditional error probability as stated in [15] and

$$p_E^{/}(\gamma) = -\frac{\varphi^{\eta} \gamma^{\lambda-1} e^{-\varphi\gamma}}{2\Gamma(\lambda)} . \quad (6)$$

Thus, for some cases of modulations, the constants φ and λ values are denoted as [15]: (φ, λ) = (1, 0.5) for BPSK, and (φ, λ) = (0.5, 0.5) for BFSK modulation. Putting the values of $F_{\gamma_t}(\gamma)$ and $p_E^{/}(\gamma)$ into (5), the ABER is obtained as

$$\bar{p}_E = \frac{\varphi^{\lambda}}{2\Gamma(\lambda)} \left(\frac{1}{\Gamma(1+mR)}\right)^L \left(\frac{m}{p\bar{\gamma}}\right)^{mRL} \left[\frac{\Gamma(m+p)}{\Gamma(p)}\right]^{RL}$$

$$\times \int_0^\infty \gamma^{\lambda+mRL-1} e^{-\varphi\gamma} \left\{ {}_2F_1\left(m+p, mR; 1+mR, -\frac{m\gamma}{p\bar{\gamma}}\right)\right\}^L d\gamma \ . \quad (7)$$

The Gauss hypergeometric function in (7) can be represented by infinite series representation using [16, (15.1.1)] as

$$\overline{p}_E = \frac{\varphi^{\lambda}}{2\Gamma(\lambda)}\left(\frac{1}{\Gamma(1+mR)}\right)^{L}\left\{\frac{\Gamma(1+mR)}{\Gamma(m+p)\Gamma(mR)}\right\}^{L}\left(\frac{m}{p\overline{\gamma}}\right)^{mRL}\left[\frac{\Gamma(m+p)}{\Gamma(p)}\right]^{RL}$$

$$\times\sum_{n_1=0}^{\infty}\sum_{n_2=0}^{\infty}\cdots\sum_{n_L=0}^{\infty}\frac{\prod_{i=1}^{L}\{\Gamma(m+p+n_i)\Gamma(mR+n_i)\}}{\prod_{i=1}^{L}\{\Gamma(1+mR+n_i)(n_i)!\}}\left(-\frac{m}{p\overline{\gamma}}\right)^{\sum_{i=1}^{L}n_i}\int_0^{\infty}\gamma^{\lambda+mRL-1+\sum_{i=1}^{L}n_i}e^{-\varphi\gamma}d\gamma\,. \tag{8}$$

The integral in (8) can be solved using [17, (3.381.4)] to obtain the expression of ABER as

$$\overline{p}_E = \frac{\{\Gamma(m+p)\}^{L(R-1)}}{2\Gamma(\lambda)\{\Gamma(mR)\}^{L}\{\Gamma(p)\}^{RL}}\times\sum_{n_1=0}^{\infty}\sum_{n_2=0}^{\infty}\cdots\sum_{n_L=0}^{\infty}\frac{(-1)^{\sum_{i=1}^{L}n_i}\prod_{i=1}^{L}\{\Gamma(m+p+n_i)\Gamma(mR+n_i)\}}{\prod_{i=1}^{L}\{\Gamma(1+mR+n_i)(n_i)!\}}$$

$$\times\left(\frac{m}{p\overline{\gamma}}\right)^{mRL+\sum_{i=1}^{L}n_i}\frac{1}{\varphi^{mRL+\sum_{i=1}^{L}n_i}}\Gamma\left(\lambda+mRL+\sum_{i=1}^{L}n_i\right). \tag{9}$$

5. EFFECTS AND DELIBERATIONS

The numerically evaluated data from the expressions derived have been analysed here. The results are plotted for different arbitrary values of transmit antennas *L*, receiving antennas *R*, fading parameter *m* and shadowing parameter *p*. In Fig. 1, Outage probability vs. Normalized SNR per branch curves are plotted, where the value of fading parameter *m* is varied, keeping the shadowing parameter *p* and the number of transmitting antennas *L* constant. It can be seen that the outage performance becomes better with an increase in *m* and *R* when there is light shadowing. In Fig. 2, the fading parameter is kept constant at $m = 2.5$ (moderate fading) and the value of shadowing parameter is varied at $p = 0.5$ (heavy shadowing) and $p = 50$ (very light shadowing). In both cases, it can be seen that system outage performs better with the increase in *R*, *m* as well as *p* for a fixed value of *L*.

In Fig. 3 and Fig. 4, the ABER performance of the system has been shown for BPSK and BFSK modulations respectively with different values of *m*, *p* and L. It is considered that $R = 2$. In both the cases, the value of fading parameter *m* is varied at $p = 0.5$ (heavy shadowing) and $p = 10$ (moderate shadowing) for different values of transmitting antenna L. As expected, in both the cases, the performance of the system becomes better with the increase in L, *m* and when the system experiences moderate shadowing.

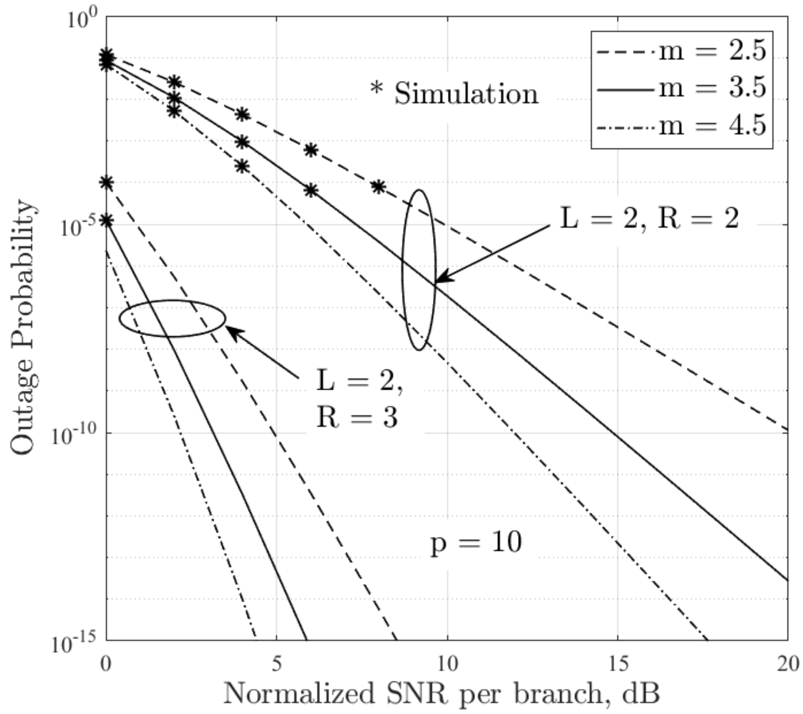

Fig.1. Outage Probability vs. Normalized SNR per branch for light shadowing (p = 10) with different values of m and R.

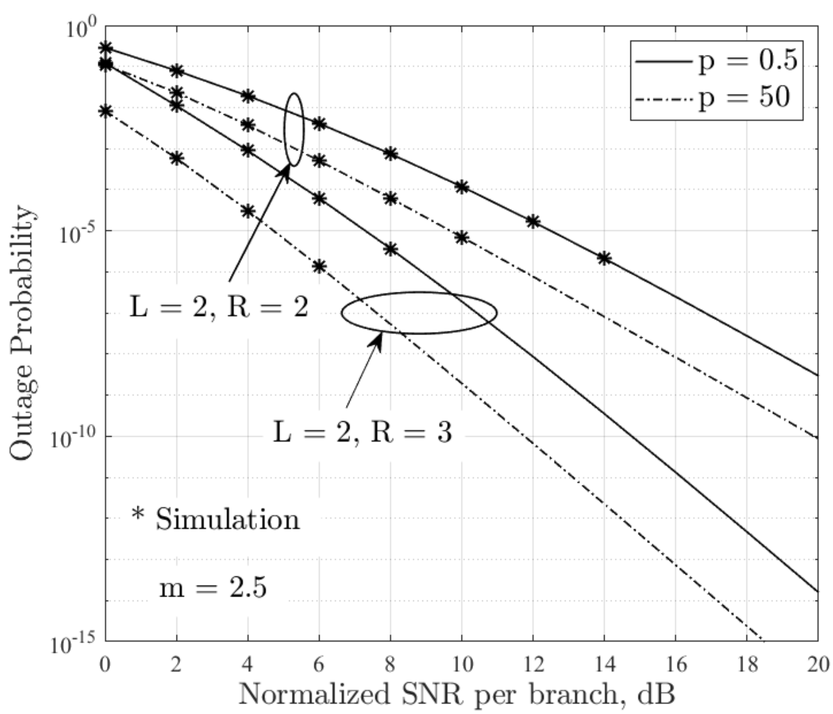

Fig.2. Outage Probability vs. Normalized SNR per branch for constant value of fading parameter ($m = 2.5$) with different values of p and R.

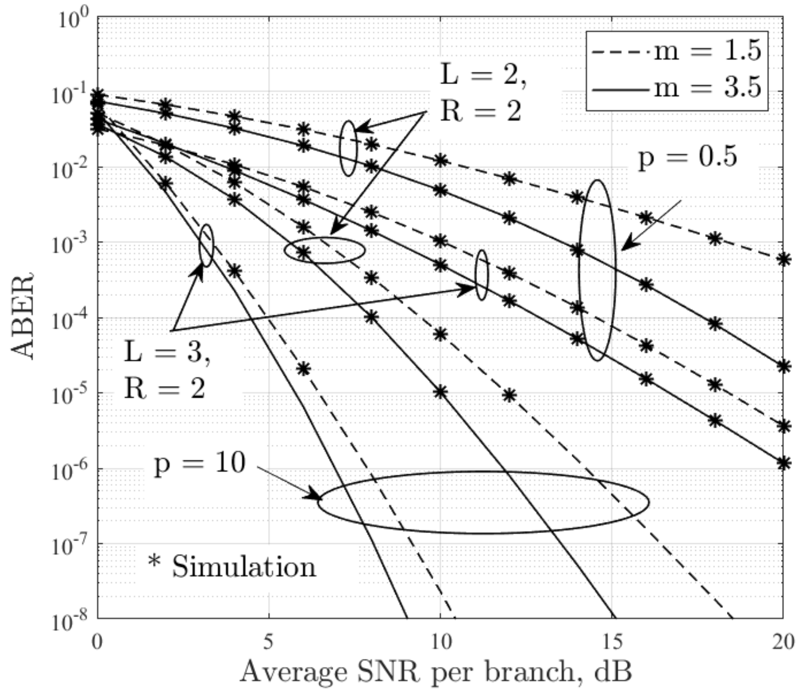

Fig.3. ABER vs. Average SNR per branch for BPSK modulation with intense shadowing ($p = 0.5$) and moderate shadowing ($p = 10$) along with different values of m and L .

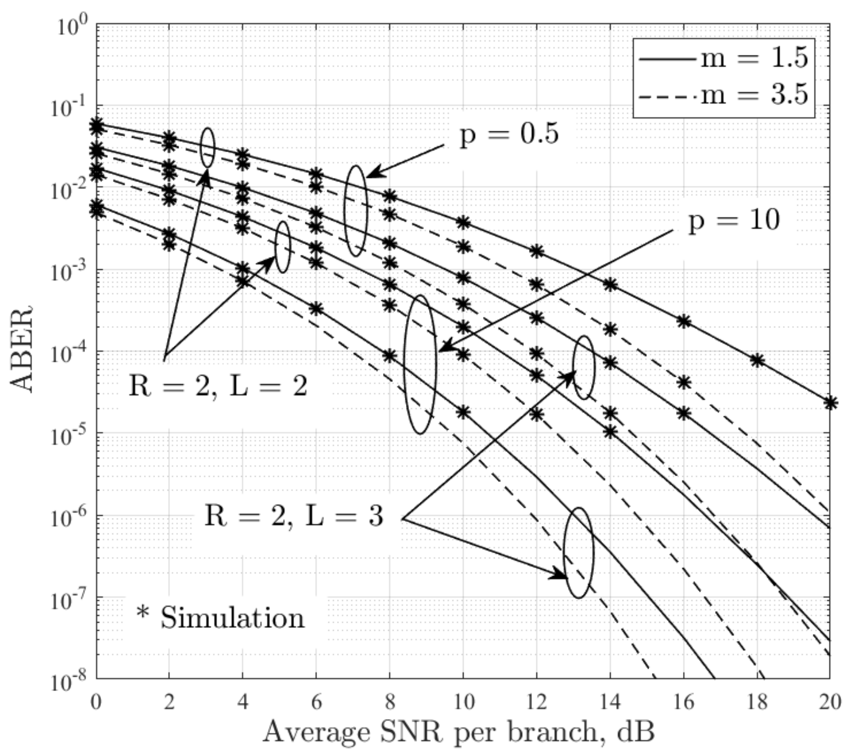

Fig.4. ABER vs. Average SNR per branch for BFSK modulation with intense shadowing ($p = 0.5$), and moderate shadowing ($p = 10$) along with different values of m and L .

6. CONCLUSIONS

This paper investigates the performance of the TAS/MRC assisted MIMO communication system under Fisher-Snedecor *F* fading channels. Closed-form expressions are obtained for outage probability and ABER with BPSK and BFSK modulations. The analytical results as well as computer-simulated data are in agreement with each other as plotted in figures. It can be noticed from the plots of outage probability and ABER that the performance of the system gets better with the increase in fading parameter when the system has specific shadowing.

REFERENCES

1. K. J. R. Liu, A. Kwasinski, W. Su and A.K. Sadek: Cooperative Communications and Networking, Cambridge University Press, First Edition, New York, 2008.
2. G. Foschini and M. Gans, "On the limits of wireless communication in fading environment when using multiple antennas," *Wireless Personal Communications*, vol.6, no.3, pp. 311-335, 1998.
3. M. O. Hasna and M. -. Alouini, "A performance study of dual-hop transmissions with fixed gain relays," *IEEE Transactions on Wireless Communications*, vol. 3, no. 6, pp. 1963-1968, Nov. 2004.
4. S. K. Yoo, S. L. Cotton, P. C. Sofotasios, M. Matthaiou, M. Valkama and G. K. Karagiannidis, "The Fisher–Snedecor F Distribution: A Simple and Accurate Composite Fading Model," *IEEE Communications Letters*, vol. 21, no. 7, pp. 1661-1664, July 2017.
5. A. M .Magableh, T. Aldalgamouni, and N. M, Jafreh, "Performance of dual-hop wireless communication systems over the α–μ fading channels," *International Journal of Electronics*, vol. 101, no. 6, pp. 808-819, 2014.
6. P. Zhang, J. Zhang, K. P. Peppas, D. W. K. Ng and B. Ai, "Dual-Hop Relaying Communications Over Fisher-Snedecor F-Fading Channels," *IEEE Transactions on Communications*, vol. 68, no. 5, pp. 2695-2710, May 2020.
7. A. M. Magableh and M. M. Matalgah, "Moment generating function of the generalized α - μ distribution with applications," *IEEE Communications Letters*, vol. 13, no. 6, pp. 411-413, June 2009.
8. Zhuo Chen, Jinhong Yuan and B. Vucetic, "Analysis of transmit antenna selection/maximal-ratio combining in Rayleigh fading channels," *IEEE Transactions on Vehicular Technology*, vol. 54, no. 4, pp. 1312-1321, July 2005.
9. T. Chaayra, F. E. Bouanani and H. Ben-azza, "Performance analysis of TAS/MRC based MIMO systems over Weibull fading channels," *2016 International Conference on Advanced Communication Systems and Information Security (ACOSIS)*, pp. 1-6, 2016.
10. D. B. Da Costa, M. D. Yacoub and J. Filho, "Highly Accurate Closed-Form Approximations to the Sum of α-μ Variates and Applications," *IEEE Transactions on Wireless Communications*, vol. 7, no. 9, pp. 3301-3306, September 2008.
11. L. Kong and G. Kaddoum, "On Physical Layer Security Over the Fisher-Snedecor F Wiretap Fading Channels," *IEEE Access*, vol. 6, pp. 39466-39472, 2018.
12. A. Jee, K. Agarwal, and S. Prakriya, "A Coordinated Direct AF/DF Relay Aided NOMA Framework for Low Outage," *IEEE Transactions on Communications,* vol. 70, no. 3, pp. 1559-1579, 2022.

13. B. Kumbhani and R. S. Kshetrimayum, “Performance Analysis of MIMO Systems with Antenna Selection over Generalized κ-μ Fading Channels,” *IETE Journal of Research*, pp. 1-10, 2015.
14. O. S. Badarneh, D. B. da Costa, P. C. Sofotasios, S. Muhaidat and S. L. Cotton, “On the Sum of Fisher-Snedecor *F* Variates and Its Application to Maximal-Ratio Combining,” *IEEE Wireless Communications Letters*, vol. 7, no. 6, December 2018.
15. J. P. Pena-Martin, J. M. Romero-Jerez and C. Tellez-Labao, “Performance of TAS/MRC Wireless Systems under Hoyt Fading Channels,” *IEEE Transaction on Wireless Communications,* vol. 12, no. 7, pp. 3350-3359, July 2013.
16. M. Abramowitz and I.A Stegun, Handbook of Mathematical Functions, With, Graphs, and Mathematical Tables, Dover Publications, Inc., USA.
17. I.S. Gradshteyn and I.M. Ryzhik, Table of Integrals, Series and Products, 6th Ed. San Diego, CA: Academic, 2000.