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Performance of MIMO-STBC Decode and Forward Cooperative Communications with Channel Estimation Error over Nakagami-m Fading Channels

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ABSTRACT

In Cooperative Wireless Communication, system performance decreases due to the improper estimation of the channel. We analyzed MIMO-STBC based Decode and Forward (DF) Cooperation Communication System, considering the effect of error, arises due to the improper estimation of channel. We have considered Decode - Forward (DF) based MIMO Space Time Block Code (STBC) Cooperative Communication Network considering channel is NAKAGAMI-m Fading Channel. Upper Bound SER expression and Theoretical Symbol Error Rate (SER) expression for MPSK system has been derived for three nodes Cooperation model. We performed simulations to verify Theoretical SER results. The Result shows that increasing the value of SNR causes no significant gain in performance and the Symbol Error Rate performance depends less on Source Node – Relay Node Channel link and depends more on Relay Node – Destination Node Channel link.

Keywords: Cooperative Communications; DF; Nakagami-m channel; SER; channel estimation error; Random Variable (RV).

I. INTRODUCTION

Without increasing the hardware complexity, System performance can be increased by Cooperative Diversity scheme. Spatial Diversity Gain at the Destination is achieved when the network nodes are allowed to cooperate with each other. A number of Cooperative diversity [2-3] schemes had been introduced and analyzed in [1- 4]. Several concepts of cooperative Communication have been projected by Laneman [1], e.g. Estimate and Forward and Amplify – Forward. With DISTRIBUTED - SPACE -TIME COOPERATION (DSTC) [2], relay node forwards modified version of source information. Symbol Error Rate performance has been analyzed in the DF Cooperation model over a Rayleigh Fading Channel in [5]. Distributed Cooperative [2] Protocols can achieve full Diversity order under certain conditions. Closed Form SER formulation and Upper Bound expressions of SER for PSK and QAM signals have been analyzed. Asymptotic expressions and performance are also given in [5]. Similar analysis has been done in [6] over the Nakagami-m channel case. Noise and Doppler shift on the Pilot signals produces performance abasement in a wireless communication network. Performance of AF based transmission under imperfect Channel Estimation has been provided in [7,8]. Assuming the Gaussian Channel Estimation Error Adaptive Power Allocation Scheme and SER closed form expression is given in [10,16] for MIMO-OFDM system. A Closed form SER expression of Maximal Ratio Combining (MRC) based MIMO Systems considering RAYLEIGH Distributed channel is given in [9]. Exact formulation of Error Rate of DF-MIMO-STBC Cooperation System has been derived considering the impact of improper channel estimation.

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Paper is organized in following manner; the Cooperation Model is given in section-II; we have explained Alamouti Coded MIMO-STBC system in section-III. SER expression and upper bound SER expression have been derived. Simulations have been performed to verify our theoretical results.

II. COOPERATION MODEL

2.1. Two Phases Realy Model

We consider a 2 Phase Cooperation model. The source transmits signals towards Destination and Relay nodes in Phase1. If the Relay node decrypts the symbol correctly, only in this case it will send the signals to the destination node in Phase 2. We have assumed that Channels were orthogonal to each other. We have considered a single Relay system with 2 Antennas. The model is given below in Figure 1.

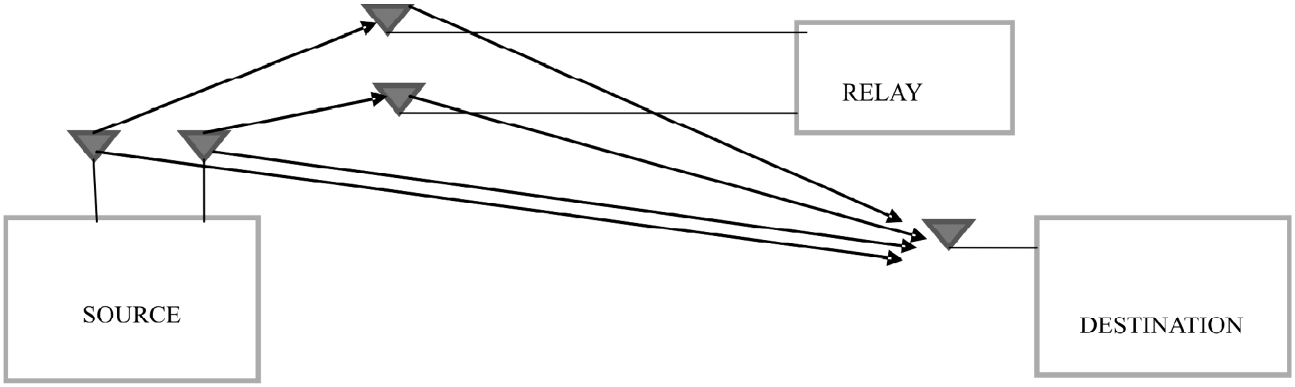

Figure 1: MIMO – STBC DF Cooperation

The source node conveys information to both destination node and Relay node in Phase1. Signals picked up at the destination node and Relay node from source $y_{sd}(1),\ y_{sd}(2),\ y_{sr}(1),\ y_{sr}(1)$ and $y_{sr}(2)$ are given as:

$$y_{sd}(1) = \sqrt{P_s} h_{sd}(1) X + \sqrt{N_0} \eta_{sd}(1) \tag{1}$$

$$y_{sd}(2) = \sqrt{P_s} h_{sd}(2) X + \sqrt{N_0} \eta_{sd}(2) \tag{2}$$

$$y_{sr}(1) = \sqrt{P_s} h_{sr}(1) X + \sqrt{N_0} \eta_{sr}(1) \tag{3}$$

$$y_{sr}(2) = \sqrt{P_s} h_{sr}(2) X + \sqrt{N_0} \eta_{sr}(2) \tag{4}$$

X is symbol transmitted from the source with unit variance and P_s transmitted Power from the source node

$$E\left[|X|^2 \right] = 1$$

$\eta_{sd}(1)$, $\eta_{sd}(2)$, $\eta_{sr}(1)$, $\eta_{sr}(2)$ are modeled as $\mathbb{N}(0,1)$ here $\mathbb{N}$ is Normal Distribution and N_o is the Noise Power.

In equation (1), (2), (3) and (4) $h_{sd}(1)$, $h_{sd}(2)$, $h_{sr}(1)$ and $h_{sr}(2)$ are the channel coefficients from the source node – destination node and source node- Relay node respectively. In Phase 2 Relay forwards decoded symbol to end node if the Relay decrypts the symbol correctly [13-14].

Thus received signal at the end node in Phase 2 is given below

$$y_{rd}(1)=\sqrt{\tilde{P}_r}\,h_{rd}(1)X+\sqrt{N_0}\,\eta_{rd}(1) \tag{5}$$

$$y_{rd}(2)=\sqrt{\tilde{P}_r}\,h_{rd}(2)X+\sqrt{N_0}\,\eta_{rd}(2) \tag{6}$$

$\tilde{P}_r = P_r$ ö’ if relay decodes correctly

$\tilde{P}_r = 0$ ö’ if relay does not decode correctly

$h_{rd}(1)$, $h_{rd}(2)$ are Relay – Destination channel coefficients. $\eta_{rd}(1)$, and $\eta_{rd}(2)$ are modeled as $\mathbb{N}(0,1)$ here $\mathbb{N}$ is normal distribution and N_o is the Noise Variance.

Total power P is

$$P = P_s + P_r \tag{7}$$

The process, while we assumed that there was fixed channel estimation error, arises due to pilot transmission.

The signal at destination is given below

$$y_{sd}(1)=\sqrt{P_s}\,(h_{sd}(1)+h_{\delta})X+\sqrt{N_0}\,\eta_{sd}(1) \tag{8}$$

$$y_{sd}(2)=\sqrt{P_s}\,(h_{sd}(2)+h_{\delta})X+\sqrt{N_0}\,\eta_{sd}(2) \tag{9}$$

By using the central limit theorem concept, error arises due to improper estimation of channel, h_δ is expressed in form of a Gaussian Random Variable (RV). The error arises due to improper estimation h_δ is Complex Gaussian RV with 0 Mean and Variance δ. From [11], equation (1) and (2) is shown as:

$$y_{sd}(1)=\sqrt{P_s}\,h_{sd}(1)X+\sqrt{\delta P_s+N_0}\,\eta_{sd}(1) \tag{10}$$

$$y_{sd}(2)=\sqrt{P_s}\,h_{sd}(2)X+\sqrt{\delta P_s+N_0}\,\eta_{sd}(2) \tag{11}$$

$$y_{sr}(1)=\sqrt{P_s}\,h_{sr}(1)X+\sqrt{\delta P_s+N_0}\,\eta_{sr}(1) \tag{12}$$

$$y_{sr}(2)=\sqrt{P_s}\,h_{sr}(2)X+\sqrt{\delta P_s+N_0}\,\eta_{sr}(2) \tag{13}$$

Relay to the Destination received signals are given below:

$$y_{rd}(1)=\sqrt{\tilde{P}_r}\,h_{rd}(1)X+\sqrt{\delta \tilde{P}_r+N_0}\,\eta_{rd}(1) \tag{14}$$

$$y_{rd}(2)=\sqrt{\tilde{P}_r}\,h_{rd}(2)X+\sqrt{\delta \tilde{P}_r+N_0}\,\eta_{rd}(2) \tag{15}$$

The Distribution (PDF) of ψ which is NAKAGAMI-m distributed is given as:

$$f(\psi,m,\Omega)=\frac{2*m^m*\psi^{2m-1}}{\Omega^m*\lceil\psi}\,\mathrm{e}^{(-\frac{m\psi^2}{\Omega})} \tag{16}$$

Here m Shape Parameter, m varies from 0.50 to ∞.

$$\Omega = E\left[\psi^2\right] \tag{17}$$

In [12], the instantaneous SER of the channel γ is Gamma distributed. Its PDF is given below

$$P_\gamma(\gamma) = \frac{m^m \gamma^{m-1}}{\overline{\gamma}^m \Gamma m} \exp\left(-\frac{m\gamma}{\overline{\gamma}}\right) \quad \gamma \geq 0 \tag{18}$$

$$\overline{\gamma} = \frac{\Omega E_s}{N_0} \tag{19}$$

III. SYMBOL ERROR RATE ANALYSIS OVER NAKAGAMI CHANNELS

In Alamouti Space Time Block Code [STBC] scheme, in first time interval we transmit symbol X_1 from Tx1 and the symbol X_2 from the second Tx2. In the second time interval, we transmit symbol $-X_2^*$ from Tx1 and the symbol X_1^* from the Tx2. For 2E2 matrix, orthogonal ST block code is given below

$$G = \begin{pmatrix} X_1 & X_2 \\ -X_2^* & X_1^* \end{pmatrix} \tag{20}$$

Now by applying the Alamouti STBC scheme, SER expression has been derived for M-PSK modulation system and also Upper bound of SER expression for MPSK modulation system also derived. Instantaneous SNR of the Maximal Ratio Combining output is given as:

$$\gamma_{MRC}^{D} = \sum_{l=1}^{l=2} \frac{P_s |h_{sd}(l)|^2}{(\delta P_s + N_0)} + \sum_{l=1}^{l=2} \frac{\tilde{P}_r |h_{rd}(l)|^2}{(\delta \tilde{P}_r + N_0)} \tag{21}$$

As in case of Alamouti scheme the power P_s is divided between the two transmitting antennas, so the instantaneous SNR of Alamouti STBC is given as

$$\gamma^{D} = \sum_{l=1}^{l=2} \frac{P_s |h_{sd}(l)|^2}{2(\delta P_s + N_0)} + \sum_{l=1}^{l=2} \frac{\tilde{P}_r |h_{rd}(l)|^2}{2(\delta \tilde{P}_r + N_0)} \tag{22}$$

The conditional error rate of Phase Shift Keying signal has been given [12] as:

$$P_{e,PSK}(E/\gamma) = \frac{1}{\Pi} * \int_0^{\frac{(M-1)\Pi}{M}} \exp\left(-\frac{\gamma b_{PSK}}{\sin^2\theta}\right) d\theta \tag{23}$$

Then,

$$P_{e,PSK}(E/\gamma^D) = \frac{1}{\Pi} * \int_0^{\frac{(M-1)\Pi}{M}} \exp\left(-\frac{\gamma^D b_{PSK}}{\sin^2\theta}\right) d\theta \tag{24}$$

$$P_{e,PSK}(E/\gamma^D) = \frac{1}{\Pi} * \int_0^{\frac{(M-1)\Pi}{M}} \exp\left(-\left(\sum_{l=1}^{l=2} \frac{P_s |h_{sd}(l)|^2}{2(\delta P_s + N_0)} + \sum_{l=1}^{l=2} \frac{\tilde{P}_r |h_{rd}(l)|^2}{2(\delta \tilde{P}_r + N_0)}\right) \frac{b_{PSK}}{\sin^2\theta}\right) d\theta \tag{25}$$

Where, $b_{PSK} = \sin^2\left(\frac{\Pi}{M}\right)$

With reference to [5], the conditional SER for the DF cooperation has been formulated as

$$P_{e,PSK}(E/\gamma^D, \gamma_{sr}) = P_{e,PSK}(E/\gamma^D)\Big|\tilde{P}_r = 0 * P_{e,PSK}(E/\gamma_{sr}) + P_{e,PSK}(E/\gamma^D)\Big|\tilde{P}_r = P_r * [1 - P_{e,PSK}(E/\gamma_{sr})] \tag{26}$$

Where,

$$\gamma_{sr} = \sum_{l=1}^{l=2} \frac{P_s \left|h_{sr}(l)\right|^2}{2(\delta P_s + N_0)} \tag{27}$$

is the expression of instantaneous SNR at relay node. In equation (26) first term states that if relay decodes incorrectly, then it will not transmit signals to destination and remained idle in Phase 2. Second term indicates that the relay had decoded correctly and it will forward the signal to destination [15,16]. Re-encoded signal from Relay node towards Destination is given as:

$$\tilde{P}_r = P_r$$

When Average $P_{e,PSK}(\gamma)$, the Avg. error probability $P_{e,PSK}(E)$ is given below

$$P_{e,PSK}(E) = \int_0^\infty P_{e,PSK}(E/\gamma) f_y(\gamma) d\gamma \tag{28}$$

$$P_{e,PSK}(E) = (1/\Pi) * \int_0^{\frac{(M-1)\Pi}{M}} \int_0^\infty \exp(-\gamma b_{PSK} / \sin^2\theta) f_y(\gamma) d\gamma \tag{29}$$

If Fading Channel is Nakagami-m distributed then Avg. Probability $P_{e,PSK}(E)$ is given as:

$$P_{e,PSK}(E) = (1/\Pi) * \int_0^{\frac{(M-1)\Pi}{M}} (1 + \frac{b_{PSK} m^{-1} \overline{\gamma}}{\sin^2\theta}) d\theta \tag{30}$$

The Avg. SER for MIMO - STBC based decodes and forward can be expressed as:

$$P_{PSK} = E[P_{e,PSK}(E/\gamma^D, \gamma_{sr})] \tag{31}$$

Here,

$$P_{PSK} = F_1 (1 + \frac{b_{PSK} P_s \Omega_{sd} m_{sd}^{-1}}{2\sin^2\theta(\delta P_s + N_0)})^{-2m_{sd}} * F_1 (1 + \frac{b_{PSK} P_s \Omega_{sr} m_{sr}^{-1}}{2\sin^2\theta(\delta P_s + N_0)})^{-2m_{sr}} +$$

$$F_1 ((1 + \frac{b_{PSK} P_s \Omega_{sd} m_{sd}^{-1}}{2\sin^2\theta(\delta P_s + N_0)})^{-2m_{sd}} * (1 + \frac{b_{PSK} \tilde{P}_r \Omega_{rd} m_{rd}^{-1}}{2\sin^2\theta(\delta \tilde{P}_r + N_0)})^{-2m_{rd}})) * [1 - F_1 (1 + \frac{b_{PSK} P_s \Omega_{sr} m_{sr}^{-1}}{2\sin^2\theta(\delta P_s + N_0)})^{-2m_{sr}}] \tag{32}$$

$$F_1(g(\tau)) = \frac{1}{\Pi} \int_0^{\frac{(M-1)\Pi}{M}} g(\tau) d\tau \tag{33}$$

The upper bound SER expression is given by

$$P_{PSKupper} \le \frac{(M-1)^2}{M^2} (1 + \frac{b_{PSK} P_s \Omega_{sd} m_{sd}^{-1}}{2\sin^2\theta(\delta P_s + N_0)})^{-2m_{sd}} * (1 + \frac{b_{PSK} P_s \Omega_{sr} m_{sr}^{-1}}{2\sin^2\theta(\delta P_s + N_0)})^{-2m_{sr}}$$

$$+ \frac{(M-1)}{M} (1 + \frac{b_{PSK} P_s \Omega_{sd} m_{sd}^{-1}}{2\sin^2\theta(\delta P_s + N_0)})^{-2m_{sd}} * (1 + \frac{b_{PSK} \tilde{P}_r \Omega_{rd} m_{rd}^{-1}}{2\sin^2\theta(\delta \tilde{P}_r + N_0)})^{-2m_{rd}} \tag{34}$$

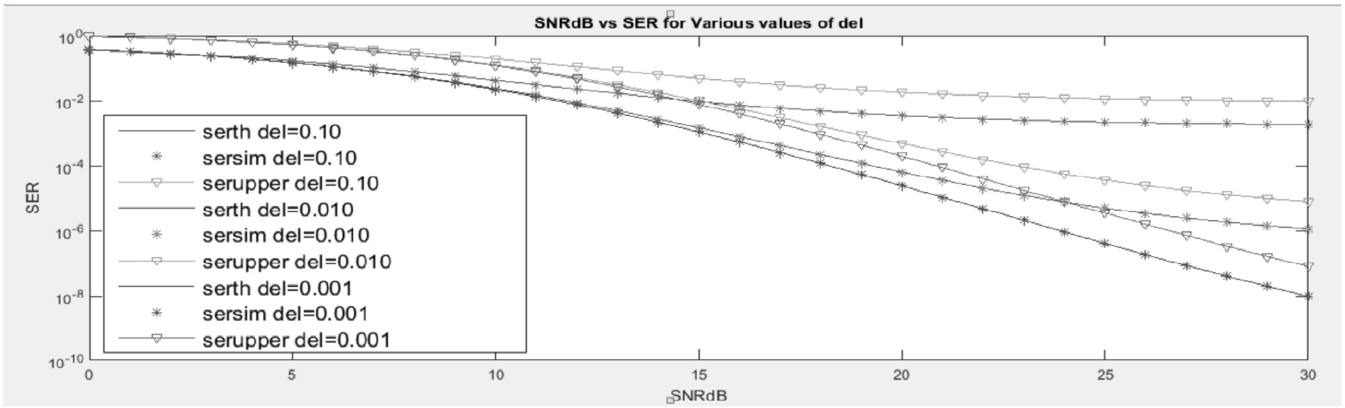

Figure 2: SER Performance over Nakagami-m fading channel ($m_{sd} = 1, m_{sr} = 1, m_{rd} = 1$ and $\Omega_{sd} = \Omega_{sr} = \Omega_{rd} = 1$) for BPSK system

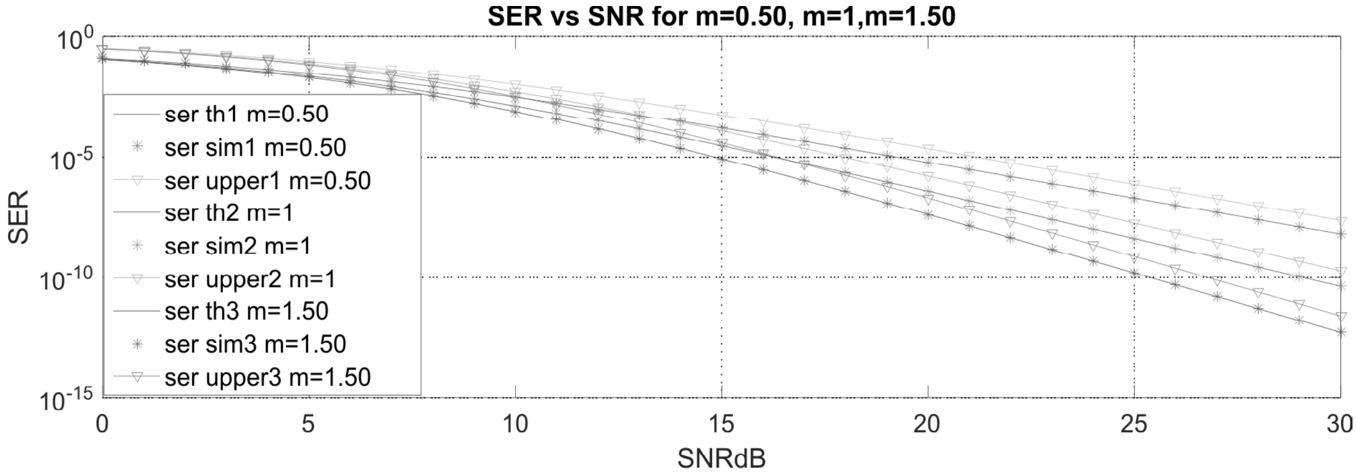

Figure 3: SER Performance over Nakagami-m fading channel ($m_{sd} = 1, m_{sr} = m_{rd} = m$ and $\Omega_{sd} = \Omega_{sr} = \Omega_{rd} = 1$ for BPSK system

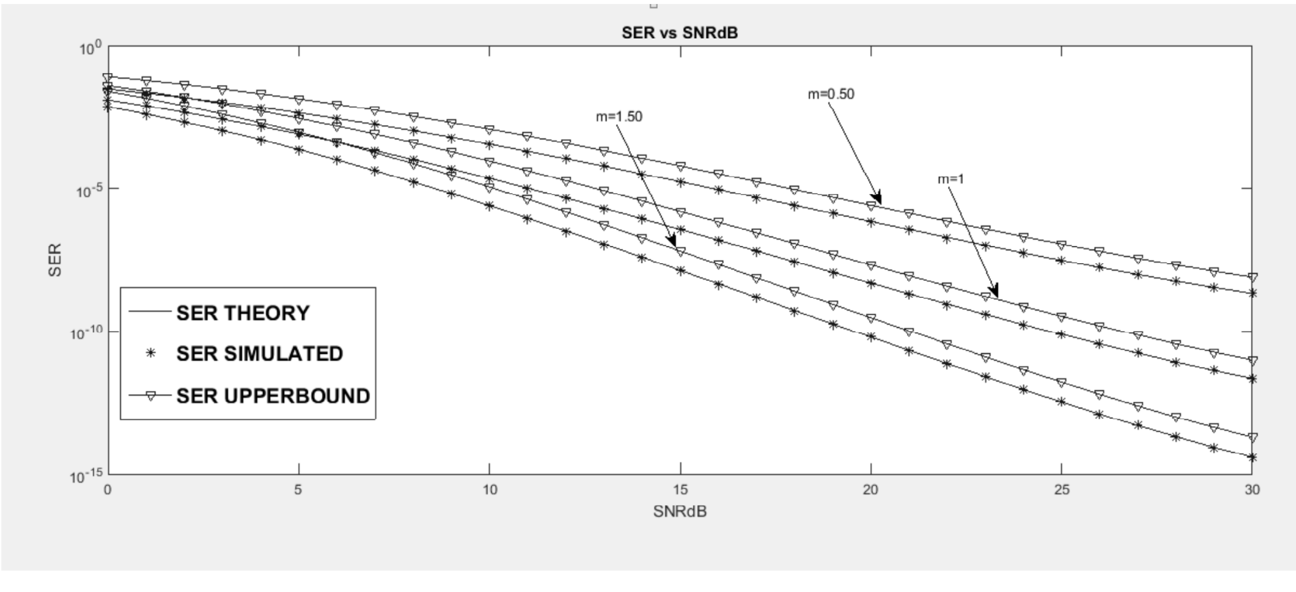

Figure 4: SER Performance over Nakagami-m fading channel ($m_{sd} = 1, m_{sr} = m_{rd} = m$ and $\Omega_{sr} = 10, \Omega_{sd} = \Omega_{rd} = 1$) for BPSK system

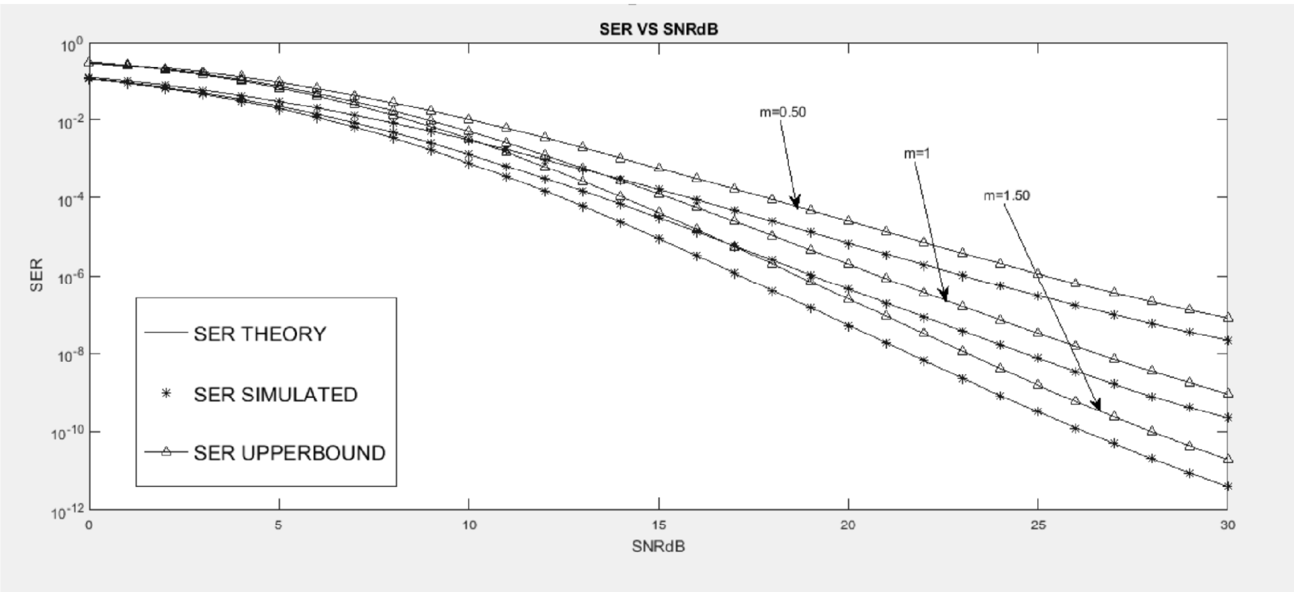

Figure 5: SER Performance over Nakagami-m fading channel ($m_{sd} = 1, m_{sr} = m_{rd} = m$ **and** $\Omega_{sr} = 1, \Omega_{sd} = 1, \Omega_{rd} = 10$**) for BPSK system**

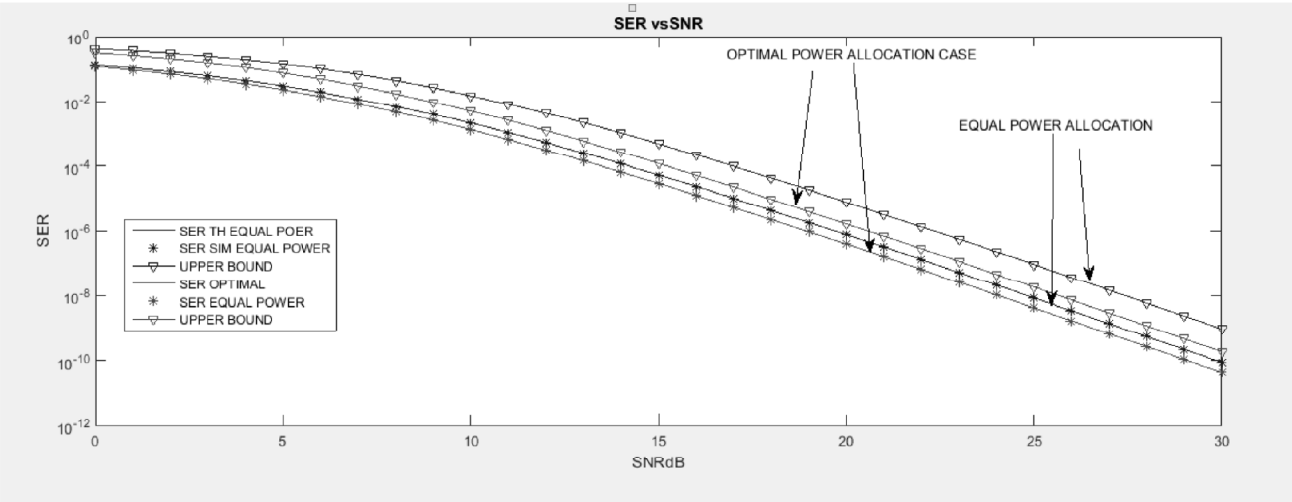

Figure 6: SER Performance over Nakagami-m fading channel ($\delta = 0.001, m_{sr} = m_{rd} = m_{sd} = 1$ **and** $\Omega_{sd} = \Omega_{sr} = \Omega_{rd} = 1$, $m = 1, P_s = P/3$ **and** $P_r = 2/3 * P$ **for BPSK system**

IV. SIMULATION RESULTS

By performing simulations, we have proven our theoretical results by assuming noise variance is equal to unity. A comparison has been made between the Analytic expressions of Exact symbol error rate and UPPER BOUND of symbol error rate with our simulation results in Figure. 2. In same diversity order, we observed that over the Nakagami-m channel for BPSK modulation, UPPER BOUND of SER is asymptotically parallel with the closed from Exact Symbol Error Rate for various values of δ (Del). As the value of δ increases, performance degrades. In Figure.3 Figure. 4. and Figure 5, we have performed simulations considering different values of m_{sd}, m_{sr}, m_{rd}, Ω_{sd}, Ω_{sr} and Ω_{rd}, while $\delta = 0.001$. From simulation, it shows that if we increase the value of m then we can get good performance as compared to increasing the value of Ω_{sr} or

$\Omega_{rd}.\Omega_{sr}=1$ and $\Omega_{rd}=10$, gives smaller Symbol Error Rate in case of MIMO-STBC Cooperation wireless system than $\Omega_{sr}=10$ and $\Omega_{rd}=1$. It shows that a high value of Ω_{rd} is more significant than a high value of Ω_{sr} for improvement in system performance. In Figure. 6 Equal Power and Optimal Power Allocation scheme have been analyzed.

V. CONCLUSION

The Performance of the MIMO - STBC DF cooperation relay system for 2 TX Antenna at source and 2 aerials at relay and 1 aerial at the destination node, considering Fading Channel distribution is NAKAGAMI-m, had been analyzed. The SER formulation has been derived for Avg. Symbol Error Rate and Upper bound of Symbol Error Rate for MPSK signal. Based on the theoretical and the simulation's result, following things arise:

The performance of the system is dynamically degraded with increasing the value of δ (Del). For SER improvement Ω_{rd} is an important parameter, then Ω_{sr} and by taking $\Omega_{rd}=10$ performance of the system improves. Also, Ω_{sr} is less significant as compared to Ω_{rd}. The performance of the system, relays more on the Ω_{rd} (Relay node-Destination node) channel link than, Ω_{sr} (Source node – Relay node) channel link. In Optimal Power Allocation event the performance improves in comparison to equal power allocation case. For m=1 and $\delta=0.001$ Optimal Power allocation scheme had been formulated. We had taken $\Omega_{rd}=\Omega_{sr}=\Omega_{sd}=1$ and, $m_{sd}=m_{sr}=m_{rd}=1$, $P_s={}^{P}\!/_{3}$, $P_r={}^{2}\!/_{3}*P$. When we compared the performance of both allocation schemes then it comes that optimal power has outperforms the equal power allocation scheme.

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