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BER Performance Analysis of Extended 4x4 Alamouti scheme with Transmitting Antenna Selection Technique in Various Wireless Channels

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***Abstract*— Space time codes whether it is Alamouti or Extended Alamouti scheme (EAS) provide better diversity advantage over various wireless channels. In this paper, Extended Alamouti scheme is combined of 4x4 diversity order with Transmitter Antenna Selection (TAS) techniques to improve the error performance. Specifically, the choice of transmitter antenna elements at the transmitter side in order to transmit the coded symbols has been provided. In this paper, comparison of error performance is shown in between EAS with TAS and without TAS by developing BER vs. SNR graph for M-PSK (Phase Shift Keying) modulation technique in various wireless communication channels such as AWGN, RAYLEIGH, RICIAN & NAKAGAMI fading channels.**

Keywords-TAS(Transmitter Antenna selection), EAS(Extended Alamouti Scheme), MIMO, M-PSK, BER.

I. INTRODUCTION

Diversity Techniques and MIMO are the most motivated topic to research. The main reason behind it is the improvement in capacity as well as BER performance of the particular wireless communication schemes. As we refer [1], the performances of the receiver diversity techniques such as MRC, EGC, etc. are generally improved by using the transmitter diversity scheme with the diversity order 2xM. Which now known as the ALAMOUTI scheme. Now, in order to improve its performance various space-time block code techniques are came into existence as in [3]. But, those techniques do not provide full code rates. So, than after Quasi-Orthogonal Space-Time Block Code (QOSTBC) with diversity factor/order 4x1 developed as in [6], [7] & [8]. Now, in order to improve the error performance, we have developed extended Alamouti scheme (EAS).

Now, in MIMO as we increase the no. of transmitting and receiving antennas, with improvement of the error performance and capacity performance, it also improves the cost, power requirements, etc. It means that with each transmitting antennas, there are RF front end components need to be connected. So, in order to reduce the size requirement, cost and mainly power requirement, which generally affect the error performance shown by BER vs. SNR graphs.

Now, this paper is composed as follows. In Section – II basic information regarding different wireless communication channel is given. In Section – III Extended Alamouti Scheme (EAS) with diversity factor 4x4 is represented. Then, in Section – IV, basic information regarding antenna selection techniques is given and then its subsection is consisting of novel technique which is combination of the Transmitter Antenna Selection (TAS) with EAS (Extended Alamouti Scheme) is shown. In Section – V results and its description is given. At last conclusion is given.

II. WIRELESS COMMUNICATION CHANNEL

There are many types of the wireless communication channels are available based on their fading affects. Before going towards different types, consider the concept of the MIMO channel.

The main idea of the MIMO channel came into existence for multiple transmitting as well as receiving antenna. Now, if we want to represent any channel parameters 'say H' between 'm' transmitting and 'n' receiving antennas than it can be represented by using equation – (1) below:-

$$\begin{pmatrix} h_{11} & \cdots & h_{1n} \\ \vdots & \ddots & \vdots \\ h_{m1} & \cdots & h_{mn} \end{pmatrix} \tag{1}$$

Now, in above equation (1), each of the matrix elements $h_{i,j}$ shows the impedance parameter of the channel between i - transmitting antenna and j - receiving antenna. So, the value of this $h_{i,j}$ parameter changes according to the value of LOS (Line-Of-Sight) parameter and fading distribution and fading effect according to the different channels. Here, fading is the effect or phenomena occur due to the fluctuation of the transmitted symbol power due to various obstacles between transmitter and receiver. Now, here for BER performance analysis we are using mainly four most commonly used wireless communication channels: - AWGN, RAYLEIGH, RICIAN and NAKAGAMI fading channel.

AWGN channel is mainly used for the analysis of any new scheme related to wireless communication system. Here, this universal channel model does nothing or in other words fading effect is very less or it is negligible. So, when transmitted symbols passed through it only AWGN noise is added.

RAYLEIGH channel model mainly represent the effect of multipath propagation effect over the transmitted symbols. So, transmitted symbols will passed through the channel which faded randomly according to the well known random/Gaussian distribution function. It is non LOS (Line – of – Sight) fading channel.

RICIAN fading channel also represent the multipath propagation fading effect but with direct LOS between transmitter and receiver.

NAKAGAMI fading channel represents the different fading channels in between Rayleigh and Rician fading channel with change in only one parameter which is denoted by '*m*' & known as the Nakagami factor. As the value of *m* increases error performances moving from Rayleigh towards Rician fading channel. It means that for m=0.5 Nakagami channel act as a Rayleigh channel. As value of *m* increases from 0.5 (i.e. m= 1, 1.5, 2) it acts as a Rician fading channel. [5].

III. EAS (EXTENDED ALAMOUTI SCHEME)

In order to improve the performance of the Alamouti scheme with 2xM diversity order, extensions in it has been done as in [6, 8, and 9]. So, one of this kind of extension is improvement of Alamouti scheme with 4x4 diversity order. [17].

So, now the basic block diagram of the extended Alamouti scheme is shown in below figure-(1). Here, Extended Alamouti scheme is extended over four time slots as in [7]. Firstly all four symbols S_1, S_2, S_3 & S_4 are transmitted during first time slot than during second time slots another four coded symbols such as S_2^*, $-S_1^*$, S_4^* & $-S_3^*$, respectively. Where, '*' represent the complex conjugate. Now, similarly other symbols are also coded and interleaved according to the below equation-(2) [7]:-

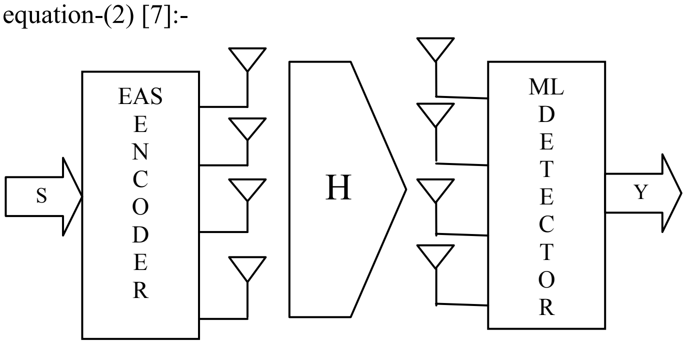

Figure 1. Block-Diagram representation of Extended Alamouti Scheme

$$\begin{pmatrix} s_1 & s_2^* & s_3^* & s_4 \\ s_2 & -s_1^* & s_4^* & -s_3 \\ s_3 & s_4^* & -s_1^* & -s_2 \\ s_4 & -s_3^* & -s_2^* & s_1 \end{pmatrix} \quad (2)$$

Now, than this transmitted symbols are passed through the wireless communication channels which can be represented in mathematical form by means of the channel matrix shown in equation – (2) :-

$$H=\begin{bmatrix} h_{1,1} & h_{1,2} & h_{1,3} & h_{1,4} \\ h_{2,1} & h_{2,2} & h_{2,3} & h_{2,4} \\ h_{3,1} & h_{3,2} & h_{3,3} & h_{3,4} \\ h_{4,0} & h_{4,2} & h_{4,3} & h_{4,4} \end{bmatrix} \quad (3)$$

Then, these symbols which are affected by channel fading parameters are generally reached at the ML detector. Here, ML detector is generally comprises of the channel estimator, combiner and ML decoder as in [1].

Now, the receiving sequences are given by: -

$$R=H*S+\eta \quad (4)$$

Where, η is additive white Gaussian noise added at the receiver side. Now, these received sequences are then given to the ML detector. Output of the combiner is given as below equation-(5):-

$$\tilde{S}=H^{\dagger}*Y \quad (5)$$

So, the output of the combiner, which is then given to the ML detector in order to detect the symbols and then they are compared with the transmitted symbols s_1, s_2, s_3 and s_4 in order to develop the error performance for this diversity technique. [5, 17 & 18]

W
here:-

$$H^{\dagger}=\begin{pmatrix} h_{1,1} & h_{1,2} & h_{1,3} & h_{1,4} \\ h_{2,1} & h_{2,2} & h_{2,3} & h_{2,4} \\ h_{3,1} & h_{3,2} & h_{3,3} & h_{3,4} \\ h_{4,0} & h_{4,2} & h_{4,3} & h_{4,4} \\ -h^*_{2,1} & h^*_{1,1} & -h^*_{1,4} & h^*_{1,3} \\ -h^*_{2,2} & h^*_{2,1} & -h^*_{2,4} & h^*_{2,3} \\ -h^*_{3,2} & h^*_{3,1} & -h^*_{3,4} & h^*_{3,3} \\ -h^*_{4,2} & h^*_{4,1} & -h^*_{4,4} & h^*_{4,3} \\ -h^*_{1,3} & -h^*_{1,4} & h^*_{1,1} & h^*_{1,2} \\ -h^*_{2,3} & -h^*_{2,4} & h^*_{2,1} & h^*_{2,2} \\ -h^*_{3,3} & -h^*_{3,4} & h^*_{3,1} & h^*_{3,2} \\ -h^*_{4,3} & -h^*_{4,4} & h^*_{4,1} & h^*_{4,2} \\ h_{1,4} & h_{1,3} & h_{1,2} & h_{1,1} \\ h_{2,4} & h_{2,3} & h_{2,2} & h_{2,1} \\ h_{3,4} & h_{3,3} & h_{3,2} & h_{3,1} \\ h_{4,4} & h_{4,3} & h_{4,2} & h_{4,1} \end{pmatrix} \quad (6)$$

$$\& \ Y=\begin{pmatrix} R^{1} \\ R^{2*} \\ R^{3*} \\ R^{4} \end{pmatrix} \quad (7)$$

IV. Antenna Selection Combined With EAS

One of the block diagram representation of transmit antenna selection is shown in figure – (2). Here, need of this antenna selection technique is to improve diversity gain more by reduce the power requirement of the RF components connected with each transmitter or receiver antennas.

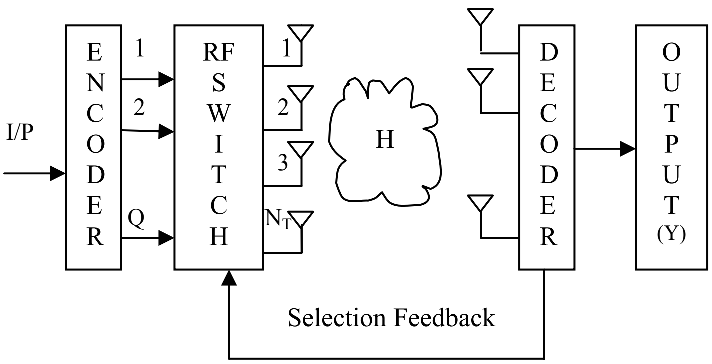

Figure 2. Block Diagram representation of TAS

As shown in above block-diagram, as the no. of antennas increased, with the increment of the diversity as well as coding gain cost, space, mainly power requirement is also increased. Main reason behind the increment of the power requirement is more no. of RF modules such as LNA, frequency up-down counters etc. So, in order to reduce the power requirement, which also improve the SINR (Signal to Interference Noise Ratio) and indirectly increase the diversity performance of wireless communication system; AS (Transmitter/Receiver Antenna Selection) technique came into existence [19].

Now, in antenna selection technique as shown in Fig.2 if we need to use only Q transmitting antennas at a time out of N_T transmitting antennas than we need to use only Q RF modules instead of N_T. So, because of that power consumption can be achieved. So as shown in end to end configuration in Fig. 2, Q RF modules are used to support N_T transmitting antennas and the value of Q must be less than N_T ($Q<N_T$) . So, Q antennas used among N_T transmitting antennas, that's why the channel matrix can be represented by Q columns among the H.

A. *TAS combined with EAS :-*

Now, here firstly, consider that there are total N_T antennas are available among them in EAS only Q antennas are being used at a time. So, the channel matrix H reshaped from N_T x N_R to Q x N_R as previously mentioned in this paper.

Then, after need to find the strong Q antennas out of N_T transmitting antennas. For that needed analysis can be done at the receiver side by analyzing the different channel fading parameters of matrix H. Now, after selecting strong Q antennas we need to apply the EAS steps. So, same steps come into picture as illustrated in above Section – III.

Considering Fig.1, the received signal can be given as:-

$$R=H*S+\eta \quad (8)$$

Where, η is additive white Gaussian noise added at the receiver side of the size (N_R x 1). Similarly, transmitted symbols can be resized as (NT x 1). Similarly, the size of H is (Q x N_R). Now, these received sequences are then given to the ML detector. Output of the combiner is given as below equation-(5):-

$$\tilde{S}=H^{\dagger}*Y \quad (9)$$

Where, Y and H^{+} can be obtained in same manner by equation – (7) & (6), respectively. These detected symbols $\tilde{S}$ are compared with transmitted symbols S bit by bit in order to develop the error performance and represent it in terms of BER vs. SNR graph.

V. Results And Discussion

In this paper we are combining EAS with TAS in order to improve error performances. For that we are taking N_T = Total no. of antennas= 8 and at a time only Q=4 antennas are transmitting information. So, only Q=4 RF modules are required which are used with selected transmitting antennas based on the feedback provided by receiving section of wireless communication system.

Now, here, we have shown the results for M-PSK (BPSK & QPSK) modulation schemes. Here, each BER vs. SNR graph is consisting of error performance of extended Alamouti scheme with and without transmitter antenna selection scheme.

Here, results are developed in four different wireless communication channels AWGN, RAYLEIGH, RICIAN & NAKAGAMI fading channels as mentioned in Section – II.

Now, here Fig.3 shows the comparison among extended Alamouti scheme with and without for AWGN channel for BPSK modulation technique. Now, here because of very less and nearly negligible fading effect we generally get nearly same results and also it is for M=2 (less order) PSK modulation scheme, because of that error performance for EAS without antenna selection is also better.

Similarly, Fig.4 shows the comparison among extended Alamouti scheme with and without transmitter antenna selection technique for QPSK. Here, with TAS provides some improvement as compared to without because of higher modulation order (M=4) PSK modulation technique. But, still it is less for AWGN channel. Here, as we can say that there is an improvement of diversity as well as coding gain in EAS + TAS combined technique.

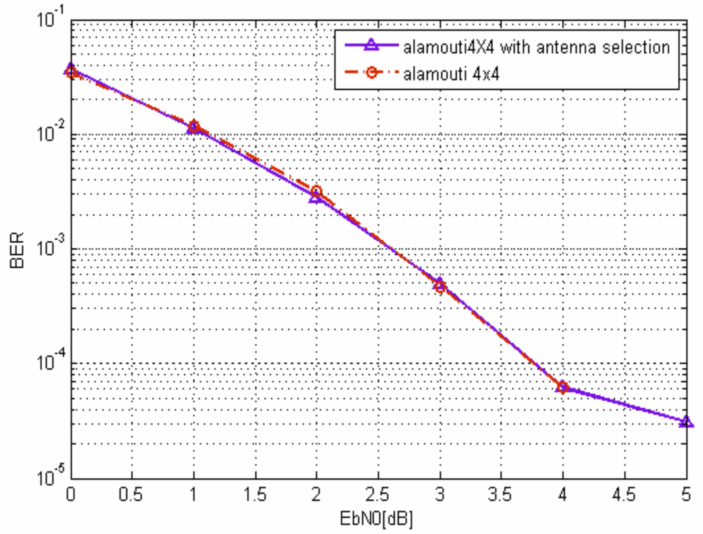

Figure 3. Error Performance for AWGN channel and BPSK modulation scheme

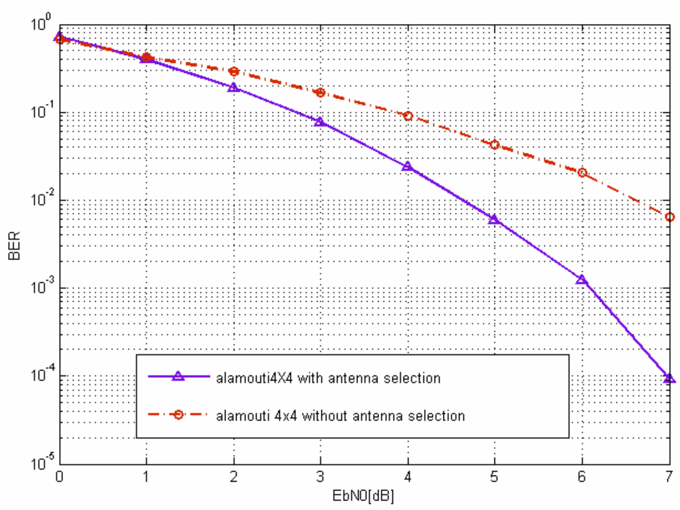

Figure 4. Error Performance for AWGN channel and QPSK modulation scheme

Here, Fig.5 and Fig.6 shows the results for RAYLEIGH channel for BPSK and QPSK modulation schemes, respectively. Now, as previously mentioned in this paper as the modulation order of modulation technique increases, the error performance degraded. So, we can see this by comparing Fig.5 and Fig.6.

Now, in both figures, extended Alamouti scheme with TAS provide better result as compared to without antenna selection. So, we can say that both diversity gain as well as coding gain is increased by large amount in case of Rayleigh channel. Reason behind it is that, in antenna selection technique out of eight transmitting antennas, strong four antennas being selected. Here, strong means, fading channels between those transmitters and related receiving antennas is comparatively less.

Similarly, same kind of error performance comparisons for RICIAN fading channel and for both BPSK & QPSK modulation techniques are shown in Fig.7 & 8, respectively.

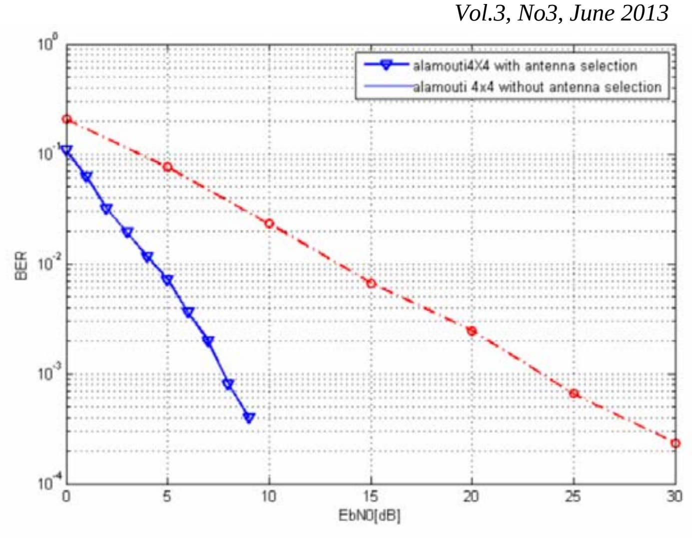

Figure 5. Error Performance for RAYLEIGH channel and BPSK modulation scheme

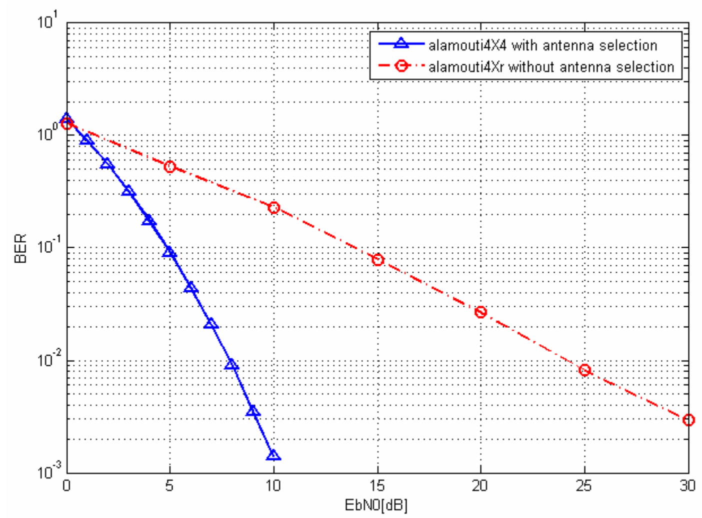

Figure 6. Error Performance for RAYLEIGH channel and QPSK modulation scheme

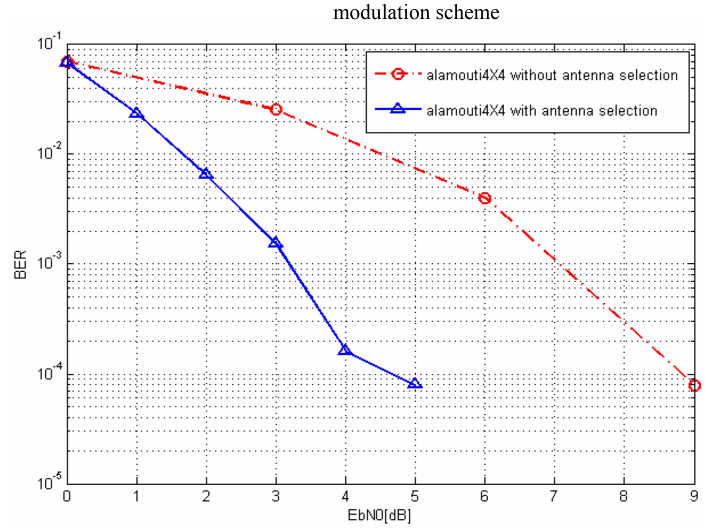

Figure 7. Error Performance for RICIAN channel and QPSK modulation scheme

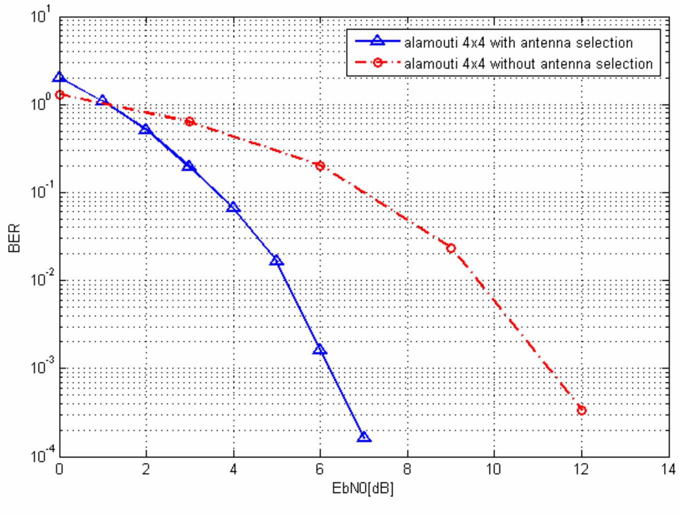

Figure 8. Error Performance for RICIAN channel and QPSK modulation scheme

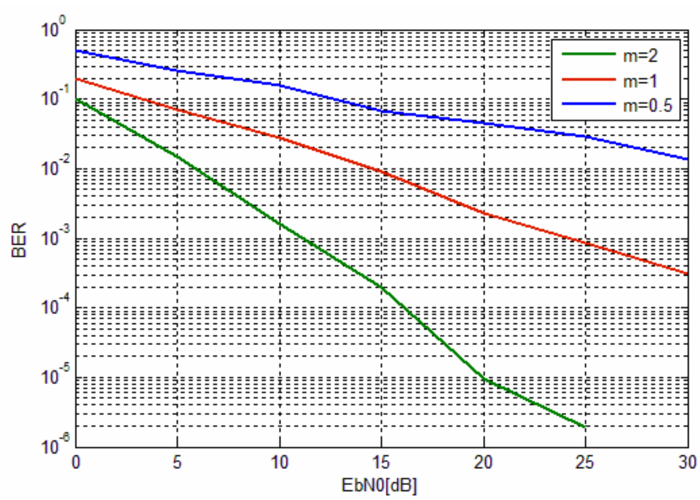

Figure 9. Error performance for NAKAGAMI channel and BPSK modulation scheme

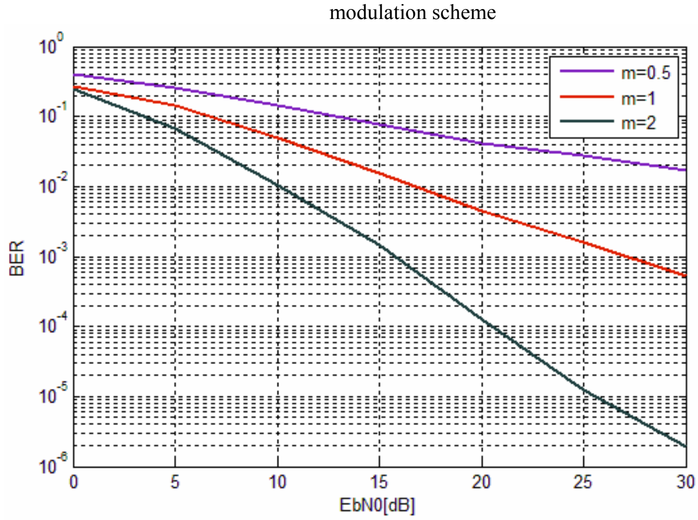

Figure 10. Error performance for NAKAGAMI channel and QPSK modulation scheme

Here, Fig.9 and Fig.10 represents the results for BPSK & QPSK for NAKAGMI fading channel with EAS scheme without antenna selection.

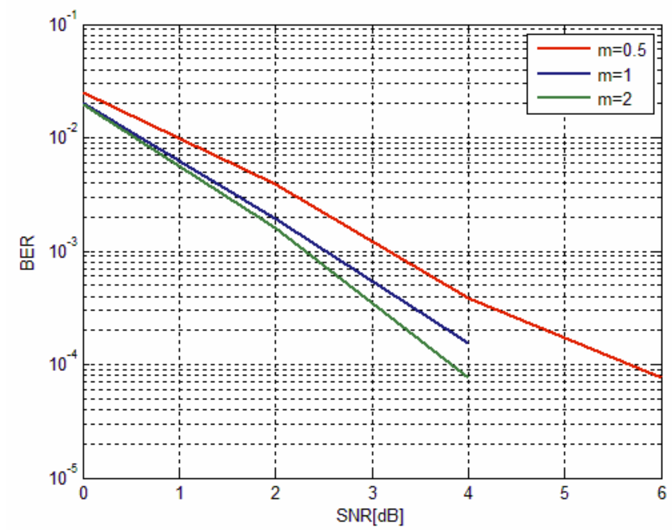

Figure 11. Error performance for NAKAGAMI channel and BPSK modulation scheme

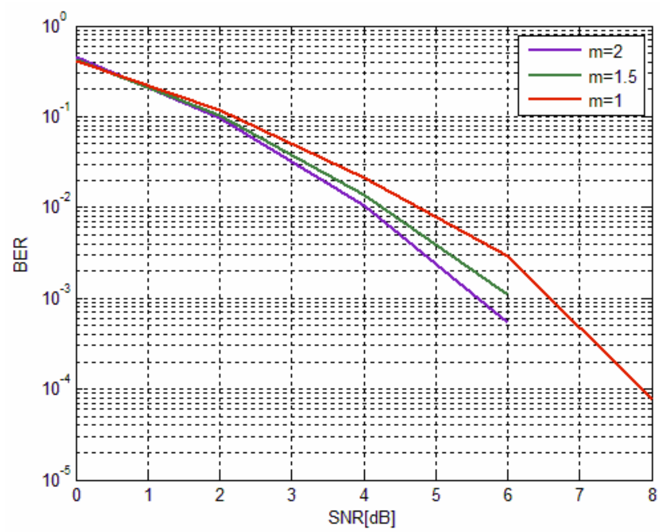

Figure 12. Error performance for NAKAGAMI channel and QPSK modulation scheme

Fig.11 and Fig.12 shows the results for EAS (Extended Alamouti Scheme) combined with antenna selection technique for both BPSK and QPSK modulation techniques, respectively. Now, here as we can see that as we increase the value of Nakagami factor '*m*' from 0.5 to 2 and more, error performances are moving towards RICAN fading channel from Rayleigh channel.

Finally, complete comparison between all wireless communication channels for EAS with and without TAS is shown in Table – I with for QPSK modulation scheme. As we can clearly see from the table that when we combined extended Alamouti scheme with TAS, than we can get more better error performance and that's why better diversity and coding gain that we can also see from the results shown in previous figures.

TABLE I. ERROR PERFORMANCE COMPARISONS FOR QPSK

DIFFERENT WIRELESS COMMUNICATION CHANNELS	AT SNR=5dB	AT SNR=10dB
AWGN	0.0011765	8.6538E-006
RAYLEIGH	0.11538	0.037063
RICIAN	0.057143	0.0012531
NAKAGAMI WITH m=0.5	0.22885	0.1359
NAKAGAMI WITH m=1	0.069615	0.026923
NAKAGAMI WITH m=1.5	0.068462	0.020588
NAKAGAMI WITH m=2	0.059231	0.010577
NAKAGAMI WITH m=3	0.053846	0.0038462
NAKAGAMI WITH m=4	0.044462	0.001717
AWGN (WITH TAS)	3.25E-004	Less than 1E-006
RAYLEIGN (WITH TAS)	0.0037	Less than 1E-006
RICIAN (WITH TAS)	4.5E-004	Less than 1E-006
NAKAGAMI WITH m=0.5 (WITH TAS)	5E-004	Less than 1E-006
NAKAGAMI WITH m=1 (WITH TAS)	3.25E-004	Less than 1E-006
NAKAGAMI WITH m=1.5 (WITH TAS)	1.75E-004	Less than 1E-006
NAKAGAMI WITH m=2 (WITH TAS)	1E-004	Less than 1E-006

VI. CONCLUSION

The bit error performances of the TAS/EAS scheme in various wireless fading channels were investigated. From table – I, it is concluded that the novel combination of the antenna selection technique extended Alamouti scheme with diversity factor of 4x4 provides the improvement into the antenna coding gain as well as for M-PSK modulation techniques the diversity performance of the results are also increased. It is achieved in most of well known wireless communication fading channels such as AWGN, Rayleigh, RICIAN and NAKAGAMI fading channels.

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