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Randomized Distributed Space Time Codes Using Nakagami-M Fading Channels in Wireless Communication

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Abstract:- In this paper, we are presenting the space time coding to analysis the performance of Nakagami-m fading channel in wireless communication. We introduce a class of space time codes known as space time block code. We propose a space time (ST) codes for multi antenna using QAM over Nakagami –m fading channel. Frame error rate and outage probability are the two basic parameters that are used in this paper to analysis the performance of the space time code. To improving the data rate and/or the reliability of communications over fading channels using multiple transmit antennas has been considered. Simulation results show the performance of STC using Frame Error Rate (FER) and outage capacity using 4-QAM and 8-QAM modulation techniques with different number of transmitting and receiving antenna. From the comparative analysis we can also show that as the number of receiver goes on increases frame error rate also goes on decreasing. Result also reveals that the outage capacity of the system increases with increase in SNR. In this paper simulations have been conducted to study the Frame Error Rate (FER) and Outage capacity of Space-Time block Coding with different number of transmit and receive antennas performance of a Nakagami-m fading channel.

Index Terms: **Nakagami-m fading channel, Space time code (STC), Frame Error Rate (FER), outage capacity, space time block code (STBC).**

I. INTRODUCTION

With the ever increasing demand of multimedia services, future wireless generations aim to achieve higher data rates and more reliable communications for Quality of Service (QoS) provision. The main aim of the communication system is the requirement of higher data rate and more reliable communication. The rapidly growing demand for these services is driving the communication technology towards higher data rates, higher mobility, and higher carrier frequencies that are needed to enable reliable transmissions over mobile radio channels [1]. Depending on the Quality-of-Service requirements and different applications per user, many broadband wireless communication systems have been proposed.

ST coding relies on simultaneous coding across space and time to achieve diversity gain without necessarily sacrificing precious bandwidth. Two typical examples of ST codes are ST trellis codes [2] and ST block codes [3]. Space-time block codes operate on a block of input symbols producing a matrix output whose columns represent time and rows represent antennas. Unlike traditional single antenna block codes for the AWGN channel, most space time block codes do not provide coding gain. Their key feature is the provision of full diversity with extremely low encoded decoder complexity [3] [7].

Space-time trellis codes [2] operate on one input symbol at a time producing a sequence of vector symbols whose length represents antennas. Like traditional TCM (trellis coded modulation) [8] for the single-antenna channel, space time trellis codes provide coding gain. Since they also provide full diversity gain, their key advantage over space-time block codes is the provision of coding gain. Their disadvantage is that they are extremely difficult to design and require a computationally intensive encoder and decoder [7]. The Nakagami-m distribution is a versatile statistical model because it can model fading amplitudes that experience either less or severe fading than that of Rayleigh variates [10] [11]. The Nakagami-m distribution is suitable for describing statistics of mobile radio transmission in complex media such as the urban environment.

In this paper, we are presenting the space time coding to analysis the performance of Nakagami-m fading channel in wireless communication. Frame error rate and outage probability are the two basic parameters that are used in this paper to analysis the performance of the space time code. To improving the data rate and/or the reliability of communications over fading channels using multiple transmit antennas has been considered. The purpose of this paper is to evaluate the performance of the space–time trellis codes (STTC) constructed in [3] with parameter as frame error rate and outage capacity is studied with different transmit and receive antennas and QAM modulation.

The outline of this paper is as follows. In Section II, we provide Space-Time codes for the multiple antenna communication systems. System model of space time block code is describe in Section III. In Section IV frame error rate and outage capacity is explained for nakagami fading channels. Section V analyzes the performance of the space–time block code. Finally, Section VII presents our conclusions and final comments.

II. SPACE-TIME CODES

Consider a mobile communications system where the base station is equipped with *n* antennas and the remote unit is equipped with *m* receive antennas At each time slot *t*, signals c_t^i, *i*=1,2,….,n are transmitted simultaneously from the *n* transmit antennas. The channel is flat-fading and the path gain from transmit antenna *i* to receive antenna *j* is denoted by h_{ij}. The path gains are modelled as samples of independent complex Gaussian random variables with variance 0.5 per real dimension, i.e., $h_{ij} \sim N(0,1)$, as we assume that signals received at different antennas experience independent fading. In this report, we will consider modeling the path gins in slow Rayleigh fading. For slow fading, it is assumed that the path gains are constant during a frame of length L and vary from one frame to another, i.e., channel is quasi-static.

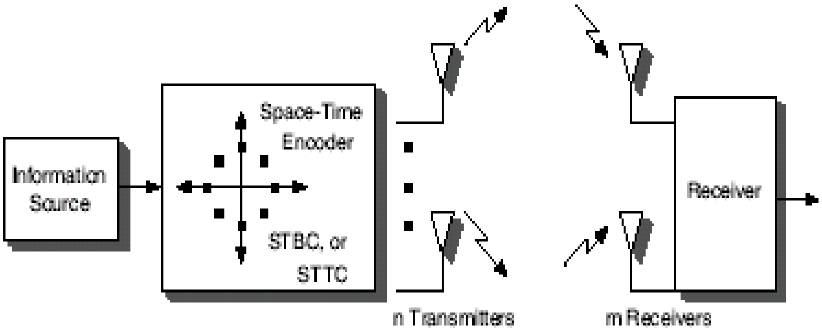

Fig 1 System Model

At time t, the signal r_t^j received at antenna j is given by

$$r_t^j = \sum_{i=1}^{n} h_{i,j} c_t^i + \eta_t^j \tag{1}$$

where the noise samples η_t^j are zero mean complex Gaussian with variance $\sigma^2 = 1/(2E_s/N_o) = 1/2SNR$ per dimension. The average energy of the symbols transmitted from each antenna is normalized to one, so that the average power of the received signal at each receive antenna is n.

It is assumed that channel state information is only available at the receiver, who uses it to compute the decision metric

$$\sum_{t=1}^{l} \sum_{j=1}^{m} \left| r_t^j - \sum_{i=1}^{n} h_{i,j} c_t^i \right|^2 \tag{2}$$

over all code words $c_1^1 c_1^2 \ldots c_1^n c_2^1 \ldots c_2^n c_l^n \ldots c_l^n$ and decide in favor of the code word that minimizes the sum.

III. SPACE-TIME BLOCK CODES

In 1998, Alamouti proposed a simple transmit diversity scheme [3], which improves the signal quality at the receiver on one side of the link by simple processing across two transmit antennas at the opposite end.

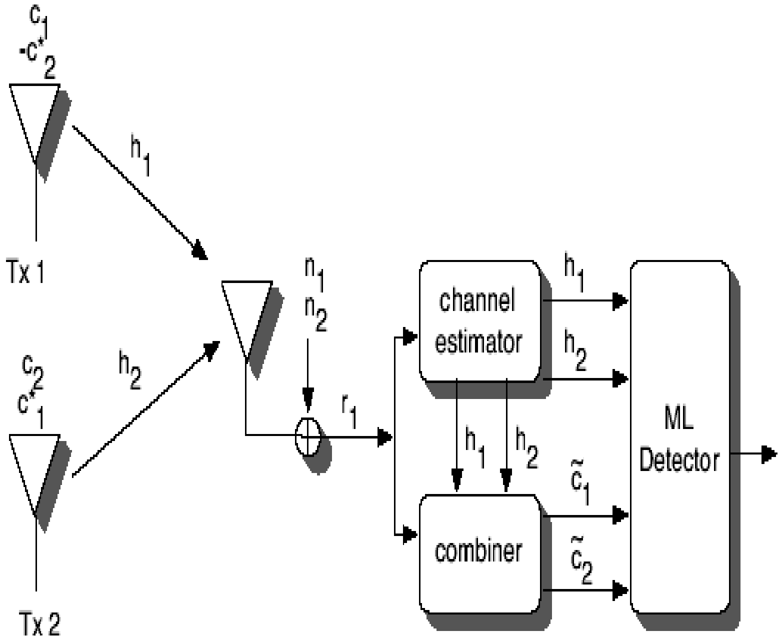

Fig 2 Two Antenna Transmit Diversity Scheme

At a given symbol period, two signals are simultaneously transmitted from the two antennas, namely c_1 from the first antenna, Tx1, and c_2 from the second antenna, Tx2. In the next symbol period, signal ($-c^*_2$) is transmitted from Tx1 and signal c^*_1 is transmitted from Tx2, where * denotes complex conjugation.

Let $h_1(t)$ denote the path gain from Tx1 to the receiver; similarly let $h_2(t)$ be that from Tx2 to the receiver. If we assume that fading is constant across two consecutive symbols, we can write

$$\begin{aligned} h_1(t) = h_1(t+T) = h_1 = \alpha_1 \exp j\theta_1 \\ h_2(t) = h_2(t+T) = h_2 = \alpha_2 \exp j\theta_2 \end{aligned} \tag{3}$$

where T is the symbol period. The received signals are

$$\begin{aligned} r_1 = r(t) = h_1 c_1 + h_2 c_2 + \eta_1 \\ r_2 = r(t+T) = -h_1 c_2^* + h_2 c_1^* + \eta_2 \end{aligned} \tag{4}$$

where r_1 and r_2 are the received signals at time *t* and *t*+T. The combiner combines the received signals as follows:

$$\begin{aligned}\tilde{c}_1 &= h_1^* r_1 + h_2 r_2^* = (\alpha_1^2+\alpha_2^2)c_1 + h_1^*\eta_1 + h_2\eta_2^* \\ \tilde{c}_2 &= h_2^* r_1 - h_1 r_2^* = (\alpha_1^2+\alpha_2^2)c_2 - h_1\eta_2^* + h_2^*\eta_1\end{aligned} \qquad (5)$$

and sends them to the maximum likelihood detector, which minimizes the following decision metric

$$|r_1 - h_1c_1 - h_2c_2|^2 + |r_2 + h_1c_2^* - h_2c_1^*|^2 \qquad (6)$$

over all possible values of c_1 and c_2. Expanding this, and deleting terms that are independent of the codewords, the above minimization reduces to separately minimizing

$$|r_1h_1^* + r_2^*h_2 - c_1|^2 + (\alpha_1^2+\alpha_2^2-1)|c_1|^2 \qquad (7)$$

for detecting c_1 and

$$|r_1h_2^* - r_2^*h_1 - c_2|^2 + (\alpha_1^2+\alpha_2^2-1)|c_2|^2 \qquad (8)$$

for decoding c2. Equivalently, using the notation $d^2(x,y) = (x-y)(x^*-y^*) = |x-y|^2$. The decision rule for each combined signal $\tilde{c}_j$; $j = 1;2$ becomes: Pick c_i if and only if (iff)

$$(\alpha_1^2+\alpha_2^2-1)|c_i|^2 + d^2(\tilde{c}_j,c_i) \le (\alpha_1^2+\alpha_2^2-1)|c_k|^2 + d^2(\tilde{c}_j,c_k), \quad \forall i \neq k \qquad (9)$$

For QAM signals (equal energy constellations), this simplifies to

$$d^2(\tilde{c}_j,c_i) \le d^2(\tilde{c}_j,c_k), \quad \forall i \neq k \qquad (10)$$

IV. NAKAGAMI FADING CHANNEL

Nakagami-m distribution is suitable for describing statistics of mobile radio transmission in complex media such as the urban environment. The Nakagami distribution is related to the gamma distribution. The Nakagami distribution can be generated from the chi distribution. The Nakagami distribution or the Nakagami-*m* distribution is a probability distribution related to the gamma distribution. It has two parameters: a shape parameter m and a second parameter controlling spread, Ω. The Nakagami-m random process is defined as an envelope of the sum of 2m independent Gauss random processes, the Nakagami-m distribution is described by the pdf

$$p_z(z,\Omega) = \frac{2}{\Gamma(m)}\left(\frac{m}{\Omega}\right)^m z^{2m-1}\exp\left(-\frac{m}{\Omega}z^2\right), \quad z>0, m\ge\frac{1}{2} \qquad (11)$$

where z is the received signal level, Γ(.) is the gamma function,

A. Channels with Rayleigh Fading

In this case $E\alpha_{i,j}=0$ and $K_{i,j}$ for all i and j. Then the inequality obtained above can be written as

$$P(\mathbf{c} \rightarrow \mathbf{e}) \leq \left(\frac{1}{\prod_{i=1}^{n} (1 + \lambda_i E_s / 4N_0)} \right)^m . \tag{12}$$

Let r denote the rank of matrix A, then the kernel of A has dimension n-r and exactly n-r eigen values of A are zero. Say the nonzero Eigen values of A are λ_1, λ_2,… ,λ_r,, then it follows from inequality above that

$$P(\mathbf{c} \rightarrow \mathbf{e}) \leq \left(\prod_{i=1}^{r} \lambda_i \right)^{-m} (E_s / 4N_0)^{-rm} \tag{13}$$

This is the expression for the Frame Error Rate (FER).

B. Outage Capacity

It is defined in terms of mutual information between input and output, *I(input,output)*. When the output is composed of independent additive noise, and multiple of the transmitted signals, then *I(input,output)* = *ε(output)*- *ε(noise)*. Here *ε()* represents *entropy*. Since *ε(output)* and *ε(noise)* are each expressed as the sum of N_T conditional entropies.

$$I(input,output) = \frac{1}{N_T} \sum_{i=1}^{N_T} \left[\varepsilon(output \mid i^{th} outcome) - \varepsilon(noise \mid i^{th} outcome) \right]$$

The Rayleigh Channel model for $H(M_R x N_T$ *channel matrix)* has complex zero mean unit variance entries:

$$H_{ij} = Normal(0, 1/\sqrt{2}) + \sqrt{-1}.(Normal(0, 1/\sqrt{2})$$

V. SIMULATION RESULTS

In this section, the analysis of space time coding (STC) in wireless communication system is presented with the channel modelling is selected to be of nakagami fading channel. We are considering basically to parameters to analysis the performance of nakagami fading channel are frame error rate and outage probability. The outage probability, P_{out}, is defined as the probability that the received SNR per symbol falls below a given threshold. If the SNR of the received signal fall be the given threshold than outage is occur at the receiver. This is one of the important parameter that is used for the analysis the performance of fading channel. Fig. 3 demonstrate the frame error rate vs SNR analysis of space time code with 4-QAM using transmitting antenna N=2 and receiver antenna M=1. Fig.4 depicts the Outage Capacity vs SNR analysis of space time code with 4-QAM using transmitting antenna N=2 and receiver antenna M=1. Fig. 5 demonstrate the frame error rate vs SNR analysis of space time code with 4-QAM using transmitting antenna N=2 and receiver antenna M=2. Fig.6 depicts the Outage Capacity vs SNR analysis of space time code with 4-QAM using transmitting antenna N=2 and receiver antenna M=2.

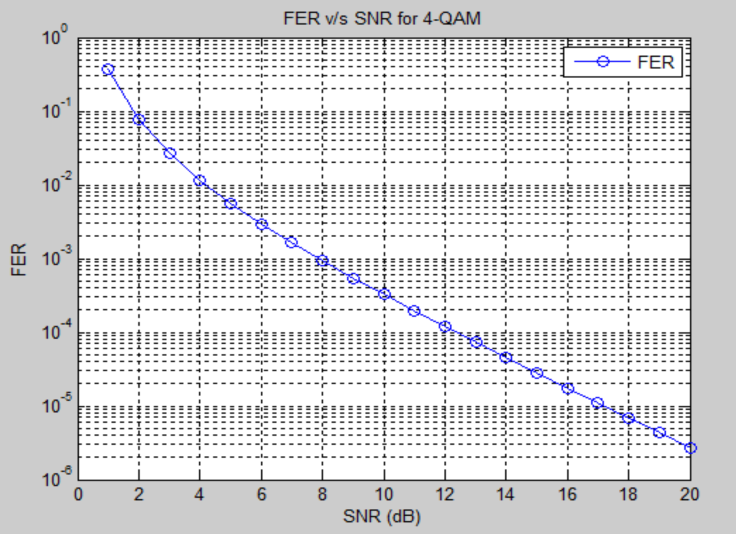

Fig. 3 frame error rate vs SNR analysis of space time code with 4-QAM using transmitting antenna N=2 and receiver antenna M=1

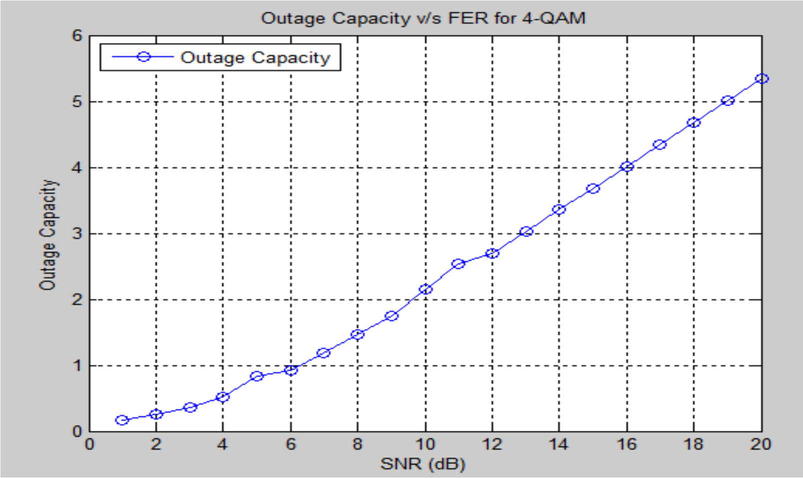

Fig. 4 Outage Capacity vs SNR analysis of space time code with 4-QAM using transmitting antenna N=2 and receiver antenna M=1

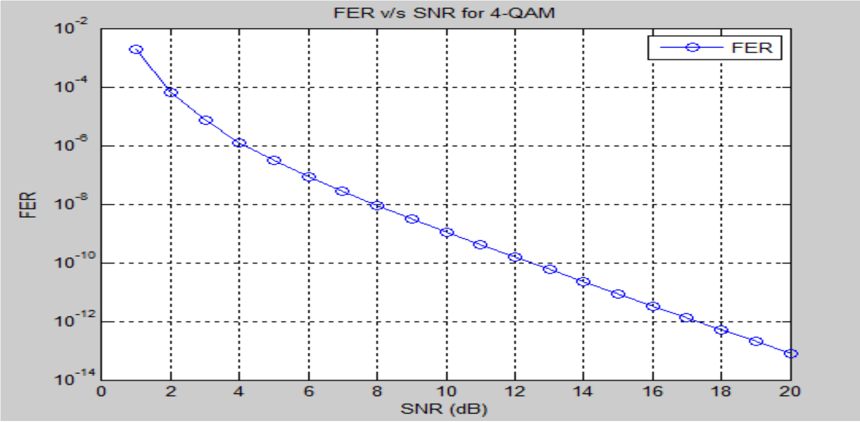

Fig. 5 frame error rate vs SNR analysis of space time code with 4-QAM using transmitting antenna N=2 and receiver antenna M=2

Fig.7 depict the comparison of frame error rate vs SNR analysis of space time code with 4-QAM using different transmitting antenna and receiver antenna. Fig. 8 shows the comparison of Outage Capacity vs SNR analysis of space time code with 4-QAM using different transmitting antenna and receiver antenna.

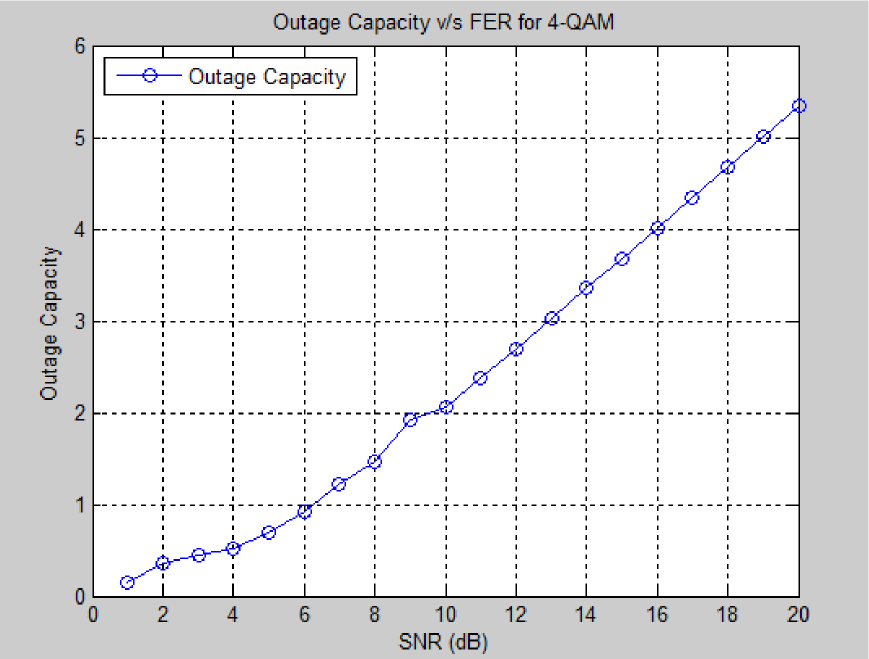

Fig. 6 Outage Capacity vs SNR analysis of space time code with 4-QAM using transmitting antenna N=2 and receiver antenna M=2

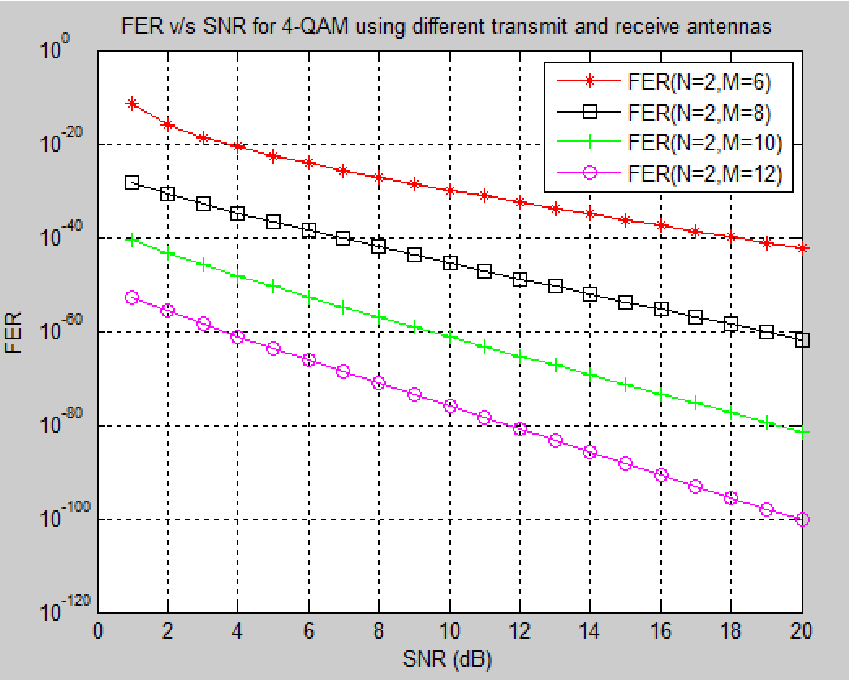

Fig. 7 comparison of frame error rate vs SNR analysis of space time code with 4-QAM using different transmitting antenna and receiver antenna

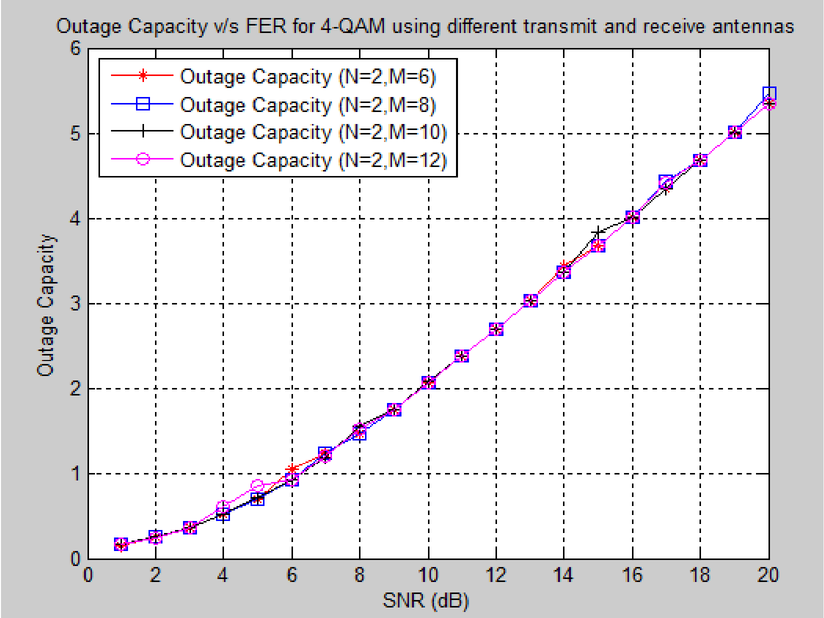

Fig.8 comparison of Outage Capacity vs SNR analysis of space time code with 4-QAM using different transmitting antenna and receiver antenna

III. CONCLUSIONS

This paper is to evaluate the performance of the space–time block codes (STBC) constructed with parameter as frame error rate and outage capacity is studied with different transmit and receive antennas and QAM modulation. We provided examples of space time trellis codes for transmission using multiple transmit antennas. We compare the performance of STBC in terms of frame error rate keeping the transmit power, spectral efficiency. Simulations have been conducted to study the Frame Error Rate (FER) performance and outage capacity in wireless communication for different number of transmit (N=2) and receive antennas (M=1,5). From the comparative analysis we can also show that as the number of receiver goes on increases frame error rate also goes on decreasing. Result also reveals that the outage capacity of the system increases with increase in SNR.

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