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Rayleigh Fading Channel Estimation Of Mimo System With Spectral Efficiency And Channel Capacity Using High Data Rate Coding Technique

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ABSTRACT-The modern wireless system consists of complex base stations with a high power transmitter in which channel characteristics should be adaptive and dynamic for broadcasting with in defined bandwidth with effective high data rate transmission. The services can be offered in NLOS and LOS with different standards to mitigate the effects of channel fading, intereference, high data rate and channel capacity. But the main challenge is transmission rate and the strength of received signal should be optimized for increased capacity in radio link. The multiple antennas allow MIMO systems to perform precoding (multi-layer beamforming), diversity coding (space-time coding), and spatial multiplexing. By doing MIMO techniques we can achieve higher data rate or longer transmit range without requiring additional bandwidth or transmit power. This paper presents a detailed simulation of coding techniques for MIMO systems with and with out CSI, Spectral efficiency simulation for ergodic capacity and BER analysis is done. Different space-time block coding (STBC) schemes including Alamouti's STBC for different range of transmitter and receiver is done. Finally, these STBC techniques are implemented in MATLAB and analyzed for performance according to their bit-error rates. In this paper a complete approach and simulations is done for multi-antenna system with capacity and BER of SIMO and MISO systems in Rayleigh fading channels has been examined with CSI and without CSI (Channel state information). In case if channel state information (CSI) is available at the receiver and the transmitter does not know the channel information, it is best to distribute the transmit power P_T equally among the antennas and generate the channel matrix H and perform singular-value decomposition (SVD or generalized Eigen-value Re-decomposition). Finally diagonalized the channel and removed all the spatial interference without any matrix inversions or nonlinear processing If the CSI is also available at the transmitter (CSIT), the optimal power allocation can be derived by applying the well-known water filling assuming that the channel coherence time. At low SNR, CSIT will always helps in increasing the capacity and were as high SNR, CSIT increases capacity for systems with Nt > Nr and CSIT has no benefit for systems with Nt ≤ Nr.

INDEX TERMS-- MIMO, STBC, SVD, SNR, BER, CSI, MRC

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1 INTRODUCTION

The major limitation for any service provider with broadband application is the bandwidth,spectral efficiency and cost effective. Certain technical challenges will araise on the user demand and type of service requirement for the satisfication of subscriber with user equipment models. The BTS offers the coverage scenior under the LOS and NLOS keeping in mind about the high data rate and capacity. But the major challenges when NLOS communication is chosen for broadband wireless application which are operating at different range of frequencies. The implementation of the transceiver model with effective demands of user faces the technical chalieneges like mitigation of multipath fading and interference,achieving high spectral efficiency and overcoming intersymbol intereference. Even though certain potential solutions have been proposed susch as diversity, channel coding,adaptive antennas with modulation and coding, OFDM, spatial multiplexing,equalization and dynamic channel allocation to with stand the telecom market strategies with enormous data rate and increase in subscribers. Recent advances in Multiple-input multiple-output (MIMO) technology demonstrate that MIMO wireless communication systems can achieve impressive data rates and system performance. They use multiple antennas at the Tx and/or the Rx to increase the Txion rate and the strength of the received signal, as compared with traditional SISO systems. Most importantly, these gains come with no additional increase in bandwidth or transmission power, which are scarce resources; rather, they come at the cost of system complexity.

Multiple antennas [10] can be used at the transmitter and receiver, an arrangement called a multiple-input multiple-output (MIMO) system. A MIMO system takes advantage of the spatial diversity that is obtained by spatially separated antennas in a dense multipath scattering environment. MIMO systems may be implemented in a number of different ways to obtain either a diversity gain to combat signal fading or to obtain a capacity gain.

Three potential approaches of MIMO [7]

1) **Spatial diversity**- To improve communication reliability by decreasing sensitivity to multipath fading.
2) **Spatial multiplexing-** Creation of multiple parallel channels for carrying unique data streams.
3) **Beamforming –** Antenna arrays used to focus energy in the desired direction

The above three are collectively referred to as MIMO communication can be used to

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I. Increase the system reliability (decrease the bit or packet error rate).
II. Increase the achievable data rate and hence system capacity.
III. Increase the coverage area.
IV. Decrease the required transmitted power

2 SIMULATION MODEL

2.1 FAST FADING CHANNEL

The numerical and simulation results obtained using MATLAB are presented for the multi-antenna system channel capacity and bit-error rate in Rayleigh fading channels. It also show the capacity and BER of MIMO systems in Rayleigh fading channels has been examined. It has been seen that the use of multiple antennas increases the capacity although significant improvement can be achieved using equal or higher number of receive antennas compared to transmit antennas.

2.1.1 DUAL ARRAY MIMO

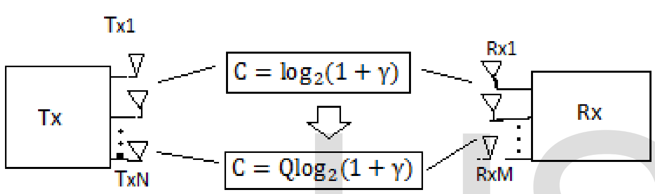

Fig 1. MIMO various antenna configuration

Multi-user MIMO or MU-MIMO is an enhanced form of MIMO technology that is gaining acceptance. MU-MIMO, Multi-user MIMO enables multiple independent radio terminals to access a system enhancing the communication capabilities of each individual terminal.MU-MIMO exploits the maximum system capacity by scheduling multiple users to be able to simultaneously access the same channel using the spatial degrees of freedom offered by MIMO.To enable MU-MIMO to be used there are several approaches that can be adopted, and a number of applications / versions that are available. [1]

$$H_{MIMO} = \begin{bmatrix} h_{1,1} & h_{1,2} \end{bmatrix} \quad (1)$$

Fig 2 . Various Antenna Configuration in MIMO

If channel state information (CSI) is available at the receiver and the transmitter does not know the channel information, it is best to distribute the transmit power P_T equally among the antennas and the ergodic capacity is written as

$$C_{CSIR} = E\{ \sum \log(1 + \frac{P_T\lambda_i}{N_T\sigma_n^2}) \} \quad (2)$$

where λ_i is the ith eigenvalue of HH*, σ_n^2 is the noise power.

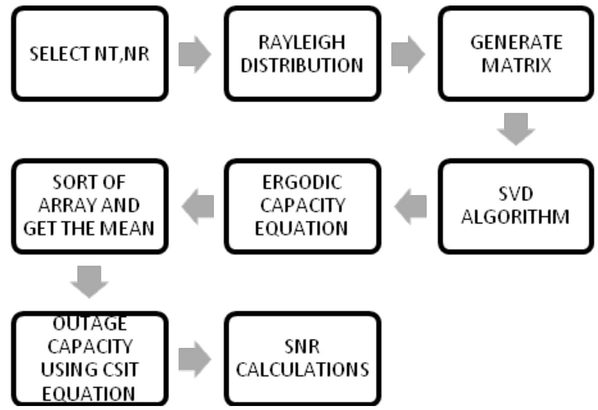

Fig 3 . BLOCK DIAGRAM FOR MIMO CHANNEL CAPACITY WITH NO CSIT

2.2 SLOW FADING CHANNEL

If the CSI is also available at the transmitter (CSIT), the optimal power allocation can be derived by applying the well-known water filling. Let's assume that the channel coherence time is larger than the interval of updating CSI at the transmitter, hence the transmitter has perfect CSI and the power allocated on every sub-channel is adjusted based on the instantaneous CSIT. Then the ergodic capacity can be written as

$$C_{CSIT} = E\{ \sum \log(1 + \frac{P_i\lambda_i}{\sigma_n^2}) \} \quad (3)$$

Where P_i is the power allocated on the ith sub-channel obtained by using the well-known water filling. [7]

$$P_i = (\varepsilon - \frac{\sigma_n^2}{\lambda_i})_+ , \quad (4)$$

Where $(x)_+$ = max{x,0} and ε is the "water-level" that is given by the criterion

$$\sum_{i=1}^{N_{min}} P_i = P_T \quad (5)$$

2.3 SVD

The singular-value decomposition (SVD or generalized Eigenvalue decomposition) of the channel matrix **H** is **H=U∑V** where **U** and **V** are unitary and ∑ is a diagonally matrix of singular values.

$$\begin{aligned} \mathbf{d} &= \mathbf{U}^*\mathbf{y} \\ &= U^*(Hx + n), \\ &= U^*(U\sum V^* Vb + n), \\ &= U^*U\sum V^*Vb + U^*n, \\ &= \sum b + U^*n. \end{aligned}$$

This has diagonalized the channel and removed all the spatial interference without any matrix inversions or nonlinear processing.

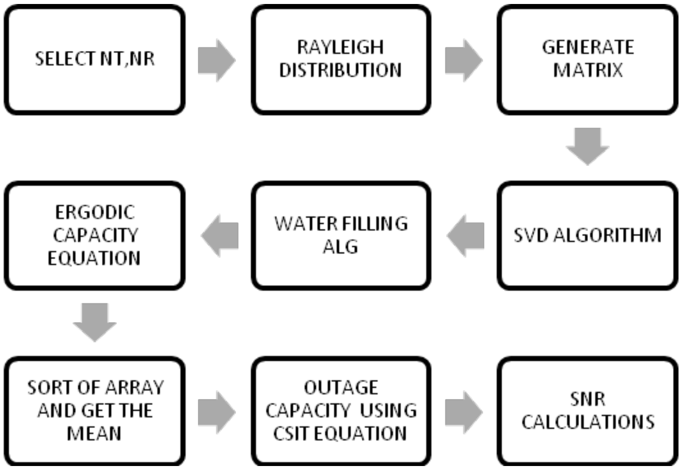

Fig 4. BLOCK DIAGRAM FOR MIMO CHANNEL CAPACITY WITH CSIT

2.4 STBC

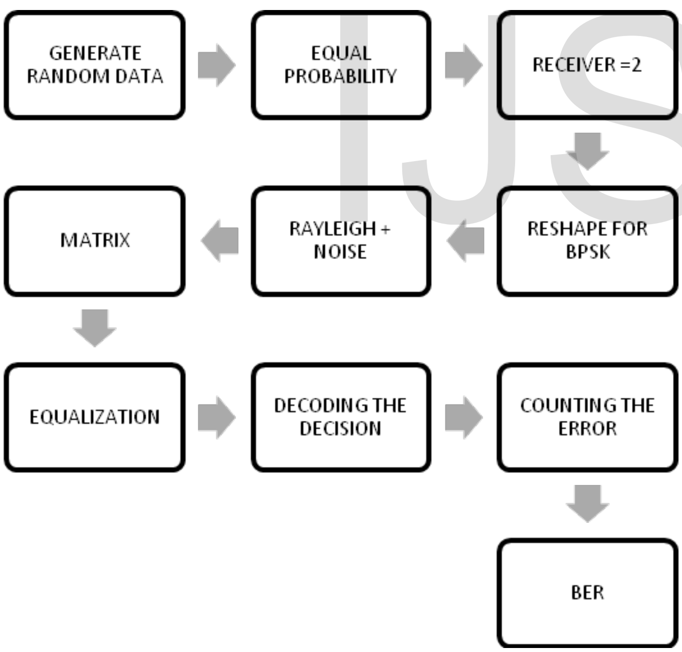

Fig 5 . BLOCK DIAGRAM FOR STBC

2.5 MRC

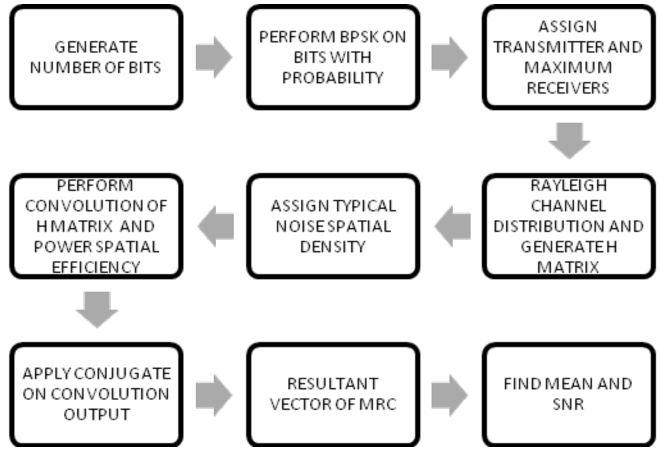

Fig 6. BLOCK DIAGRAM FOR MRC

Consider a receive diversity system with NR receiver antennas. Assuming a single transmit antenna as in the single input multiple output (SIMO) channel , the channel is expressed as

$$h = [h_1 h_2 \ldots h_{N_R}]^T \qquad (6)$$

for NR independent Rayleigh fading channels. Let x denote the transmitted signal with the unit variance in the SIMO channel. The received signal y 2 CNR_1 is expressed as

$$y = \sqrt{\frac{E_x}{N_0}} hx + z \qquad (7)$$

where z is ZMCSCG noise with E{zZ^H} = I_{N_R}. The received signals in the different antennas can be combined by various techniques. These combining techniques include selection combining (SC), maximal ratio combining (MRC), and equal gain combing (EGC). In SC, the received signal with the highest SNR among NR branches is selected for decoding. Let ϒi be the instantaneous SNR for the ith branch, which is given as

$$\Upsilon_i = |h_i|^2 \frac{E_x}{N_0}, \; i = 1,2,\ldots\ldots,N_R \qquad (8)$$

Then the average SNR for SC is given as

$$\rho_{sc} = E\{\max_i(|h_i|^2)\}.\frac{E_x}{N_0}, \quad i= 1,2,\ldots\ldots,N_R \qquad (9)$$

In MRC, all N_R branches are combined by the following weighted sum

$$y_{MRC} = \underbrace{[W_1^{(MRC)} W_2^{(MRC)} \ldots W_{N_r}^{(MRC)}]}_{w^T} y = \sum_{i=1}^{N_R} w_i^{(MRC)} y_i \qquad (10)$$

Where y is the received signal in Equation (7) and w_{MRC} is the weight vector. As $y_i = \sqrt{E_x/N_0}\, h_i x + z_i$ from Equation (7), the combined signal can be decomposed into the signal and noise parts, [1] that is,

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$$y_{MRC} = w_{MRC}^T\left(\sqrt{\frac{E_x}{N}}h_x + z\right)$$
$$= \sqrt{\frac{E_x}{N}}w_{MRC}^T h_x + w_{MRC}^T z \quad (11)$$

Average power of instantaneous signal part and that of the noise part in equation (11) are respectively given as

$$P_s = E\left\{\left|\sqrt{\frac{E_x}{N}}w_{MRC}^T hx\right|^2\right\} = \frac{E_x}{N}E\{|w_{MRC}^T hx|^2\} = \frac{E_x}{N}|w_{MRC}^T h|^2 \quad (12)$$

And

$$P_z = E\{|w_{MRC}^T z|^2\} = \|w_{MRC}^T\|_2^2 \quad (13)$$

From equation (12)(13), the average SNR for the MRC is given as

$$\rho_{MRC} = \frac{E_x|w_{MRC}^T h|^2}{N_0\|w_{MRC}^T\|^2} \quad (14)$$

Invoking the Cauchy-Schwartz inequality,

$$|w_{MRC}^T h|^2 \le \|w_{MRC}^T\|_2^2\|h\|_2^2 \quad (15)$$

Equation (14) is the upper-bounded as

$$\rho_{MRC} = \frac{E_x|w_{MRC}^T h|^2}{N_0\|w_{MRC}^T\|^2} \le \frac{E_x\|w_{MRC}\|_2^2\|h\|_2^2}{N_0\|w_{MRC}^T\|_2^2} = \frac{E_x}{N_0}\|h\|_2^2 \quad (16)$$

Note that the SNR in Equation (16) is Maximized at $w_{MRC} = h^*$, which yields $\rho_{MRC} = E_x\|h\|_2^2/N_0$. In other words, the weight factor of each branch in equation (10) must be matched to the corresponding channel for maximal ratio combining (MRC). Equal gain combining (EGC) is a special case of MRC in the sense that all signals from Multiple Branches are combined with equal Weights. In fact, MRC achieves the best performance maximizing the post-combining SNR. [1],[3],[5]

3. Results

3.1 MIMO with No CSIT for Fast Fading Channels

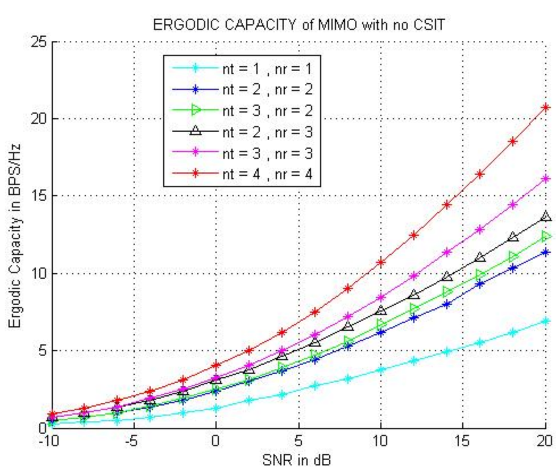


Fig 7. Ergodic Capacity with no CSIT

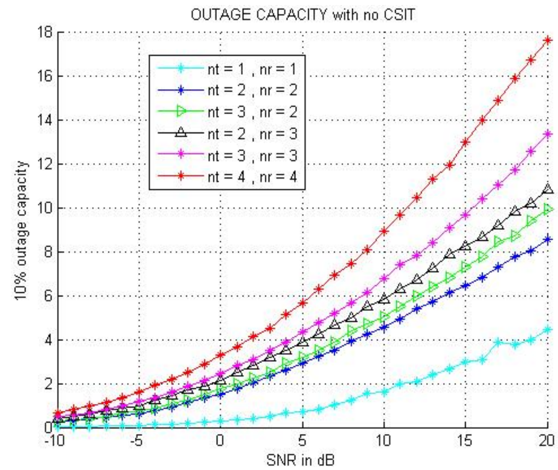


Fig 7. Outage Capacity with no CSIT

3.2 MIMO with CSIT for Slow Fading Channels

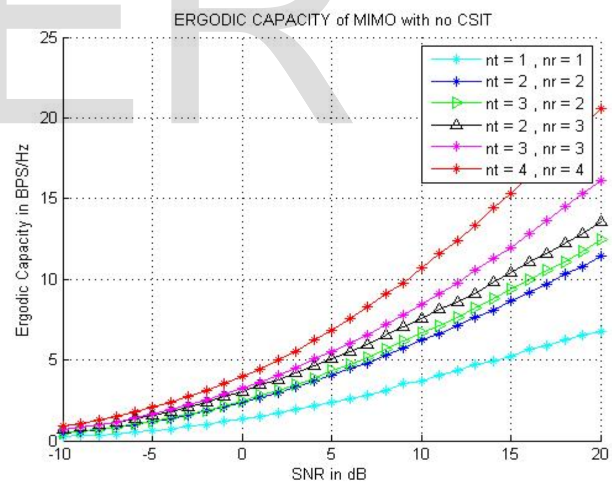


Fig 8. Ergodic Capacity with CSIT

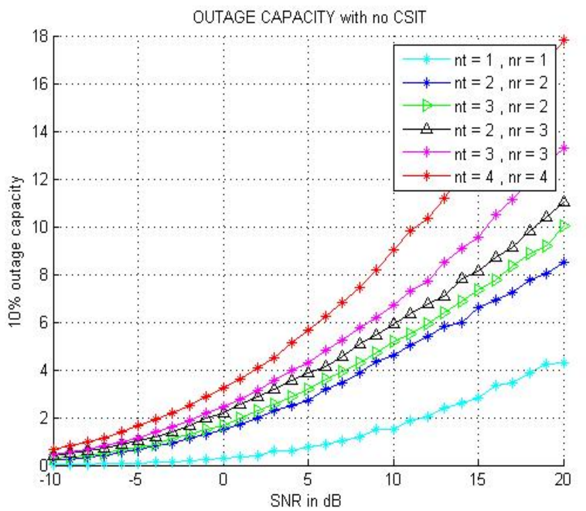


Fig 9. Outage Capacity with CSIT

3.3 INFLUENCE OF SPATIAL FADING CORRELATION

The signal components at a particular point in space may experience correlation due to the finite separation distance between the antenna elements.

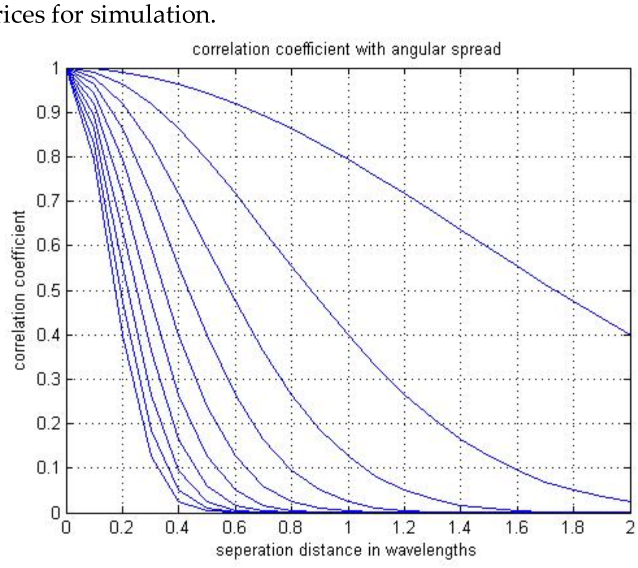
The spatial cross-correlation function, p(r) determines the correlation between voltages envelopes separated in space by **a** distance r.

$$r(d) \approx \exp\left(-23.\Delta^2.d^2\right) \quad (17)$$

Δ is the angular spread and *d* is the distance in wavelengths between the antenna elements [10]
Now, with fading correlation effect, we model the MIMO channel H as

$$H = R_r^{\frac{1}{2}} H_w R_t^{\frac{1}{2}}. \quad (18)$$

Where H_w is a N_r x N_t matrix with i.i.d complex Gaussian elements. R_r is N_r x N_r reception correlation matrix and R_t is N_t x N_t transmission correlation matrix. First model, in which these matrices are calculated as a function of distance between elements given by the following toeplitz structure correlation matrices for simulation.



$$R_T = \left| \; r_T^4 \quad r_T \quad 1 \quad \ddots \quad r_T^4 \; \right| \quad (19)$$

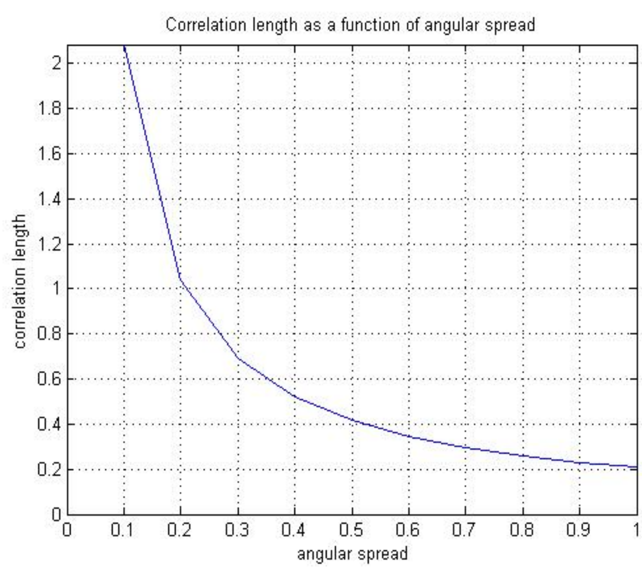
$$R_R = \left| \; r_R^4 \quad r_R \quad 1 \quad \ddots \quad r_R^4 \; \right| \quad (20)$$

where r_T and r_R is the fading correlation between two adjacent antenna elements at TXer and Rxer respectively and it is approxmated by the expression given above.

Fig 10. Correlation coefficient with angular spread

Fig 11. Correleation length as a function of angular spread

3.4 STBC (Space Time Block Code)



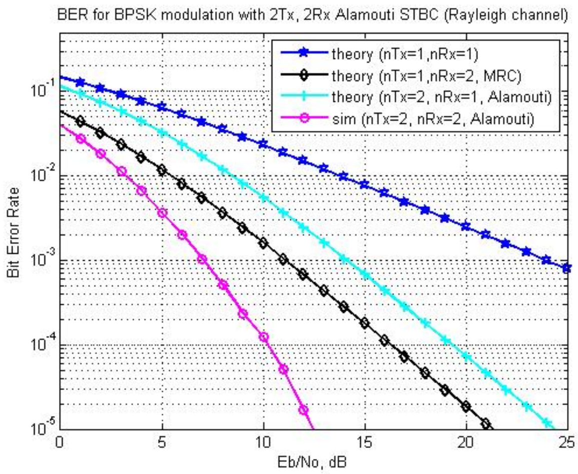


Fig 12. BER FOR BPSK modulation with 2Tx, 2Rx Alamounti STBC (Rayliegh Channel)

3.5 MRC (MAXIMAL RATIO COMBINING)

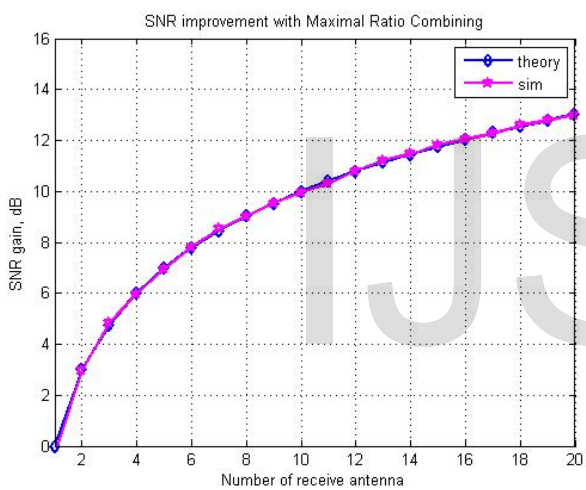


Fig 13. SNR improvement with Maximal Ratio Combining

4 CONCLUSION

This paper presents a detailed simulation of coding techniques for MIMO systems with and with out CSI, Spectral efficiency simulation for ergodic capacity and BER analysis is done. Different space-time block coding (STBC) schemes including Alamouti's STBC for different range of transmitter and receiver is done. Finally, these STBC techniques are implemented in MATLAB and analyzed for performance according to their bit-error rates. In this paper a complete approach and simulations is done for multi-antenna system with capacity and BER of SIMO and MISO systems in Rayleigh fading channels has been examined with CSI and without CSI(Channel state information). In case if channel state information (CSI) is available at the receiver and the transmitter does not know the channel information, it is best to distribute the transmit power P_T equally among the antennas and generate the channel matrix **H** and perform singular-value decomposition (SVD or generalized Eigen-value decomposition). Finally diagonalized the channel and removed all the spatial interference without any matrix inversions or nonlinear processing. If the CSI is also available at the transmitter (CSIT), the optimal power allocation can be derived by applying the well-known water filling assuming that the channel coherence time. At low SNR, CSIT will always helps in increasing the capacity and were as high SNR, CSIT increases capacity for systems with Nt > Nr and CSIT has no benefit for systems with Nt ≤ Nr.

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