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Channel Capacity of MIMO System in Rayleigh Fading Channel with Receiver Diversity Technique

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Abstract

In this paper, we have evaluated the channel capacity of SISO and MIMO system with respect to Rayleigh fading channel. We have compared the results with respect to different receiver diversity techniques like MRC, EGC, SC. We have presented the results of SER v/s SNR with respect to 16-QAM modulation technique. We have also presented the results of SNR v/s capacity of SISO and MIMO system. For simulation, we have used MATLAB R2014 software.

1 Introduction

In wireless communication era, one of the communication systems which is very famous for its antenna technology called as MIMO system in that multi antennas are used at transmitter and receiver side to increase the data rates and minimize the error in transmitted data without requiring additional bandwidth or transmit power. MIMO system are established due to the concept of diversity in which information signal transmitted over independent fading path using multiple antenna at transmitted side and same information signal received by multiple antenna at receiver side. By increasing the number of antenna we can improve the channel capacity for

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effective wireless communication system. So here we are comparing the channel capacity of different communication system by applying the different receiver diversity technique. We are correlating here channel capacity in terms of spectral efficiency with different receiver diversity technique like Equal Gain Combining, Selection combining, and Maximum ratio combining.

Channel Capacity:
Channel is a medium to forward information from source to destination. During this process, the information at destination may be distributed by noise as well as channel distortion. Here the two parameters are different in nature because channel distortions are fixed function while the noise is statistical and unpredictable in nature. Here, we are considering discrete time additive white Gaussian noise (AWGN) channel [4].

Here, g(t) is input and w(t) is output signal. The relation between input and output signal after transmitting through the channel is given by,

$$w(t) = g(t) + N(t) \quad (1)$$

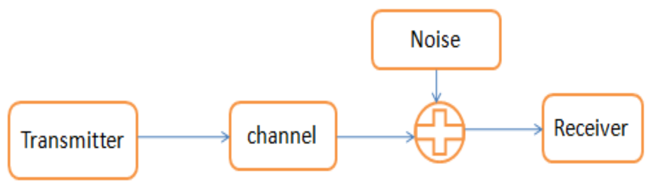
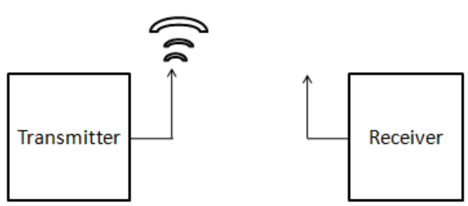


Figure 1: Discrete time AWGN Channel

From the Bulk of information, Let we transmit 'M' amount of signal states in a limited time duration 'T' over a communication Channel.
If T tends to infinity, The rate of transmission R approaches the channel capacity 'C' in terms of the number of bits per transmission.

2 Different Communication system with channel capacity

2.1 Single input single output (SISO) and Single input multiple output (SIMO) system



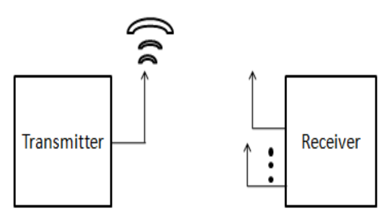


Figure 2: SISO System
Figure 3: SIMO System

Channel capacity of SISO system can be represented by

$$C = \text{Log}_2(1+ \alpha|y|^2) \quad (2)$$

Where, y is the normalized complex gain of fixed wireless channel and α is the SNR at the received antenna.

Channel capacity of SIMO system can be represented by,

$$C = \log_2 (1 + \alpha \sum_{i=1}^{m} |yi|) \tag{3}$$

2.2 Multiple input single output (MISO) and Multiple input multiple output (MIMO) system

The channel capacity of MISO system can be represented by

$$C = \log_2 (1 + \alpha/nt \sum_{i=1}^{nt} |yi|) \tag{4}$$

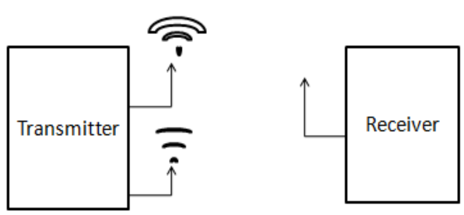
In equation, $y_{i,}$, i = 1,2……..n_t. represents the constant gain of the channel. which is established between the i_{th} transmitter antenna and the single receiver antenna over a symbol period. The unit of channel capacity is b/s/Hz.[4]

The channel capacity of MIMO system is given by

$$C = \log_2 (\det [I_m + (\alpha/N)\, y * y^y]) \tag{5}$$

In this equation, 'det' means determinant, I_m means n*m identity matrix transport conjugate, where the number of antenna 'n' and 'm' are important . the expected value function of capacity for a Rayleigh channel grows proportionally to 'm'.

$$E(c) = m * \log_2 (1+SNR) \tag{6}$$



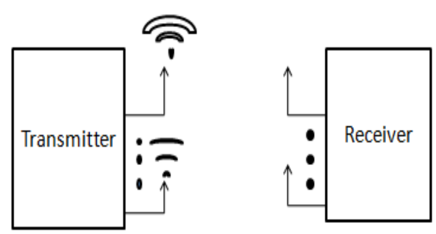


Figure 4: MISO System
Figure 5: MIMO System

3 Receiver Diversity technique

3.1 Selection Combining (SC) Technique

There are M multiple copies of information signal transmitted with M different channel. Here, SNR achieved at each channel is γ_i (i=1,2,……..M). The signal received is independent and Rayleigh distributed with mean power of $2\sigma^{2.}$ To combat small scale fading, we can use this type of microscopic diversity.

The PDF of Rayleigh distribution is given by,

$$P(\gamma) = (1 - \exp\left(\frac{-\gamma}{\gamma_0}\right))^M \tag{7}$$

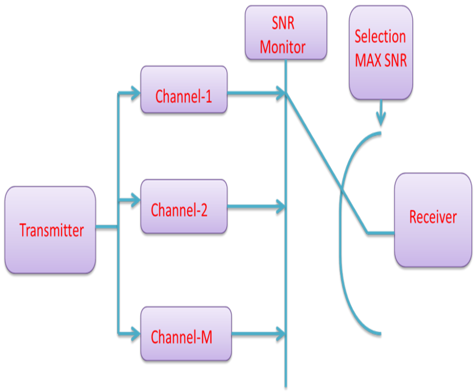


Figure 6: Selection Combining Diversity

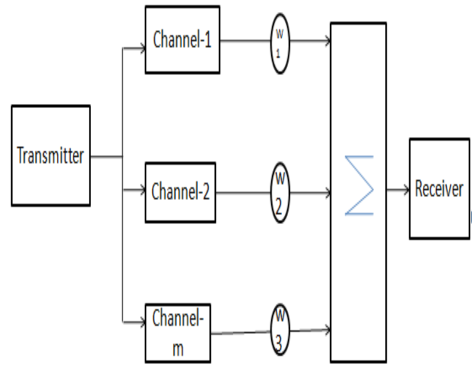


Figure 7: Maximum Ratio Combining

Average signal to Noise ratio due to selection diversity combining technique is

$$E[\max_i \gamma_i] = \gamma_0 \sum_{K=1}^{M} \frac{1}{K}$$

$$E[\max\{\gamma_i\}] = \int_0^{\infty} \gamma p(\gamma) d\gamma \tag{8}$$

3.2 Maximum Ratio Combining (MRC) Technique

At the receiver side, Summing and phase matching are done with the appropriate circuit.

$$a = \sum_{i=1}^{M} a_i g_i$$

Then the PDF of γ is given by

$$p(\gamma) = 1/(M-1)! * \gamma^{M-1} / \gamma_0^M * \exp(-\gamma/\gamma_0) \quad \text{with } \gamma \geq 0;$$

$\gamma 0$ is the mean SNR in each branch and is given by $2\sigma^2$ Eb/N

The CDF of γ is

$$P(\gamma) = \int_0^{\gamma} \frac{1}{(M-1)!} \frac{x^{M-1}}{\gamma_0{}^M} \exp\left(-\frac{x}{\gamma 0}\right) dx$$

$$= 1 - \exp\left(-\frac{\gamma}{\gamma_0}\right) \sum_{i=1}^{M} \frac{1}{(i-1)!} \left(\frac{\gamma}{\gamma_0}\right)^{i-1} \tag{9}$$

3.3 Equal Gain Combining (EGC) Technique

In this method g_i of MRC scheme are all made equal to 1, For all i =1,2,….M. So, problem of co-phasing is resolved in this technique. [3]

$$a = \sum_{i=1}^{M} a_i$$

and the resulting SNR is [3]

$$\gamma = a^2 E_b / (M * N_0) = E_b / (M * N_0) * (\Sigma ai)^2 \tag{10}$$

Where γ is the parameter associated with Rayleigh random variable.

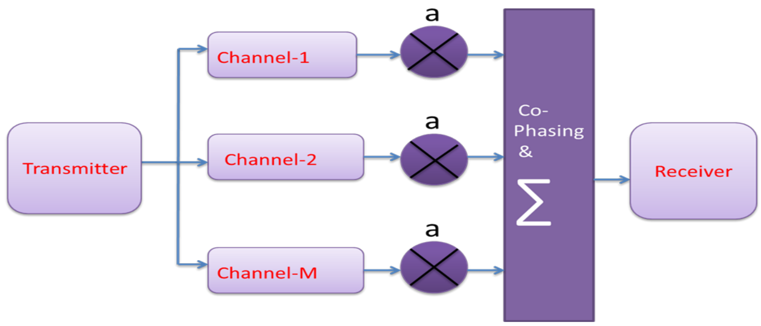


Figure 8: Equal Gain Combining

4 Simulation Results

4.1 Channel Capacity of SISO and MIMO System

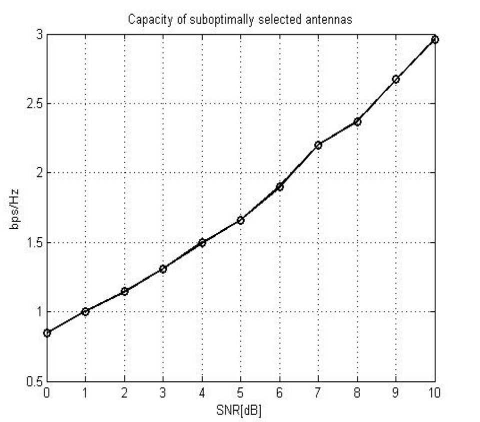


Figure 9: SNR v/s channel capacity of SISO system

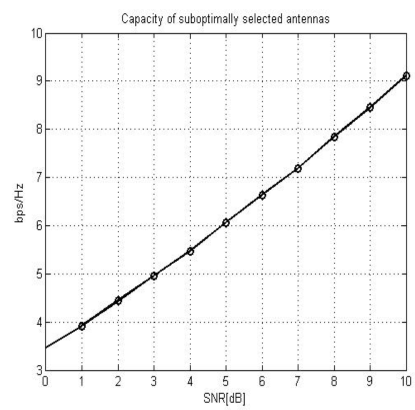


Figure 10: SNR v/s channel capacity of MIMO system

4.2 Simulation Parameters of SISO and MIMO System

SNR (dB)	No.of tx ant.	No.of rx ant.	Speed(bps/Hz)
1	1	1	1
3	1	1	1.4
6	1	1	1.9

Table 1: Simulation Parameters of SISO System

SNR (dB)	No.of tx ant.	No.of rx ant.	Speed (bps/Hz)
1	2	2	4
3	2	2	5
6	2	2	6.88

Table 2: Simulation Parameters of MIMO System

4.3 SNR Vs SER for 16-QAM with Selection combining, Equal Gain combining, Maximum ratio combining receiver diversity technique

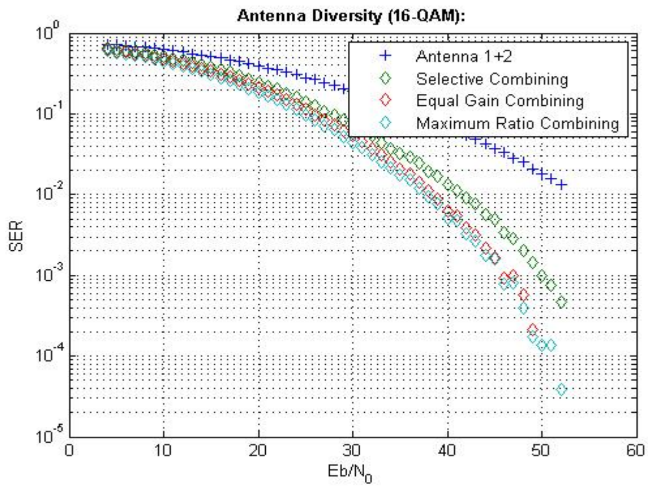


Figure 11: SNR v/s SER for 16-QAM modulation technique with different receiver diversity types

5 Conclusion

We have concluded that as we increase the number of antenna the SER performance is improved. Compared to SISO and MIMO system, in MIMO system the lowest value of SER is achieved. We have also concluded that spectral efficiency or capacity of MIMO system is much higher than SISO system. We have also concluded that compared to all receiver diversity technique in MRC technique the value of SER is lowest.

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