International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 6 Issue 3, March-2017

To Analyze the MIMO Channel Capacity

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ABSTRACT

In this thesis, the analysis of channel capacity has studied which depends on various parameters. The ergodic, outage capacity and the correlation effects on capacity has analyzed when CSI is available or not at both the sides. This thesis also analyzes the BER performance of the MIMO channel with different detection or equalizing techniques in Rayleigh fading channel with appropriate results using MATLAB.

Keywords: MIMO channel capacity, deterministic capacity, Ergodic capacity, CSI, Correlation, ZF, MMSE-SIC.

INTRODUCTION

MIMO system uses multiple input multiple output. They are defined by Spatial Diversity and Spatial Multiplexing.

A MIMO system is able to provide improved power and bandwidth efficiencies without use of extra bandwidth. Space-time coding schemes(STBC) have been designed for MIMO single-user systems to achieve diversity gain or achieve high data rates by taking advantage of multiplexing gain of MIMO systems[26]. As defined by [8] STBC offers high diversity gain and among which orthogonal STBC are very attractive due to its simple design and low decoding complexity. One drawback of orthogonal STBC is that it is not bandwidth coefficient, so various kinds of ST codes had been proposed and because of its low decoding complexity and full diversity, so it can be reliably used in wireless communication [29].

MIMO Channel

Consider a MIMO channel as shown in Fig. 1.2 with K transmit and M receive antennas (if K = 1, it is SIMO, if M = 1, it is MISO, and if K = M = 1, it is a SISO system). There are K ×M paths and each path has a channel response denoted by hi j, which is between ith receiver and jth transmitter.

The MIMO channel (H) is shown below,

H= $h \quad \cdots \quad h$
$\vdots \quad \ddots \quad \vdots$

if the transmitted signal is, h
x = [, ,... ... ...]

The signal received at the receive antenna is as follows:

$$= \quad + $$
$$\times \quad \times \quad \times \quad \times$$

Where n is the noise vector consisting complex-gaussian elements with zero mean and variance .

II. MIMO CHANNEL CAPACITY

Channel capacity is a measure of how much information transmitted and received with a negligible probability of error. The channel capacity can be defined in terms of CSI available or not. The Deterministic Channel Capacity can be defined in a spatial multiplexing system in a frequency non-selective fading channel and is defined as-

C = max ( ) log & +

— bps/ Hz

When CSI is unknown

It is a condition when transmitter have no idea about channel information and is available at receiver side then, the equal power spread equally among all the transmit antennas. The channel capacity is given as

C = log & +

= $\sum$ log 1 + —

Where

( ) and

with,

When CSI is Known

The main tool for performing the maximization is a technique, which is commonly referred to as water-filling algorithm. The capacity can be maximized by solving the power allocation problem-

C = max{ } $\sum$ log 1 +

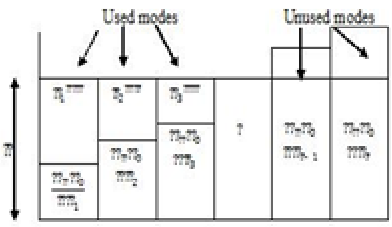

Fig. 1 Water Filling Algorithm

The solution to optimization problem is given as:

@ = – —— , i = 1,2……r

The above equation shows the water filling algorithm and is illustrated in fig. It shows that high power must be allocated to those modes which has high SNR and when SNR drops below the threshold, then the modes must not be used and hence, no power is allocated to them.

III. ANAYSIS OF CHANNEL CAPACITY

In this section various capacities analyzed in terms of its ergodic and outage capacities. Generally, MIMO channels are random in nature and therefore, we assumed H is a random matrix, which means that its channel capacity is randomly time-varying.

G = E{ ( )}

=E max (·) log & +

This is known as ergodic channel capacity. The **outage capacity** is another measure of channel capacity that is used frequently. It is associated with an outage probability. The capacity may be regarded as random variable which depends on channel response and remains constant during the transmission of block coded information. If the channel capacity drops below the outage capacity, then there will be no possibility of error free decoding of block coded information.

Correlation in MIMO System

The channel correlation is related to the MIMO channel capacity.

C=log & +
/ /

Equalizers

The wireless technology offers better quality video, pictures, voice etc. Communication generally impaired by multipath fading which causes intersymbol interference (ISI) in the received signal at receiver end. To reduce or eliminate ISI, a strong detector must be used or different equalization techniques are used which compensate it by using channel impulse response.

Types of Equalizers-
1. Linear Signal Detection

This detection method detects the desired signal from the target transmit antenna and the interferences from the signals of other transmit antenna are minimized. The linear detection includes two techniques namely zero forcing and MMSE technique.

a) Zero Forcing Detector

It is a linear equalization technique and is inverse of the frequency response of the channel. It restores signals after the channel by using inverse of channel frequency response of received signal. It allows recovery of signals when the channel information is known. It reduces mainly ISI to zero by using appropriate linear time invariant filter.

2. MMSE Detector

It is a method which reduces the mean square error and is the optimal detection that seeks balance between cancellation of the interference and reduction of noise. It uses the squared error as performance measurement. It allows some residual ISI to minimize the overall distortion, as it does not completely exclude ISI [3]

MSE-Let z be an unknown random variable and ybe a known random variable. An estimator is any function of the measurement y and MSE is given as

P = {(̂−)}

The linear MMSE estimator is that estimator which achieves minimum MMSE.

2. Maximum Likelihood Detector

It detects the Euclidean distance between received signal vector and all possible transmitted signal vectors. ML detector is the optimal receiver in terms of bit error rate but it is a known linear detector with high complexity.

3) MMSE–SIC

In this section we can now define the basic bank of linear MMSE receivers by allowing successive cancellation of streams as well.The bank of linear MMSE receivers with successive cancellation and equal power allocation achieves the capacity of the i.i.d. Rayleigh fading channel.

IV. SIMULATION RESULTS

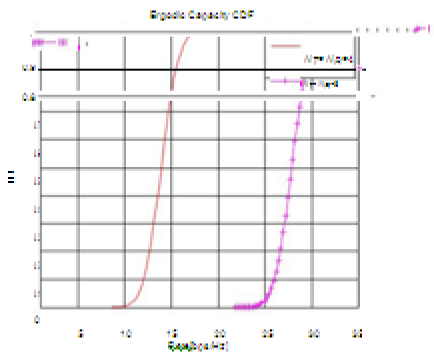

Fig. 2 Ergodic Capacity CDF

The CDF of the Ergodic capacity of 4x4 and 8x8 MIMO is shown in Fig. In this figure, it shows that the capacity increases when number of antennas increases.

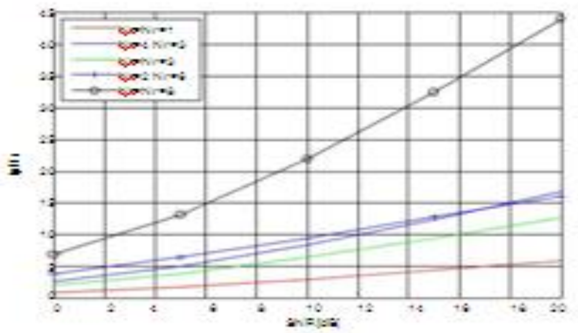

Fig. 3 Ergodic channel capacity when CSI is unknown

The Fig. shows the Ergodic channel capacity for various values of SNR

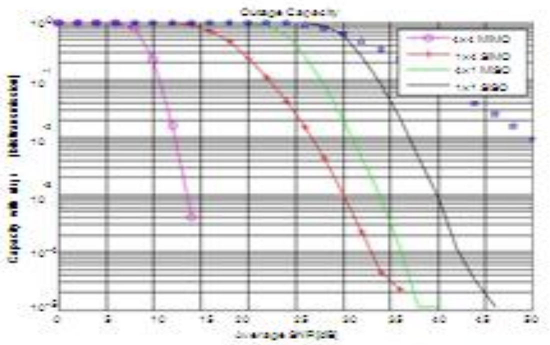

Fig. 4 Capacity with the Outage

The Fig.3 above shows the outage capacity of different schemes. If received SNR value is less then there is probability that burst cannot be decoded properly. Thus receiver declares as outage.

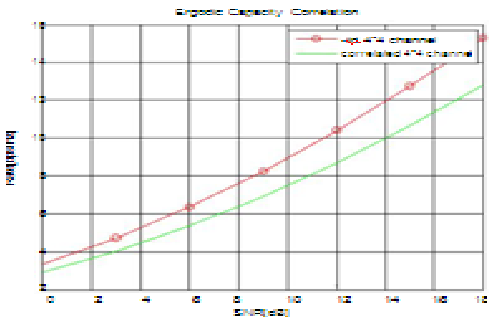

Fig. 5 Channel Correlation

Due to correlation channel capacity decreases. The BER performance of all the techniques are shown below and it shows that MMSE-SIC is the best technique to work with as it provides better efficiency and throughput.

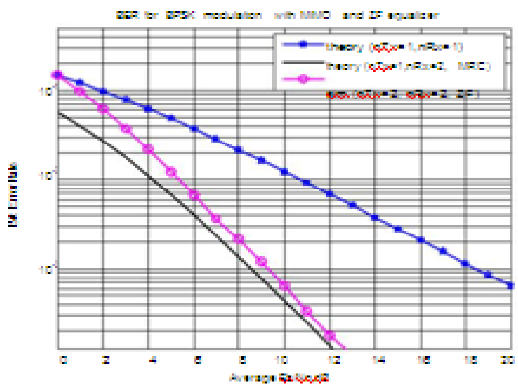

Fig. 6 BER for BPSK modulation with MIMO and ZF

ZF equalizer shows its performance by changing the values of ⁄ and reduces the bit error rate. It is shown that the bit error rate decreases and gives its throughput

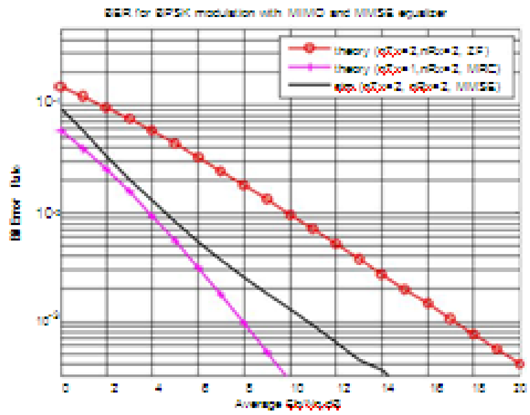

Fig. 7 BER for BPSK modulation with MIMO and MMSE

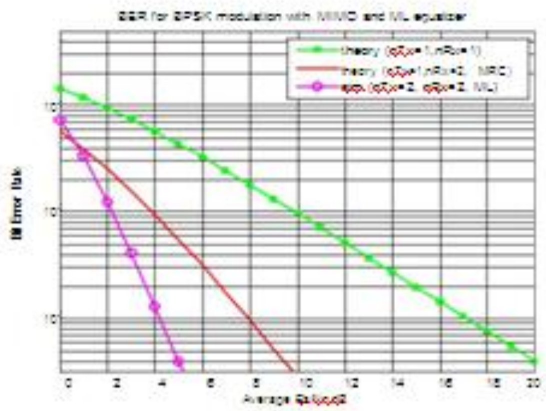

Fig. 8 BER for BPSK modulation with MIMO and ML

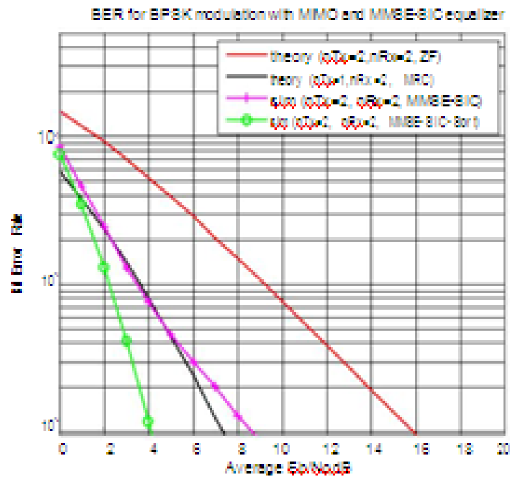

Fig. 9 BER for BPSK modulation with MIMO and MMSE-SIC

The Fig.7 shows the BER performance for ZF equalizer and MMSE-SIC and shows the comparison and it is concluded that the MMSE-SIC shows the better performance and capacity by reducing the bit error rate.

CONCLUSION

The capacity of MIMO system increases by increasing the number of antennas but somehow, it increases the complexity of the system. The MIMO reduces BER and increases the capacity. The CSI highly affects the capacity of the system, when it is not present at the transmitter side. Correlation also plays its important role in capacity. It reduces the capacity and becomes Gaussian channel.

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