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Characteristic Parameters Evaluation for MIMO based Communication Systems

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Abstract *:*

MIMO systems i.e. multiple input multiple output systems are the systems which are largely employed for increasing channel capacity and thereby increasing the data rate of the system. The MIMO system helps in increasing the spectral efficiency of a communication system by increasing the number of transmitting and receiving antennas. In this paper, we demonstrate how capacity and spectral efficiency increases with the increase in the number of antennas at the transmitter side. The paper is based on open-loop analysis i.e. the transmitter does not have any knowledge regarding the channel. The implementation is done using MATLAB.

Keywords- MIMO Systems, Spectral Efficiency, Shannon Capacity

I. INTRODUCTION

The concept of Multiple- antenna systems was introduced when the need of higher data rate with limited amount of bandwidth was demanded [3]. Spatial Multiplexing using MIMO was proposed in 1993 by Arogyaswami Paulraj and Thomas Kailath. In 1994, the applications to broadcast wireless got more emphasis. In 1996, Greg Raleigh and Gerard J. Foschini introduced new approaches to MIMO technology to refine or to improve the link throughput effectively using multiple antennas at the transmitter side[8].

In 1998, Bell Labs demonstrated a laboratory prototype of spatial multiplexing (SM) to improve the performance of MIMO communication systems where spatial multiplexing is a principal technology. As RF technology is becoming more widespread, more MIMO routers and other items of wireless MIMO equipment will be employed [2]. The initial work on MIMO systems focused on basic spatial diversity - here the MIMO system was used to limit the degradation caused by multipath propagation. However this was only the first step as system then started to utilize the multipath propagation as advantage, i.e. multipath can take advantage by considering additional channels to carry additional data or we can say, to use different paths to carry same data[5].

Limitations associated with MIMO technology as a result of Shannon's Law is the multipath interference, and the data throughput. Unlike, MIMO systems provide a significant capacity gain over

conventional single antenna systems, along with more reliable communication [5]. The benefits of MIMO lead many to believe that it is the most promising of new developing wireless technologies. With the help of table written below, we can have clear idea of how tremendously the users for internet are increasing. And so the requirement for the analysis of different parameters discussed has been increased.

World regions	Population	Internet users in 2000	Internet users in 2011
ASIA	3,879,740,877	114,304,000	922,329,554
AFRICA	1,037,524,058	4,514,400	118,60,620
AMERICA	347,394,870	108,096,800	272,066,000

Table:1 Number of internet in different countries

Thus with the increase in the number of internet users the need for the analysis of different parameter for communication system increases, as the MIMO technology is a technique which is highly required for the internet.

II. MIMO SYSTEMS

Information handling MIMO systems are multiple input and multi output systems where at both the sides of communication i.e. at the transmitter side and receiver side, multiple transmitters are employed. With the increase in number of antennas there are lot of changes that could be observed in the communication system. There are advantages and lots of other things to be taken care of. For example the complexity of the system increases with the increase in the number of antennas. Also the interference due to each antenna to every other antenna also increases. So we have to compute the capacity of the system to find the effect of interference and noise in the system [6].

Capacity in the channel is termed as channel capacity. There are parameters which effects channel capacity:

- The attenuation of a channel which varies with frequency as well as channel length.
- The noise induced into the channel which increases with distance.
- Non-linear effects such as clipping on the signal.

Some of the effects may change with time e.g. the frequency response of a copper cable changes with temperature and age. Obviously we need a way to model a channel in order to estimate how much information can be passed through it. Although we can compensate for non linear effects and attenuation but it is extremely difficult to remove noise.

III. FACTS FOR THE MIMO SYSTEMS

We are here to discuss different parameters associated with the MIMO system and why the study of such parameter is important in any communication systems. We can also prove with the help of below discussion that the study of these parameters will definitely improve the system performance.

A. Channel:

Channel can be understood in many terms like a channel can be physical or logical source through which data source and data sink are connected or it can be said as a connecting path between home to destination.

B. Capacity:

It could be said as the maximum limit on data rate or information that could be sent over the channel. If the information rate R is less than C, then one can approach arbitrarily small error probabilities by using intelligent coding techniques. To get lower error probabilities, the encoder has to work on longer blocks of signal data. This entails longer delays and higher computational requirements. Thus, we can say that the transmission of the information can be done without errors, even in the presence of noise with the following condition:

$$\text{If} \quad R \leq C \qquad (1)$$

C. Spectral Efficiency

This is basically how well our bandwidth is utilized i.e. the maximum data rate that could be achieved in a given bandwidth. This could also be understood as the maximum no. of users that could use the spectrum efficiently, in the presence of noise. It could be calculated in (bits/s)/Hz. I could also be understood as the total data to be transmit per second per bandwidth from transmitter to the receiver[1].

The theoretical maximum limit on the capacity of channel is given by the below written below and was given by Shannon's law. The graph for MIMO system has been proposed with the capacity formulae given by shannon's law i.e.

$$C = W \log_2(1 + S/N) \qquad (2)$$

Where C = capacity of system in bits per sec, W is bandwidth in hertz, S/N is the signal to noise ratio[7]. Although the formula gives the maximum limit but the capacity of the channel can be increased by the use of some high order modulation technique but the signal to noise ratio should be higher as compared with the low order modulation technique.

The calculation for the spectral efficiency could be done in accordance with the thought that the spectrum efficiency is, how well the transmitted data could be sent within the bandwidth with no loss of

information. Therefore we can say that the bandwidth is fully utilized with no loss of information. We will define spectral efficiency as:

Spectral efficiency(η) = C/B Hz (2)

where B is the bandwidth and C is the capacity of the channel.

I. RESULT

Here, the experimentation has been done for the behavior of the spectral efficiency and the channel capacity for different number of antennas, considered at any side of transmission either receiver or transmitter.

Here, behavior of Spectral efficiency has been studied with the help of eq.(2).

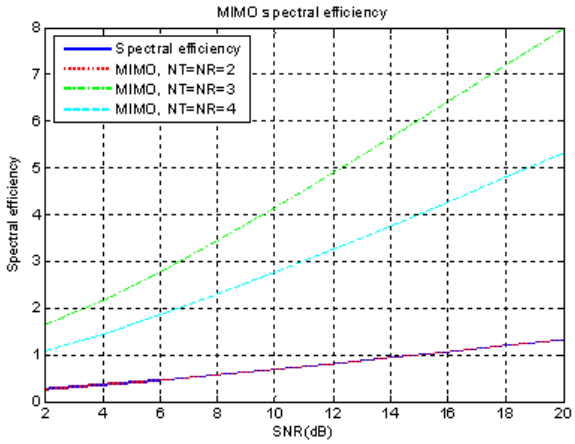

figure:1 Spectral efficiency of MIMO system

Further, study has been done on the channel capacity where we have proved with the help of graphical representation that the number of bits sent per second from the transmitter to the receiver increases as we increase the number of antennas. That is, the capacity varies linearly with the increase number of antennas.

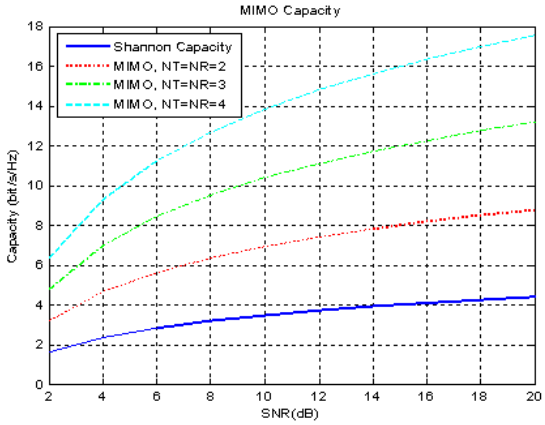

figure:2 Channel capacity for the MIMO system

Here all the analysis has been done for maximum up to 4*4 antennas i.e. 4 transmitters and 4 receivers as the maximum limit. Also we have considered the equal number of antennas both sides at time. As we can see from the above graphs, we have calculated for the capacity for different number of transmitter antennas and the receiver antennas. And we can also say that the capacity of the system increases with the increased number of antennas, which is why we say that the MIMO system are used to increase the channel capacity.

Number of Antennas	Channel Capacity(bits/s/Hz)	Spectral efficiency
NR=NT=1	1.6	0.2
NR=NT=2	3	0.3
NR=NT=3	5	1.1
NR=NT=4	6.2	1.8

Table:2 Analysis of Capacity and Spectral efficiency

Also we can notice from figure 1, with increased number of antennas at both sides, the spectral efficiency is increasing. And this a reason why it is said that the spectrum is better utilized or we can say that the bandwidth efficiency has been realized in MIMO systems.

CONCLUSION

The need of high capacity with increasing subscribers has highlighted the use of MIMO systems. This paper analyzed the capacity and spectral efficiency of communication systems using MIMO. It is shown that with the help of increased number of antennas at the transmitter and the receiver side the capacity as well as the spectral efficiency in the system is increased. This work can further be extended by analyzing more performance parameters and implementing it with real time communication systems mixing with diversity techniques.

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