Performance Analysis of MIMO Antenna Systems Over Rayleigh Fading Channel

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Abstract--- MIMO (multiple input, multiple output) is an antenna technology for wireless communications in which multiple antennas are used at both the source (transmitter) and the destination (receiver). The antennas at each end of the communications circuit are combined to minimize errors and optimize data speed. MIMO is one of the several forms of smart antenna technology. As compared to the conventional single-input single output(SISO) systems. This is due to the high spectral efficiency of a MIMO channel and it offers significant capacity gain as compared to a conventional SISO channel. In this paper the capacity of Raleigh fading MIMO channel is investigated. The receiver or at the transmitter or at both consider being vital part in information transfer across the channel. MIMO technology has aroused interest because of its possible applications in digital television (DTV), wireless local area networks (WLANs), metropolitan area networks (MANs), and mobile communications. By using MATLAB tool simulating the effectiveness of Rayleigh fading MIMO channel capacity over SISO channel. and by increasing the number of transmitting and receiving antennas for a wireless MIMO channel will improve the channel capacity is to be observed.

Keywords--- SISO, MIMO, Raleigh Fading, Efficiency

I. Introduction

Compared with wired communication the wireless communications offers a number of significant benefits. To meet the recent and future demand of the users, wireless systems continue to struggle for high data rate. The channel capacity of a MIMO antenna system can be significantly improved over conventional SISO antenna systems. The use of multiple antennas we can overcome limitations of SISO antenna systems.Fading channels are common in today's wireless communication system. The term fading is used to describe the rapid fluctuations of the amplitudes, phases are multi-path delays of a radio signal over a short period of time or distance. This is most prominent when signal or path loss caused by the obstruction such as buildings, mountains and foliage between the transmitter and the receiver are ignored. Multipath signal propagation has long been through an impairment limiting the system capacity and reliable communication in wireless channels together with the constraint of signal power and bandwidth. However, with the introduction of new techniques, such as MIMO systems.Unlike the wired channels they are stationary and predictable, radio channels are extremely random and the analysis is very difficult and typically done in a statistical fashion. Various probability distributions have been used to model fading process. The most commonly used distribution is known as Rayleigh distribution, in which the time and frequency dependence of the transmitted signal is well understood. Fading plays a significant role in information recovery at the receiver in wireless communication system.This significant capacity improvement is opened up the research activity using multi-antenna at both the transmitter and receiver sides. This is an attractive solution to the high capacity demand for future wireless systems since it increases the capacity without using the extra bandwidth or transmitted power consumption. Since the MIMO channel can offer a significant capacity gain over a traditional SISO channel, MIMO systems are today regarded as one of the promising research area of wireless communication systems. Therefore, in this paper we analyze the capacity and performance of Rayleigh fading MIMO channel.

II. MIMO Antenna System Model

Where there are more than one antenna at either end of the radio link, these are termed MIMO-multiple input multiple output. MIMO can be used to provide improvements in both channel robustness as well as channel throughput.In MIMO systems a transmitter sends multiple streams by multiple transmit antennas. The transmit

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stream goes through matrix channel. The input and output relationship of MIMO link is commonly represented by the following vector notation

$$y = Hx + n \tag{1}$$

$$H = \begin{bmatrix} h_{11}h_{12}.........h_{1N_T} \\ h_{21}h_{22}.........h_{2N_T} \\ h_{N_{R1}}h_{N_{R1}}........h_{N_RN_T} \end{bmatrix} \tag{2}$$

We consider H is a random matrix, which means that its channel capacity is also randomly time-varying.

Fig 1 : MIMO - Multiple Input Multiple output

MIMO channel capacity will be given by

$$C = E\{C(H)\} = E\left\{T_r(R_{xx}) - N_T \log_2 \det\left(I_{N_R} + \frac{E_x}{N_T N_0}\lambda_i\right)\right\} \tag{3}$$

Which is frequently known as an ergodic channel capacity. Now the ergodic channel capacity without using CSI at the transmitter side is given as

$$C = E\left\{\sum_{i-1}^{r} \log_2\left(1 + \frac{E_x}{N_T N_0}\lambda_i\right)\right\} \tag{4}$$

Similarly, the ergodic channel capacity using CSI at the transmitter side is given as

$$C = E\left\{\sum_{i-1}^{r} \log_2\left(1 + \frac{E_x}{N_T N_0}\gamma_i^{opt}\lambda_i\right)\right\} \tag{5}$$

Where, $\gamma_i = E\{|x_i|\}$ is the transmitted power for the i^{th} trasmitting antenna and λ_i is the channel gain.

III. Rayleigh Fading Channel

When there are large numbers of paths, by the applying central Limit Theorem, each path can be modeled as a circularly symmetric complex Gaussian random variable with time as the variable. This model is called the Rayleigh fading channel model. When there is no line of sight that is no direct path between the transmitter and receiver then constructive and destructive natures of the multipath component in a fading channel can be approximated by the Rayleigh distribution. A circularly symmetric complex Gaussian random variable is of the form,

$$h = X + jY \tag{6}$$

Where, real X and imaginary Y parts are zero mean independent and identically distributed Gaussian random variables, respectively. For a circularly symmetric complex random variable Z,

$$E[h] = E\left[e^{j\theta}h\right] = e^{j\theta}E[h] \tag{7}$$

The statistics of a circularly symmetric complex Gaussian random variable is completely specified by the variance,

$$\sigma^2 = E\left[h^2\right] \tag{8}$$

The magnitude |Z| which has a probability density function as follows,

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$$p(z)=\frac{z}{\sigma^2}e^{\frac{-z^2}{2\sigma^2}},z\geq 0 \quad (9)$$

The received signal in a Rayleigh fading channel is

$$y = zx + n \quad (10)$$

Where, y is the received signals, h is Rayleigh fading channel response, x is the transmitted signals and n is the AWGN. As the channel is randomly various with time, so each transmitted signal gets multiplied by a random varying complex number h. Since h is modeled as a Rayleigh fading channel, the real and imaginary paths of the Gaussian distribution have a mean 0 and a variance of ½.

IV. Simulation Results

To compare the performance and capacity of a Rayleigh fading MIMO channel with SISO channel as a function of number of received antennas and a function of transmit antennas we conduct a MATLAB simulation 2*2 MIMO channel and 4*4 MIMO channel are used to show the advantages 4*4 MIMO channel configuration in term of its bps/Hz and average SNR over other channels.

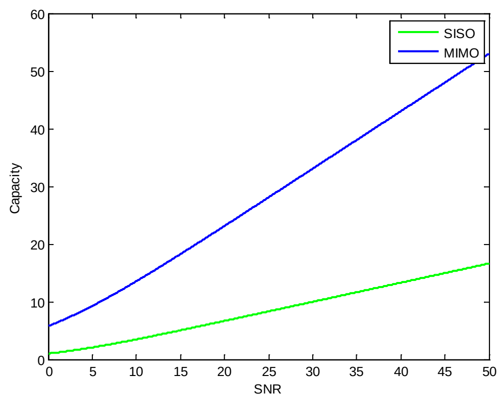

Fig. 2 : Channel Capacity Comparision between SISO and MIMO

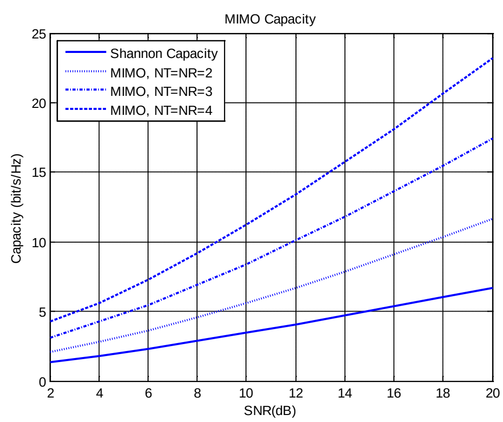

Fig. 3: MIMO Antenna Systems Channel Capacity Comparision Between 2x2,3x3,4x4 Configurations

V. Conclusion

The performance of MIMO channels capacity operating over Rayleigh fading channel from the simulation result it is clear that MIMO channels capacity improves with increasing the number of transmit and receive antennas .The Rayleigh fading MIMO channels with 4x4 antenna configurations provide better performance in term of its bps/Hz as compared to the 2x2 antenna configuration.

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