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Performance Analysis Of Rayleigh Fading Channel Over MIMO Wireless Communication System

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ABSTRACT: Multiple antennas at both the transmitter and receiver are used in Multiple-Input and Multiple-Output (MIMO) system to improve the efficiency of wireless communication. MIMO technology has fascinated attention; because it can significantly improves data throughput and wireless link coverage without additional transmit power or channel bandwidth constraint. In this research paper, the performance of Rayleigh fading channel in 3x3 MIMO systems with channel capacity and probability error is studied and investigated. Space-Time Block Code (STBC), an effective and efficient transmit diversity scheme is implemented in MIMO systems to investigate and analyze the performance of fading channel. Simulation model is implemented and experiments are performed using MATLAB simulation software by varying the Signal to Noise Ratio (SNR). Simulation result shows that the Rayleigh fading channel provides significantly higher channel capacity and lower probability error with a very little fluctuation with increasing SNR. The simulation result also clarify that 3x 3 MIMO systems outer perform with respect to channel capacity and probability error than 2X2 MIMO system which will be very helpful for high speed wireless communication system.

Keywords : Channel capacity, probability error, Rayleigh fading, STBC, and MIMO System

1. INTRODUCTION

Due to providing high data throughput and link range without additional bandwidth or transmit power restriction, MIMO technology has fascinated attention in wireless communication. It achieves this by granting higher spectral efficiency and link reliability or diversity to combat detrimental effect of wireless fading channel. Because of these properties, MIMO is an attractive issue for international researcher [1]. The multiple transmitting and receiving antennas permit MIMO systems to achieve multi-layer beam-forming, space-time coding (STC), and spatial multiplexing. Beam-forming transmits the same signal with different gain and phase over all transmit antennas in such a way that the received signal is maximized. Diversity consists of transmitting a STC stream throughout all antennas. Spatial multiplexing increases network capacity by splitting a high rate signal into multiple lower rate streams and transmitting them through the different antennas. In spatial multiplexing, the receiver can successfully decode each stream given that the received signals have sufficient spatial signatures and that the receiver has enough antennas to separate the streams [2]. Among two types of space time coding used in MIMO system, space-time block coding(STBC) provide better bit error rate performance, diversity gain and simple encoding and decoding system than space-time trellis coding(STTC) [3]. A wireless channel suffers from time varying impairments like multipath fading, interference and noise. Diversity and Rayleigh fading channel is robust and effective statistical model to combat the fading of the wireless channel [4]. Rayleigh fading channel refers to a multiplicative distortion h(t) of the transmitted signal s(t) and noise as, $y(t)=h(t).s(t)+n(t)$, where y(t) is the receive waveform and n(t) is the noise [10]. The Rayleigh fading is more reasonable model where the signal scattered between the transmitter and receiver. Sometimes Rayleigh fading is considered as the specialized model in heavily built-up city centre's when there is no distinct line-of-sight propagated signal between the transmitter and receiver and many buildings and other objects attenuate, reflect, refract, and diffract the signal [5]. For this reason many researcher proposed an improved reference model for simulation of Rayleigh fading channel [11] [12]. The purpose of this research is to study performance of STBC in fading channels and investigates the effects of channel capacity and probability error for analyzing the Rayleigh fading channel performance over 3X3 MIMO communication system.

2. MATHEMATICAL MODEL

In this paper we analysis Rayleigh fading channel performance using STBC (especially Alamouti‟s code) which is used to increase channel capacity, reliability of data transmission and decrease probability error by increasing diversity into 3X3 MIMO system.

2.1 SPACE TIME BLOCK CODE SCHEME

STBC is used for MIMO systems to enable the transmission of multiple copies of a data stream across a number of antennas and to extend the various received versions of the data to recover the reliability of data-transfer. STBC compensate for the channel problems such as fading and thermal noise [13]. When using STBC, the data stream is encoded in blocks former to transmission. These data blocks are then distributed among the multiple antennas and the data is also spaced across time. STBC is represented by MxN matrix where each row represents a time slot and each column represents one antenna's transmissions over time.

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Transmit antennas

Time-slots

$$\begin{pmatrix} S_{11} & S_{12} \dots \dots \dots \dots \dots \dots \dots S_{1N} \\ S_{21} & S_{22} \dots \dots \dots \dots \dots \dots \dots S_{2N} \\ \cdot & \cdot \qquad\qquad\qquad\qquad \cdot \\ \cdot & \cdot \qquad\qquad\qquad\qquad \cdot \\ S_{M1} & S_{M2} \dots \dots \dots \dots \dots \dots \dots S_{MN} \end{pmatrix}$$

Here, S_{ij} is the modulated symbol to be transmitted in time slot i from antenna j. There are T time slots and NT transmits antennas and NR receives antennas.

2.2 SIGNAL DETECTION SCHEME

The whole system for 3X3 diversity is illustrates the figure

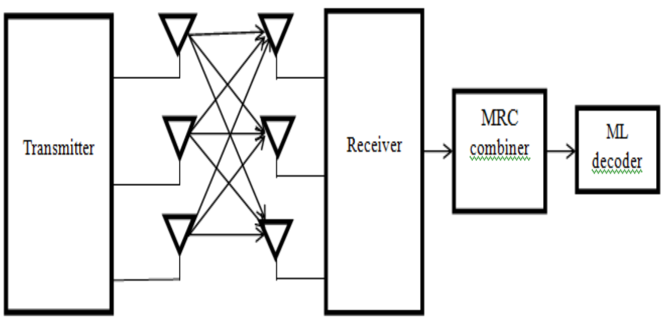

Fig.1.*MIMO system with 3X3 diversity*

The transmitting data Matrix, X is represented as

$$X = \begin{bmatrix} x_1 & x_2 & x_3 \\ -x_2^* & x_1^* & x_3 \\ x_3^* & -x_1^* & x_2 \end{bmatrix} \dots\dots\dots\dots\dots\dots \text{(1)}$$

The received signals $y_{11}, y_{12}, y_{13}, y_{21}, y_{22}, y_{23}, y_{31}, y_{32}$ and y_{33} are the combination of the signals from antennas 1, 2 and 3, plus additive noise. The received signals for 3x3 MIMO can be represented as

$$Y = Hx + n = h_1x_1 + h_2x_2 + h_3x_3 \dots\dots\dots\dots \text{(2)}$$

Where n is additive noise. This relation represents the transfer function between the transmit vector x of the STBC encoder and the receive vector y of the MIMO channel, where H is the orthogonal channel matrix of the equivalent channel formed by the Space Time (ST) encoder and the MIMO channel, n is the noise vector respectively. With perfect Channel State Information at the receiver (CSIR), we suppose to use the Maximal Ratio Combining (MRC) technique. Combining coefficients is optimally chosen which is equal to the complex conjugated equivalent channel matrix

$$X = H^H y \dots\dots\dots\dots\dots\dots \text{(3)}$$

Finally the combined symbols $\widetilde{x_1}, \widetilde{x_2}, \widetilde{x_3}$ are applied to a classical Maximum Likelihood (ML) decoder to obtain reliable estimations of the transmitted symbols. Even if a path is severely faded, we still may be able to recover the transmitted symbols through other propagation paths.

2.3 CHANNEL CAPACITY AND PROBABILITY ERROR EQUATION

Channel capacity is the highest rates at which information can be relatively send over communication channel and recovery the same information at the output with fading probability error [14]. Channel capacity can be measured by the following equation,

$$C = \log_2\left[\det\left(I_M + \frac{\xi}{N}HH^*\right)\right] \quad \text{Bit / Sec / Hz} \dots\dots \text{(4)}$$

Where det = determinant matrix, ξ = average SNR, I= identity matrix and H = transfer matrix. The probability error is the average number of bits received with error transmitted bits. In wireless channel it is difficult to get very small probability error due to multi-path fading but it is still possible to obtain it by using either transmit or receive diversity technique [14]. For MIMO system Probability error can be measured by the following equation,

$$P_b = 2Q\left(\sqrt{\frac{2Eb}{No}}\right) \dots\dots\dots\dots\dots\dots \text{(5)}$$

Where Q(x) is the Q-functions

$$Q(x) = \int_x^{\infty} \frac{1}{\sqrt{2\pi}} e^{-u^2}\, du \dots\dots\dots\dots \text{(6)}$$

Where Q(x) is approximated numerically, E_b is the average bit energy, E_s is the average symbol energy and N_0 is the noise power spectral density.

3. SYSTEM MODEL

The primary assumption in the context of system is considered 2x2 and 3x3 MIMO communication systems over Rayleigh Fading Channel. The information modulated using QPSK modulation. STBC is applying after modulating the original information and then transmitted that information through transmitting antenna. Then Rayleigh fading channel modeling is considered to analyze and investigate channel behavior and this model is used to determine the impact of the propagation parameters on the capacity of the channel. After channel modeling, transmitted signal are received at the receiver antenna. After that the received signal is processed for demodulation serially and then decoded the channel. Eventually, the transmitted information is retrieved.

4. SIMULATION RESULTS AND DISCUSSION

The result of this simulation study are separately considered the relation between channel capacity vs. SNR and probability error vs. SNR in Rayleigh fading channel over 3x3 MIMO communication systems. The simulation model parameters which have been considered for performance analysis are provided in table 1.

Table-1: *Summary of the simulated model parameter*

Antenna configuration	2x2, 3x3
Channel coding/Decoding	STBC
Modulation	QPSK
Channel	Rayleigh Fading Channel

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Code	Alamouti Code
SNR	-20, -10, 0, 10, 20, 30, 40 dB

Fig. 2 The relation between average channel capacity Vs. SNR for Rayleigh fading channel for 2X2 and 3X3 MIMO system.

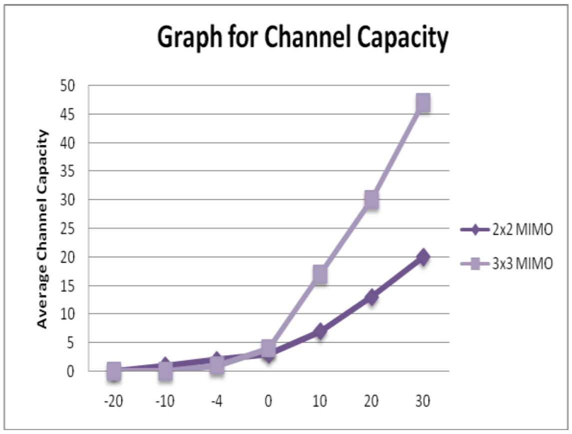

Fig. 2: *Average channel capacity Vs. SNR for Rayleigh fading channel for 2X2 and 3X3 MOMO system*

From Fig. 2 it is observed that for diversity 3X3 MIMO system, the average channel capacity start increasing slowly when SNR value is greater than -4 dB and after that channel capacity raises rapidly with increasing SNR. From fig. 2 it is also clarify that for diversity 2X2 MIMO system the channel capacity also starts growing gradually when SNR value is greater –10 dB and after that capacity increases quickly with increasing SNR. From fig. 2 it is seen that 3X3 MIMO communication system provides better performance than 2X2 MIMO communication system for Rayleigh fading channel. Because the capacity gain obtained for 2x2 and 3x3 MIMO system highly depends on the available channel SNR value, nature of CSI/CDI and co-relation between the channel gains on each antenna element. In MIMO communication system if the number of antenna element grows the capacity will increase. It increases linearly in proportion to large number of antenna elements. Fig. 3 shows the relation between probability errors Vs. SNR for 2x2 and 3x3 antenna for Alamouti code with QPSK over Rayleigh fading channel.

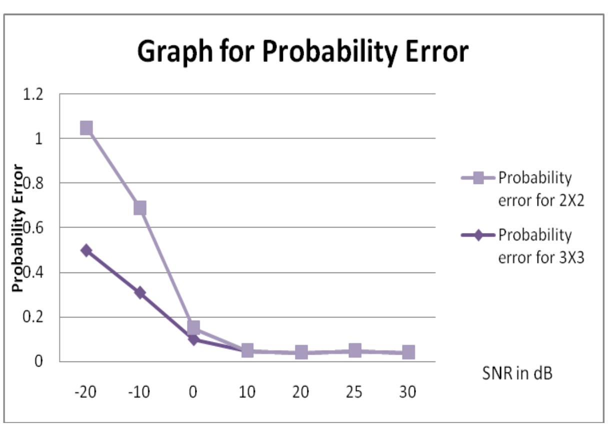

Fig. 3: *Probability error VS. SNR for 2X2 and 3X3 antenna for Alamouti code with QPSK over Rayleigh fading channel*

Fig. 3 illustrates that the probability error of both 2X2 and 3x3 MIMO systems are decreased exponentially with increasing SNR value. From fig. 3 it is also seen that 3X3 MIMO communication system provides lower probability error than 2X2 MIMO communication system for Rayleigh fading channel. After a certain time when SNR is greater than or equal to 10dB, the probability error provides nearly zero and constant value with a little fluctuation. So in case of probability error 3X3 MIMO communication system provide better performance than 2X2 MIMO communication system for Rayleigh fading channel. This is due to the fact that the probability error for wideband non-coherent MIMO channel depends on SNR value, diversity size and coherence length. With increasing SNR, the coherence length of MIMO channel is also increased and hence the channel probability error is decayed. We also show that the probability error of 3x3 MIMO systems is lower than 2x2 MIMO systems. This is because of the fact that the probability error decayed exponentially with the product of the number of transmit and receive antennas.

5. CONCLUSION

In wireless communication system, transmitting data with high rate requires higher channel bandwidth. MIMO communication system can transmit data with higher rate without supplementary bandwidth requirement. This paper analyzed and investigated channel capacity and probability error in case of MIMO communication system over Rayleigh fading channel. Rayleigh fading channel performance is increased significantly with increasing SNR in terms of probability error and channel capacity. Finally we compare the results on the channel capacity and probability error fading channel for both 2X2 and 3x3 MIMO communication system. 3x3 MIMO system provides robust performance with less probability error and higher channel capacity in terms of SNR.

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