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PERFORMANCE ANALYSIS OF MIMO WIRELESS SYSTEM WITH ARRAY ANTENNA

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ABSTRACT

High data rate in wireless communication is a great demand in modern age, but the limited available bandwidth motivates the investigation and new area of research in wireless systems. Increasing demand for higher wireless system capacity has catalyzed several transmission techniques, among which is the multiple-input/multiple-output (MIMO) technology has an attraction. In this paper, it has been compared among various multi-antennas (MA) at both the transmitter and receiver ends for significant capacity achievement. The use of antennas at both sides of the wireless communication link can result in high channel capacity provided the propagation medium is rich. Rayleigh fading has been considered as the propagation medium for verification. Also the performance has been measured in terms of bit error rate (BER) along with the capacity measurement. The result shows its performance. As the number of antennas to be increased for better performance, array structure is the suitable solution. The radiation pattern for linear array has been observed for maximum of 16 elements.

Keywords: MIMO, wireless, channel capacity, BER, multi-antenna, diversity.

1. INTRODUCTION

Wireless systems continue to strive for higher data rates. This goal is particularly challenging for systems that are power, bandwidth, and complexity limited. However, another domain can be exploited to significantly increase channel capacity by the use of multiple transmit and receive antennas. The employment of multiple antennas at both the transmitter and receiver, known as Multiple Input Multiple Output (MIMO) technologies, enables to greatly improve the link reliability and increase the overall system capacity. It is a method of transmitting and receiving two or more unique data streams through a single radio channel [1]. MIMO systems are equipped with multiple antennas, at both the transmitter and receiver in order to improve communication performance.

MIMO technologies overcome the deficiencies of the traditional methods through the use of spatial diversity. Data in a MIMO system is transmitted over *M* transmit antennas to *N* receive antennas supported by the receiver terminal. MIMO systems are used in wireless communication for enhancement of capacity and BER. Diversity gain and spatial multiplexing gain are the two main advantages of MIMO systems that are used to study the effect of increase in bit rate with increasing the number of transmitter and receiver antennas [2].

The spectral efficiency that can be exploited in MIMO systems depends on a number of phenomena, including the average received power of the desired signal, thermal and implementation-related noise, as well as co-channel interference [3]. In [4], authors investigate the effect of Rician factor (*K*) and the correlation coefficient (*r*) on the capacity and diversity of multi-input multi-output (MIMO) systems. In [5], authors investigate the capacity distribution of spatially correlated, multiple-input - multiple-output (MIMO) channels. In particular, authors derive a concise closed-form expression for the characteristic function (c.f.) of MIMO system capacity with arbitrary correlation among the transmitting antennas or among the receiving antennas in frequency-flat Rayleigh-fading environments. In [6], the paper reviews recent research findings concerning antennas and propagation in MIMO systems. MIMO systems have become an especially attractive potential solution for wireless applications that are inherently power and complexity limited [7]. The multiple antennas in MIMO systems can be exploited in two different ways. One is the creation of a highly effective antenna diversity system; the other is the use of the multiple antennas for the transmission of several parallel data streams to increase the capacity of the system [8]. For spatial MIMO configurations, all the sub channels of *H* are identically distributed. MIMO architecture has the potential to dramatically improve the performance of wireless systems [9]. A lot of attention has been drawn to systems with multiple element transmitter and receiver arrays, because they can achieve very high spectral efficiencies.

It is of great interest to characterize and model the MIMO channel for different conditions in order to predict, simulate, and design high performance communication systems. The simulation results shows that the performance of the MIMO system improves with the number of transmit and receive antennas in terms of capacity and bit error rate (BER).

The paper is organized as follows. Section-II describes the model approach and the performance measure of this work. Section-IV shows the result and finally section-V concludes the work along with the future direction.

2. PROPOSED MODEL

In MIMO systems, the propagation of electromagnetic waves from a transmitter to a receiver is characterized by the presence of multi-paths due to various phenomena such as reflection, refraction, scattering and diffraction and the performance of MIMO systems is largely dependent on the propagation medium.

By applying MIMO technology, we can directly take the advantage of two important properties, i.e., Diversity and Multiplexing. Diversity indicates the replicas of the signal, bearing the same information at the receiving end and Multiplexing is a transmission technique in MIMO wireless communication to transmit independent and separately encoded data signals, so-called streams from each of the multiple transmit antennas. Therefore, the space dimension is reused, or multiplexed, more than one time. The simplified model for the MIMO system can be characterized by its impulse function. The input-output relation using the transmitted and received signal along with the channel noise can be represented by equation (1).

The elements of narrowband MIMO channel matrix are assumed to be independent and identically distributed (i.i.d.) to study the MIMO channel capacity. In reality, however, due to insufficient spacing between antenna elements and limited scattering in the environment, the fading is not always independent causing a lower MIMO channel capacity compared to the ideal, i.i.d. case. Therefore the proposed MIMO channel models should take this effect into account.

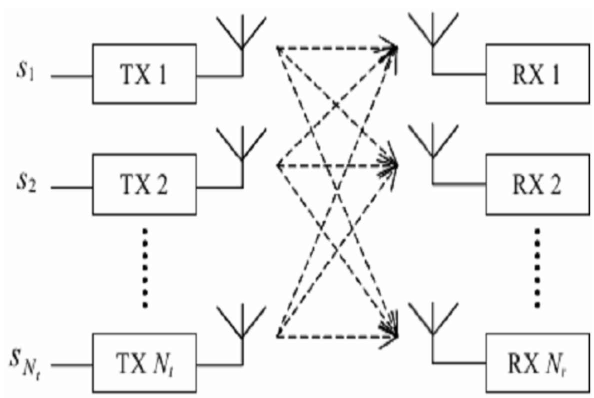

Figure-1. MIMO system with *m* transmits and *n* receive antenna elements.

$$y^{(f)}=H^{(f)}x^{(f)}+n^{(f)} \quad (1)$$

where

$x^{(f)}=[x_1^{(f)},....,x_N^{(f)}]$, transmitted signal
$y^{(f)}=[y_1^{(f)},....,y_N^{(f)}]$, received signal
$n^{(f)}=[n_1^{(f)},....,n_N^{(f)}]$, is additive white Gaussian noise (AWGN).
$H^{(f)}$ is the Channel impulse response matrix

The assumptions have been made for evaluation is as follows:

a) The fading at the different antenna elements is assumed to be i.i.d Rayleigh fading. This is fulfilled if the directions of the multipath components at the transmitter and receiver are approximately uniform. Also the antenna elements are spaced far apart from each other.
b) The flat fading can be satisfied provided that the coherence bandwidth of the channel is significantly larger than the transmission bandwidth.
c) It has been assumed that the receiver has perfect knowledge of the channel. For the transmitter, we will analyze both cases where the transmitter has no channel knowledge, and where it has perfect channel knowledge.
d) When talking about capacity, we also assume that the channel is quasi-static. By quasi-static, we mean that the coherence time of the channel is so long that "almost infinitely" many bits can be transmitted within this time. Thus, each channel realization is associated with a (Shannon - AWGN) capacity value. The capacity thus becomes a random variable, described by its cumulative distribution function (cdf).

A. Channel capacity and BER

It is well known from Shannon's theorem that a particular SNR can give only a fixed maximum capacity [10]. In the system it has been considered that for the fading channel, the SNR constantly changes. As the rate of fade changes, the capacity changes with it. The channel capacity can be represented as:

$$C = B\ \log_2(1+SNR) \quad (2)$$

For a Correlated-MIMO system the channel capacity is expressed as:

$$C = M \log_2 \det\,(I+SNR) \quad (3)$$

where

C = channel capacity
M = M is the minimum of N_T and N_R
I = identity matrix
N_T = number of transmitting antennas
N_R = number of receiving antennas

The channel capacity gradually increases, with increase in number of transmitting and receiving antennas. The BER is an approximate estimation of the bit error probability. The number of bit errors is the erroneous number of received bits of a data stream over a communication channel. The error may cause due to noise, interference, distortion or bit synchronization. BER for QPSK modulation is given by:

$$BER = \frac{1}{2}\ erfc\ \sqrt{(\frac{2E_b}{N_o})} \quad (4)$$

where

E_b = Energy per bit
N_o = Noise spectral density

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3. ARRAY ANTENNA

Antenna array on a single structure can achieve better performance than the use of multiple antennas. Since the electromagnetic signal received by each antenna array element differs from the signals received by other array elements in terms of amplitude and phase, they must be combined coherently to achieve the desired output. Though it is more complex to set up an antenna array compared to a single antenna, weighting the signals before combining them enables enhanced performance features. In linear antenna array, all the antenna elements are rearranged in a single line with equal spacing between them. The array factor for *N* number of elements were considered and assumed that the elements of an array are spaced linearly and separated by $\lambda/2$ where λ is the wave length [11-12]. The basic linear array structure for *N* number of elements is shown in the Figure-2.

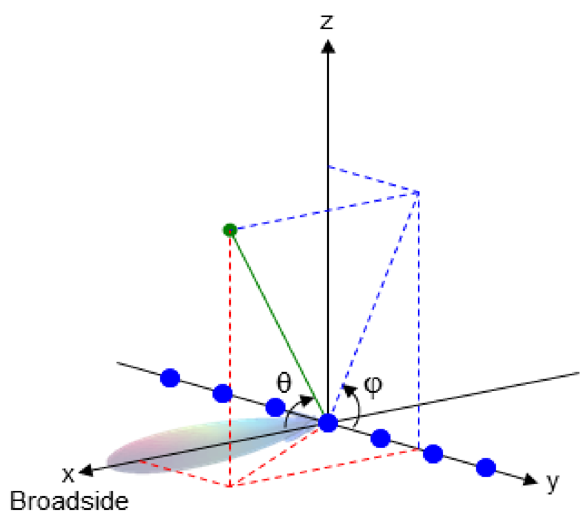

Figure-2. Basic linear antenna array.

4. RESULT AND DISCUSSIONS

Radiation pattern of antenna array is most important problem in communication applications. In many communication applications, it is required to design a highly directional antenna. Array antennas have high gain and directivity compared to an individual radiating element. Antenna array is formed by assembling of radiating elements in an electrical or geometrical configuration that can be compact as compared to multiple antennas. In this work, the linear array antenna has been verified. In case of linear antenna array, all the antenna elements a rearranged in a single line with equal spacing between them. According to the antenna array synthesis and design it is often desired to achieve the minimum side lobe level apart from the narrow beam and efficiency. In Antenna Theory, the radiation pattern response is constructed based on a realization of an analytical or desired model by an antenna model. It has been implemented on various Array configurations (with 4, 8, and 16 elements) and their response as the radiation pattern as shown in Figure-3. The radiation patterns have been observed for different phase shift in excitation between the elements. This improves the performance greatly to achieve the maximum reduction in side lobe level and provide the maximum directivity towards the direction. This technique proved its effectiveness in improving the performance. The computation of the ideal beam pattern is performed on MATLAB using the beam pattern equation. All beam pattern plots shown in this chapter have been normalize with reference to the beam pattern's maximum value.

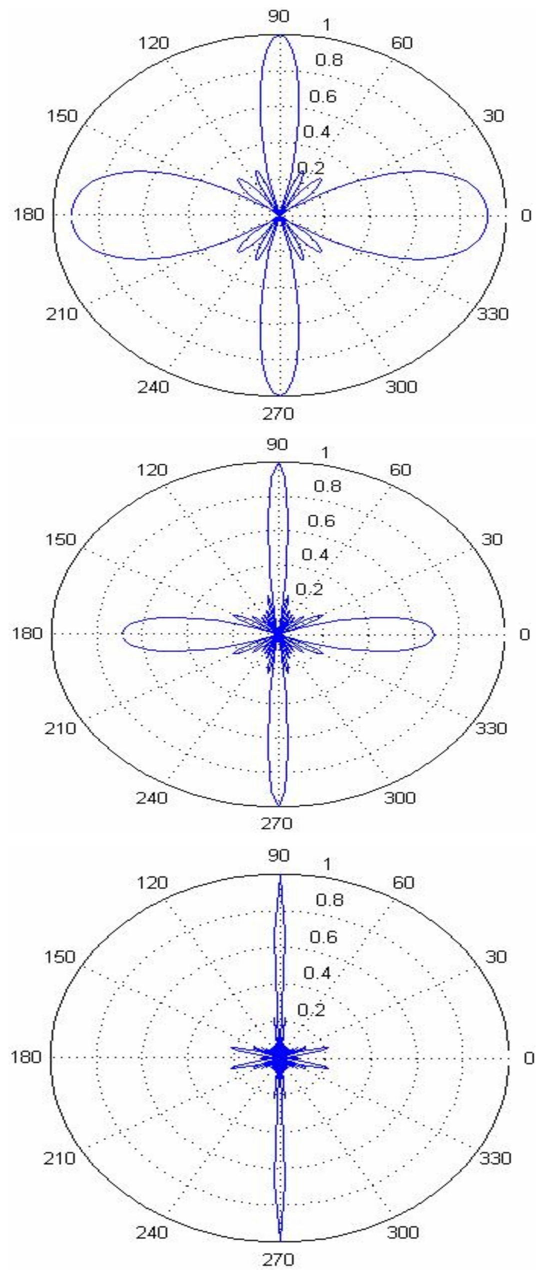

Figure-3. Radiation pattern of linear antenna arrays with 4, 8, and 16 elements respectively.

Figure-4 shows the performance capacity in the wireless channel. The result is measured according to the various SNR values. The capacity of the MIMO channel has been simulated for number of transmitter and receiver antennas, such as 2 x 2, 3 x 3, 4 x 4, and 8 x 8 MIMO systems. It is observed that capacity gradually increases with the number of antennas. The proposed analysis allows evaluation of the capacity and the outage capacity for MIMO systems. The system capacity with respect to the outage probability has been shown in Figure-5. It is noticed that low probability means low capacity. We can increase the number of antennas to increase capacity for a given outage probability. As BER is one of the performance parameters, it has been verified with various modulation techniques such as BPSK, QPSK, and QAM. BER performance for QPSK has been shown in Figure-6, i.e., BER versus SNR, with different number of transmitting and receiving antennas (2 x 2, 3 x 3, 4 x 4, and 8 x 8). We find that antenna array pattern is a promising approach for improving the robustness at a reasonable complexity and feasibility. Radiation pattern of antenna array is most important problem in communication applications.

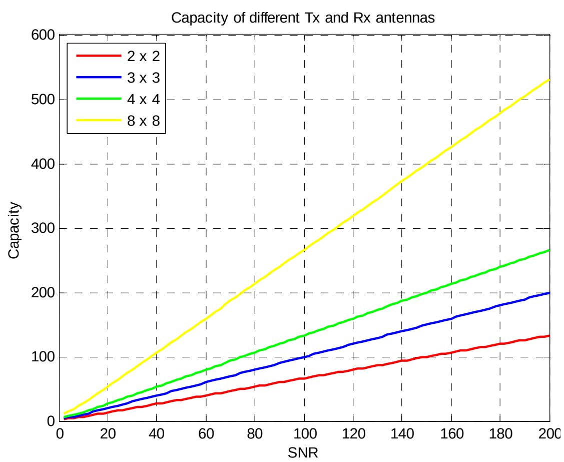

Figure-4. Performance of capacity with respect to SNR.

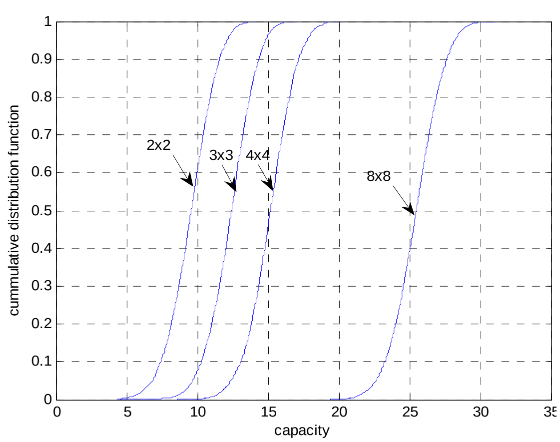

Figure-5. System capacity as a function of outage probability.

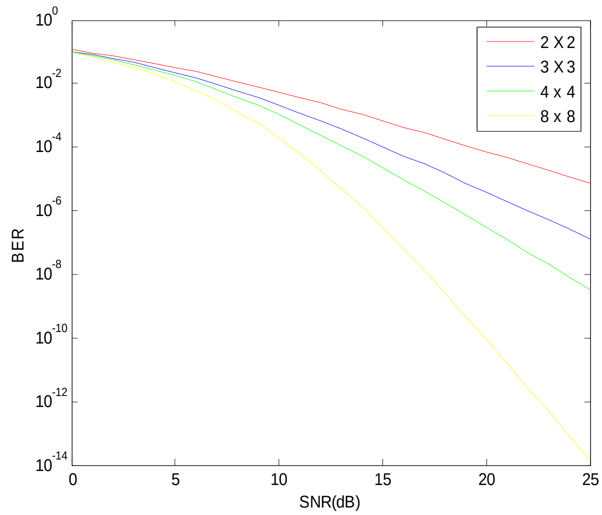

Figure-6. Performance of BER with correlation coefficient = 0.6.

5. CONCLUSIONS

MIMO systems with reduced complexity are now being used for third-generation cellular systems (W-CDMA), and are discussed for future high-performance mode of wireless networks. The multiple antennas in MIMO systems can be exploited in two different ways. One is the creation of a highly effective antenna diversity system; the other is the use of the multiple antennas for the transmission of several parallel data streams to increase the capacity and increase the BER performance of the system. Multiple antenna communications technologies offer significant advantages over single antenna systems. These advantages include extended range, improved reliability in fading environments and higher data throughputs.

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