CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Multiple Input Multiple Output (MIMO) communication refers to a technology in which the system uses an array of antennas (i.e. multiple antennas) at either the transmitter or the receiver. By employing multiple antennas at both ends of the link, the performance of the transmission is enhanced, in higher data rates without extra frequency and power resources. Bolcskei and Paulraj (2002), has proposed that the use of multiple antennas at transmitter and receiver side, increases gain in terms of spectral efficiency and more wireless link reliability.

1.2 WIRELESS COMMUNICATION SYSTEM

Wireless communication has the potential to provide high-speed high-quality information exchange between portable devices located in any distance apart. Since 1960s, wireless communication area has got a rapid growth due to many factors like increase in capacity. Due to Very Large Scale Integration (VLSI) technology which has enabled small-area and low-power implementation of sophisticated signal processing and coding algorithms, possibility to transmit voice and low volume digital data, offer users advanced and special wireless services in mobile communication, and greater capacity through improved spectral efficiency. There are many potential applications that uses this technology such as multimedia internet-enabled cell phones, smart homes and appliances, autonomous sensor networks, video
teleconferencing and distance learning, and automated highway systems. There are two significant challenges in these applications: first, is the phenomenon of fading, and the second, signal interference between them.

The challenges are mostly due to limited availability of radio frequency spectrum and a complex time-varying wireless environment (fading and multipath). Nowadays, wireless communication is to increase data rate and improve transmission reliability. In other words, because of the increasing demand for higher data rates, better quality of service, fewer dropped calls, higher network capacity and signal clarity are some of key goals. Technology such as MIMO, Orthogonal Frequency Division Multiplexing (OFDM) and improved modified methods offer high spectral efficiency, and better link reliability.

1.3 OVERVIEW OF MIMO TECHNOLOGY

Hochwald and Brink (2003) investigated channel codes and turbo codes to achieve near-capacity on a single-antenna Gaussian channel. Comparing to the Single Input Single Output (SISO) system, MIMO provides a better performance under the same transmission conditions. Chizhik et al (2000), derived the general expression for link capacity, when there is correlation among receive antennas and among transmit antennas. Loyka (2001), derived the MIMO channel capacity in correlated channels using the exponential correlation matrix model. It is further shown in the model that, an increase in correlation is equivalent to a decrease in signal-to-noise ratio. Pedersen et al (2000) in their contribution demonstrated that the Shannon capacity of the channel is highly dependent on the considered environment. MIMO system greatly increases the channel capacity, which is proportional to the total number of transmitting and receiving arrays. Winters et al (1994) has showed that there will be a significant increase in system capacity using spatial diversity and optimum combining.
Wallace and Jensen (2001), have experimentally showed the statistical behavior of the channel coefficients and the resulting channel capacity using 10 x 10 MIMO system. Zhang .X and Kung .S .Y (2003) has investigated the channel capacity performance for parallel and sequential MIMO equalizer schemes. Zhen and Tse (2003), also has shown that by employing multiple antennas, one can increase the diversity over Rayleigh-fading channel.

MIMO system also provides the advantage of spatial variety, where each transmitting signal is detected by the complete detector array, and thus increases the robustness. In MIMO system, the array gain is also increased, which means Signal to Noise Ratio (SNR) gain achieved by focusing energy in desired direction is increased and MIMO technology employs many transmitting antenna and receiving antennas. Comparing to the Single-input-single-output (SISO) system, MIMO provides a better performance under the same transmission conditions. MIMO system greatly increases the channel capacity, which is in proportion to the total number of transmitter and receiver arrays. The basic model of an MIMO is as shown in Figure 1.1.

Figure 1.1 MIMO Model

MIMO technology offers many potential advantages like diversity gain in fading channel, increased antenna gain, interference rejection, multipath rejection, Direction of Arrival (DOA), and spatial multiplexing
and thus increases the robustness and reliability of the system with reduced ISI and channel fading. Bolcskei (2006), has presented an overview of the basics of MIMO-Orthogonal Frequency Division Multiplexing (OFDM) technology focused on space-frequency signaling, receiver design, multiuser systems, with the hardware implementation. Fabbri et al (2009), showed an increase in data rates with low complexity for Ultra Wide Band (UWB) MIMO-OFDM system. Narula et al (1998), discussed about MIMO array and the possibility of beam forming technique and the quality of received signal strength.

The receiver can exploit the diversity by receiving signal from more than one branch and close or combine from one or more channel. The capacity in a MIMO system is a linear growth in characteristics with increase in number of antennas thus increasing the capacity without extra bandwidth. Broad classes of MIMO receivers are Class1 and Class2. Non equalizer based and equalizer based receivers are in class1. Linear and Non Linear receivers are in class 2. Zero forcing (ZF) and Minimum Means Squared Error (MMSE) receiver fall in category of linear receivers and Maximum Likelihood (ML) detection falls on non Linear receiver. Mohsen Eslami et al (2010), proposed efficient transmission schemes based on ZF linear receiver processing, eigen mode transmission, and partial Channel State Information (CSI) at the base station transmitter. The performance of linear receivers is only moderate but they are less complex receivers. Non Linear receiver shows a better performance than linear receiver. Melsa, Younce and Rohrs (1996) showed the Impulse response shortening for discrete multitone transceivers. Paulraj et al (2004) provided overview of MIMO wireless technology covering channel models, performance limits, coding, and transceiver design.

1.4 OBJECTIVES

MIMO receivers are complex receivers with more computations. Hence linear receivers are considered as an attractive low-complexity alternative compared to non linear optimal signal processing receivers. For any MIMO communication receivers, the Bit error rate is a very important performance factor with increase in the number of antennas for a fixed ‘E_b/N_0’.

The aim of present work is to investigate the BER performance of MIMO receivers for wireless channel .In order to achieve this aim, the following objectives are set:

1. To study the performance of classical MIMO receivers and device a novel approach of symbol detection.

2. To study the Successive Interference Cancellation (SIC) in SISO system, SIC in MIMO receivers, and to find a solution for successive interference cancellation multi-user detection with MMSE –Vertical-Bell-lab Layered Space-Time (VBLAST).

3. To study the effect of thermal noise in Successive Interference Cancellation.
4. To study the different types of diversity combining techniques and to modify the basic Alamouti scheme. To simulate study and compare the performance of two generalized MIMO receivers namely generalized space time Sum-of-Squares (SoS) Selection and Sum of Magnitude (SoM) scheme.

5. To investigate the performance of MIMO receiver using the concept of equalization and compare the performance of receivers with all the three types of equalizers, namely ZF, Maximum Likelihood (ML) Detection, and MMSE.

6. To make a simulation study on performance analysis and compare the full chip and half chip rate of Noncoherent (NC) and Differentially Coherent (DC) code acquisition scheme in MIMO, assisted by Direct Sequence spread spectrum (DS – CDMA) wireless system when communicated over uncorrelated Rayleigh channel. The objective is set to investigate four schemes namely SISO with full chip rate and half chip rate, MIMO with full chip rate and half chip rate. The performance factors considered for investigation are namely Bit Error Rate (BER) and Mean Acquisition Time (MAT).

1.5 PROBLEM STATEMENT

In this thesis, Bit Error Rate (BER) is considered as a main factor for investigation and BER performance Characteristics of large antenna numbers in the presence of channel correlations is considered. The research problem is to mathematically model, study and simulate a novel MIMO receiver whose BER performance is better than classical MIMO receivers and less in computational complexity.
1.6 RESEARCH METHODOLOGY

The mathematical modeling is done and simulation is carried out at RF signal processing lab using Matlab communication tool box version 7.0. An investigation is carried out right from the literature survey of classical MIMO receivers and a new symbol detection algorithm is proposed. The performance of Successive Interference Cancellation (SIC) is considered. The role of thermal noise in SIC is also studied. The performance of MIMO receiver with equalizers is discussed. The thesis later investigates MIMO spread spectrum receivers. Differential Coherent (DC) and Non Coherent (NC) methods of code acquisition for Direct Sequence – Code Division Multiple Access (DS-CDMA) is studied and from simulation results and novel algorithm is proposed.

1.7 OUT LINE OF THE THESIS

The thesis is organized in eight chapters as follows:

Chapter 1 introduces the evolution, fundamental concepts of MIMO wireless communication system, the objective and scope of this research.

Chapter 2 deals with literature survey related to the thesis. It describes about definitions, channel model, modulation schemes, and types of fading.

Chapter 3 investigates classical MIMO receiver and a new symbol detection algorithm for MIMO channels, with V-BLAST/MAP which combines the elements of the V-BLAST algorithm and the Maximum a-posteriori (MAP) rule.

Chapter 4 investigates about SIC receivers. This chapter considers ZF and MMSE SIC based receiver with different transmission paths. Two
modulation schemes are considered namely Binary Phase Shift Keying (BPSK) and 16 Quadrature Amplitude Modulation (QAM) scheme.

Chapter 5 explore the types of diversity selection techniques from the basic 2x2 Alamouti schemes and is modified to two schemes namely generalized space time Sum-of-Squares (SoS) Selection and Space-time Sum of magnitude (SoM) scheme.

Chapter 6 deals with equalizer based MIMO receivers. In this chapter the BER performance of MIMO receiver using the concept of equalization is discussed and the performance of receivers is compared with all the three types of equalizers, namely ZF, Maximum Likelihood (ML) Detection, and MMSE.

Chapter 7 investigates about spread spectrum MIMO receivers. Performance analysis and comparison of full chip and half chip rate of Noncoherent (NC) and Differentially Coherent (DC) code acquisition scheme in MIMO assisted by Direct Sequence Spread Spectrum Code Division Multiple Access (DS–CDMA) wireless system when communicated over uncorrelated rayleigh channel, were presented.

Chapter 8 provides the conclusion and the future work that can be extended.

1.8 APPLICATIONS

All algorithms considered for investigation and the novel algorithms can be applied to potential application areas like Wireless Local Area Network (WLAN) - WiFi 802.11, mesh networks WIMAX 802, 4G networks, RFID Digital home, Adhoc network and RADAR applications and Wireless Communication.