CHAPTER 1

INTRODUCTION

I. Introduction

Physical limitations of the wireless medium create a technical challenge for reliable wireless communication. Techniques that improve spectral efficiency and overcome various channel impairments such as signal fading and interference have made an enormous contribution to the growth of wireless communications. Moreover, the need for high-speed wireless Internet has led to the demand for technologies delivering higher capacities and link reliability than achieved by current systems. Multiple -input multiple-output (MIMO) based communication systems are capable accomplishing these objectives.

Multiple input multiple output (MIMO) systems take advantage of spatial diversity obtained through the spatially separated antennas in a dense multipath scattering environment [1]. Spatial diversity can increase the gain diversity consequently increase the reliability of the wireless link. Theoretical studies indicate that the capacity of MIMO systems grows linearly with the number of transmit antennas used. Many recent works have focused on exploiting the added spatial dimension to increase capacity [2]-[5]. In particular, the revolutionary vertical Bell Laboratory Layered Space Time (V-BLAST) architecture proposed by Foschini achieved the theoretical capacity limits of the MIMO architecture [6].

The multiple antennas configuration exploits the multipath effect to accomplish the additional spatial diversity. However, the multipath effect also causes the negative effect of frequency selectivity of the channel. Orthogonal frequency division multiplexing (OFDM) is a promising multi-carrier modulation scheme that shows high spectral efficiency and robustness to frequency selective channels. In OFDM, a frequency-selective channel is divided into a number of parallel frequency-flat sub channels, thereby reducing the receiver signal processing of the system. The combination of OFDM and MIMO is a promising technique to achieve high bandwidth efficiencies and system performance. In fact, MIMO-OFDM is being considered for the upcoming IEEE 802.11n standard, a developing standard for high data rate WLANs [1].

1.2 Motivation

MIMO-OFDM has the potential to meet the increasing high speed and reliability demands of the future. However, this technology to truly succeed in commercial deployment there are still several technical obstacles that must be tackled. A major impediment in MIMO-OFDM is the complicated receiver signal processing. The simultaneous emission of the signals from the multiple transmit antennas increases the mutual interference imposed on the signals, therefore, much more complex detection schemes are required to extract the transmitted signals. For example, the complexity of a maximum likelihood detector increases exponentially with the number of transmit antennas. Spatial equalizers and space-time coding has been proposed to simplify the detection for MIMO-OFDM systems [7]-[8]. Note, coherent detection requires knowledge of the channel; therefore, accurate channel estimation is crucial in realizing the full potential of MIMO-OFDM. Channel estimation for OFDM has been well researched in literature. The extension of the results to MIMO-OFDM channel estimation is substantially more complicated. In a MIMO system, multiple channels have to be estimated simultaneously. The increased number of channel unknowns significantly increases the computational complexity of the channel estimation algorithm. Previous works have investigated the problem of channel estimation in MIMO-OFDM [15]-[18]. The most common approach is training-based estimation, where a known pilot sequence is transmitted and used at the receiver to determine the channel. The least square (LS) approach is the common method for training-based estimation. The LS solution is relative simple compared to other estimation techniques such as blind estimation. However, this solutions still require complex matrix inversions, which are undesirable in real time implementation. In [9], specific training sequences design and pilot placement patterns are used to obtain the channel frequency response (CFR) of the channel in attempt to reduce the estimation complexity. Note that the number of unknowns of the CFR is usually significantly greater than the number of unknowns in the channel impulse response (CIR). In [10], it is proven that computational complexity can be reduced by estimating the CIR as opposed to the CFR. The proposed solution reduces the number of unknowns to be solved, but the solution still requires a matrix inversion. The main objective of this research after performance analysis of MIMO-STBC is investigating QR decomposition algorithm for reducing the complexity of the channel estimation for MIMO-OFDM. As the results have shown, QR decomposition can be good solution for finding the channel unknowns, which eliminates the matrix inversion operation.

The QR decomposition is low in complexity, stable and can be efficiently implemented in hardware.

1.3 Objectives

The project had three objectives. The first one was performance analysis of space-time orthogonal block coded MIMO system. For doing so, OSTBC (Orthogonal Space Time Coded) Transmission was considered in the system. The block code was 2 by 2 complex Alamouti code. The number of transmit and receive antenna was assumed two and M respectively. Second objective of the project was to assess the performance of MIMO system and MIMO-OFDM with imperfect channel estimation. In this part comparison analysis in the system with and without perfect channel knowledge has been made. Third and main objective of the project was comparison analysis between LS and QR-LS channel estimation for MIMO-OFDM system in terms of computational complexity and performance efficiency. The first two objectives were supporting this part technically. For the last objective, structure of the system was assumed MIMO-OFDM with STBC transmission. OFDM system make the MIMO structure robust in frequency selective channel, and also it make the data equalization and channel estimation algorithms simpler.

1.4 Scope of works

The project was based on theoretical results and software modeling. MIMO system had STBC structure with $2 \times M$ Antenna constellation. Channel was assumed Rayleigh flat fading with additive white Gaussian noise with zero mean and variance one. Simulation has been done at baseband. The performance of the system investigated using the BER parameter.

Second phase of the project simulation has been done for two different systems with two different conditions. The first one was MIMO system with flat fading channel condition. This part had the same structure similar to the first phase of the project. Second part of phase two, the system was assumed MIMO-OFDM system. For this part antenna constellation was 2 by 2, Channel was frequency selective with additive white Gaussian noise. Also Channel was assumed quasi-static within two transmission block. Number of sub-carrier and CP (cyclic prefix) has been assumed to 64 and 16 respectively.

In the third phase of the project MIMO-OFDM structure had similar structure to phase two. However LS and QRD channel estimation have been applied to the system separately. It should be mention that the software used for the project is MATLAB. This choice has been made because of provided facilities in MATLAB for engineering programming.

1.5 Thesis outline

In Chapter 2, background information and basic principle in MIMO-STBC is given. Alamouti schemes as a base stone of this theory is clearly interpreted. The simple mathematical formula in matrix form for general structure of Alamouti scheme with antenna configuration of 2×N is developed. Then space-time trellis coding as a perfect space-time coding schemes for high data rate wireless communication is briefly introduced. At the end of the chapter brief introduction about spatial multiplexing or MIMO-BLAST as a mean to increase spectral efficiency or in the other words increasing the data rate of wireless system is given.

In Chapter 3, OFDM system is fundamentally discussed. Firstly an introduction of this system is given then data transmission and reception in OFDM is mathematically expressed. In this chapter the most important feature of this system which is robustness in ISI is explained, and the ability of system to overcome inter carrier interference (ICI) is discussed.

In Chapter 4, MIMO-OFDM system with OSTBC transmission in frequency selective channel is modeled. Mathematical expression in time-domain and frequency domain for data transmission and reception in a very simple and understandable form is developed . This model is used in chapter five to estimate the channel using LS or QRD channel estimation.

In Chapter 5, a literature review of previous works on channel estimation for MIMO-OFDM is presented. Basic estimation theory of classical estimation is discussed. The derivation of the LS is presented. The LS is adapted to the OFDM and MIMO-OFDM channel estimation. And finally QRD channel estimation as a mean to reduce computational complexity of LS channel estimation is briefly presented.

In Chapter 6, simulation results for MIMO system performance and MIMO-OFDM channel estimation is given. Any simulation section has its own conclusion. In this chapter a performance comparisons using simulation results is made between the LS and QRD for estimating the CIR of MIMO-OFDM systems. The basic principle for relative computational complexity comparison has been given by Katryn in [43] is interpreted. At the end of this chapter, final conclusion of the work is presented, and some possible future works are suggested.