# VLSI Implementation of Least Square Channel Estimation and QPSK Modulation Technique for 2×2 MIMO System

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## 1. Introduction

Future Wireless communication systems have to be designed to integrate features such as high data rates, high quality of service and multimedia in the existing communication framework.

Increased demand in wireless communication systems has led to the demand for higher network capacity and performance. Higher bandwidth, optimized modulation offer practically limited potential to increase the spectral efficiency. Hence MIMO systems utilizes space multiplex by using array of antenna's for enhancing the efficiency at particular utilized bandwidth.

MIMO use multiple inputs multiple outputs for a single channel. These systems are defined by spectral diversity and spatial multiplexing. MIMO describes the ways to send data from multiple users on the same frequency/time channel using multiple antennas at the transmitter and receiver end.

A transmitter/receiver system uses multiple antennas not only for transmitting data between corresponding antennas but also between adjacent antennas. The data is received in the form of MIMO Channel Matrix.
MIMO system is used in many applications like WiMax, Wi-Fi, WLANs, and many more applications.

**MIMO Systems, Theory and Applications**:

In recent years the telecommunications industry has experiencing a tremendous growth in the area of wireless communication.

This growth has been ignited the widespread popularity of mobile telephones and wireless computer networking. But there are limits to growth, and the radio spectrum used for wireless communications. Hence considerable effort has been invested in making more efficient use of the resources. Using the spectrum more efficiently caters for the ever increasing demand for faster communications since more bits per second can be transmitted using the same bandwidth. Recent major industry research focus in this area has been the use of multiple antennas for transmitting and receiving instead of the single antenna systems. The uses of multiple transmit and receive antennas, and efficient coding techniques could increase the performance of wireless communication systems. The implementation carried is for 2x2 MIMO systems with good channel estimation method and better coding techniques for better performance. The design is carried till the backend VLSI flow. The design is to implementing 2x2 MIMO systems with QPSK modulation technique and estimating channel coefficients using LS channel estimation method.

**Back ground discussion**

Due to demand in the wireless products, the high data rates, capacity, accuracy, with less hardware and the reliability of the system is a greater challenge. Hence numerous efficient channel estimation and modulation techniques are to be modified for greater performance of the overall system. In this, literature review is carried for different MIMO architectures for different modulation techniques and the channel estimation methods.

In digital communication system the channel accepts electrical/electromagnetic signals, and the resultant output is smeared or distorted version of the input due to the non-ideal nature of the communication channel. Also the information-bearing signal is corrupted by unpredictable noise.

The smearing and noise introduce errors in the information being transmitted and limits the rate at which information is to be communicated from the source to the destination. The probability of incorrectly decoding a message symbol at the receiver is often used as a measure of performance of digital communication systems.

The main function of modulator and the demodulator is to combat the degrading effects of the channel on the signal and maximize the information rate and accuracy.

In digital modulation, information signals to be modulated is digital. Therefore, digital information modulates an analog carrier and hence called as “digital modulation”.

There are basically three types of digital modulation techniques i.e Amplitude Shift Keying (ASK), Phase Shift Keying (PSK) and Frequency Shift Keying (FSK).

Phase Shift Keying is a digital modulation technique which is one most used.

In PSK modulation, the phase of the carrier is altered in accordance with the input binary coded information. The PSK is further subdivided into BPSK, 8-PSK, 16-PSK, QPSK, DPSK.

In binary phase shifting keying the transmitted signal is sinusoid of fixed amplitude .It has one fixed phase.

The in-phase and the quadrature phase components are very important component in QPSK. Any imbalance in these the performance of the whole system crashes down at the detectors. Either the phase or the amplitude imbalances lead to the introduction of ICI, there may be cross- talk between in-phase and quadrature channels.

Channel Estimation and QPSK Modulation Technique for 2×2 MIMO System system. Different channel models are compared by applying different diversity schemes. The goal is to analyze the performance of WiMax system. Performance study is carried for 2x2 and 2x1 MIMO systems. The configuration of WiMax transmitter and receiver are done for MIMO and SISO. Initially a model was implemented in MATLAB/Simulink.

The main objective of this paper is an iterative channel estimation algorithm for MIMO OFDM. Compared to common least square channel estimation, this has greatly improved estimation accuracy and, low pass filtering in time domain reduces AWGN and ICI significantly.

MIMO-OFDM is used in

mobile applications. Many techniques have been applied to the MIMO channel both in time and frequency domains which increases the capacity and increase the reliability of wireless link.

In this paper the study of the performance of the MIMO channel estimation using training sequence is carried out.

The Least Square, MMSE and new scaled least square approaches to the channel estimation are studied and the optional choice of the training signals is investigated for each of these techniques. The minimization of energy is carried by reducing

the hardware, also by using a low rank equalization at the receiver. A scalar energy reduction at channel estimation is explained.

The performance of MIMO system degrades due to
inaccurate channel estimation over frequency selective fast-varying channels.

Pilot-aided
turbo channel estimation improved by addition of linear algorithm in the iterative process is discussed. This improves the channel estimation and reduction in the use of number of pilots.

The capacity of channel depends on MIMO Systems, Theory and Applications the knowledge of the channel matrix gains at the transmitter and receiver. The estimation iscarried out by transmission of set of pilot symbols known to transmitter and receiver.

## Problem definition/statement

While designing VLSI circuits for very efficient implementations the designer should
consider algorithmic and hardware architectures trade-offs.

Rapid prototyping for such applications will imply the short designs satisfying all the design constraints, such as timing and silicon area.

The wireless systems are operated under harsh and challenging channel
conditions.

A 2x2 MIMO system is been designed, simulated, implemented, synthesized and physical design is carried in macro level to tape out the design.

The aim of this work is VLSI implementation of LS channel estimation method and QPSK modulation technique for 2×2 MIMO system.

The design specifications are verified using MATLAB.

The RTL coding is carried for the design to be implemented on Xilinx FPGA.

Design synthesis and macro level physical designing is also carried out.

## Least square channel estimation and QPSK modulation for 2x2 MIMO systems

The MIMO system has multiple transmitter antennas and multiple receive antennas so that the data is transmitted in parallel.

This work demonstrates simple working of a 2x2 MIMO
system carried till backend of the VLSI flow. The MIMO system is designed with least
square channel estimation method and QPSK modulation technique.

In communication systems, channels are usually multi-path channels, which cause intersymbol interference in the received signal.

As discussed in literature review various detection algorithms offer a very good receiver performance and reduced computations.

Channel estimators require the channel impulse response.

The channel estimation is based on the known sequence of bits called training sequence which is unique for each transmitter.

Here the known training sequence is transmitted so that the channel coefficients are obtained. There are different standards used for transmitting training sequence like IEEE 802.16 standard.

## Conclusion

The simple working of a MIMO system is carried till backend of the VLSI flow. The design is simulated in MATLAB to arrive at the specifications. The RTL code is successfully simulated in Modelsim.

The design is synthesized and implemented on Virtex2Pro FPGA board. The synthesis and timing is verified and the timing is met for both setup and hold in DC and PT. DFT is also carried without timing violation.

The top design takes about 3999 number of slices out of 4928 slices i.e. in Virtex2Pro the device selected is 2vp7ff896 at speed grade of 6 with operating frequency 7.27MHz and minimum period of 137.548ns. Timing verified is all met with positive slack with zero violations.

In the design the channel is considered to be ideal. In the future work the noise is to be added and the estimation of channel using different channel models is to be carried.

Different channel estimation is to be simulated in MATLAB and then taken to the complete VLSI flow. The frequency of the design is to be optimized. The complete backend flow has to be completed till the tape-out of the design.

• Scope of the future work is to improve the design further for the noise to be included in the channel and use any improved matrix inversion technique for improving the design frequency of operation. This can be done using QRD algorithm.

• Iterative algorithm is applied for the design so as to reduce the effect of noise on data. The iterative algorithms like Recursive LS, Least Mean Square, MMSE, etc. Channel estimation and compensation for different channel models for delays is to be implemented.

• Fixed point implementation of the design is to be carried out by obtaining the floatingpoint values from MATLAB because the fixed- point representation will be more efficient.

• MIMO performance can be improved by using OFDM. By incorporating OFDM the performance of the overall system can be improved.