UNIVERSITI TEKNOLOGI MARA

LOW DENSITY PARITY CHECK (LDPC) FOR SPACE TIME FREQUENCY CODING IN MIMO-OFDM

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SUPERVISOR'S DECLARATION

A thesis submitted to the Faculty of Electrical Engineering, Universiti Teknologi MARA in fulfillment for the award of the Master of Science in Telecommunication and Information Engineering.

This thesis is approved by:

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CANDIDATE'S DECLARATION

I declare that the work in this thesis was carried out in accordance with regulations of Universiti Teknologi MARA. It is original and is result of my own work, unless otherwise indicated or acknowledge as referenced work. This topic has nor been submitted to any other academic institution or non-academic institution for any degree or qualification.

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ABSTRACT

MIMO-OFDM offers significant high data rates transfer without increasing the bandwidth or transmit power. By adopting diversity coding such as Space Time coding (STC), Space Frequency Coding (SFC), Space Time Frequency Coding (STFC), the major challenge of transmitting information over a long distances can be improved in terms of reliability and security of the data due to ISI and ICI. Low Density Parity Check which is introduced by Gallager in 1962 has attracted much attention to the needs of efficient and reliable coding theory in digital data communication system. In this paper together with STFC, the simulation of LDPC under 8, 16 and 64 QAM is conducted in 4x4 MIMO-OFDM over Additive White Gaussian Noise (AWGN) and Raleigh fading channel. The propose system is analyzed based on BER with signal to noise ratio (SNR). The simulation using Matlab, shows the BER comparison between AWGN and Rayleigh fading channel, which LDPC works better in Rayleigh fading channel while in digital modulations the system outperforms with 8-QAM . The performance of LDPC between MIMO-OFDM and MISO OFDM is also being compared and it is further prove that MIMO performs better than MISO [1].

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LIST OF ABBREVIATIONS

ANSI	American National Standard Institutes
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
CP	Cyclic Prefix
DVB	Digital Video Broadcasting
DVB-T	Digital Video Broadcasting – Terrestrial
FDM	Frequency Division Multiplexing
FEC	Forward Error Check
FFT	Fast Fourier Transform ICI
GI	Guard Interval
IEEE	Institute of Electrical and Electronics Engineers
IFFT	Inverse Fast Fourier Transform
ISI	Inter Symbol Interference
ICI	Inter Carrier Interference
LDPC	Low Density Parity Check
MIMO	Multiple Input Multiple Output
MISO	Multiple Input Single Output
OFDM	orthogonal frequency division multiplexing
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
SCTE	Society of Cable Telecommunications Engineers
SM	Spatial Multiplexing
SNR	Signal-to-Noise Ratio
ST	Space Time
STC	Space Time Coding
STFC	Space Time Frequency Coding
STFB	Space Time Frequency Block
SF	Space Frequency

STF	Space Time Frequency
WiMAX	Worldwide Interoperability for Microwave Access

CHAPTER 1

INTRODUCTION

1.0 CHAPTER OVERVIEW

This chapter presents an overview of this thesis. It consists of four parts. The first part presents an overview of this research and the background of the study. Previous research conducted is explained briefly as well as the need to continue the research. The second part explains the objectives and goals of this research. The scope of the research is explained in the next part. It specifies the boundaries of the research by explaining the limitations and constrains of the research. The last part outlines the work carried out in this research as well as the thesis structure for every chapter.

1.1 OVERVIEW

Orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation technique which divides its wide signal bandwidth into many narrowband sub-channels. This technique gives a significant increase in data rates in wireless communication system. In conjunction of its robustness to frequency selective fading, high spectral efficiency and low computational complexity, OFDM can transform MIMO channel into a set of parallel frequency [2,3]. MIMO which is known as a capacity booster work perfectly with OFDM system by enhancing the data rates in order to fulfill the future demands. Several companies had developed MIMO-OFDM based solution for IEEE 802.16e WIMAX broadband mobile standard.

The orthogonality of the carriers indicates that for each carrier has integer carrier of cycles over a symbol period. As a result, each carrier spectrum has a null at centre frequency of each carrier in the system.

MIMO-OFDM support both spatial multiplexing and diversity coding such as Space Time Coding and Space Time Frequency Coding. This paper used Space Time Frequency Coding (STFC) in order to combine the advantages in MIMO and OFDM systems. STF coding is done across space, time and frequency to achieve maximum diversity gain. STFC technique allows maximum diversity order against Rayleigh fading channel [12]. In telecommunications, diversity refers to a method that can increase the reliability of a message signal with many characteristics. Diversity plays an important role in resisting Rayleigh fading which may utilize resulting in a diversity gain.

Some data might be interfered by multipath environment and some are completely lost because of the deep fade. Hence, even though most subcarriers maybe detected without errors, the overall BER will be largely dominated by a few subcarriers with small amplitudes [4]. Forward error correction codes such as convolutional codes, Turbo codes, Reed Solomon codes and so on have been applied to OFDM system in order to avoid this problem.

One code that is very close to Shannon limit was proposed by Gallager in 1962 applied to BPSK and 8PSK is Low Density Parity Check. The fundamental of the research was evaluated over an additive white Gaussian noise channel and it has been shown LDPC codes have a large gain with the respect to convolutional code for large packet length [5]. The performance of LDPC has been evaluated using BPSK and 8PSK in AWGN. Only the fundamental performance has been evaluated [4].

1.2 PROBLEM STATEMENT

Many communication transmissions cannot escape from channel noise, thus errors may occur and sometimes data loss also happens. Error detection concept allows detecting such errors, and error correction help to retrieve the original data. Block codes such as Reed-Solomon codes, Turbo Codes and LDPC codes are being used in order to face with this problem. LDPC codes has been introduced by Gallager about 50 years ago but only been recognized as a good error-correcting achieving near Shannon limit performance nowadays [4]. The adaptation of LDPC in MIMO-OFDM using STF is considered new and the performance of LDPC in STF Coding for MIMO-OFDM hopefully does not disappointed.

1.3 OBJECTIVES

1. To show the process involve in the transmission of OFDM signal carriers in a physical channel.
2. To evaluate the performance of LDPC Codes in MIMO-OFDM using STF Codes in terms of Bit Error Rate (BER) with Signal to Noise Ratio (SNR).

1.4 SCOPE OF THE RESEARCH

There are several scopes and limitations of the study takes into account. There are; the simulation of this project is developed using Matlab Software version 7.11.0.584 (R2010b) by Math Works. The LDPC codes design is based on DVB-S produced by Math Works and the simulation of LDPC is conducted in 8, 16 and 64 QAM using STFC for 4 by 4 MIMO-OFDM over AWGN and Rayleigh fading channel. The simulation result is shown in BER with SNR.

1.5 THESIS STRUCTURE

This thesis consists of five chapters including this chapter. The content of every chapter is briefly summarized as below to give an overview the work done for this research.

The next chapter will start with literature review of the modulation techniques and process involved in transmitting signals. A detailed explanation of OFDM, MIMO-OFDM, STF Diversity Coding, LDPC codes and Channel Model will be presented in Chapter 2. In Chapter 3, the framework of the methodology for the project will be discussed. Followed by that, the results as well as the analysis and evaluation of the measured parameters will be discussed in Chapter 4. Finally, Chapter 5 will conclude the whole research and recommendation for future development also is mentioned in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.0 CHAPTER OVERVIEW

This chapter presents the previous research of the technology under studies. Details about the studies will be provided in sub topics in this chapter.

2.1 Orthogonal Frequency Division Multiplexing (OFDM)

Orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation technique which divides its wide signal bandwidth into many narrowband subchannels which are transmitted in parallel. Orthogonality between the subcarriers allows their overlapping while at the same time disabling the incident of crosstalk. Thus, the used of orthogonal technique can achieved the power saving and increase the data rate.

The binary data firstly will be modulated by digital mapping constellation method for example BPSK, QPSK, 4 QAM or whatever and the outputs are now in the form of complex number. Next, the output will be sent in parallel to IFFT in order to implement a discrete time signal.

Figure 2.1 shows the comparison between FDM and OFDM. The upper figure shows the independent 5 frequencies which is not overlap with each other which represent Frequency Division Multiplexing (FDM) while in lower figure shows the 5 frequencies overlapping with each other which represent OFDM.

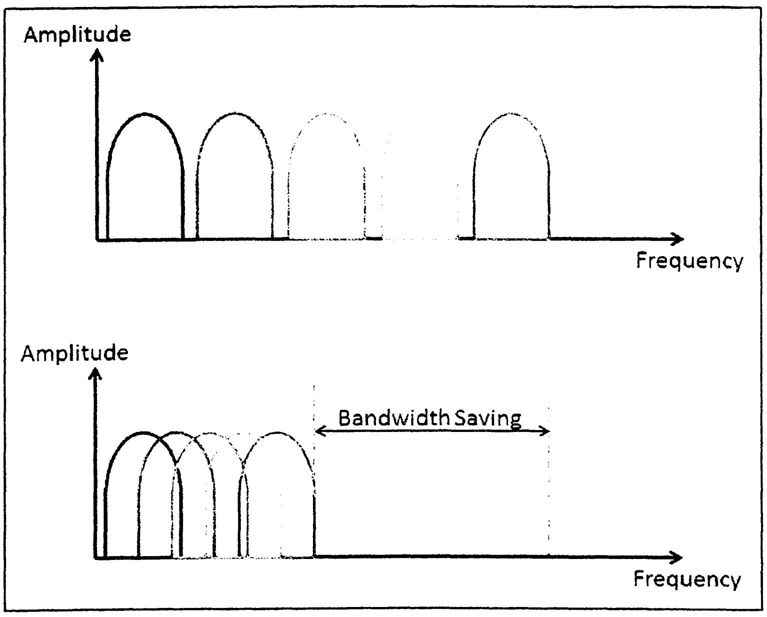

Figure 2.1. Bandwidth Saving in OFDM compare to FDM.

The expression of OFDM subcarriers is achieved by using Inverse Fast Fourier Transform (IFFT). The generated OFDM signals are frequency domain coefficient and the samples at the output of IFFT stage are in time domain sample. The OFDM signals can be expressed as in below equation.

Baseband OFDM Signal,

$$s(t) = \sum_{k=0}^{N-1} a_k^{j2\pi k\Delta f t} \quad ,0 \leq t \leq T \qquad \text{(Equation 2.1)}$$

Passband OFDM signal,

$$s(t) = \mathrm{Re}\left\{\sum_{k=0}^{N-1} a_k^{j2\pi(f_c + k\Delta f)t}\right\} \quad ,0 \leq t \leq T \qquad \text{(Equation 2.2)}$$

where,

a_k = complex-valued modulated symbols

N = number of subcarrier

f_c = carrier frequency

t = sampling period

Δf = subcarrier spacing

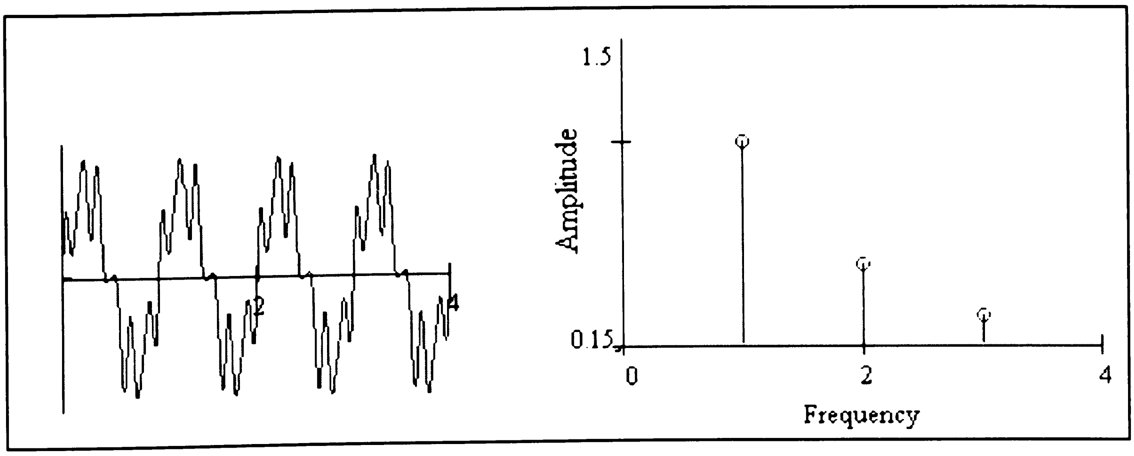

Figure 2.2(a). OFDM signal in time domain

Figure 2(b). OFDM signals in frequency domain

In figure 2.2 (a), it is shown that OFDM signals in time domain view which are the convolution of several signals while in figure 2.2(b), the OFDM signals are in frequency domain view which we can see how much of the frequency is presented in this convolution of signals.

Each subcarrier is capable to carry part of the current input data stream. Not all subcarriers are used in that way, for example, 802.11a/g uses 64 subcarriers but only 48 of these subcarriers are used to carry bits from the original input data stream. Others are work as guards and pilots. Guard subcarriers are inactive or null while pilot subcarriers carry some information regarding timing and frequency in order to assist the receiver side to synchronize with transmitted signal.

The key of guards' application are to prevent ISI where each symbol is preluded by periodic extension of the signal itself. Linear distortion such as multipath fading cause sub channel to spread energy in adjacent channel. The total symbol duration in other way helps to solve this problem. Usually, the insertion of guard interval is less than T/4. This is because, if it is longer than that, the guard interval will reduce the data throughput. Cyclic prefix is one of the conventional used of guard interval. The main reason cyclic prefix is widely used are because of its ability to maintain the receiver carrier synchronization and it can be applied between the OFDM signals.

2.2 MIMO-OFDM

MIMO is known to be a booster for a high data rate transmission. The combination between MIMO and OFDM is very attractive and has become a most promising broadband wireless access scheme [9].

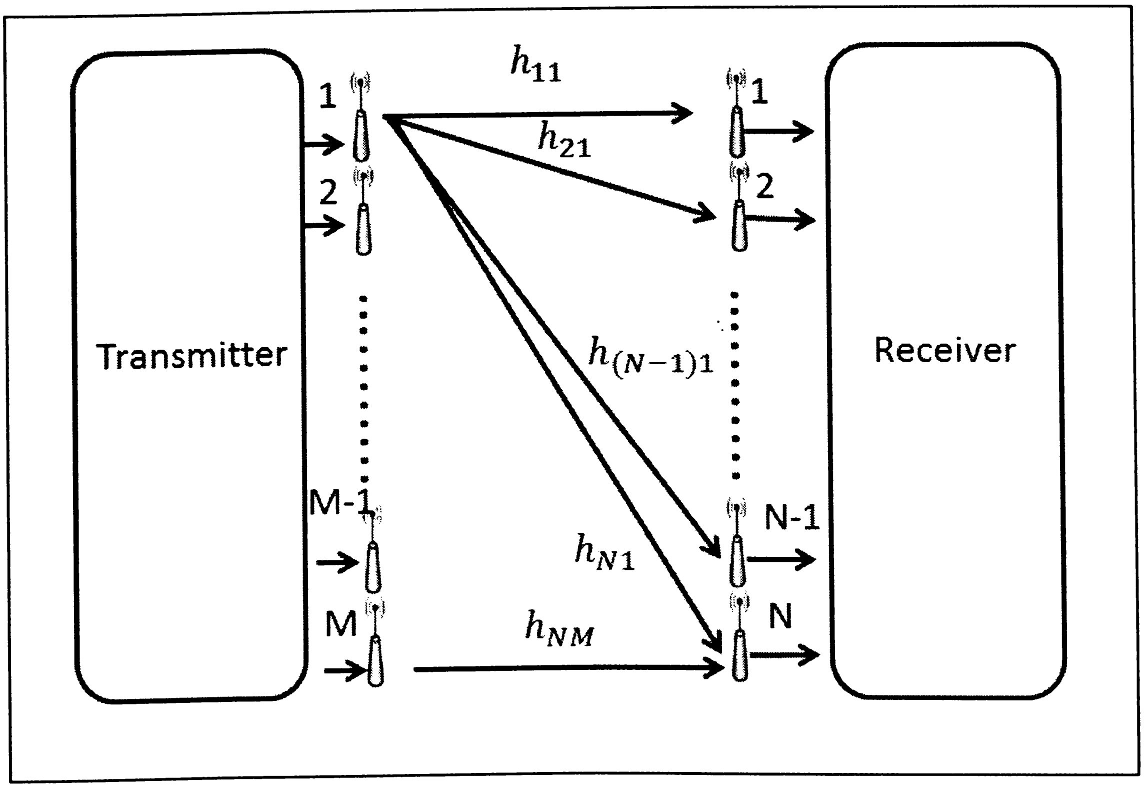

Figure 2.3. MIMO System Block Diagram.

In the system with M transmit antennas and N receive antenna as shown in figure 2.3, the received signal to noise ratio (SNR) can be increased in proportion to $M \times N$. MIMO takes advantage of multipath propagation to increase throughput, coverage and reliability. MIMO use multipath signals to work more by transmitting more information rather than countering the multipath signals.

Because of transmitting multiple signals across the communication channel, MIMO has the ability to increase capacity of the information and shoot up the speed and efficiency.

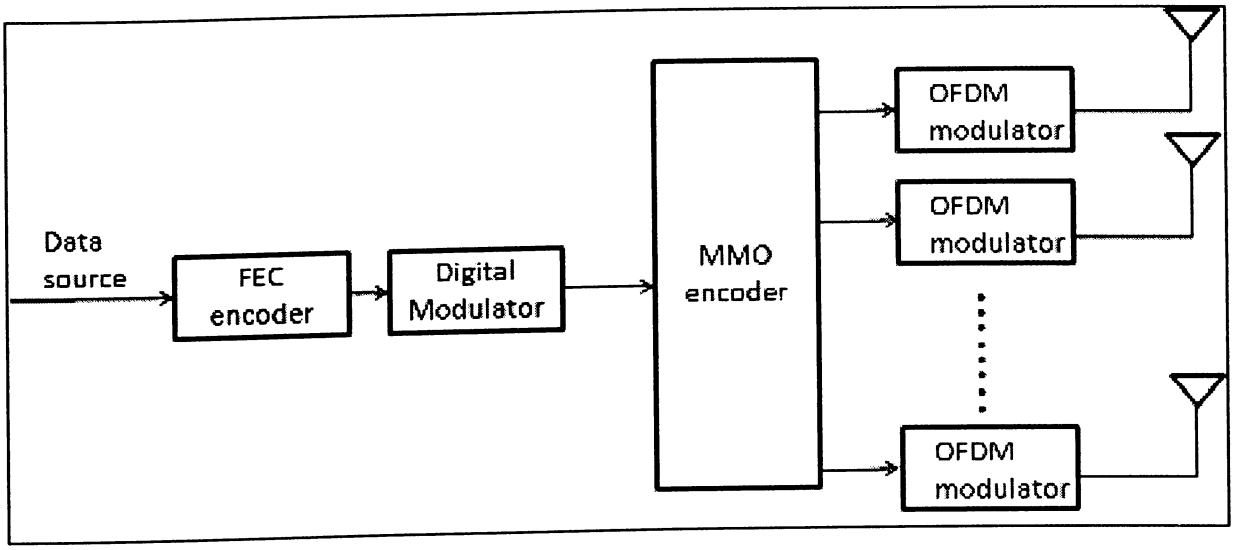

Figure 2.4. A simplified MIMO-OFDM transmitter block diagram

Figure 2.4 shows the block diagram of MIMO-OFDM transmitter. The data source firstly will be encoded by forward error correction (FEC). Next, the encoded data will be modulated into digital mapping constellation by digital modulator which converts the binary data into complex number. After that, the symbol data is encoded by MIMO encoder and the parallel output then will be transmitted to OFDM modulator. Each parallel output corresponds to each transmit antenna. At the OFDM modulator, the symbol data is modulated by IFFT and cyclic prefix is inserted to every OFDM symbol in order to optimize inter-symbol interference (ISI). Afterwards the output is modulated to construct analog data and upconversion process is done.

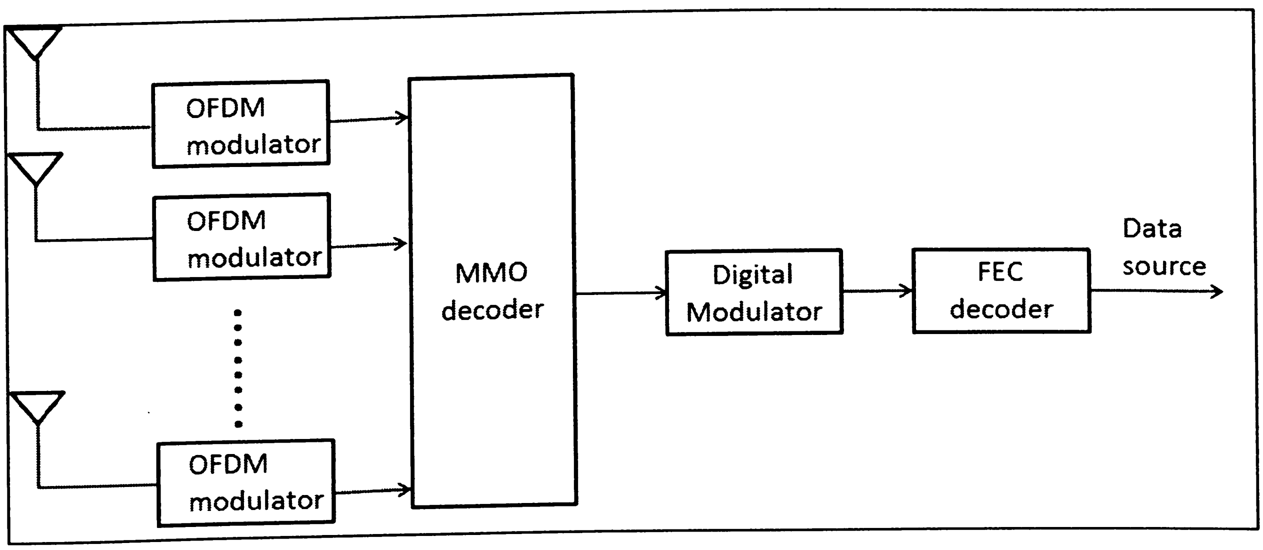

Figure 2.5. A simplified MIMO-OFDM receiver block diagram

The design for OFDM receiver is open and there are only transmission standard. So, we can assume basic receiver structure is just follow the inverse of the transmission process.

There are three basic parameters that completely describe the quality and usefulness of any wireless link which is speed, range and reliability. Prior to the development of MIMO-OFDM, these three parameters were interrelated according to strict rules. Speed could be increased only by sacrificing range and reliability. While, range could be extended at expense of speed and reliability and reliability could be improved by reducing the speed and range. MIMO-OFDM has redefined the tradeoff clearly demonstrating that it can boost all three parameters simultaneously.

The building of MIMO can be divided into three major techniques, precoding, spatial multiplexing (SM) and diversity coding. Precoding is transmitting the same signals from each antenna with appropriate phase weighting. This technique works well in directional pattern but it is not a good analogy when it comes to typical cellular conventional channel. It requires information of channel state at the receiver. Refer to figure 2.6 for precoding illustrations diagram.

Take figure 2.6 as an example of precoding technique, 2 blocks of data A and B are encoded in MIMO encoder. Then, each antenna will transmit both types of data to the radio channel simultaneously. Each receive antennas will receive both blocks A and B.

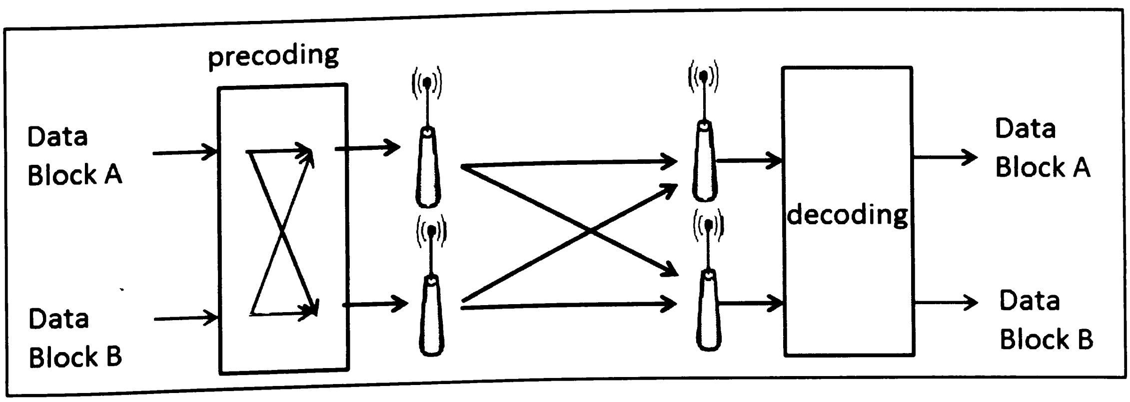

Figure 2.6. Precoding illustrations diagram.

Spatial multiplexing split the high rate signal into various lower rate streams and each stream is transmitted from a different antennas. The benefit of spatial multiplexing is to increase the capacity of MIMO link because of its ability to transmit multiple blocks of data in the same time slot and frequency band simultaneously from each antenna. Refer to figure 2.7 for the spatial multiplexing illustration diagram.

In figure 2.7, the 2 blocks of data, A and B are encoded using spatial techniques by MIMO encoder. The data block A is assigned to antenna 1 and data block B is assigned to antenna 2. Both blocks data are transmitted simultaneously from different antennas to the radio channel. At the receiver, each antenna receives both types of block data. At the decoding process, the original data will be retrieved.

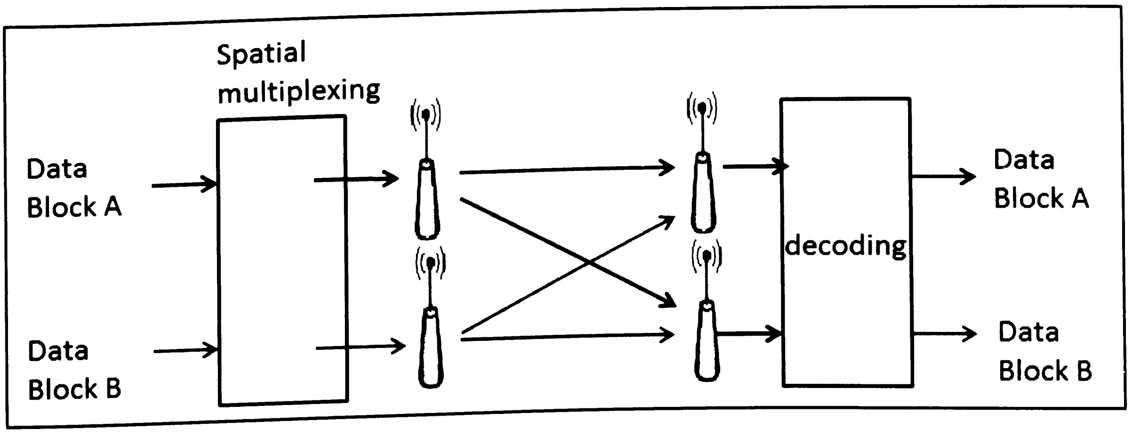

Figure 2.7. Spatial Multiplexing illustrations diagram.

Diversity Coding is a method that has been used to improve the reliability of the signal by using two or more communication channels with different characteristics. There are three common method are using in Diversity Coding. There is space diversity, time diversity and frequency diversity. From this methods, then we have three techniques been produced in order to transmit multiple data to the communication channel. There is Space time coding, space frequency coding and space time frequency coding. Refer to figure 2.7 for the spatial diversity coding illustration diagram.

Figure 2.8 shows the two blocks of data A and B are encoded using Space Time Coding. The data is diverted to A, B, -A* and B* by MIMO encoder using STC. Antenna 1 transmits A and B* according to time slot t and T+1 and antenna 2 transmit B and –A* according to time slot t and T+1. At the receiver, each antenna receives all types of encoded data, and then at the decoding process, the original data can be derived using some estimation equation.

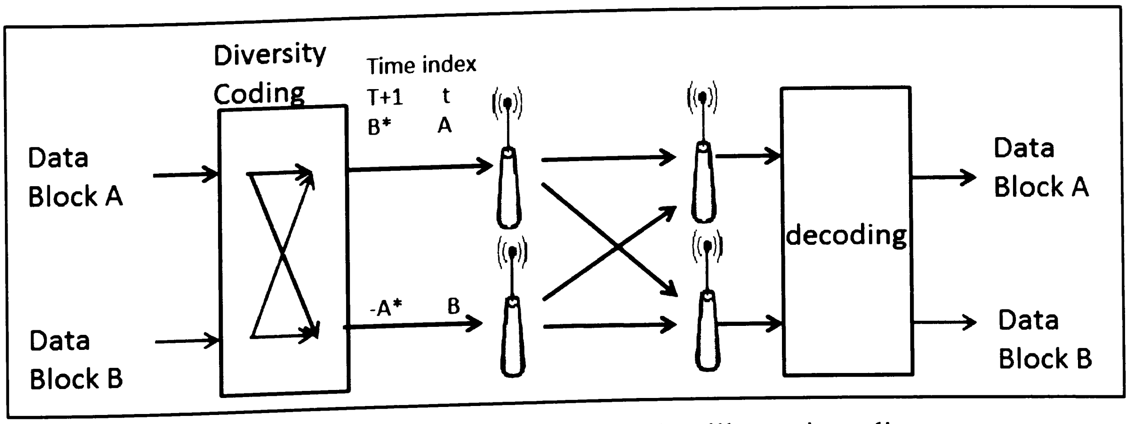

Figure 2.8 Diversity coding using Space Time Coding illustrations diagram.

* means conjugate.

2.3 DIGITAL MODULATION

In this project, we are using 8, 16 and 64 QAM modulation techniques in order to investigate the behavior of the system performance. This modulation process of varying a periodic waveform, typically a sinusoid signal carrier is used to convey the information. In sinusoidal form, there are three important things to focus at. There are amplitude, phase and frequency. These three parameters can be modified by depending on the information signal. The device that works to perform modulation is known as modulator and the reverse process is done by demodulator.