AN IMPROVEMENT OF SCRAMBLING TECHNIQUE BY USING MODIFIED SELECTED MAPPING IN OFDM SYSTEM

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AN IMPROVEMENT OF SCRAMBLING TECHNIQUE BY USING MODIFIED SELECTED MAPPING IN OFDM SYSTEM

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BER	: Bit Error Rate
CCDF	: Complementary Cumulative Distribution Function
CP	: Cyclic Prefix
DFT	: Discrete Fourier Transform
DQPSK	: Differentially Quadrature Phase Shift Keying
FFT	: Fast Fourier Transform
GI	: Guard Interval
ICI	: Inter-carrier Interference
IDFT	: Inverse Discrete Fourier Transform
IFFT	: Inverse Fast Fourier Transform
ISI	: Inter-symbol Interference
MIMO	: Multiple Input Multiple Output
MSLM	: Modified Selected Mapping
OFDM	: Orthogonal Frequency-Division Multiplexing
PAPR	: Peak-to-Average Power Ratio
QPSK	: Quadrature Phase Shift Keying
SLM	: Selected Mapping

ABSTRAK

Ortogonal Frekuensi Divisi Pemultipleksan (OFDM) merupakan sejenis bentuk isyarat digital modulasi yang kerap digunakan dalam banyak sistem komunikasi digital, seperti televisyen digital, akses internet, rangkaian tanpa wayar dan komunikasi mudah alih 4G. Ia adalah satu kaedah pengekodan data digital pada pelbagai pembawa frekuensi. Oleh kerana kelajuan penghantaran yang tinggi dan kecekapan, OFDM sering dipilih untuk dilaksanakan dalam banyak aplikasi untuk tujuan komunikasi. Walau bagaimanapun, kelemahan utama sistem OFDM adalah Nisbah Kuasa Puncak-ke-Purata (PAPR) yang tinggi dan ini juga menyebabkan peningkatan Kadar Ralat Bit (BER) dan penggunaan kuasa. Oleh itu, PAPR menjadi isu yang paling penting untuk ditangani. Terdapat pelbagai teknik boleh digunakan untuk mengurangkan PAPR. Teknik-teknik itu umumnya boleh dikelaskan kepada dua kumpulan, iaitu teknik berebut isyarat dan teknik herotan isyarat. Projek ini mencadangkan kaedah yang dipanggilkan skim Pengubahsuaian Pemetaan Dipilih (MSLM) untuk mengurangkan PAPR. Pada dasarnya, teknik ini adalah gabungan Pemetaan Dipilih (SLM) dan kaedah blok kod linear yang kedua-duanya dianggap sebagai teknik berebut isyarat. Objektif projek ini adalah untuk membangunkan satu sistem untuk mengurangkan PAPR dalam sistem OFDM dengan menggunakan skim MSLM dan untuk menentukan bagaimana jumlah subpembawa menjejaskan prestasi PAPR sistem OFDM. Kesimpulannya, skim MSLM dapat mengurangkan jumlah PAPR 8.27% lebih daripada SLM konvensional dalam purata. Kajian ini juga mendapati bahawa PAPR dalam sistem meningkat dengan jumlah subpembawa yang digunakan.

ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is a form of digital signal modulation format that is being used in many digital communication system, such as digital television, internet access, wireless network and 4G mobile communication. It is a method of encoding digital data on multiple carrier frequencies. Due to the high transmission speed and efficiency, OFDM is often been chosen to implement in many applications for communication purpose. However, the major drawback of OFDM system is the high Peak-to-Average Power Ratio (PAPR) which also resulting in the increase of Bit Error Rate (BER) and power consumption. Hence, PAPR become the most important issue to tackle. There are various techniques can be used to reduce PAPR. They generally can be classified into two groups, signal scrambling technique and signal distortion technique. This project proposed a method called Modified Selected Mapping (MSLM) scheme to reduce the PAPR. Basically, this technique is the combination of selected mapping (SLM) and linear block coding method which both of them are considered as signal scrambling technique. The project’s objectives are to develop a system to reduce the PAPR in OFDM system by using MSLM scheme and to determine how the number of subcarriers affect the PAPR performance of OFDM system. In conclusion, MSLM scheme was able to reduce the amount of PAPR 8.27% more than the conventional SLM in average. This research also found out that the PAPR of the system increases with the number of subcarriers used.

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, wireless communication play an essential part in daily life of every social class around the world. Many of the remote region on earth also has been impacted. The commercialization of mobile technology has forced the exponential growth of wireless communication.

Recently, the development of fourth generation (4G) mobile communication systems has begun to been concern in communication industry. It is predicted that 4G will provide a secure and comprehensive IP solution where data, voice, and multimedia can be provided to the users at anywhere and anytime. Next generation of mobile communication system is expected to provide higher data rate to meet the requirement of future multimedia application. 4G system require a minimum data rate of 10-20Mbps and at least 2Mbps in fast moving vehicles. To improve spectrum performance and efficiency to achieve as high as 100Mbps in wireless transmission rate, 4G requires more advanced communication technique to be implemented [1].

Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) have been adopted due to their excellent performance. OFDM is more suitable and preferred for future wireless communication systems as it offers a high tolerance to multipath signals and is spectrally efficient. It also have advantages such as high immunity to inter-symbol interference (ISI), and robustness to channel fading.

1.2 Problem Statement

Although OFDM technique have a lots of advantages over others, but there is a major drawback that needs to be handled properly to obtain efficient transmission. The Peak to Average Power Ratio (PAPR) is the main problem in this system. The OFDM transmitting signal is a composite signal characterised by large peaks. The non-linear behaviour of the power amplifiers (PAs) employed caused the increasing in the amount of inter-modulation interference. This results in high PAPR which is undesirable [2].

High PAPR set rigid requirements for the linearity of the power amplifier. High linearity requirement for the power amplifier also will cause low power efficiency. Consequently, the power consumption would also be high. Due to the non-linearity of the power amplifier, the bit error rate (BER) also will degrades. This also increase the complexity of the analogue-to-digital and digital-to-analogue conversion [3].

Therefore, the unwanted PAPR reduction is one of the main concern in design OFDM system. There are few of useful techniques that can be used to tackle this problem, such as partial transmit sequence (PTS), selected mapping (SLM), block coding, tone reservation (TR), tone injection (TI) and also clipping and filtering [4].

In this project, a modified selected mapping (MSLM) technique will be the major approach concerned because the conventional SLM and standard arrays of linear block codes have some main weaknesses, such as low PAPR reduction capability and high computational complexity.

1.3 Objectives

The main objectives of this project are:

i. To develop a system to reduce the Peak to Average Power Ratio (PAPR) in OFDM system by using modified selected mapping (MSLM) scheme.
ii. To determine how the number of subcarriers affect the PAPR performance of OFDM system.

1.4 Scope of Research

The scope of this project will be focused on how to reduce the PAPR in OFDM system by using the modified selective mapping (MSLM) technique. The PAPR performance will be analysed by calculated the complementary cumulative distribution function (CCDF) based on the MATLAB simulation results. The simulation is also limited with the used of varies number of subcarriers which are 32, 64, 128 and 256. This project is only a software based research which without involve any hardware component.

1.5 Thesis Organization

The thesis organization is as follows. Chapter 1 introduces the overview and background of the OFDM system. It also contains the problem statement that describes the challenges need to be overcome in this project. After that, there are project's objectives and research scope that point out the main purpose of this research. Then, thesis organization is explained at the end of chapter.

Chapter 2 reviews and summarizes the literatures of the work done before that related to this project. Theoretical concepts of OFDM system will be discussed and explained based on previous research. Some advantages and applications of OFDM system also been mentioned. Besides the effect of PAPR to the system, some previous studies of different techniques to reduce PAPR also will be discussed and analyse. Some others relevant fundamental backgrounds of past researches are also covered in this chapter.

In Chapter 3, the details methodology on how the research been carried out was discussed. The flow of project implementation will be shown. It also provide an in-depth discussion of procedure on how conventional SLM technique being modified. All the important parameters used are mentioned and the requirement to carry out the project also been stated. At the end of the chapter, some summary have been made to give reader a clear view of this chapter.

For Chapter 4, the results of the simulation was displayed. Some discussion was carried out to discuss and explain the figures or tables in details. Based on the simulation results, data has been analyse and compare with the previous proposed techniques.

Chapter 5 conclude the research project in a brief manner. It describes the whole project comprehensively in a big picture of view. It also mentioned the need to carry out this research project. Besides that, it also summarize and point out some important findings of this project. Whether objective have been achieved or not is also one of the major concern. At the end, some suggestions for future works regarding to this topic also been made.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, literatures that relevant to the research will be review. Theoretical principle of OFDM will be explained in details. It will also discussed about the advantages, disadvantages and implementation of OFDM. One of the major problems of OFDM, peak to average power ratio (PAPR) also will point out. Number of techniques that can be used to reduce PAPR will be explained.

2.2 Orthogonal Frequency Division Multiplexing (OFDM)

Orthogonal frequency division multiplexing (OFDM) is a form of digital modulation used in a wide array of communication systems [5]. It is a multicarrier modulation (MCM) system, where a single data stream is transmitted over a number of lower rate subcarriers. OFDM is a multiplexing technique but can also be called as a modulation technique [6].

It is a digital communication method that breaks a large bandwidth into small subcarriers using the Inverse Fast Fourier Transform (IFFT). Having the subcarrier frequency be integer multiples of symbol rate enable it to removes Inter-symbol Interference (ISI). By dividing total bandwidth into independent sub-channels, multiple access is achieved by allocating sub-channels between users. Besides that, it can achieve higher data rates by distributing power and sub-channels to users through Adaptive Modulation [5].

2.2.1 Theoretical Background

The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. This results in the spectrum of each carrier has a null at the centre frequency of each of the other carriers in the system. Therefore, there are no interference between the carriers, they are allowed to be spaced as close as theoretically possible. Figure 2.1 illustrate the orthogonality in frequency band.

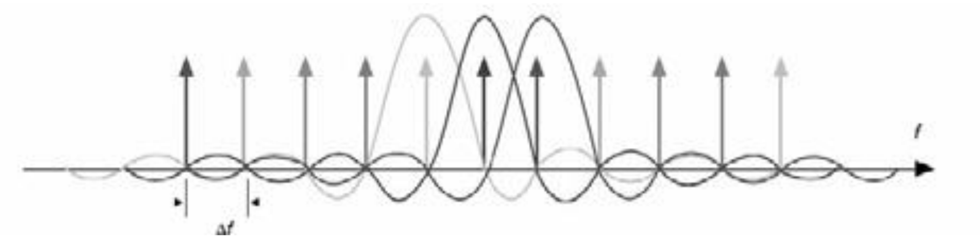

Figure 2.1: Orthogonality of subcarriers

In order to successfully generate OFDM, the relationship between all the carriers must be cautiously controlled to maintain the orthogonality of the carriers. Therefore, the first step to generate OFDM is by choosing the spectrum needed based on the modulation scheme used and input data. Each carrier to be produced is assigned same data to transmit. Based on the scheme of modulation, the required phase and amplitude of them are calculated. Then, the required spectrum is converted to its time domain signal using an Inverse Fourier Transform (IFT). But, an IFFT is used in most application because it can perform the transformation very efficiently and ensure the carrier signals produced are orthogonal [1].

An IFFT converts a number of complex data points of length that is in power of 2, into time domain signal of the same number of points. Each data point in frequency domain used for an FFT or IFFT is called a bin. By setting the phase and amplitude of each frequency bin, the orthogonal carrier needed for OFDM signal can be generate easily, thus performing the IFFT.

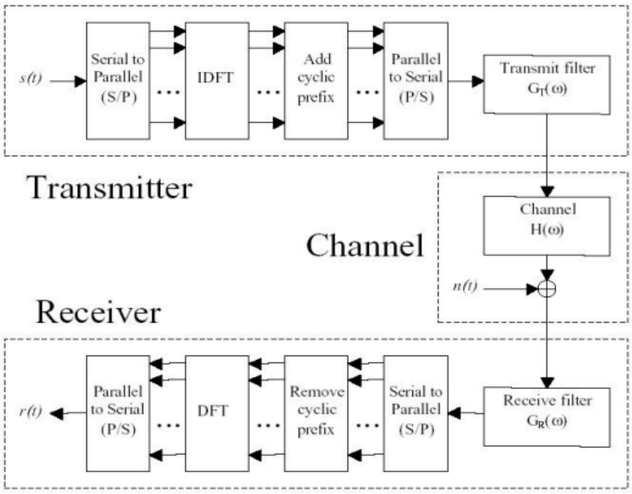

Figure 2.2: Conventional OFDM system block diagram

As shown in Figure 2.2, the input data stream go through the serial-to-parallel converter, the data has been converted into N parallel data streams. The duration of the data is prolong by N times. After parallel data streams produced, the IDFT substitutes the local subcarrier oscillators, getting $f(k)$ from $F(n)$ using equation:

$$f(k) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} F(n) \exp\left(\frac{j2\pi kn}{N}\right) \tag{2.1}$$

The orthogonality of discrete-time Fourier bases can be described as follows:

$$\sum_{k=0}^{N-1} \cos\left(\frac{2\pi kn}{N}\right) \times \cos\left(\frac{2\pi km}{N}\right) = \delta\,(n-m) \tag{2.2}$$

Due to the absence of local oscillators, OFDM system's complexity is reduced and the output sequences are also orthogonal to each other. Next, the data stream pass through the cyclic prefix block. Cyclic prefix (CP), also known as the guard interval (GI) which is used to remove the Inter Block Interference (IBI). Sometimes, IBI also referred as ISI. As shown in Figure 2.3, ISI is eliminated by using guard interval (GI). If CP or GI is not employed, many waveforms might be occur at the receiver and causes problems of interference. When CP or GI is implemented, part of the waveforms would be discarded. In order to remove ISI completely, the GI duration must be larger than the maximum channel delay time.

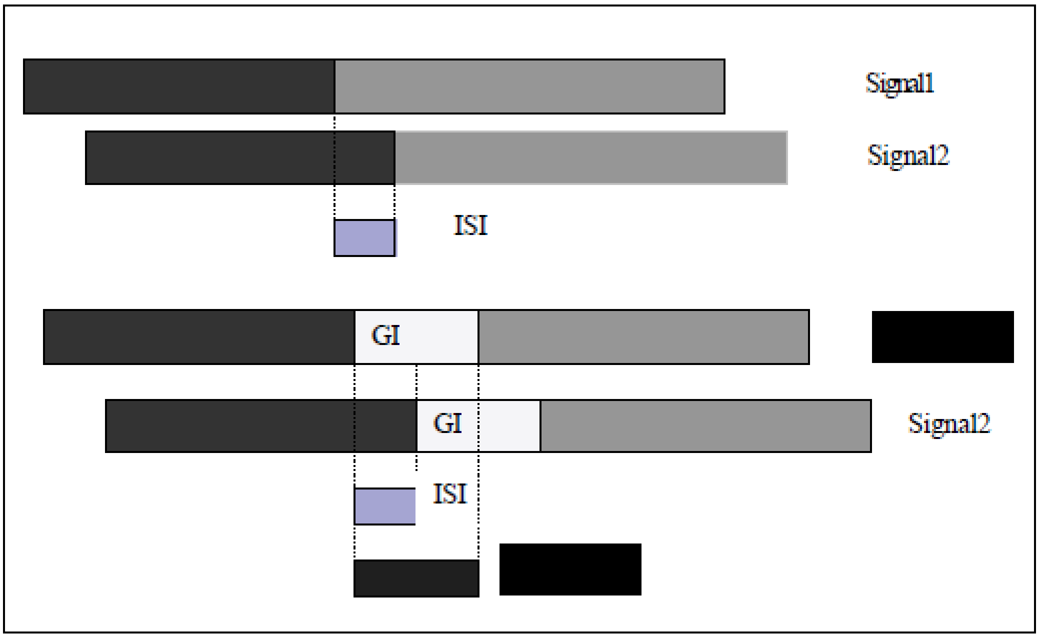

Figure 2.3: Elimination of ISI using guard interval (GI)

If GI is in zero padding, the subcarriers' orthogonality properties would be affected and cause Inter-carrier Interference (ICI). Thus, cyclic prefix (CP) is used to substitute the zero padding GI. GI appeared to be a copy of partial waveform in CP scheme. Based on the Fourier bases of periodic functions, the orthogonality of subcarriers can be maintained. As depicted in Figure 2.4, the end portion of the waveform is copied and placed at the beginning of the waveform. The period of CP is denoted as

$$T_G = \frac{T}{2^K} \quad (2.3)$$

Where K is an integer that depends on maximum delay time of the channel. Both ICI and ISI problems could eliminated by using CP scheme.

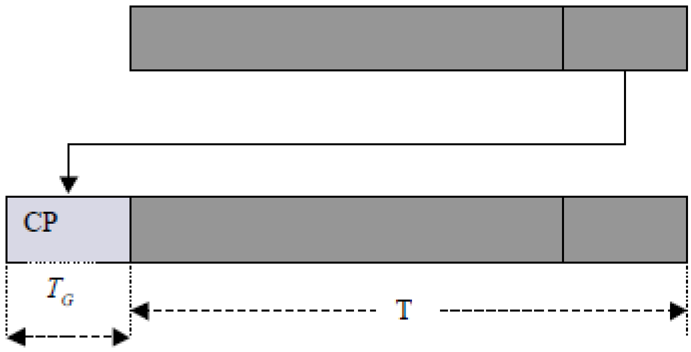

Figure 2.4: Cyclic Prefix scheme

After the cyclic prefix is added, the data are then converted from parallel back to series. Before transmit into the channel, it pass through a transmitter filter to filter out some unwanted signal. At the receiver side, the retrieved data is first pass through a receiver filter, usually a low pass filter is used. Then, the data is being convert from serial to parallel form. To retrieve back the original signal, cyclic prefix is removed and followed by DFT transformation. After that, the data is converted back to serial again before being demodulate. Finally, the binary stream of transmitted data was retrieved after demodulation performed [7].

2.2.2 Advantages and Applications

There are tons of advantages provided by OFDM system. Among all the advantages, robustness against ISI and high spectral efficiency are essential. Besides that, IFFT/FFT operation ensures that subcarriers do not interfere with each other. Compare to single carrier systems, equalization of OFDM is much simpler, thus the used of equalizer can be eliminates [5]. It also tolerates to impulse noise and multipath delay spread. Furthermore, OFDM can immunes to the frequency selective channels. The used of cyclic prefix allows the receiver to capture multipath energy more efficiently. It also have the ability to comply with world-wide regulations and coexist with current and future systems [8].

OFDM technique is used in various applications, which included Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN) and digital audio/video broadcasting. In addition, it also support high speed cellular data and digital subscriber line (DSL) [9].

2.3 Type of Modulation

Quadrature amplitude modulation (QAM) is both analogue and digital modulation scheme. By modulating the amplitudes of two carrier waves, it transmit two analogue message signals or two digital bit streams at a unit time. The two carrier waves are of the same frequency and usually sinusoids. They are 90° out of phase with each other and thus called quadrature carriers. After modulated, the waves are summed and the final waveform is the combination of both phase-shift keying (PSK) and amplitude-shift keying (ASK), or in the case of analogue are phase modulation (PM) and amplitude modulation (AM). In digital QAM, a finite number of at least two phases and at least two amplitudes are used. QAM is the commonly used modulation scheme for digital telecommunication systems due its' high spectral efficiencies.

As in others digital modulation schemes, the constellation diagram is useful for QAM. Normally, the constellation points of QAM are arranged in a square grid with equal horizontal and vertical spacing. The number of points in the grid is usually a power of 2 because in digital communication system, data is usually in binary form. Some of the simple forms are 4-QAM, 16-QAM and 64-QAM. The Figure 2.5, Figure 2.6 and Figure 2.7 show the constellation diagram of 4, 16 and 64-QAM respectively.

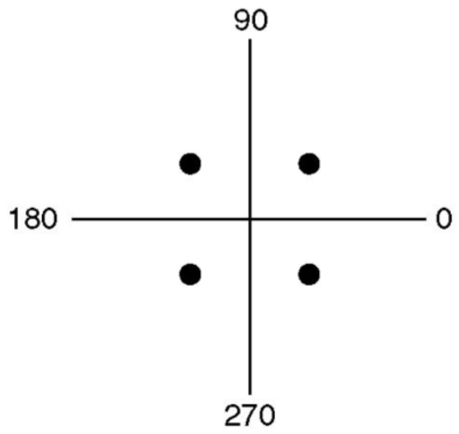

Figure 2.5: Constellation points of 4-QAM

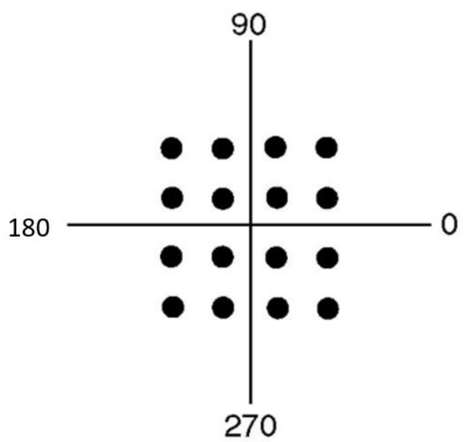

Figure 2.6: Constellation points of 16-QAM

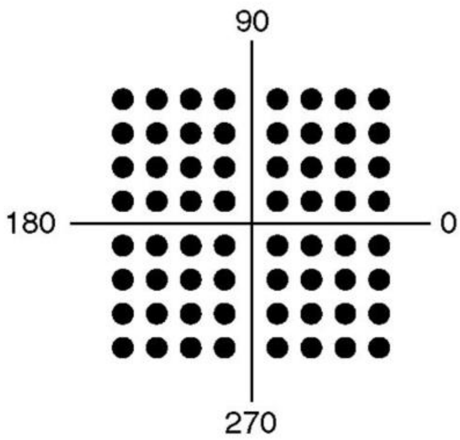

Figure 2.7: Constellation points of 64-QAM

By increasing the order of constellation, it may increase the bits per symbol and thus increase the transmission rate. However, if the mean energy of the constellation remain the same, the constellation points must be closer together. It will then cause the system more susceptible to noise and other corruption. As a results, bit error rate would become higher. Therefore, for constant mean constellation energy, higher-order QAM can transmit more data less reliably than lower-order QAM. Hence, 16-QAM has been chosen as the modulation scheme in this project.

2.4 Number of subcarriers

By modulating the number of subcarriers used in the system, the effect of number of subcarriers towards the PAPR performance in OFDM system can be determined. The subcarriers of ODFM signal can mathematically described as Eq. (2.4):

$$s_k(t) = \begin{cases} \sin(2\pi k \Delta f t), & 0 < t < T, \quad k = 1,2,3,\dots N \\ 0 \quad , & t = 0 \quad otherwise \end{cases} \tag{2.4}$$

Where Δ is the subcarriers spacing, T is the data symbol period and N is the total number of subcarriers.

In OFDM system, there are multiple carriers in each of the symbols. Each of the carriers are called subcarrier. All of those subcarriers are orthogonal to each other as shown in Figure 2.8. Due to the orthogonality nature of transmission, the peak of each subcarriers are corresponding to the nulls of all other subcarriers. This can prevent the interference between carriers to occur.

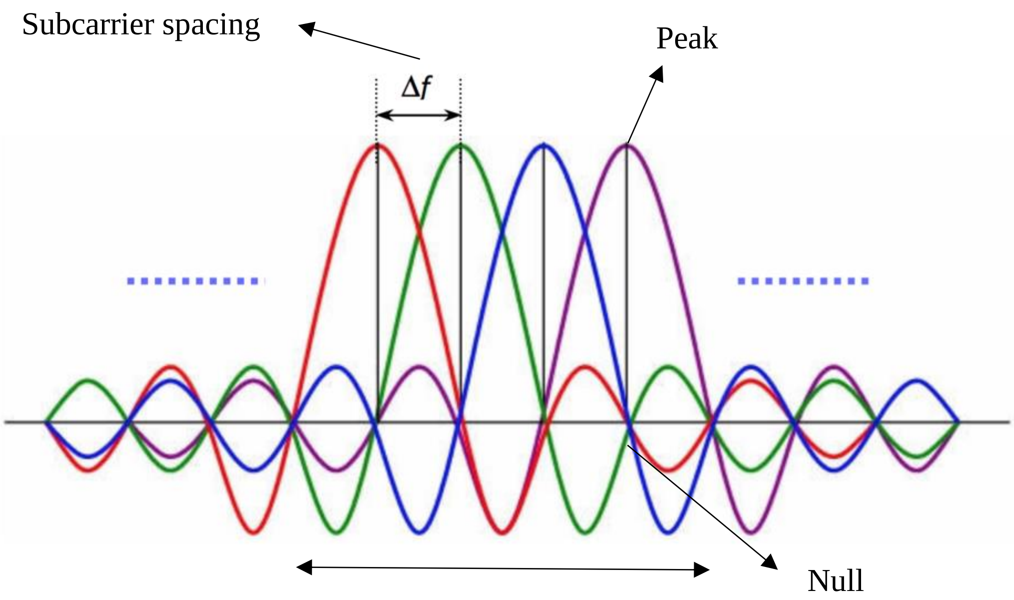

Figure 2.8: Frequency spectrum of OFDM system

In this project, various number of subcarriers has been used, which are 32, 64, 128 and 256. The purpose of using different number of subcarriers is to analyse the effect of it towards PAPR performance in OFDM system.

2.5 Peak-to-Average Power Ratio (PAPR)

The PAPR is the relation between the maximum power of a sample in a given OFDM transmit symbol divided by the average power of that symbol. In a multicarrier system, the different sub-carriers are out of phase with each other results in PAPR to occur [2].

PAPR is one of the major drawbacks in OFDM signals. The quadrature time domain series formed as a weighted sum of sinusoids by IFFT leads to large PAPR formed. According to central limit theorem, when number of carriers are large, a real and imaginary values of time domain signal are Gaussian distributed. Hence, the amplitude of multicarrier signal is Rayleigh distributed.

An OFDM system need a linear power amplifier (PA) with large dynamic range as it has high undesirable PAPR. If PA used is not linear, it results in in-band distortion and increases of out-of-band radiation. When PAPR is high, the conversion of OFDM signals from A/D and D/A will be more difficult. The in band interference caused will increase the ISI while out band interference will leads to high Adjacent Channel Interference (ACI). These phenomena are unwanted in communication system. As conclusion, the advantages of OFDM system that can immune to ICI and have less ISI is eliminated by PAPR. Besides that, high PAPR may also disturb the orthogonality of OFDM signal.

Figure 2.9 clearly shown that the peak power of the signal is very high which distorts the output of the power amplifier. The signal is the combination of a number of sinusoids. These will then cause a high peak magnitude but average value of the signal might be low due to destructive interference. Consequently, the PAPR is high and leads to low efficiency and high power consumption hence it is undesirable. This is the reason why reduction of PAPR is necessary. There are various proposed techniques to reduce the effect of PAPR in OFDM system [6].

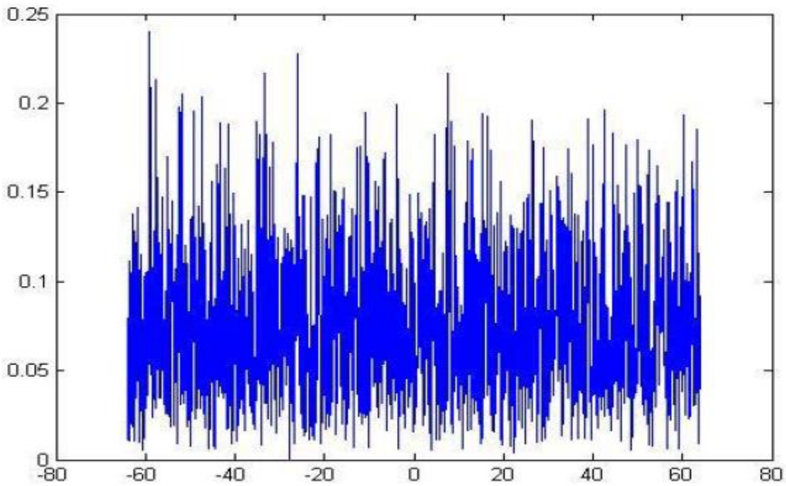

Figure 2.9: OFDM signal containing sinusoidal high peaks

Definition of PAPR:

$$PAPR = \frac{P_{peak}}{P_{average}}$$

$$= 10\log_{10}\frac{\max[|x_n|^2]}{\mathrm{E}[|x_n|^2]} \qquad (2.5)$$

P_{peak} = Peak power of the OFDM system

$P_{average}$= Average power of the OFDM system

$E[\cdot]$ is the expectation operator

2.6 PAPR Reduction Techniques

There are variety of techniques have been proposed to reduce PAPR. PAPR reduction methods vary according to the system requirement and also much dependent on some parameters, such as increase in transmit signal power, complexity of computation, PAPR spectral efficiency, loss in data rate, increase of BER and capacity reduction at the receiver end. Many techniques have been suggested for PAPR reduction and basically the techniques can be classified into two groups, which are signal scrambling techniques and signal distortion techniques as shown below [10]:

Signal Scrambling Techniques

- Selected Mapping (SLM)
- Partial Transmit Sequence (PTS)
- Interleaving Technique
- Block Coding Techniques
- Block Coding Scheme with Error Correction
- Tone Reservation (TR)
- Tone Injection (TI)

Signal Distortion Techniques

- Clipping and Filtering
- Peak Windowing
- Envelope Scaling
- Peak Reduction Carrier

In this project, Selected Mapping (SLM) technique is the one to be discussed and analysed as it is one of the most effective PAPR reduction methods.

2.6.1 Conventional SLM

The basic concept in SLM technique is to generate a set of different candidate data blocks by the transmitter where all the data blocks carry the exactly same information as the original data block. Then, the block having the least PAPR is selected for transmission. The SLM technique block diagram is shown in Figure 2.10.

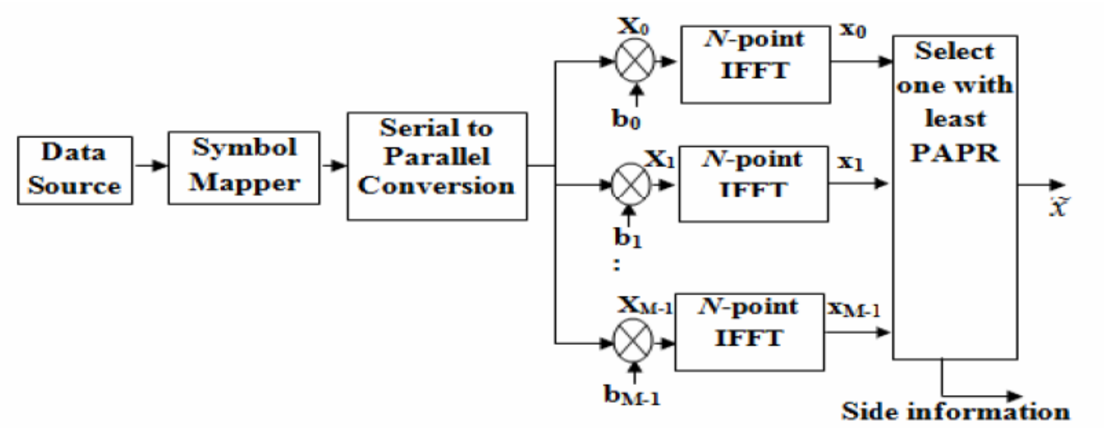

Figure 2.10: Block diagram of conventional SLM scheme [11]

First, let the input data block be $X = [X_0, X_1, \dots \dots X_{N-1}]$, this data block is then multiplied with M different phase factors $b_m = [b_m^0, b_m^1, \dots \dots b_m^{N-1}]$, where m=0,1,2,……..M-1.

$$b_m^n = e^j \theta_m^n$$

$$\theta_m^n \in [0,2\pi]$$

for n=0,1,2,……N-1. Next, N-point IFFT has been carried out for each of the data block, these transformations generates M sequences in time domain given by:

$$x_m(n) = \sum_{n=0}^{N-1} X_n \, b_m^n e^{\frac{j2n\pi t}{N}} \quad (2.6)$$

for m=0,1,2,……M.

Now, the lowest PAPR among all the generated x_m is selected for transmission.

There are some side information about the phase factor are generated in the process. They are required to transmit separately to decode the OFDM symbol at receiver side. For M phase sequences, the side information bits are $\log_2 M$. In SLM, an N-point IFFT involves $N \log_2 N$ additions and also $\frac{N}{2} \log_2 N$ complex multiplications. If oversampling happens, those calculations are increased by a factor of L. The major problems existed in SLM technique included PAPR reduction capability and computational complexity. Therefore, some modification on the conventional SLM scheme are necessary to increase the efficiency of this technique [11].

2.6.2 Standard Arrays of Linear Block Codes

In this method, the key idea is to use the standard array for reduction of PAPR in OFDM system, not for error-correction. The standard array of a linear block code is a fundamental tool for its minimum distance decoding. Consider an $[n, k]$ binary linear code C with parity-check matrix H, where n is the length and k is the dimension of C.

Based on [12], Table 2-1 shows the standard array of an $[n, k]$ linear block code. Let $e + C$ be the coset of C containing e, it can be express mathematically as $e + C \triangleq \{X | x = e + c, c \in C\}$. For any codeword $c \in C$, any vector $x \in e + C$ has the same syndrome as e due to $H_{c^t} = 0$. This mean:

$$H_{X^t} = H(e + c)^t = H_{e^t} \tag{2.7}$$

The standard array of C is a $U \times K$ array, where $U = 2^{n-k}$ and $K = 2^k$. Totally, there are 2^n binary vectors of length n and each of the vector appears in the array only once. In the array, there are U number of cosets and each coset has exactly K vectors.

Table 2-1: Standard array of an $[n, k]$ linear block code [12]

1st coset	$\mathbf{e}_1 = \mathbf{c}_1 = 0$	$\mathbf{c}_2$	$\mathbf{c}_3$	$\dots$	$\mathbf{c}_K$
2nd coset	$\mathbf{e}_2$	$\mathbf{e}_2 + \mathbf{c}_2$	$\mathbf{e}_2 + \mathbf{c}_3$	$\dots$	$\mathbf{e}_2 + \mathbf{c}_K$
3rd coset	$\mathbf{e}_3$	$\mathbf{e}_3 + \mathbf{c}_2$	$\mathbf{e}_3 + \mathbf{c}_3$	$\dots$	$\mathbf{e}_3 + \mathbf{c}_K$
$\vdots$	$\vdots$			$\vdots$	
Uth coset	$\mathbf{e}_U$	$\mathbf{e}_U + \mathbf{c}_2$	$\mathbf{e}_U + \mathbf{c}_3$	$\dots$	$\mathbf{e}_U + \mathbf{c}_K$

By using the standard array of a linear block code, PAPR in the OFDM system with N carriers can be reduced. Figure 2.11 illustrate the block diagram of the PAPR reduction scheme using standard array.

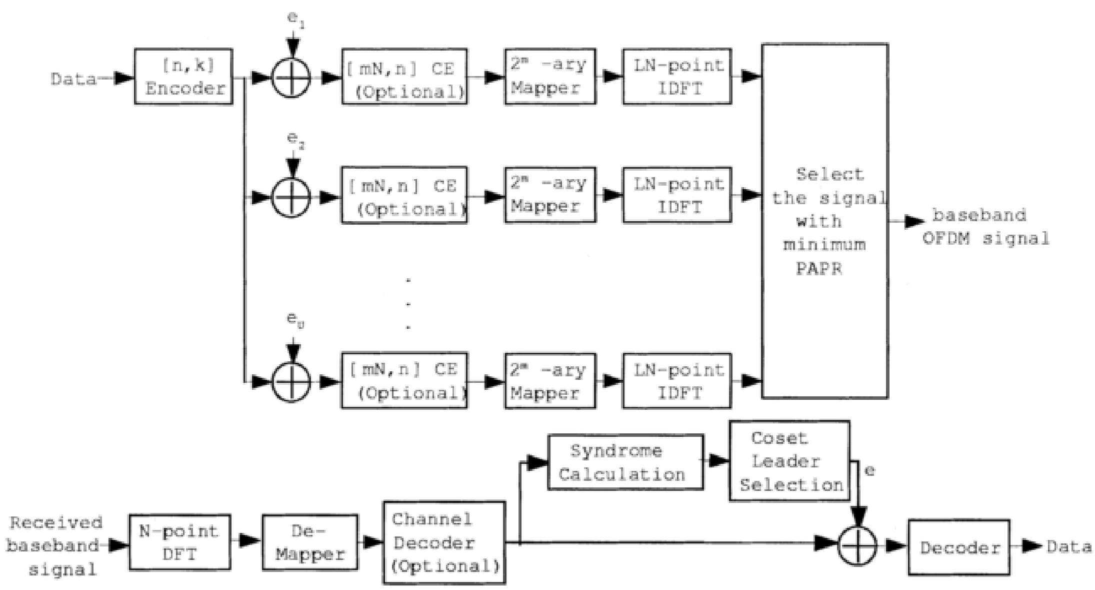

Figure 2.11: Block diagram of scheme using standard array of linear block code [12]

For first step, a binary information sequence is divided into blocks of k bits. Then, the data blocks is encoded into a codeword c after pass through the $[n, k]$ linear block encoder. Next, the U distinct vectors are constructed as $c + e_1, c + e_2, \dots, c + e_U$, where $e_1 = 0$ and $e_2, \dots, e_U$ are selected as the coset leaders of the given code based on their PAPR. Then, this step is optional, for correcting the errors in the channel, the scrambled vectors may be further encoded to an $[mN, n]$ code by a channel encoder (CE). (If CE is not used, then $mN = n$). Each of the scrambled vectors of mN bits is then mapped to a sequence of N modulation symbols by a 2^m-ary signal mapper. Next, it is converted to an OFDM signal by LN-point IDFT, where L is an oversampling factor and N is the number of carriers. Lastly, a signal from U distinct signals with minimum PAPR is selected as the transmitted signal.

At receiver side, by going through the N-point DFT and signal demapper (If necessary, the channel decoder), the received signal is transformed into a received binary vector r. Then, the syndrome calculated from r is used to find out the coset leader e chosen at the transmitter. Finally, the codeword c is achieved by adding e to r and then is converted into an information block sequence of k bits [12]. However, the PAPR reduction capability of this scheme was relatively low to produce a power efficient system.

To summaries, both the techniques, conventional SLM and standard arrays of linear block codes have the weakness of low PAPR reduction capability. Moreover, the conventional SLM still having the problem of high computational complexity. Therefore, there is a need to do some modification on the schemes mentioned.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, steps and approaches on how to propose a modified selected mapping scheme to reduce PAPR in OFDM system will be discussed in details. In previous chapter, the working principle of conventional SLM has been discussed. There are some major issues associated with conventional SLM. In order to achieve better performance SLM, the original technique was modified by adding in standard arrays of linear block codes.

The implementation and simulation of the scheme includes the analysis of results will all be done by using MATLAB software. This chapter being organised by first explaining the project implementation flow. Next, it will step by step describe the modified technique in details. Then, the parameters used for modification and project requirement also will be discussed. At the end, the point stated in each subtopic will be summarise. This can give a clear view on how this project can be executed.

3.2 Project Implementation Flow

The Figure 3.1 below shows the flow of how the project is being implemented.

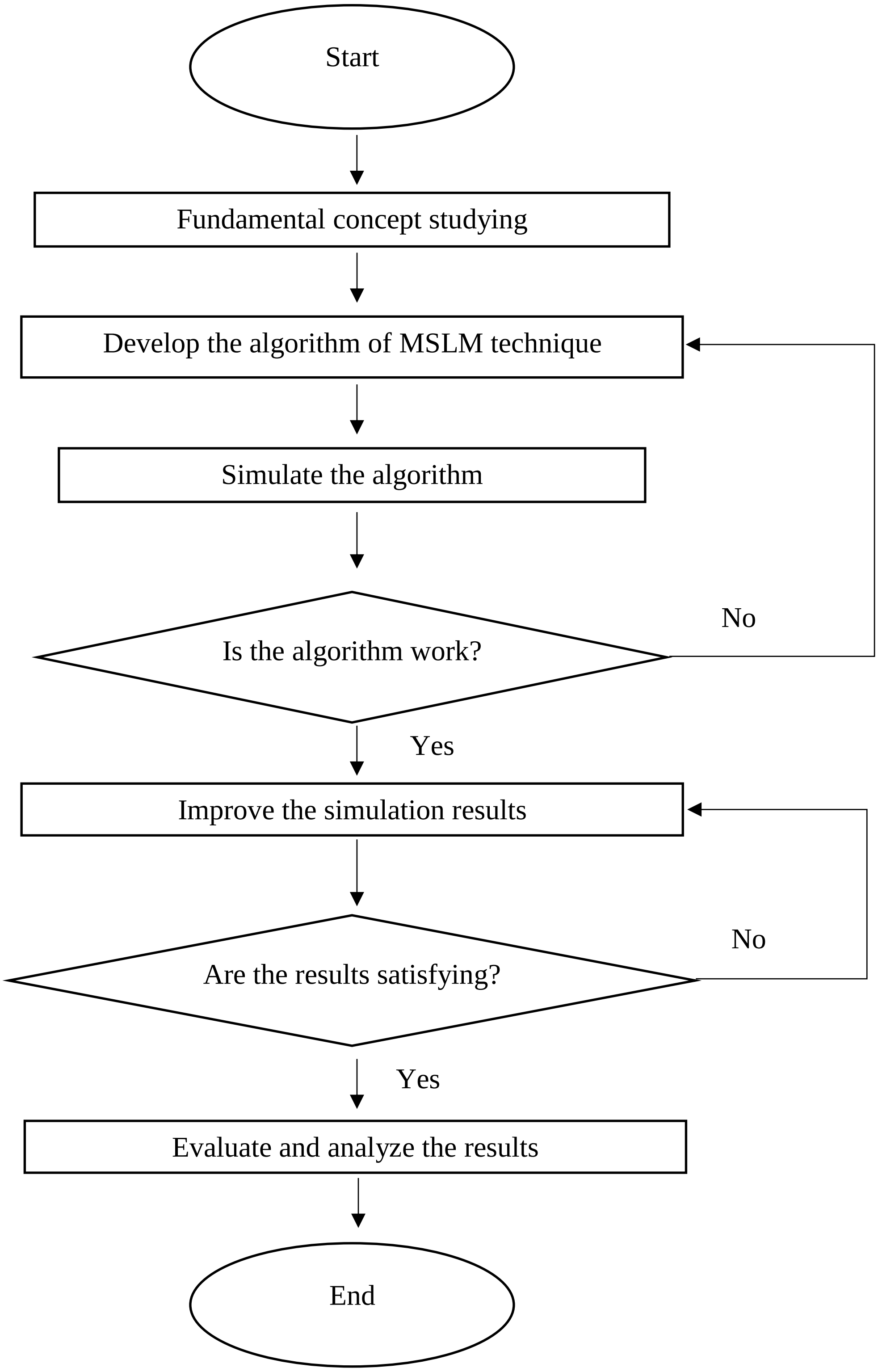

Figure 3.1: Flowchart of project implementation

At the beginning, studies and researches been done on the fundamental concept of OFDM system and methods to reduce PAPR. These are covered in Chapter 1 and Chapter 2 respectively. Next, develop the algorithm of MSLM technique by using MATLAB software. Then, run the algorithm simulation and get the result. If the simulation done successfully, then try to improve the simulation result by manipulating the variables in the algorithm, such as modulation technique, number of subcarriers and also the phase sequence used. Doing this process continuously until get the satisfying output result. Finally, evaluate and analyse the results simulated which will be described in chapter 4.

3.3 Modified Selected Mapping (MSLM) Technique

The MSLM scheme's block diagram is shown in Figure 3.2. First of all, the data source will be send into a linear block encoder. Then, a divider divide the binary information source into blocks of 4 bits. By using [7, 4] hamming encoder, each of the information block is encoded into a codeword c. A control bit is added to the most significant side of codeword c to produce an extended hamming code of 8 bits. Next, construct the standard array of an $[n, k]$ linear block code by calculating the error table and assign coset leader, 16 in number. The sixteen vectors are constructed as $c + e_1, c + e_2, c + e_3,$ ……..etc. Then, calculate the decision criteria, Z for each of the scrambled codeword using the formula $Z = U^2 + V^2 + W^2$. After that, scrambled codeword with the minimum value of Z is selected and then performed the constellation mapping. Then, the data blocks is multiplied with D different phase factors $p_D = [p_1, p_2, \dots \dots p_D]$, where d=1,2,3,……D. After that, the frequency domain signals are converted to time domain by going through IFFT block. Finally, one of the signal with the lowest PAPR is selected for transmission [13].

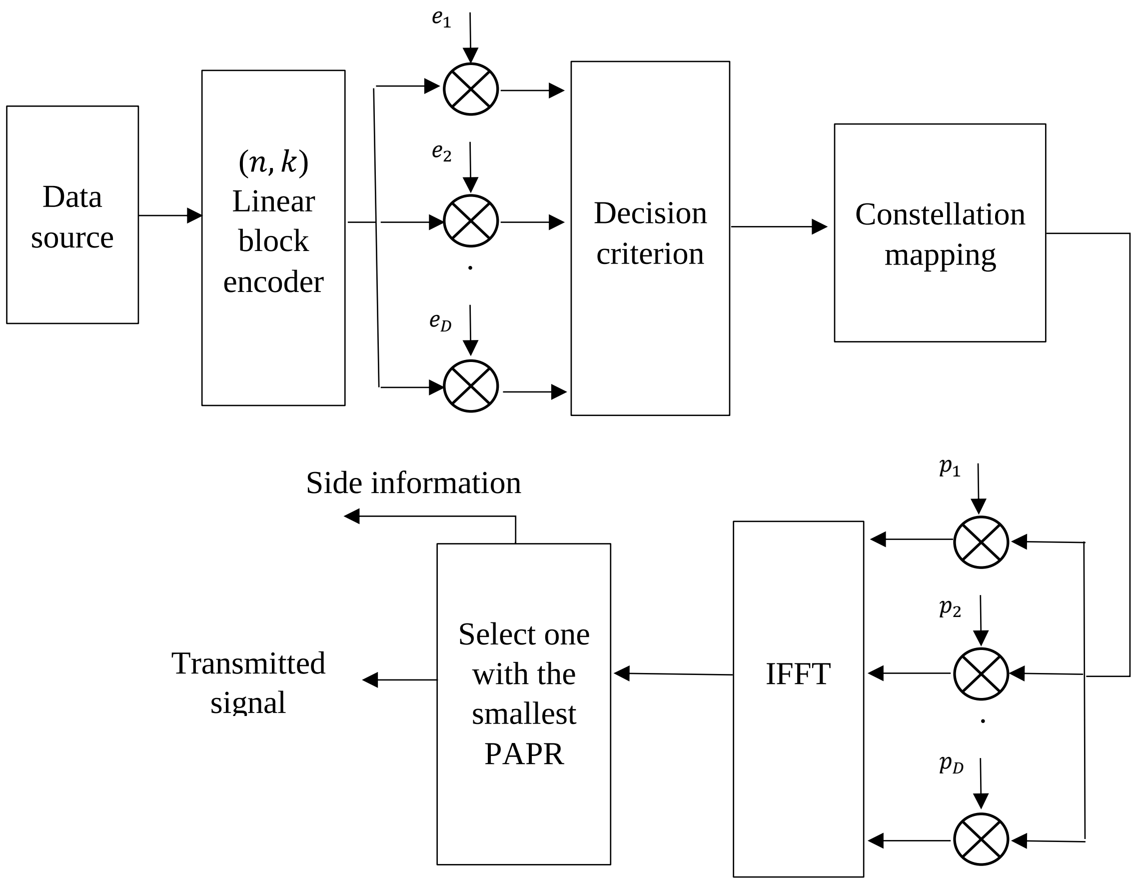

Figure 3.1: Block diagram of MSLM scheme [13]

3.3.1 Linear Block Codes

Consider an $[n, k]$ linear code C with parity-check matrix H, where n is the length and k is the dimension of C. Since ${H_x}^t = 0$ for any code word $c \in C$, any vector $X \in e + c$ has the same syndrome as e, that means

$$ {H_x}^t = H(e+c)^t = {H_e}^t \qquad (3.1) $$

A stream of binary data sequence is divided into blocks of 4 bits. By using [7, 4] hamming encoder, each message block is encoded into a 7 bits codeword C. The purpose of designing hamming codes were correction. The parameters for the family of binary hamming codes are typically denoted as a function of a single integer $m \geq 2$.