EVALUATION PERFORMANCE OF OFDM SYSTEM USING THE SELECTED MAPPING TECHNIQUE FOR WIMAX TECHNOLOGY

MOHAMED SALEH KHALIFA

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Faculty of Electrical and Electronic Engineering
University Tun Hussein Onn Malaysia

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is a promising technique used in the wireless broadband communication systems these days. It is a form of multicarrier modulation technique with high spectral efficiency, robustness to channel fading, immunity to impulse interference, uniform average spectral density, capacity to handle very strong echoes and very less nonlinear distortion are the properties of the OFDM. One major disadvantage of OFDM is that the time domain OFDM signal which is the sum of several sinusoids leading to high peak to average power ratio (PAPR). This work, a technique is proposed in the literature for reducing the PAPR in OFDM systems selected mapping technique (SML) for reducing the PAPR in the simulation result shows the PAPR reduction of OFDM signals. The aim is to come up with an approach for a new modified selected mapping (SLM) technique. The modified technique has the inclusion of the idea of sub block partitioning of signals. The comparative analysis between the conventional SLM scheme and the modified SLM scheme shows that the modification gives better complementary cumulative distributive function (CCDF) of the PAPR of transmitted signal.
ABSTRAK

Orthogonal Frequency Division Multiplexing (OFDM) adalah teknik yang digunakan lidalam sistem komunikasi jalur lebar tanpa wayar pada hari ini. Ia adalah satu bentuk teknik multicarrier modulasi. Ketahanan terhadap kehilangarsalvran, imuniti kepada gangguar impulse, purata seragam ketumpatan spektrum, kapasiti untuk mengendalikan gema yang sangat kuat dan sangat kurang herotan tak sekata adalah arri yang terjapat pada OFDM. Salah satu kelemahan utama OFDM adalah bahawa isyarat OFDM didalar domain masa yang dimara beberapa sinusoids membawa kepada puncak tinggi nisbah kuasa purata (PAPR) untuk, perambahar beberapa sirusoid membawa epade kenaikan pureau (PAPR), teknik yang dicadangkan dalam literatur untuk mengurangkan PAPR dalam sistem OFDM selected mapping technique (SLM) bagi mengurangkan PAPR. hasil daripada simulasi menunjukkan pengurangan PAPR bagi isyarat OFDM. Tujuannya adalah untuk meneari untuk teknik baru pemetaan dipilih diubahsuai (SLM). Teknik yang diubahsuai mempakan idea pembahagian subblock isyarat. Kemudian, dari analisis perbandingan antara skim SLM konvensional dan skim SLM yang diubah suai, ia menunjukkan bahawa slm ya diubahsuai memberikanfungsi yang lebih baik complementary cumulative distributive function (CCDF) daripada isyarat PAPR ya dihantar.
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<th>Description</th>
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<td>ADSL</td>
<td>Asymmetric Digital Subscriber Line</td>
</tr>
<tr>
<td>BRAN</td>
<td>Broadband Radio Access Networks</td>
</tr>
<tr>
<td>Bc</td>
<td>Coherence Bandwidth</td>
</tr>
<tr>
<td>CCDF</td>
<td>Complementary Cumulative Distribution Function</td>
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<tr>
<td>CDF</td>
<td>Cumulative Distribution Function</td>
</tr>
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<td>CP</td>
<td>Cyclic Prefix</td>
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<tr>
<td>DAB</td>
<td>Digital Audio Broadcasting</td>
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<tr>
<td>DFT</td>
<td>Discrete Fourier Transform</td>
</tr>
<tr>
<td>DVB-T</td>
<td>Digital Video Broadcasting-Terrestrial</td>
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<td>FDM</td>
<td>Frequency Division Multiplexing</td>
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<tr>
<td>FFT</td>
<td>Fast Fourier Transform</td>
</tr>
<tr>
<td>HF</td>
<td>High Frequency</td>
</tr>
<tr>
<td>ICI</td>
<td>Inter Carrier Interference</td>
</tr>
<tr>
<td>IDFT</td>
<td>Inverse Discrete Fourier Transform</td>
</tr>
<tr>
<td>IFFT</td>
<td>Inverse Fast Fourier Transform</td>
</tr>
<tr>
<td>ISI</td>
<td>Inter Symbol Interference</td>
</tr>
<tr>
<td>LOS</td>
<td>Line of Sigh Path</td>
</tr>
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<td>MC</td>
<td>Multicarrier Modulation</td>
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<td>OFDM</td>
<td>Orthogonal Frequency Division Multiplexing</td>
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<td>PAPR</td>
<td>Peak to Average Power Ratio</td>
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<td>PSK</td>
<td>Phase Shift Keying</td>
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<td>PTS</td>
<td>Partial Transmit Sequence</td>
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<td>Quadrature Amplitude Modulation</td>
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<td>Radio Frequency</td>
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CHAPTER 1

INTRODUCTION

1.1 Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a Multi-Carrier Modulation technique in which a single high rate data-stream is divided into multiple low rate data-streams and is modulated using sub-carriers which are orthogonal to each other.

The Orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Due to this, the spectrum of each carrier has an null at the center frequency of each of the other carriers in the system. This results in no interference between the carriers, although their spectra overlap. The separation between carriers is theoretically minimal so there would be a very compact spectral utilization [1].

OFDM systems are attractive for the way they handle Inter Symbol Interference (ISI) which is usually introduced by frequency selective multipath fading in a wireless environment. Each sub-carrier is modulated at a very low symbol rate, making the symbols much longer than the channel impulse response.

High capacity and variable bit rate information transmission with high band width efficiency are just some of the requirements that the modern transceivers have to meet in order for a variety of new high quality services to be
delivered to the customers. Because in the wireless environment signals, are usually impaired by fading and multipath delay spread phenomenon, traditional single carrier mobile communication systems do not perform well. In such channels, extreme fading of the signal amplitude occurs and Inter Symbol Interference (ISI) due to the frequency selectivity of the channel appears at the receiver side. This leads to a high probability of errors the overall performance of the system becomes very poor. Techniques like channel coding and adaptive equalization have been widely used as a solution to these problems. However, due to the inherent delay in the coding and equalization process and high cost of the hardware, it is quite difficult to use these techniques in the systems operating at high bit rates, for example, up to several Mbps. An alternative solution is to use a multi carrier system. Orthogonal Frequency Division Multiplexing (OFDM) is an example of it and it is used in several applications such as asymmetric digital subscriber lines (ADSL), a system that make high bit-rates possible over twisted-pair copper wires. It has recently been standardized and recommended for digital audio broadcasting (DAB) in Europe and it is already used for terrestrial digital video broadcasting (DVB-T). The IEEE 802.11a standard for wireless local area networks (WLAN) is also based on OFDM [2].
1.2 Motivation / Problem Statements of The Study

Orthogonal Frequency Division Multiplexing (OFDM) is a promising technology which can be used in many applications and is an efficient method of data transmission for high speed communication systems. There are still some problems that need to be overcome. One of the main problems is the high Peak to Average Power Ratio (PAPR) of the transmitted signals. OFDM (Orthogonal frequency division multiplexing) consist of a large number of independent subcarriers, as a result of which the amplitude of such a signal can have high peak values.

1.3 Aim of The Study

Work to reduce the high Peak to Average Power Ratio (PAPR) of the transmitted signals using the Selected Mapping technique (SLM).

1.4 Objectives of Project

I. To understand and analyze the OFDM system and definition of OFDM transmitter and OFDM receiver.

II. To implement and simulate OFDM system using MATLAB software in order to have better understanding of the standard and the system performance.

III. To analyze the problem using equations and analysis technique which will to PAPR reduction by using MATLAB software.
1.5 Project Scopes

The project scopes include:
Understanding and analysis of OFDM system performance and definitions of the components of the system and the calculate of high average power ratio, analyzed using equations, and calculate of the Selected Mapping (SLM) used and analyzed by using specific equations. It is the work of simulation of OFDM system and to calculate the results of high average power ratio reduction using Selected Mapping technique (SLM) by MATLAB software.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

OFDM is a special case of multicarrier transmission, where single data stream is transmitted over a number of lower-rate subcarriers (SCs). OFDM can be seen as a modulation technique or multiplexing technique. One of the main reasons to use the OFDM is to overcome the frequency selective fading or narrow band interference. In a single-carrier system, a single fade or interference can cause the entire link to fail but in a multicarrier system, only a small percentage of the SCs will be affected. Error-correction coding can be use to correct the few erroneous SCs.
2.2 OFDM system

2.2.1 Concept of OFDM

Orthogonal Frequency Division Multiplexing is based on the principal of transmitting data by dividing the stream into several parallel bit streams of multi-carrier transmission. In an OFDM technique, a large number of orthogonal, overlapping, narrow band sub-channels or subcarriers, transmitted in parallel, divide the available transmission bandwidth. This avoids the need to have non overlapping subcarrier channels to eliminate inter-carrier interference. OFDM is being used in a number of wired and wireless voice and data application due to its flexible system architecture. Some examples of OFDM applications are Digital Audio broadcasting (DAB), and High Rate Digital Subscribers Line (HDSL), and very high rate digital subscriber line (VHDSL) systems, which operate over twisted pair channels. The basic idea behind multi-tone modulation is to replace one wideband signal with several simultaneously transmitted narrowband signals with the same overall bandwidth as the original signal. In principle, the two techniques are equivalent in an AWGN channel. To implement OFDM transmitters and receivers in discrete time, Inverse fast Fourier transform (IFFT) and Fast Fourier transform (FFT) are used respectively. OFDM transmits symbols that have long time duration, which is less or equal to the maximum delay spread. To eliminate ISI, guard intervals are used between OFDM symbols[3].
Figure 2.1 illustrates the spectrum of an individual data subcarrier. In the individual spectra the OFDM signal equal to the bandwidth of each subcarrier. Figure 2.2 shows the spectrum of the OFDM symbol.

Figure 2.1: Spectra of OFDM individual subcarrier

Figure 2.2: Spectra of OFDM symbol
2.3 OFDM advantages & disadvantages

2.3.1 Advantages of the OFDM are:

- The OFDM is an efficient way to deal with multipath and delay spread.
- The implementation of the OFDM system is significantly lower than that of a single carrier system with an equalizer.
- The OFDM is resistance to frequency selective fading. This is because such interference affects only a small percentage of the Subcarries (SC).
- The bandwidth usage of the OFDM is efficient.

2.3.2 The disadvantages of the OFDM are:

- The OFDM is more sensitive to frequency offset and phase noise.
- OFDM has a relatively large peak-to-average-power ratio, which tends to reduce the power efficiency of the radio frequency (RF) amplifier.

2.4 OFDM system model (transmitter and receiver system in OFDM)

The OFDM signal generated by the system in Figure 2.3 shown at baseband, in order to generate a radio frequency (RF) signal at the desired transmit frequency filtering and mixing is required. OFDM allows for a high spectral efficiency as the carrier power and modulation scheme can be individually controlled for each carrier. However in broadcast systems these are fixed due to the one-way communication [4].
2.4.1 Interleave and Deinterleave

All encoded data bits shall be interleaved by a block interleaver with a block size corresponding to the number of coded bits per the specified allocation, $N_{cbps}$. Due to different modulation scheme BPSK, QPSK, 16QAM, 64-QAM. The interleaver is defined by a two-step permutation. The first ensures that adjacent coded bits are
mapped onto nonadjacent carriers. This ensures that if a deep fade affects a bit, its neighboring bits are likely to remain unaffected by the fade, and therefore is sufficient to correct the effects of the fade. The second permutation insures that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation. This makes detection accurate and long runs of low reliability bits are avoided. Deinterleaver is performed in reverse order of operations [5].

2.4.2 Modulation and Demodulation

After bit interleaving, the data bits are entered serially to the constellation mapper. The specified modulation scheme in the downlink (DL) and uplink (UL) is binary phase shift keying (BPSK), quaternary PSK (QPSK), 16 quadrature amplitude modulation (QAM) and 64QAM to modulate bits to the complex constellation points. The FEC options are paired with the modulation schemes to form burst profiles.

2.4.3 Cyclic Prefix Insertion

To explain the cyclic prefix for OFDM let us start by assuming two OFDM symbols that they have experienced a delay spread $td$ and channel dispersion. Figure 2.4a illustrates slow subcarrier (slow delay spread at $td$) and fast subcarrier (fast delay spread at $td$) inside each OFDM symbol on the transmitted signal. Figure 2.4b shows slow subcarrier delayed by $td$ against fast subcarrier on the received signal. As it can be seen from the figure 2.4b that the slow subcarrier in the OFDM symbol interfere with another OFDM symbol and that is called inter symbol interference (ISI). Moreover, the OFDM waveform in the discrete Fourier transform (DFT) window is incomplete so that the orthogonality condition for the subcarrier is lost which result in inters carrier interference (ICI).

Cyclic prefix is a technique that is used to resolve ISI and ICI. Figure 2.4c shows a cyclic prefix of the OFDM symbol into the guard interval $\Delta G$. And the waveform in the guard interval is a copy of that in the DFT window with shift $ts$. The
OFDM signal with guard interval on the received signal is shown in figure 2.4d. As it can be seen from the figure 2.4d the OFDM symbol of the slow subcarrier is in the DFT window because the cyclic prefix has moved into the DFT window to replace the signal that has shifted out of this OFDM symbol.

Thus, the main idea of this technique is to replicate part of the OFDM waveform from the back to the front to develop a guard period. And at the receiver, certain position within the cyclic prefix is picked as the sampling starting point, which satisfies the condition $t_d < \Delta G$ where $t_d$ is the delay spread and $\Delta G$ the guard interval [6].

![Diagram of OFDM signals with and without cyclic prefix]

Figure 2.4: OFDM signal (a) without cyclic prefix at the transmitter, (b) without cyclic prefix at the receiver, (c) with cyclic prefix at the transmitter, and (d) with cyclic prefix at the receiver.
The inverse Fourier transform converts the frequency domain data stream into the corresponding time domain. Then a parallel to serial convertor is used to transmit time domain samples of one symbol. The Fast Fourier Transformation (FFT) is used to convert data in time domain to the frequency domain at the receiver. The serial to parallel block convertor is placed to convert this parallel data into a serial stream to the original input data. IFFT (Inverse Fast Fourier Transformation) block allocates the different orthogonal subcarrier for transmitted bits and thus no interference exists between subcarriers. In this situation sub-carriers can be closer together, which means that bandwidth can be saved signification [7].

Figure 2.5: IFFT and FFT description
2.4.5 Serial to parallel Conversion

The input serial data stream is changed into the word size which is required for transmission and is shifted into a parallel format. The data is then transmitted in parallel by assigning each data word to one carrier in the transmission.

2.4.6 Time frequency synchronization

In OFDM systems, the main synchronization parameters to be estimated are a sync flag indicating the presence of the signal (especially for burst-mode transmission), the starting time of the FFT window (timing synchronization), the frequency offset due to the inaccuracies of the transmitter and receiver oscillators, and the Doppler shift of the mobile channel, as well as the channel estimates if coherent reception is adopted. The sync flag can be generated by automatic gain control (e.g., ramp-up indication via power measurement and threshold decision) or using a training symbol (which can also be used for timing synchronization and possibly frequency synchronization). For the latter case, the same metric used for timing synchronization may be used together with the threshold decision, in order to generate the sync flag. After detecting the presence of the signal, the other sync parameters are estimated. In the following, the effect of timing synchronization errors is briefly described for the later use [8].

2.4.7 Quadrature Phase Shift Keying (QPSK)

QPSK is one of the modulation process where it only differ in terms of phase but its amplitude and frequency is constant. QPSK have four probabilities because they are in an array of PSK system. Each of the elements represents two bits and shift of $\pi/2$ or $90^0$. The Figure 2.6 shows the constellation diagram for QPSK.
for gray coding and each adjacent symbol only differs in one bit and has constant amplitude.

Figure 2.6: Constellation Diagram for QPSK

2.4.8 QAM Modulator

Figure 2.7 shows the QAM modulator block diagram. The binary input is the first to be transmitted is split into two equal parts. This process generates two independent signals which are d1 and d2 are ready to be transmitted. One of the channels is multiplied by the cosine which is generated by the carrier oscillator, while the other channel is multiplied by a sine that is $90^\circ$ phase shift from the carrier oscillator. These two signals are sum up and become the QAM signal.
2.5 PAPR Reduction Techniques

One of the major disadvantages of OFDM systems is that the OFDM signal has high Peak to Average Power Ratio (PAPR), and to deal with this problem many typical techniques have been proposed. Each one is different from others in complexity and performance, and can be divided into three major categories:

2.5.1 Signal distortion techniques

. Signal Clipping

. Peak windowing

. Peak cancellation

. Symbol-scrambling techniques

. Partial Transmit Sequences

. Selected Mapping
2.5.1.1 Signal Clipping

Clipping is the simplest technique that is used to reduce PAPR in OFDM system. The basic idea of this technique is to clip the parts of the signals that have high peak outside of the allowed region. The following equation shows the amplitude clipping [9].

\[
c(x) = \begin{cases} 
M & |M| \leq A \\
A & |M| > A
\end{cases}
\]

(2.1)

Where A is a positive real number and it presents the clipping level.

Since the clipping is always performed at the transmitter, signals at the receiver have to estimate the clipping that has occurred at the receiver. In general, one clipping occurs per OFDM symbol, and the receiver has to calculate two important parameters: location and size of the clipping signals. Clipping method is a nonlinear process and may cause in or out distortion into the OFDM system, which may affect the bit error performance (BER), besides, it may cause peak regrowth. Peak regrowth happens when clipping exceed the clipping level. And by repeating clipping and filtering process again the effect of this distortion can be eliminated [9].
2.5.1.2 Peak windowing

Another method used to reduce the PAPR in OFDM system is Peak windowing. The main idea of this method is to multiply large signal peaks by a Gaussian shaped window to reduce the out of band radiation. As the matter of fact, any window could be used to minimize out band radiation. The window has to be as narrowband as it needed, however, it should not be too long in time domain because many signals might be affected which will result in increasing bit error rate (BER). Appropriate windows that offer good result in reduction PAPR in OFDM are Kaiser, Cosine and Hamming functions. Figure 2.9 shows an example of reducing PAPR by using peak windowing and indicates that how by increasing the window level the distortion will decrease [10].
2.5.1.3 Peak Cancellation

The basic idea of peak cancellation is to reduce the amplitude of the data samples when the magnitude exceeds a certain threshold. A comparator can be used to check whether the OFDM symbol exceeds the threshold or not. In case the amplitude is above the threshold, the peak and the side lobes are scaled in way so that they maintain the certain threshold. Figure 2.10 demonstrates the block diagram of an OFDM transmitter with peak cancellation which is located after the cyclic prefix (CP). And an example is shown in Figure 2.11 which indicates the peak amplitude is reduced to 3 dB corresponding to the peak cancellation.
2.5.1.4 Partial Transmit Sequences (PTS)

Partial transmit sequences (PTS) is one of the most important methods that is used to reduce PAPR in the OFDM system. And it can be presented in two main steps. First, by dividing the original OFDM signal into a number of sub-blocks.
Secondly, adding the phase rotated sub-blocks to develop a number of candidate signals to pick the one with smallest PAPR for transmission. There is another way that it can also be used to express PTS method by multiplying the original OFDM signal with a number of phase sequences [11].

Let us assume that $M = \{M_k\}$, where $(k = 0,\ldots,N-1)$, is the frequency domain (FD) data of an OFDM signal $x_n = \text{inverse discrete Fourier transform (IDFT)} \{M_k\} (n = 0,\ldots,N-1)$, where $N$ is the number of subcarriers. It can be reduced the PAPR of signal $m = \{m_n\}$ by using PTS method in the following steps:

1. Make $F$ is the frequency domain (FD) data sequences, $M^\mathcal{E} (\mathcal{E} = 1,\ldots,F)$, by multiplying the phase sequences $P^\mathcal{E} = \{P^\mathcal{E}_k\} (k = 0,1,\ldots,N-1)$ with $X$ elements , it can get the following result,

$$M^\mathcal{E} = [M^\mathcal{E}_0, M^\mathcal{E}_1,\ldots,M^\mathcal{E}_{N-1}] = 1,\ldots,F \quad (2.2)$$

Where $P^\mathcal{E}_k = \exp (j\phi^\mathcal{E}_k)$, $\phi^\mathcal{E}_k$ is uniformly distributed in $(0, 2\pi)$.

2. Get $M$ candidates time domain (TD) via IDFTs

$$X^\mathcal{E} = \text{IDFT} \{M^\mathcal{E}\}, \mathcal{E} = 1,\ldots,M \quad (2.3)$$

All the candidates have the same information $m$, but different PAPRs. The one with the smallest PAPR in is $M^\mathcal{E}$ selected for transmission. Figure 2.12 shows an example of PTS technique.
2.5.1.5 Selected Mapping

Selected mapping (SLM) is a promising PAPR reduction technique of OFDM system. The main idea of SLM technique is to generate a number of OFDM symbols as candidates and then select the one with the lowest PAPR for actual transmission. This technique will be discussed in details in the next chapter.
2.6 Previous studies

2.6.1 Lakhendrakuma Gupta, Brajendra Kumar, Ashish Mishra, Asutosh Kumar

This paper studied multicarrier modulation as an attractive technique for fourth generation wireless communication. Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier transmission scheme. Its high peak to average power ratio (PAPR) of the transmitted signal is a major drawback. The paper also compared PAPR QPSK-OFDM with and without SLM. A modified selective mapping technique is proposed in this paper to improve the performance of the OFDM system with respective PAPR. Results of simulation of modified SLM technique show that the PAPR reduction of OFDM system, which further results in high performance of wireless communication. With the rising demand for efficient frequency spectrum utilization, OFDM proves valuable to next generation communication systems.

2.6.2 Seung Hee Han, Student Member, and Jae Hong Lee, Senior Member
“Modified Selected Mapping Technique for PAPR Reduction of Coded OFDM Signal” 11, November 2013.

This paper studied high peak-to-average power ratio (PAPR) of the transmitted signal as a major drawback of orthogonal frequency division multiplexing (OFDM). They propose a modified selective mapping (SLM) technique for PAPR reduction of coded OFDM signal. This technique, they embed the phase sequence, which is used to lower the PAPR of the data block, in the check symbols of the coded OFDM data block. They achieve both PAPR reduction from the SLM technique as well as error performance improvement from the channel coding with no loss in data rate from the transmission of side information. In addition, approximate expression for the complementary
cumulative distribution function (CCDF) of the PAPR of the modified SLM technique is derived and compared with the simulation results.

2.6.3 Hybrid scheme Polytechnic “PAPR reduction of OFDM signals using selective mapping and clipping” University, Faculty of Electronics and Telecommunications, Communication Department, Bucharest, Romania, August 27, 31-2012.

This paper studied The Orthogonal Frequency Division Multiplexing is one of the modulation techniques widely used in the broadband wireless technology. One of the main problems of this technology is the high peak-to-average power ratio of transmission signal due to the superposition of many subcarriers. This paper studied too a new hybrid peak-to-average power ratio reduction technique, which combines a selective mapping method with the clipping method.
CHAPTER 3

METHODOLOGY

3.1 Introduction

The goal of this project is to evaluate the performance of OFDM system. This discusses the definition of PAPR and the high PAPR issues. And then represent existing popular PAPR reduction schemes such as, Clipping, Interleaving, and Coding and discusses selected mapping (SLM) technique which is a well known technique to reduce the peak-to-average power ratio (PAPR).

3.2 Simulation Methodology

Flowchart Clipping based PAPR decrease plans exhibited in this project have normal execution steps. Indeed, these strategies can be spoken to utilizing a typical piece outline, indicated in Figure below.
References


14. ARUNA, S., & MALLIKA, Y. Reducing Peak to Average Power Ratio of OFDM by Using Selected Mapping.