PAPR REDUCTION USING GENETIC ALGORITHM (GA)

IN OFDM SYSTEM

FATIN NAJWA NURSYADZA BINTI MOHD RAMDAN

UNIVERSITI SAINS MALAYSIA

2018

PAPR REDUCTION USING GENETIC ALGORITHM (GA)

IN OFDM SYSTEM

By

FATIN NAJWA NURSYADZA BINTI MOHD RAMDAN

Thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Engineering (Electronic Engineering)

June 2018

ACKNOWLEDGMENT

First and foremost, I would like to thank to my supervisor, Mr Aeizaal Azman bin Abd Wahab for giving me this opportunity to handle the thesis under his supervision. He has help me in doing my thesis, and an optimistic supervisor that assured me on doing my thesis. Without his guidance, completing my thesis will be a difficult task.

I also would like to give a special thanks to my family and friends who always give me an inspiration, support and encouragement towards completing this thesis. Without them, it is impossible for me to complete this final year thesis with flying colours

TABLE OF CONTENTS

CHAPTER 2:LITERATURE REVIEW

CHAPTER 3:METHODOLOGY

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

A/D	Analog to Digital Converter
ACE	Active Constellation Extension
ASE	Active Set Extension
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
CCDF	Complementary Cumulative Distributive Function
CDMA	Code Division Multiple Access
D/A	Digital to Analog Converter
DFT	Discrete Fourier Transform
ES	Evolution Strategies
FDM	Frequency Division Multiplexing
FFT	Fast Fourier Transform
GA	Genetic Algorithm
HPA	High Power Amplifier
IDFT	Inverse Discrete Fourier Transform
IFFT	Inverse Fast Fourier Transform

ISI	Intersymbol Interference
LBC	Linear Block Coding
MOOP	Multi-objective Optimization
OFDM	Orthogonal Frequency Division Multiplexing
PA	Power Amplifier
PAPR	Peak-To-Average Power Ratio
PSD	Power Spectral Density
PTS	Partial Transmit Sequence
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase-Shift Keying
SLM	Selective Mapping
SNR	Signal-To-Noise Ratio
TR	Tone Reservation

LIST OF SYMBOLS

P_{av}	-	Average Power
A	-	Amplitude
$\hat{x}$	-	Transmitted OFDM
p_m	-	Phase Sequence
F_i	-	Fitness chromosome
b_m	-	Phase factor

PENGURANGAN NISBAH KUASA PUNCAK KE PURATA (PAPR) MENGGUNAKAN ALGORITMA GENETIK (GA) DALAM SISTEM PEMBAHAGIAN FREKUENSI ORTOGON (OFDM)

ABSTRAK

Komunikasi mudah alih tanpa wayar adalah teknologi yang terpantas yang sedang bertambah baik. Sistem pembahagian frekuensi ortogon pemultipleksan (OFDM) dipilih untuk teknologi ini, kerana ia adalah teknik transmisi berbilang carrier yang paling banyak digunakan untuk memenuhi permintaan yang semakin tinggi penghantaran. Sistem ortogon pemultipleksan pembahagian frekuensi (OFDM) mempunyai masalah nisbah kuasa puncak-ke-rata skor tinggi (PAPR). Tinggi PAPR akan memacu penguat kuasa pada pemancar ke dalam tepu, menghasilkan gangguan antara subpembawa yang mempersendakan prestasi BER dan merosakkan spektrum isyarat. Dalam usaha untuk mengurangkan prestasi PAPR dalam sistem OFDM, teknik pengurangan banyak akan diterokai Dalam tesis ini satu teknik (GA) algoritma genetik adalah dicadangkan. GA adalah sejenis algoritma pengoptimuman, ia adalah pilihan berasaskan alam semula jadi dan digunakan untuk mencari penyelesaian optimum kepada masalah pengiraan yang maksimum atau minimum fungsi tertentu. Tujuan karya ini adalah untuk membandingkan dan menganalisis prestasi PAPR berdasarkan jumlah subpembawa dan modulasi menggunakan perisian Matlab pelengkap fungsi taburan kumulatif (CCDF) Graf antara OFDM asal dan cadangan kaedah OFDM-GA. Keputusan simulasi menunjukkan bahawa jika dibandingkan dengan OFDM asal, cadangan kaedah OFDM-GA mengurangkan

prestasi PAPR di sekitar 50%. Cara GA yang dicadangkan telah berjaya mengurangkan prestasi PAPR dalam sistem OFDM.

PAPR REDUCTION USING GENETIC ALGORITHM (GA) IN OFDM SYSTEM

ABSTRACT

Wireless mobile communication are the fastest technology that are being improve. Orthogonal frequency division multiplexing (OFDM) system is chosen for the technology, since it is the most widely employed multi-carrier transmission technique to cater the growing demand of high transmission. An orthogonal frequency division multiplexing (OFDM) system has the problem of high peak-to-average power ratio (PAPR). High PAPR would drive the power amplifier at the transmitter into saturation, producing interference among the subcarriers that degrades the BER performance and corrupts the spectrum of the signal. In order to reduce the PAPR performance in OFDM system, many reduction technique are explored. In this thesis, a Genetic algorithm (GA) technique is proposed. GA is a type of optimization algorithm, which is natural-based selection and is used to find the optimal solution to the computational problem that maximizes or minimizes a particular function. The aim of this thesis is to compare and analyze the PAPR performance based on the number of subcarrier and modulation size using Matlab software of complementary cumulative distribution function (CCDF) graph between original OFDM and the proposed method OFDM-GA. The simulation result demonstrates that comparing to the original OFDM, the proposed method OFDM-GA decreases the PAPR performance around 50%. The proposed GA method successfully reduces the PAPR performance in OFDM system.

CHAPTER 1

INTRODUCTION

1.1 Introduction

In this thesis, chapter 1 will introduce briefly about the information of the research. This chapter also state clearly about the research background and the aim of this research. The introduction will start with the introduction of orthogonal frequency division multiplexing (OFDM) and it history. Then, its problem analysis with peak to average power ratio (PAPR).

1.2 Research Background

The growing demand for wireless multimedia services requires reliable and high-rate data communications over a wireless channel. However, high-rate data communications are significantly limited by intersymbol interference (ISI) because of time dispersive nature of wireless channel. Multicarrier systems spark interest in recent years as a potential solution to the problem of transmitting data over wireless channels. An OFDM system is one of the widely used multicarrier systems because OFDM technique is especially effective which includes the strong immunity to multipath fading, high spectral efficiency and easy compensation for frequency-selective channel[1, 2].

OFDM used a digital multicarrier modulation method which are a scheme under frequency division multiplexing (FDM), where on parallel data streams or channels a large number of closely spaced orthogonal subcarriers signals are used to carry data [3]

For each subcarriers, the data is divided into several parallel streams of channel. Each subcarrier is modulated with conventional modulated scheme, such as quadrature amplitude modulation (QAM) or quadrature phase-shift keying (QPSK) at a low symbol rate. These subcarriers are generated in the frequency domain and an Inverse Fast Fourier transform (IFFT) is used to generate the corresponding time-domain signal. The signal power after the IFFT stage can be increased, especially when the output signals are in phase. This yields a high PAPR, which forces the system to employ nonlinear amplification [3, 4]. PAPR is one of the major hindrance in OFDM communication system since nonlinear amplification degrades the OFDM system by distorting the transmitted signals. The PAPR reduction in OFDM system is still an active area of research [5]. The High PAPR increases the complexity of analog-to-digital (A/D) and digital-to-analog (D/A) converters, and lowers the efficiency of power amplifiers. Over the past decade various PAPR reduction techniques have been proposed[1].

This thesis paper proposes and evaluates PAPR effectively using Genetic algorithm (GA). Where, Genetic algorithm (GA) is a type of optimization algorithm, it is a natural-based selection and used to find the optimal solution to the computational problem that maximum or minimum particular function [6].GA are widely used to search for the global optimum in combinatorial problem [7]. GA imitate the biological process of reproduction and natural selection to solve the fittest solution [6]. In a genetic algorithm, a population of candidate solutions to an optimization problem is evolved. Where, each candidate solution has a set of properties which can be mutated and altered where, GA use a solution of bit string that use sequence of 1's and 0's [7].GA process are random, but allows one to set the level of randomization and the level of control which made them more efficient, yet it required no extra information about the given problem [6].

Therefore, in order to reduce the PAPR the GA technique is used. GA is used as the selection mechanism for an appropriate phase rotation vector (called a chromosome) for minimizing the PAPR of OFDM signals.

1.3 Problem Statement

OFDM system are widely used in communication system because of its advantages. But the major drawback of the OFDM system is the PAPR of the transmit signals. If the peak transmit power is limited by either regulatory or application constraints, the effect is it will reduce the average power allowed under multicarrier. This in turn will reduce the range of multicarrier transmission. Moreover, to prevent spectral growth of the multicarrier signal in the form of intermodulation among subcarriers and out-of-band radiation, the transmit power amplifier must be operated in its linear region, where the power conversion is inefficient. This may lead to a deleterious effect on battery lifetime [8].

GA (a type of evolutionary computing), are search techniques based on probabilities that reflect natural genetics [6]. These algorithms are widely used to search for a global optimum in combinatorial problems due to their simplicity [5]. Therefore, GA method is used because it can obtain an optimal object with respect to the parameters.

The performance of a PAPR reduction scheme is usually demonstrated by three main factors, the complementary cumulative distributive function (CCDF), bit error rate (BER), and spectral spreading. This thesis paper will evaluate based on CCDF.

With OFDM-GA technique, the PAPR performance decreases. From reference OFDM-GA perform better in reducing the PAPR than OFDM. Therefore, genetic algorithm is used to analysis the performance of PAPR in OFDM signal.

1.4 Objectives

The objectives of this thesis are:

1. To analyze and reduce PAPR using original OFDM and OFDM-GA technique in OFDM system.
2. To evaluate PAPR performance based on different number of subcarriers and QAM modulation based on proposed method.

1.5 Research scope

This thesis is limited on OFDM system and only based on software and no hardware implementation. The focus of this thesis is on PAPR reduction using original OFDM and the proposed OFDM-GA .The result will be analyzed based on the PAPR performances.

The method will be analyzed with four number of subcarrier (64, 128, 256, 512) with a 16QAM and 64QAM modulation in order to observe the effect of number of subcarriers and modulation number in PAPR reduction

1.6 Thesis structure

This thesis consist of 5 chapter. In the first chapter, a brief introduction on the OFDM, PAPR and GA are introduce. The research background and its motivation of the research is also been stated on this chapter. The research problem and it objective are also been explain and state clearly in chapter 1.

Chapter 2 is Literature review. Literature review is basically the review summary of an important information about the research and have been combined together from different sources that are related to the research topic .This chapter will explain about the history, concept and aim of OFDM, the PAPR reduction technique, GA and it history.

In chapter 3, the methodology or flow taken in this research will be discussed and explained in detail in this chapter.   In chapter 4, result and discussion. The results obtain from the simulation of OFDM and OFDM-GA is explained in detail. Finally in chapter 5, conclusion. A conclusion is drawn and some area of research are suggested for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will explain more deeply about the research topic. Firstly, OFDM is introduce briefly and the important of OFDM is explain. Then, OFDM advantages and disadvantages are listed and explain briefly. After that, the evolution of OFDM and the theory of the OFDM is included in this chapter.

Next is the explanation about the problem of OFDM and what method are to be used. In this thesis the main focus is to reduce the PAPR. The definition of PAPR are been explain in words and mathematically and the factor effecting the PAPR is listed and explain in this chapter.

GA is the most popular technique in the Evolutionary Algorithm. This is because GA offer easy to implement optimization strategies. Which is why GA is used in this thesis paper. In this part, the important process in GA technique is explained and it example of application is stated.

2.2 Orthogonal Frequency Division Multiplexing

Modern wireless communication systems are aimed at providing high-speed data transmission to support Internet, high quality multimedia, and high definition streaming videos. Therefore, OFDM has emerged as a key technology to increase the reliability of communication system and also as to achieve a high data rates in today wireless environment [9]. Because OFDM main advantages is high spectral efficiency compared to double side band modulation scheme, computationally efficient by using fast fourier transform (FFT) techniques to implement the modulation and demodulation functions, provides high data rate and supports different modulation size of quadrature amplitude modulation (16QAM and 64QAM), binary phase shift keying (BPSK) and quadrature phase shift keying (QPSK) based on channel conditions [10].

OFDM is one of multicarrier modulation techniques. It utilize the orthogonality properties and has the ability to cope with severe channel conditions without complex equalization filters. By applying the cyclic prefix technique and sending multiple low rates of symbol in parallel, the OFDM achieve higher data rate, able to eliminate inter-symbol interference (ISI), and can utilize echoes and time-spreading [9].

In OFDM systems, as shown in Figure 2.1 and Figure 2.2, the baseband operations at the transmitter include mapping the information data bit stream to symbols according to a certain modulation scheme, such as M-PSK or M-QAM a fixed number of successive input data samples are modulated first such as QAM, . The data streams transmitted simultaneously by subcarriers. Each of the subcarriers is independently modulated and multiplexed. Then it is combined together using IFFT at the transmitter side. IFFT is used to produce orthogonal data subcarriers. Let data block of length N be represented by a vector

$$X = [X_0, X_1, \dots, X_{N-1}]^T \qquad (2.1)$$

Duration of any symbol X_k in the set X is T and represents one of the subcarriers set.

The complex data block for the OFDM signal to be transmitted is given by [11]

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_N \, e^{j2\pi n \Delta f t} \quad 0 \le t \le NT \qquad (2.2)$$

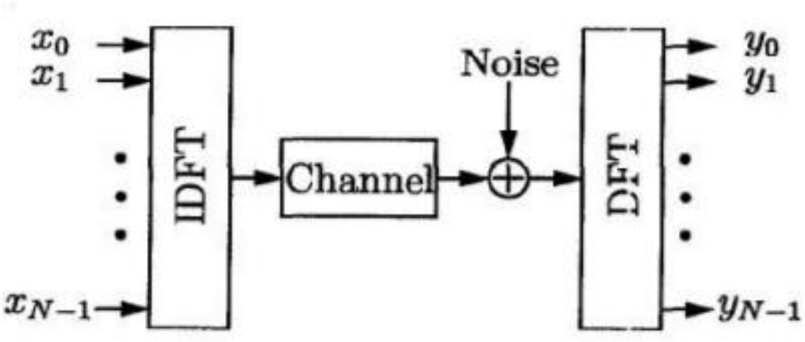


Figure 2.1: Implementation of OFDM[11]

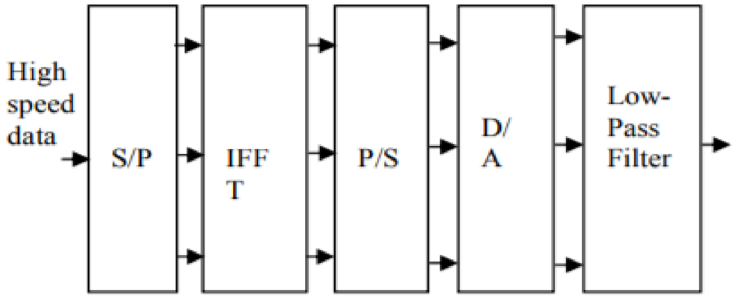


Figure 2.2: OFDM block diagram[11]

2.2.1 Advantages and Disadvantages

Advantages of OFDM are as follows [12]:

- OFDM makes resourceful utilization of the spectrum by overlapping and dividing the channel into narrowband flat fading sub channels, these make OFDM more resistant to frequency selective fading than single carrier systems.
- OFDM can easily adapt to severe channel conditions without complex time-domain equalization.
- OFDM reduces ISI through the use of a cyclic prefix and fading caused by multipath propagation.
- Channel equalization becomes simpler than by using adaptive equalization techniques with single carrier systems.
- OFDM is computationally capable by using FFT techniques to implement the modulation and demodulation functions.
- OFDM is less sensitive to sample timing offsets than single carrier systems are.
- Tuned sub-channel receiver filters are not required in OFDM, unlike conventional FDM

Disadvantages are as follows[12]:

- The OFDM signal has a noise like amplitude with a very large dynamic range, hence it requires RF power amplifiers with a high peak to average power ratio.
- OFDM is more sensitive to carrier frequency offset and drift than single carrier systems. These is due to the leakage of the DFT.
- It is sensitive to Doppler shift.
- It requires linear transmitter circuitry, which suffers from poor power efficiency.
- It suffers loss of efficiency caused by cyclic prefix

2.2.2 Evolution Of OFDM

The evolution of OFDM is divided into three parts [13] :

1. Frequency Division Multiplexing (FDM):
   - FDM has been used to carry more than one signal over a telephone lines. FDM concept is to carry information of different users using different frequency channels. Some gap or guard band was left between different channels to ensure that the signal of one channel did not overlap with the signal from an adjacent one. Thus, the guard band will lead to inefficiencies.

2. Multicarrier Communication (MC):
   - MC concept uses FDM form but only between a single data source and a single data receiver. It enabled an increase in the overall capacity of communications, thereby increasing the overall throughput. MC is the splitting a signal into a number of signals, modulating each of these new signals over its own frequency channel, multiplexing these different frequency channels together in an FDM manner.

3. Orthogonal Frequency Division Multiplexing (OFDM):
   - OFDM is a form of multicarrier modulation where the carrier spacing is selected carefully so that each subcarrier is orthogonal to the other subcarriers. Where, orthogonality is when the subcarrier frequencies is carefully selected, means they are harmonics to each other.

2.2.3 OFDM Theory

OFDM is a method for transmitting data in parallel by using a large number of modulated subcarriers. The subcarriers (or sub-channels) are orthogonal when it divide the available bandwidth and frequency spacing. The Orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Hence, the spectrum of each carrier has a null at the centre frequency of each carriers in the system. Therefore, there are no interference between the carriers, although their spectra overlap [12].

The separation between carriers is theoretically minimal so there would be a very compact spectral utilization. OFDM systems are attractive because it can handle ISI, which is usually introduced by frequency selective multipath fading in a wireless environment. To make the symbols much longer than the channel impulse response, so that it can lower the ISI is by modulated each subcarrier at a very low symbol rate. Moreover, the effects of ISI can completely vanish if a guard interval between consecutive OFDM symbols is inserted. The guard interval must be longer than the multipath delay. Although each subcarrier operates at a low data rate, a total high data rate can be achieved by using a large number of subcarriers [13].

2.3 Peak to Average Power Ratio

The main reason of the occurrence of high PAPR in OFDM is due to addition of data symbols across a number of independent modulated sub-carriers with same phase. The main impact of large peaks is Saturation of the high power amplifier (HPA) as a result reduced in efficiency of amplifier and Complexity in A/D and D/A rise up[14].

The peak-to-average power ratio (PAPR) is a related measure that is defined as the peak amplitude squared (giving the peak power) divided by the RMS value squared (giving the average power). The PAPR is mostly used in signal processing applications. As it is a power ratio, it is normally expressed in decibels (dB) [8].

The PAPR of an OFDM signal ($x(t)$), is defined as the ratio of the maximum instantaneous power to its average power (P_{av}).

$$PAPR\ (\ x(t)\ ) = \frac{\frac{max}{0 \leq t \leq T}\ |x(t)|^2}{P_{av}} \qquad (2.3)$$

$$P_{av} = \frac{1}{N} \sum_{k=0}^{N-1} E[|X_k|^2] \qquad (2.4)$$

The performance of a PAPR reduction scheme is usually demonstrated by three main factors: the CCDF, BER, and spectral spreading [15]

- Complementary Cumulative Distributive Function (CCDF):

The empirical CCDF is the most informative metric used for evaluating the PAPR. PAPR reduction is measured by the amount of CCDF reduction. CCDF provides an indication of the probability of the OFDM signal's envelope exceeding a specified PAPR threshold [15]. The complementary cumulative distribution function (CCDF) of PAPR provides information about the percentage of OFDM signals that have PAPR above a particular level. It denotes the probability that the PAPR of an OFDM symbol exceeds the given threshold PAPR0, which can be expressed as

$$CCDF(N, PAPRR_0) = P_r\{PAPR > PAPRR_0\} \qquad (2.5)$$

or

$$CCDF = 1 - P_r\{PAPR > PAPRR_0\} \qquad (2.6)$$

- Bit Error Rate (BER):

The performance of a modulation technique can be quantified in terms of the required signal-to-noise ratio (SNR) to achieve a specific bit error rate (BER). Although the main focus of PAPR reduction techniques is to reduce the CCDF, this is usually achieved at the expense of increasing the BER. Clipping the high peaks of the OFDM signal by the power amplifier (PA) causes a substantial in-band distortion that leads to higher BER. Other techniques may require that side information be transmitted as well. If the side information is received incorrectly at the receiver, the whole OFDM symbol is recovered in error and the BER performance degrades [12, 15].

- Spectral Spreading:

  Due to the limit imposed on the maximum peak of the OFDM signal by the PA, an increase is encountered in both the in-band and out-of-band distortions. The second causes undesirable increase in the power of the side lobes of the power spectral density (PSD) of the OFDM signal. This effect is referred to as spectral spreading or spectral regrowth. When the nonlinearity of the PA is higher, IBO is smaller, and the spectral spreading is higher. Spectral spreading leads to higher interference between the subbands of the OFDM signal, unless the frequency separation between adjacent subcarriers is also increased to maintain orthogonality. However, this solution has the disadvantage of lowering the spectral efficiency [15]

2.4 PAPR Technique

A large PAPR would drive PAs at the transmitter into saturation, producing interference among the subcarriers that degrades the BER performance and corrupts the spectrum of the signal. To avoid driving the PA into saturation, the average power of the signal may be reduced. However, this solution reduces the signal-to-noise ratio and, consequently, the BER performance. Therefore, it is preferable to solve the problem of high PAPR by reducing the peak power of the signal. Many PAPR reduction techniques have been proposed in the literature. The most well-known signal techniques are:

A. Clipping and Filtering

One of the simplest PAPR reduction methods is the method of clipping the high peaks of the OFDM signal before passing it through the PA. Clipping is a nonlinear process that leads to both in-band and out-of-band distortions. In-band distortion causes spectral spreading and can be eliminated by filtering the signal after clipping, while out-of-band distortion can degrade the BER performance and cannot be reduced by filtering. However, oversampling by taking longer IFFT can reduce the in-band distortion effect as portion of the noise is reshaped outside of the signal band that can be removed later by filtering. Filtering the clipped OFDM signal can preserve the spectral efficiency by eliminating the out-of-band distortion and, hence, improving the BER performance but it can lead to peak power regrowth [11].

QPSK data symbols passed through an inverse fast Fourier transform (IFFT) module to realize the OFDM modulation. If the digital OFDM signals are clipped directly, the resulting clipping noise will all fall in-band and cannot be reduced by filtering. Hence an oversampling is done. Then, the real-valued bandpass samples, x, are clipped at an amplitude A as follows:

$$y = \begin{cases} -A & if\ x < -A \\ x & if -A \le x \le -A \\ A & if\ x > A \end{cases} \tag{2.7}$$

Then the clipped signal is passed through a filter and transmitted. At the receiver, the reverse operations are done [11].

B. Peak Windowing

Peak windowing limits high peaks by multiplying them by a weighting function called a window function. Many window functions can be used in this process as long as they have good spectral properties. The most commonly used window functions include Hamming, Hanning and Kaiser Windows. To reduce PAPR, a window function is aligned with the signal samples in such a way that its valley is multiplied by the signal peaks while its higher amplitudes are multiplied by lower amplitude signal samples around the peaks. This action attenuates signal peaks in a much smoother way compared to hard clipping, resulting in reduced distortion [15].

C. Companding Transforms:

Companding transforms are typically applied to speech signals to optimize the required number of bits per sample. Since OFDM and speech signals behave similarly in the sense that high peaks occur infrequently, same companding transforms can also be used to reduce the OFDM signal’s PAPR. Besides having relatively low computational complexity compared to other PAPR reduction techniques, companding complexity is not affected by the number of subcarriers. Also, companding does not require side information and hence does not reduce bit rate. Their simplicity of implementation and the advantages they offer make companding transforms an attractive PAPR reduction technique. The PAPR reduction obtained by companding transforms comes though with the price of increasing the BER [15].

D. Peak Cancellation

This technique, a peak cancellation waveform is appropriately generated, scaled, shifted and subtracted from the OFDM signal at those segments that exhibit high peaks. The generated waveform is band limited to certain peak cancellation tones that are not used to transmit data[16]. Peak cancellation can be carried out after the IFFT block of the OFDM transmitter by subtracting the peak cancellation waveform from the OFDM signal whenever a potential peak higher than a certain threshold is detected.

E. Selective Mapping (SLM)

SLM is a simple approach to reduce PAPR [12]. In this method, a set of sufficient different OFDM symbols $x_m, 0 \leq m \leq M-1$ are generated, each of length N , all representing the same information as that of the original OFDM symbol x, then the one with the least PAPR is transmitted [2] . Mathematically, the transmitted OFDM symbol $\hat{x}$ is represented as:

$$\hat{x} = argmin_{0 \leq m \leq M-1} [PAPR(x_m)] \quad (2.8)$$

.

The OFDM symbols set can be generated by multiplying the original data block$X = [X_1, X_2, \dots, X_N]$, element-by-element, by M different phase sequences pm, each of length N, before taking IDFT. For simplifying the implementation, the phase sequences $p_m$can be set to [11] as these values can be implemented without multiplication. Then the modified OFDM symbol $x_m, 0 \leq m \leq M-1$, is the IDFT of the element-byelement multiplication of X and p_m

$$x_m = IDFT\left[X_1 e^{j\varphi_{m,1}} \quad X_2 e^{j\varphi_{m,2}} \quad \dots\dots \quad X_N e^{j\varphi_{m,N}}\right] \quad (2.9)$$

The selected phase sequence should be transmitted to the receiver as side information to allow the recovery of original symbol sequence at the receiver, which decreases the data transmission rate. The phase sequences $p_m, 0 \leq m \leq M-1$, should be stored at both the transmitter and receiver. An erroneous detection of the side information will cause the whole system to be destroyed. Hence strong protection of the side information is very important [19].

F. Partial Transmit Sequence (PTS)

PTS, an input data block having length N is partitioned into a number of disjoint subblocks by pseudo-random partitioning [14]. The IDFT is computed separately for each one of these sub-blocks and then weighted by a phase factor. The phase factors are selected such that the PAPR of the combined signal of all the sub-blocks is minimized. Let an input data block X be partitioned into M disjoint sub-blocks, X_m = [$X_{m,1}$ $X_{m,2}$ $X_{m,N}$] , 1 ≤ m ≤ M ,such that any two of these sub-blocks are orthogonal and X is the combination of all the M sub-blocks [8].

$$X = \sum_{m=1}^{M} X_m \qquad (2.10)$$

G. Linear block coding (LBC)

Instead of dedicating some bits of the codeword to enhance BER performance, these bits are now dedicated to reduce PAPR. The codewords with low PAPR have to be chosen for transmission. A simple LBC scheme was proposed in, where 4 bits are mapped into 5 bits by adding a parity bit. It is based on the observation that irrespective of codeword length, four specific codewords will always have disproportionately large PAPR values [18]. These are the codewords where the odd and even bit values are equal, i.e. the all-zero, all-one, (1010 ...) and (0101 ...) codewords. The PAPR can hence be very easily reduced by eliminating these codewords using a simple added bit code. If the codeword length is equal to n, then a single extra bit b_{n+1} , is added with a value equal to the inverse of the penultimate codeword bit . Then the four codewords with high power are now eliminated [19].

2.5 Genetic Algorithm

A genetic algorithm (GA) is a stochastic search method based on the principles of natural evolution and employs selection and recombination operations. The GA has been successfully applied in various signal processing areas, including PAPR reduction of OFDM signals[17].

2.5.1 Multi-objective optimization problem

Multi-objective optimization technique has been widely adopted to solve the problem given a number of objective functions having conflict relationship each other. The optimization problem like this is usually called as multi-objective optimization problem (MOOP), which can be formulated as

$$\frac{min}{\max\{F(x)]} = [f_1(x), f_2(x), \dots, f_k(x)] \,,$$

$$s.t. x = [\, x_1, x_2, \dots, x_n] \in S \qquad (2.11)$$

where $[f_1(x), f_2(x), \dots, f_k(x)]$ are contradictory objective functions, $[\, x_1, x_2, \dots, x_n]$ are the optimization parameters, and S is the solution or parameter space. In multi-objective optimization problem a solution is obtained at best and satisfies all objective functions maximally or minimally. Therefore, the aim to solve MOOP is designated as the determination of the tradeoff surface, which is a set of non-dominated solution points, known as Pareto-optimal solutions. A non-dominated solution is one that is not dominated by any feasible solutions else. A solution x , for instance, is said to dominate y if x is better or equal to y in all attributes, and strictly better in at least one attribute. Considering minimization problem and two solution vectors $x, y \in S, x$ is said to dominate y, denoted as[18]

$$x \succ y, \;\; if \; \forall \, i \;\; \in \{1,2, \dots., k\} : \; f_i(x) \le f_i(y) \;\; and \; \exists j \in \{1,2, \dots, k\} : \; f_j(x) \le f_j(y),$$

$$s.t. x, y \in S \qquad (2.12)$$

2.5.2 Weighted-sum based genetic algorithm

A genetic algorithm (GA) is one of adaptive searching methods used to solve an optimization problem. The basic concept of genetic algorithm is based on Darwin's theory of evolution by natural selection. Due to its advantageous features, GA has been adopted to many applications to find a solution close to the optimum in complicated combination problems [16]. Towards this, genetic algorithm evaluates the level of fitness to every element in population and generates offspring by genetic operations such as crossover and mutation. These consecutive reproduction operations are repeated until the end of evolving pre-determined number of generations denoted as G. Through evolution, the best chromosome in the final group of population can be designated as a highly evolved solution set to the optimization problem. The weighted and sum genetic algorithm to solve multi-objective optimization problem, the algorithm must linearly combine various fitness functions into a single fitness function. Single weighted-sum fitness function in -dimension case is formulated by

$$f(x) = \sum_{i=1}^{m} w_i f_i(x), \quad s.t. x \in S, \qquad \sum_{i=1}^{m} w_i = 1 \qquad (2.13)$$

In (2.13), the weighting factors tell the preference of decision maker. For example, to focus on PAPR performance of OFDM system, the weight corresponding to the objective function for PAPR is bigger than any other weights to emphasize minimization of PAPR[18].

2.5.3 GA method

GA is the most popular technique in the Evolutionary Algorithms (EA) because, GA based methods offer favourable optimization strategies as they are easy to implement. There are three other type of EA that are Evolution Strategies (ES), Evolutionary

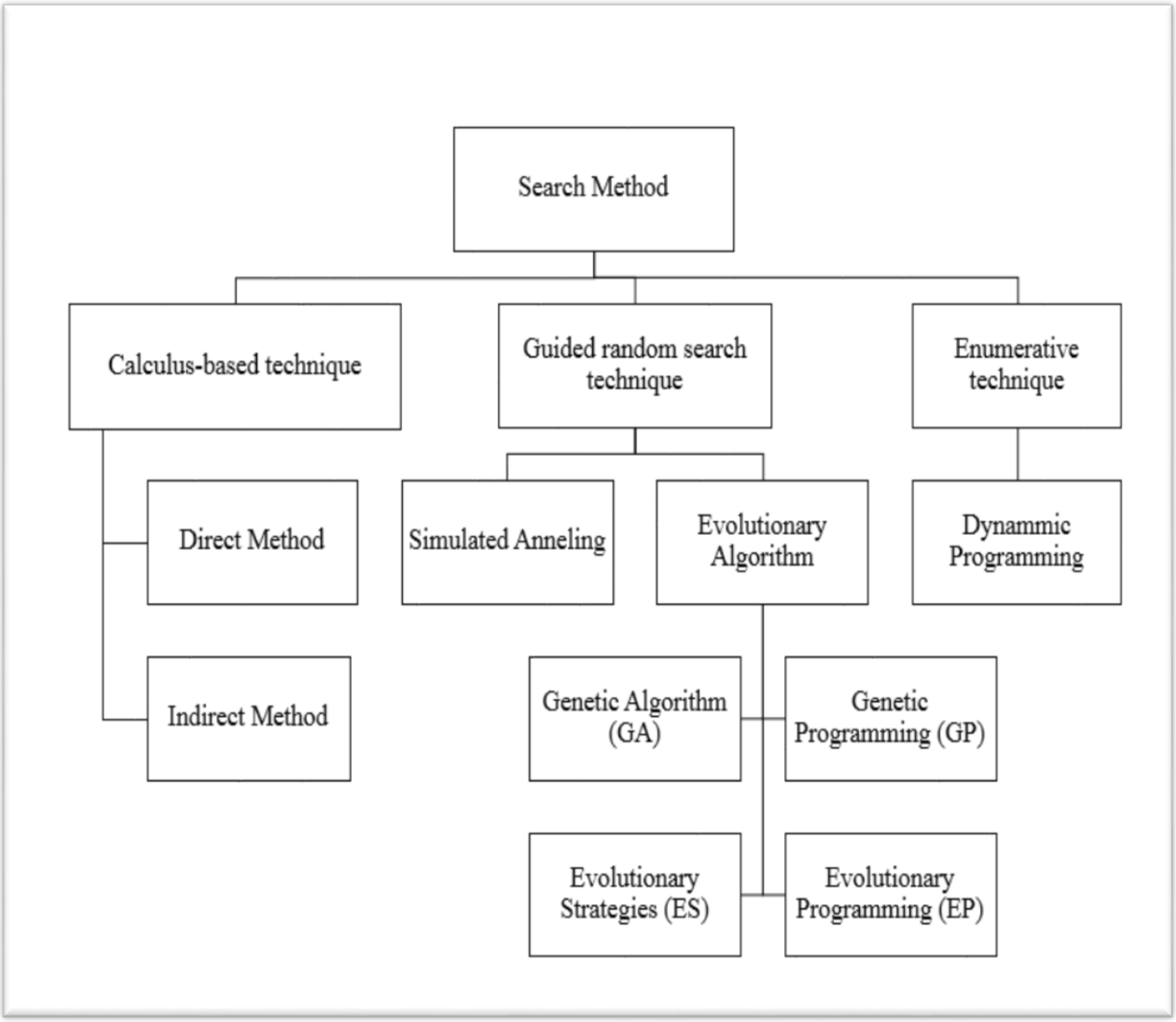
Programming (EP) and Genetic Programming (GP) [19]. Figure2.3 show other method under search method. Evolutionary Algorithms (EA) is where the elements of the search space are binary strings or arrays of other elementary types. GA are computer based search techniques patterned after the genetic mechanisms of biological organisms that have adapted and flourished in changing highly competitive environment.

GA are the solution for optimization of hard problems quickly, reliably and accurately. As the complexity of the real-time controller increases, the GA applications have grown in more than equal measure.

GA is one of the most fundamental principal in our world is the search for an optimal state. Optimization is the process of modifying the inputs or characteristics of a device, mathematical process to obtain minimum or maximum of the output. The input to the optimization process is the

- cost function
- objective function or fitness function

and the output is the fitness function of the system.



.

Figure 2.3: Block diagram of search method

The GA introduced by Holland is a stochastic search method inspired from the principles of biological evolution observed in nature. GA uses a population of candidate solutions randomly over the entire solution space. Based on the principle of Darwinian survival of the fittest, GA produces a better approximation to the optimal solution by evolving this population of candidate solutions over success iterations or generations as shown in Figure 2.4 [20]. The GA's evolution uses the following genetic operators:

1. Selection is a genetic operator that chooses a chromosome from the current generation's population in order to include in the next generation's mating

pool. In general, chromosomes with a high fitness (merit) should be selected and at the same time chromosomes with a low fitness should be discarded.

2. Crossover is a genetic operator that exchanges the elements between two different chromosomes (parents) to produce new chromosomes (offsprings). The new population of the next generation consists of these offsprings.
3. Mutation is a genetic operator that refers to the alteration of the value of each element in a chromosome with a probability.

GA has been applied to extensive optimization problems, such as pilot location search of OFDM timing synchronization waveforms, joint multiuser symbol detection for synchronous Code Division Multiple Access (CDMA) systems, the search of low autocorrelated binary sequences and thinned arrays [21].

2.5.4 Encoding Technique in Genetic Algorithms (GA)

Encoding techniques in genetic algorithms (GAs) are problem specific, which transforms the problem solution into chromosomes. Various encoding techniques used in genetic algorithms (GAs) are binary encoding, permutation encoding, value encoding and tree encoding[22].

A. Binary encoding

It is the most common form of encoding in which the data value is converted into binary strings. Binary encoding gives many possible chromosomes with a small number of alleles. A chromosome is represented in binary encoding as shown in Figure 2.4.