DEVELOPMENT OF A MODIFIED ARTIFICIAL FISH SWARM ALGORITHM PARTIAL TRANSMIT SEQUENCE TECHNIQUE FOR PEAK TO AVERAGE POWER RATIO REDUCTION IN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

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APRIL, 2018

DECLARATION

I ABBAS Abdulhafeez, hereby declare that this Dissertation titled "Development of a Modified Artificial Fish Swarm Algorithm-Partial Transmit Sequence Technique for Peak to Average Power Ratio Reduction in Orthogonal Frequency Division Multiplexing" was carried out by me under the supervision of Dr. K. A. Abubilal and Dr. A. M. S. Tekanyi as part of the requirements for the award of degree of Master of Science in Telecommunications Engineering. To the best of my knowledge, this research work has never been submitted anywhere for the award of any certificate. All literature used and cited in this report, are duly acknowledged by means of references.

Abdulhafeez ABBAS _____ _____

CERTIFICATION

This Dissertation titled "Development of a Modified Artificial Fish Swarm Algorithm-Partial Transmit Sequence Technique for Peak to Average Power Ratio Reduction in Orthogonal Frequency Division Multiplexing" meets the requirements for the award of degree of Master of Science (MSc) in Telecommunications Engineering by Ahmadu Bello University, Zaria and it is approved for its contribution to knowledge and literature.

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(Dean Postgraduate School)	Signature	Date

DEDICATION

This research work is dedicated to all Kids as they make the world a beautiful place.

ACKNOWLEDGEMENT

In the name of Allah (SWT), the most beneficent, the most merciful. All praises are due to Allah (SWT), the creator of heaven and earth, the Lord of universe. Peace and blessings be upon His prophet, Muhammad (SAW) and his companions as well as those who follow the right path until the day of judgement.

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier frequency multiplexing scheme used in broadband wireless communication systems and has advantages such as high spectral efficiency, simple channel equalization and flexibility.One of its major challenges is the high Peak-to-Average Power Ratio (PAPR) of the signal which can cause a nonlinear signal distortion and reduction in power efficiency. One of the techniques used to reduce PAPR is the Partial Transmit Sequence (PTS) technique which can be applied to the transmit data. However, selecting the right phase factor sequence that can give the least PAPR is the major challenge faced by the PTS technique due to its non-linear optimization problem of phase factor sequence selection. Also, it suffers from high complexity and memory use when there is a large number of non-overlapping sub-blocks in one symbol. In order to address this, an intelligent search optimization algorithm is required to aid selecting the right phase factor sequence that gives the least PAPR. Therefore, this research work developed a modified Artificial Fish Swarm Algorithm (AFSA) based PTS technique and generated an optimum phase factor sequence, which in turn aided in PAPR reduction. The proposed technique was implemented using MATLAB R2015a and simulations were carried out using Bit Error Rate (BER) and Complementary Cumulative Density Function (CCDF) as performance metrics to evaluate its performance. Simulation results showed that the modified AFSA based PTS technique outperformed the AFSA based PTS technique in PAPR reduction with a percentage improvement of (6.67%), (3.33%) and (3.13%), when the number of subcarriers were 32, 128 and 256 respectively. Subsequently, the obtained results were compared with those of Zhou *et al.*, (2014) as a means of validation and it was found out that the modified AFSA based technique had an improved percentage performance of (1.69%) in PAPR reduction over MECAFSA-PTS technique. These results showed that the modified AFSA-PTS technique is effective in reducing the PAPR of an OFDM system.

TABLE OF CONTENT

TITLE PAGE i

DECLARATION ii

CERTIFICATION iii

DEDICATION iv

ACKNOWLEDGMENT v

ABSTRACT vi

TABLE OF CONTENT vii

LIST OF FIGURES x

LIST OF TABLES xi

LIST OF ABBREVIATIONS xii

CHAPTER ONE: INTRODUCTION

1.1 Background 1

1.2 Motivation 4

1.3 Problem Statement 5

1.4 Aim and Objectives 5

1.5 Dissertation Organization 6

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction 7

2.2 Review of Fundamental Concepts 7

2.2.1 Orthogonal Frequency Division Multiplexing (OFDM) 7

2.2.1.1 Clipping 9

2.2.1.2 Coding 10

2.2.1.3 SeLective Mapping (SLM) 11

2.2.1.4 Tone Injection and Tone Reservation Technique 12

2.2.1.5 Active Constellation Extension 12

2.2.1.6 Partial Transmit Sequence (PTS) 13

2.2.2 BFO based PTS for PAPR Reduction 15

2.2.3 ABC based PTS for PAPR Reduction 15

2.2.4 AFSA based PTS for PAPR Reduction 16

2.2.4.1 Preying 16

2.2.4.2 Swarming 17

2.2.4.3 Chasing 18

2.3 Review of Similar Works 21

CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction 28

3.2 Materials used for the Research Work 28

3.3 Methodology 28

3.4 Modified AFSA based PTS Scheme 29

3.5 Partial Transmit Sequence technique for PAPR reduction 34

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction 38

4.2 Generated Signal Power 38

4.3 PAPR Reduction using Modified and Standard AFSA based PTS 39

4.4 Validation 46

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary 48

5.2 Conclusion 49

5.3 Significant Contributions 49

5.4 Recommendation 50

REFERENCES 51

APPENDIX A

mFile of the Modified AFSA 55

APPENDIX B

mFil: MATLAB Program for the PTS objective Function 60

APPENDIX C

mFile of the QPSK Modulation 64

LIST OF FIGURES

Figure 2.1:	Block Diagram of the OFDM System Model	9
Figure 2.2:	Block Diagram of Selective Mapping Technique	11
Figure 2.3:	Diagram of the PTS Model	13
Figure 2.4:	Flow chart implementation of the standard AFSA	20
Figure 3.1:	Diagram of the Modified AFSA based PTS Model	31
Figure 3.2:	Flow chart Implementation of the modified AFSA	33
Figure 4.1:	OFDM Generated Signal Power	38
Figure 4.2:	CCDF of the PAPR with L=8, No. of Subcarrier=32	40
Figure 4.3:	BER performance with L=8, No. of Subcarrier=32	41
Figure 4.4:	CCDF of the PAPR with L=8, No. of Subcarrier=128	42
Figure 4.5:	BER performance with L=8, No. of Subcarrier=128	43
Figure 4.6:	CCDF of the PAPR with L=8, No. of Subcarrier=256	44
Figure 4.7:	BER performance with L=8, No. of Subcarrier=256	45

LIST OF TABLES

Table 3.1: Model Parameters used 37

Table 4.1: PAPRo Tabular Result for mAFSA, sAFSA and Original (no. of subcarriers=128) 46

Table 4.2: PAPRo Tabular Result for MECAFSA-PTS, QEA-PTS, SLM-PTS and Original, deduced from Zhou *et al* (2014), (no. of subcarriers=128) 46

LIST OF ABBREVIATIONS

ABC	Artificial Bee Colony
ACE	Active Cancellation Extension
ACE-POCS	Active Constellation Extension-Projection Onto Convex Sets
ADC	Analogue-to-Digital Converter
AFSA	Artificial Fish Swarm Algorithm
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BFO	Bacterial Foraging Optimization
BPS0	Boolean Particle Swarm Optimization
CCDF	Complementary Cumulative Density Function
CI	Computational Intelligence
DAC	Digital-to-Analogue Converter
DFT	Discrete Fourier Transformation
DWT	Discrete Wavelet Transformation
ED-SLM	Euclidean Distance Selected Mapping
EPD	Euclidean Phase distance Detection
FFT	Fast Fourier Transform
FHT	Fast Hartley Transform
FMT	Filter Multi-Tone

GAPTS	Genetic Algorithm Partial Transmit Sequence
GHS-PTS	Global Harmony Search Partial Transmit Sequence
HPA	High Power Amplifier
ICI	Inter-Carrier-Interference
IFFT	Inverse Fast Fourier Transform
mAFSA	modified Artificial Fish Swarm Algorithm
mAFSA-PTS	modified Artificial Fish Swarm AlgorithmPartial Transmit Sequence
Matlab	Matrix Laboratory
MCM	Multi-Carrier-Modulation
MCS	Mobile Communication Services
MECAFSA	Modified Elite Chaotic Artificial Fish Swarm Algorithm
MIMO	Multiple Input Multiple Output
OFDM	Orthogonal Frequency Division Multiplexing
OGA	Orthogonal Greedy Algorithm
QEA	Quantum Evolutionary Algorithm
PAPR	Peak-to-Average Power Ratio
PRC	Peak Reduction Carriers
PSO	Particle Swarm Optimization
PTS	Partial Transmit Sequence

RF	Radio Frequency
RGA	Relaxed Greedy Algorithm
sAFSA-PTS	standard Artificial Fish Swarm AlgorithmPartial Transmit Sequence
SLM	Selective mapping
SNR	Signal to Noise Ratio
SOPTS	Sub Optimum Partial Transmit Sequence
SQNR	Signal-to-Quantization Noise Ratio
STBC	Space Time Bloc Coding
TI	Tone Injection
TR	Tone Reservation
WHT	Walsh Hadamard Transform
WPM	Wavelet Packet Modulation

CHAPTER ONE

INTRODUCTION

1.1 Background of Research

Basically, the performance of wireless communication generally depends on the optimal behaviour of the wireless channel environment. The unpredictable nature of wireless channels makes the exact and appropriate analysis of wireless communication difficult(Cho *et al.,* 2010). Over the years, optimization of the wireless communication system has become a critical subject for both academic and industrial researchers due to the rapid growth of Mobile Communication Services (MCS) and emerging broadband mobile Internet access services.One of the major focus of researchers is how to simplify the channel equalization under several channel conditions without necessarily introducing complex equalization filters(Cho *et al.*, 2010).In a scenario where spectrum is limited, the demand for high speed data degrades the quality of service. Therefore, a method of encoding digital data (which is expected to overcome the problem of limited spectrum) on multiple carrier frequencies called Orthogonal Frequency Division Multiplexing (OFDM) was proposed.

The OFDM is a special case of Multi-Carrier-Modulation (MCM) technique which divides the high data rate input bit stream into a large number of lower rate sub streams and each sub stream is transmitted over orthogonal subcarriers (Venkatachalam & Manigandan, 2015). In OFDM, a large number of closely spaced orthogonal sub-carriers are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation technique(such as quadrature amplitude modulation or phase-shift keying) at a very low symbol rate and maintaining data rates similar to conventional single-carrier modulation schemes using the same bandwidth.OFDM has gained appreciable popularity and attention in the field of

wireless communication due to its numerous advantages. Some of the numerous advantages which make OFDM more advantageous in high speed data transmission over others include(Jaya *et al.*, 2015; Shigei *et al.*, 2014; Shyam *et al.*, 2014; Suyama *et al.*, 2009):

i. High Spectral Efficiency
ii. More resistant to frequency selection fading than single carrier system
iii. Simple channel equalization
iv. Robustness to channel fading
v. Immunity to impulse interferences
vi. Flexibility
vii. Easy equalization, etc.

However, due to large number of independently modulated subcarriers in OFDM, the peak value can be very high compared to the average of the whole system. This leads to the following drawbacks associated with the use of OFDM (Gangwar & Bhardwaj, 2012), its signal:

i. exhibits very high PAPR,
ii. is very sensitive to frequency errors (Transmitters and Receivers offset),
iii. suffers Inter-Carrier-Interference (ICI) between the subcarriers.

In recent past, there have been several research works and efforts to deal with the PAPR problem resulting in several articles and papers(Baro & Ilow, 2008; Cuteanu & Isar, 2012; Liang *et al.*, 2011; Mohanty & Ramavath, 2015; Palanivelan & Anand, 2010; Sahoo & Patra, 2015; Soliman *et al.*, 2015; Venkatachalam & Manigandan, 2015; Zhao *et al.*, 2014; Zheng & Wang, 2013).Up to date, the PAPR problem still prevents the adoption of OFDM in the uplink of mobile communication standards, as well as placing

severe constraints on output power and therefore coverage in the downlink (Wunder *et al.*, 2012). In addition, high PAPR brings about OFDM signal distortion in the nonlinear region of High Power Amplifier (HPA) and the signal distortion induces the degradation of Bit Error Rate (BER) (Xiaowen *et al*, 2011).The non-linear signal distortion also results in high adjacent channel interference that makes the system performance worse because the signal distortion caused by the power amplifier introduces intermodulation within the OFDM subcarriers and out of band radiation. Also the power amplifier operates with large power back-off that leads to very inefficient amplification and expensive transmitters.

Some of the popular methods of reducing PAPR include:Amplitude clipping (Wang & Luo, 2011), Coding (Naeiny *et al.*, 2010), Active Cancellation Extension (ACE) (Krongold & Jones, 2003), Selective Mapping (Li *et al.*, 2010), etc.Due to the complexity of this PAPR reduction methods, many researchers have proposed solutions based on Computational Intelligent (CI) techniques, which are relatively easy to implement and requires less computational power. Reduction of PAPR using Artificial Bee Colony (ABC) optimization algorithmwas proposed in Taspinar *et al.*, (2011) and Yu *et al.*, (2013). Bacterial Foraging Optimization (BFO) algorithm which entails the foraging behaviour of bacterial E. Coliwas used in Manjith & Suganthi, (2013) for PAPR reduction, and an idea based on Particle Swarm Optimization (PSO) algorithm for PAPRreduction was proposed in Bi *et al.*, (2012) and El Mouhib *et al.*, (2011).Also a modifiedGenetic Algorithm Partial Transmit Sequence (GA-PTS) technique with error correction for PAPR reduction was presented inLiang *et al.*, (2010).However due to the poor balance between exploration and exploitationin ABC and PSO, poor convergence due to unnecessary oscillation in BFO and the inability of GA-PTS to provide near optimal solution due to its discrete nature, hence there is a need for more research works

on PAPR reduction techniques in OFDM systems.This research work develops a PTS PAPR reduction technique in OFDM based ona modified Artificial Fish Swarm Algorithm (AFSA).

An optimization algorithm which is inspired by the intelligent swarming behaviours of the school of fish is called the AFSA. Generally, the primary behaviour of fish in water is to search for regions with more food either by its own swarming behaviours or by following the swarming behaviours of its neighbouring fish(es)(Mu'azu *et al.*, 2015). However, the individual behaviour of the artificial fish is to search for local minima, which makes it difficult to move towards the global solution individually when dealing with multi-modal complex problems. This leads to some problems such as blindness of search and poor convergence(Mu'azu *et al.*, 2015). In this research, a modified AFSA algorithm which works based on a feedback of the best individual result found to guide the evolution of the algorithms is proposed for PTS based PAPR reductionin OFDM systems. The proposed scheme is expectedto reduce the computational complexity involved in phase factor selection and improvesPAPR reduction.

1.2 Motivation

Reduction of PAPR in OFDM systems is the main motivating factor for this research work, and it is hoped to be achieved with the development and implementation of a modified AFSA-PTS technique for PAPR reduction. A significant reduction in PAPR would led to the adoption of OFDM system in the uplink of mobile communication systems which would in turn revolutionized the broadband wireless communication systems with faster uplink/downlink data transfer rates and reduction in the sizes of the transceiver equipment. Hence the need for continuous study in this field.

1.3 Problem Statement

OFDM is one of the most popular multi-carrier multiplexing technique used in broadband wireless communications. By adding frequency diversity through subcarrier redundancy, OFDM greatly improves the spectral efficiency of a wireless communication system. However, the OFDM system is prone to high PAPR due to the fact that the same source information is transmitted on multiple subcarriers. Hence, one of the major problems encountered in OFDM systems is the high PAPR of the transmitted signal which introduces nonlinear signal distortion, resulting to high adjacent channel interference that makes the system performance bad. Several approaches based on PTS technique have been proposed to address this problem. However, the conventional PTS scheme requires an exhaustive search over all combinations of allowed phase factors. Consequently, this increases the computational complexity exponentially with the number of the sub blocks. Therefore, this research develops a fast and robust meta-heuristic optimization-based PTS technique using a modified AFSA for PAPR reduction.

1.4 Aim and Objectives

The aim of this research is to develop a modified Artificial Fish Swarm Optimization algorithm-based Partial Transmit Sequence (AFSA-PTS) technique for Peak-to-Average Power Ratio (PAPR) reductionin Orthogonal Frequency Division Multiplexing (OFDM) systems.

In order to achieve the aim of this research, the following objectives were pursued:

i. Replication ofthe standard Artificial Fish Swarm Algorithm (AFSA) and development of the modified AFSA algorithm.

ii. Modelling of the OFDM transmission system and the modified Artificial Fish Swarm Algorithm based Partial Transmit Sequence (AFSA-PTS) using MATLAB R2015a communication/optimization toolbox.

iii. Evaluation of the performance of the modified AFSA-PTS based PAPR reduction technique and validation of the results using the work ofZhou*et al.,* (2014).

1.5 Dissertation Organization

This research work is divided into five chapters, with chapter one highlighting the general introduction of the theme of this research. Chapter two deals with review of related literatures and relevant fundamental concepts on OFDM, AFSA, SLM, ABC and the PTS technique in general. Chapter three details the approach adopted and relevant mathematical models relating to AFSA and the modified AFSA, applying both to the PTS technique. Result, performance evaluation, analysis and discussion of results were analysed in chapter four, while lastly chapter five is made up of conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter comprises of section 2.2and section 2.3. Concepts fundamental to the scope of this research work are presented in subsection 2.2, while relevant literature that are directly related to the scope of this research work arepresented in subsection 2.3.

2.2 Review of Fundamental Concepts

This section presents some of the fundamental concepts of OFDM, its performance analysis and the AFSA algorithm. Other optimization methods used for PAPR reduction in OFDM are also discussed in order to have a clear understanding of the OFDM concept, problems and model solutions.

2.2.1 Orthogonal Frequency Division Multiplexing (OFDM)

OFDM is a multiple carrier frequency modulation technique in which the available channel is split into several sub-channels and symbols which are transmitted using different subcarriers. The OFDM is a widely used wireless communication system multiplexing technique that entails a high bit rate and high capacity transmission (Taspinar *et al.*, 2011). In OFDM, there exists a precise mathematical relationship between the frequencies of the carrier system and the processing signal is made digital in the frequency domain using the Inverse Fast Fourier Transform (IFFT)/Fast Fourier Transform (FFT).The IFFT/FFT algorithms eliminate arrays of sinusoidal generators and coherent demodulation required in parallel data systems,this makes the implementation of the technology cost effective. Therefore, both transmitter and receiver are implemented using efficient FFT techniques that reduce the number of

operations from N^2in Discreet Fourier Transform (DFT) to $N\log_{10}(N)$ in FFT(Cho *et al.*, 2010). OFDM does not use individual band-limited filters and oscillators for each sub-channel.Furthermore, the spectra of subcarriers are overlapped for bandwidth efficiency, unlike the Filter Multi-Tone(FMT) scheme, where the wideband is fully divided into N orthogonal narrowband sub-channels. The major challenge is that, OFDM signals exhibit a very high PAPR due to the high peak values of the OFDM transmit signals in the time domain. In fact, the high PAPR is one of the most detrimental aspects in theOFDMsystem, as itdecreases the Signal-to-Quantization Noise Ratio(SQNR) of Analogue-to-Digital Converter (ADC) and Digital-to-Analogue Converter (DAC), while degrading the efficiency of the poweramplifier in the transmitter(Taspinar *et al.*, 2011). The PAPR problem is more important in the uplink since theefficiency of power amplifier is critical due to the limited battery power in a mobile terminal.Therefore, Radio Frequency (RF) power amplifiers need to be operated in a very large linear region. Otherwise, the signal peaks get into a non-linear region of the power amplifier causing signal distortion. This signal distortion introduces intermodulation among the subcarriers and out of band radiation(Daoud & Alani, 2009). Thus, the power amplifiers should be operated with large power back-offs. On the other hand, this leads to very inefficient amplification and expensive transmitters. Hence, PAPR reduction is highly desirable. Some of the popular and most used PAPR reduction techniques are(Taspinar *et al.*, 2011): Clipping, Coding, Selective Mapping (SLM), Tone Injection (TI), Tone Reservation (TR), Active Constellation Extension (ACE), and Partial Transmit Sequence (PTS). The block diagram of theOFDM system model is given in Figure 2.1(Taspinar *et al.*, 2011).

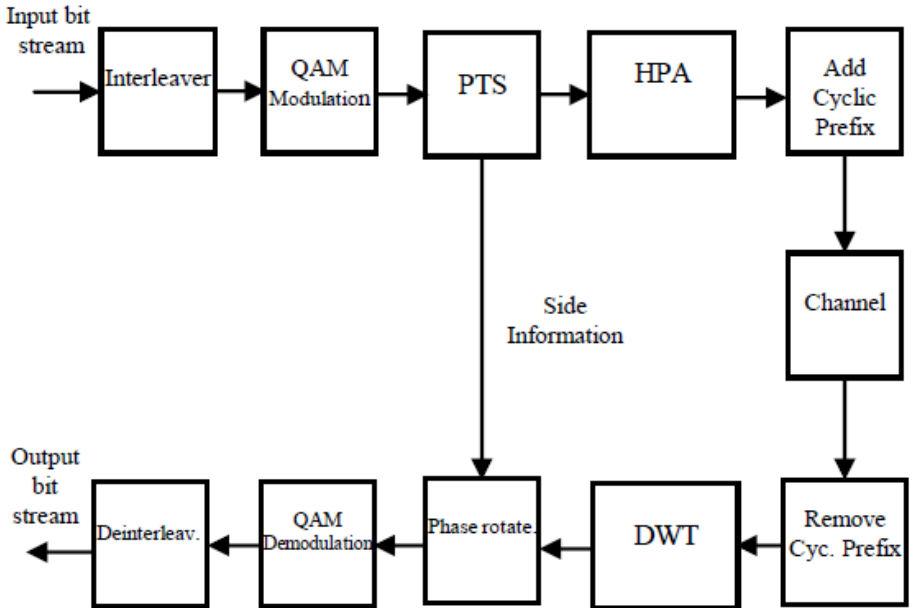


Figure 2.1: Block Diagram of the OFDM System Model(Taspinar *et al.*, 2011).

The general system model of OFDM adopted by many researchers is given in Figure 2.1. Usually, the user bits are interleaved to avoid burst errors in the communication channel and the signal is modulated with QAM (Taspinar *et al.*, 2011). The PTS is used to reduce the PAPR value of the signal. Side information is sent tothe receiver to obtain the original Wavelet Packet Modulation (WPM) signal. The signal is amplified by the High-PowerAmplifier (HPA). To avoid Inter Carrier Interference (ICI) a cyclic prefix is added immediatelyafter the HPA. At the receiving end, cycle prefix is extracted and then the Discrete Wavelet Transformation (DWT) is taken. Phase rotation is made to obtain phase of theoriginal WPM signal with the aid of the side information andthen the signal is demodulated. Deinterleaver carries eachQAM symbol to the original place in the bit stream(Yu *et al.*, 2013).

2.2.1.1 Clipping

An OFDM signal with N subcarriers happens to exhibit the maximum power when all the subcarrier components coincidently have the largest amplitude with identical phases (Cho *et al.*, 2010). As the number of subcarriers increases, the maximum power becomes larger and the probability that maximum-power signal will occur decreases as

N increases. One of the simplest method to address this shortcoming (PAPR) is to clip the amplitude of the signal to a fixed level(Wen *et al.*, 2009).The pseudo-maximum amplitude in this approach is referred to as the clipping level and denoted by μ. In other words, any signal whose amplitude exceeds μ will saturate its amplitude to the clipping level μ. While reducing PAPR, the clipping approach helps improve the SQNR in ADC(Cho *et al.*, 2010).Even though Clipping is a simple technique; it causes in-band signal distortion and out-of-band radiation, thus decreasing theBER of the system.

2.2.1.2 Coding

Coding technique involves selecting a code word that minimize or reduce the PAPR. It causes no distortion and creates no out-of-band radiation, but it suffers from bandwidth efficiency as the code rate is reduced. It also suffers from complexity to find the best codes and to store large lookup tables for encoding and decoding, especially for a large number of subcarriers(Cho *et al.*, 2010). Two sequences $x_1[n]$ *and* $x_2[n]$consisting of -1 or +1 and an equal length *N* are said to be complementary if they satisfy the following conditions (Baro & Ilow, 2008):

$$\sum_{n=0}^{N-1}\left(x_1[n]x_1[n+i]+x_2[n]x_2[n+i]\right)=\begin{cases}2N, & i=0\\ 0, & i\neq 0\end{cases} \qquad (2.1)$$

Taking the Fourier transform of equation (2.1)

$$\left|X_1[k]\right|^2+\left|X_2[k]\right|^2=2N \qquad (2.2)$$

where $X_i[k]$ is the DFT of $\{x_i[n]\}$, such that

$$X_i[k]=\sum_{n=0}^{N-1}x_i[n]e^{-2\pi nkT_s} \qquad (2.3)$$

T_s is the sampling period and $X_i[k]$ is the spectral density given by the DFT of the autocorrelation of $X_i[k] = x_i[n]$. The value of $|X_i[k]|^2$ is the power spectral density of a sequence $\{x_i[n]\}$.

2.2.1.3 SeLective Mapping (SLM)

Selective mapping is another effective technique for PAPR reduction. The SLM neither distorts the signal nor causes energy increase in the signal, but the spectral efficiency decreases with an increase in the application'scomplexity, as the number of subcarriers increases. SLMmethod cannot guarantee the PAPR below a specified level(Yu *et al.*, 2013). The block diagram of SLM technique for reducing PAPR in OFDM is given in Figure 2.2.

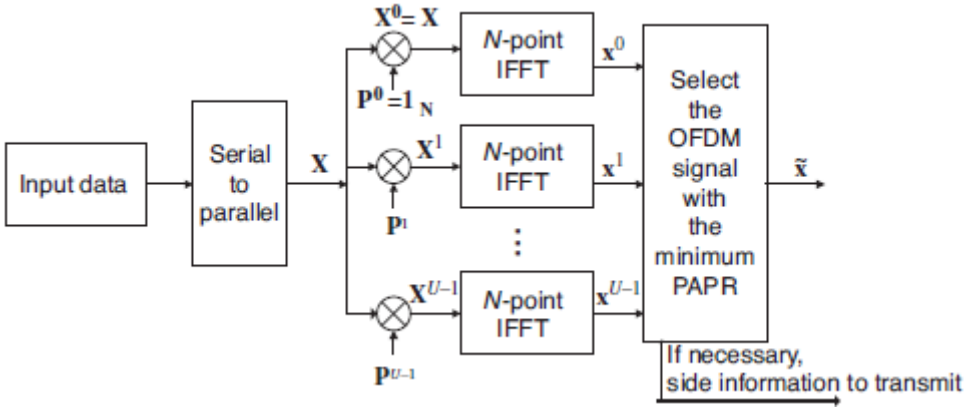


Figure 2.2: Block Diagram of Selective Mapping Technique(Yu *et al.*, 2013).

From Figure 2.2, the input block

$$X = [X[0], X[1], \ldots X[N-1]] \tag{2.4}$$

is multiplied with *U* different sequences

$$P^u = [P_0^u, P_1^u, \ldots, P_{N-1}^u]^T \tag{2.5}$$

where $P_v^u = e^{j\varphi_v^u}$ *and* $\varphi_v^u \in [0, 2\pi)$ for $V = 0,1,...,\mathrm{N}-1$ and $u = 1,2,...,U,$ which produce a modified data block.

$$X^u = \left[X^u[1], X^u[2], ..., \mathrm{X}^u[N-1] \right]^T \tag{2.6}$$

IFFT of U independent sequences $\left\{ X^u[v] \right\}$ are taken to produce the sequences

$$X^u = \left[x^u[0], x^u[1], ..., x^u[N-1] \right]^T \tag{2.7}$$

and the one with the lowest PAPR is selected for transmission as described by equation (2.7)(Cho *et al.*, 2010).

2.2.1.4 Tone Injection and Tone Reservation Technique

The basic idea of Tone Injection (TI) technique is to increase the constellation size so that each of the points in the original constellation can be mapped into several equivalent points in the expanded constellation, where the extra degrees of freedom can be exploited for PAPR reduction (Cho *et al.*, 2010).However, the Tone Reservation (TR) technique partitions the N subcarriers (tones) into data tones andpeak reduction tones(Cho *et al.*, 2010). The TI and TR do not distort the signal, but these methods cause energy increases of the transmitted signal (Taspinar *et al.*, 2011).

2.2.1.5 Active Constellation Extension

The active constellation extension technique is usually employed to introduce redundancy but can be continuously formulated so that other methods such as convex optimization techniques can be applied(Wunder *et al.*, 2012).

2.2.1.6 Partial Transmit Sequence (PTS)

The PTS is one of the most popular technique for reducing the PAPR in OFMD systems. The PTS technique partitions an input data block of *N* symbols into an *S* disjoint sub blocks as follows (Cho *et al.*, 2010):

$$X_i = \left[X^0, X^1, X^2, ..., X^{S-1} \right]^T \tag{2.8}$$

Where X^i are consecutively located subblocks of equal size. Each of this subblock are partitioned with corresponding multiplication by a complex phase factor $b^S = e^{j\varphi S}$. Taking the IFFT yield:

$$X = IFFT\left\{ \sum_{s=1}^{S} b^S X^S \right\} = \sum_{s=1}^{S} b^s . IFFT\left\{ X^s \right\} = \sum_{s=1}^{S} b^s X^s \tag{2.9}$$

where $\left\{ X^s \right\}$ is referred to as a PTS.Figure 2.3 shows the PTS model diagram.

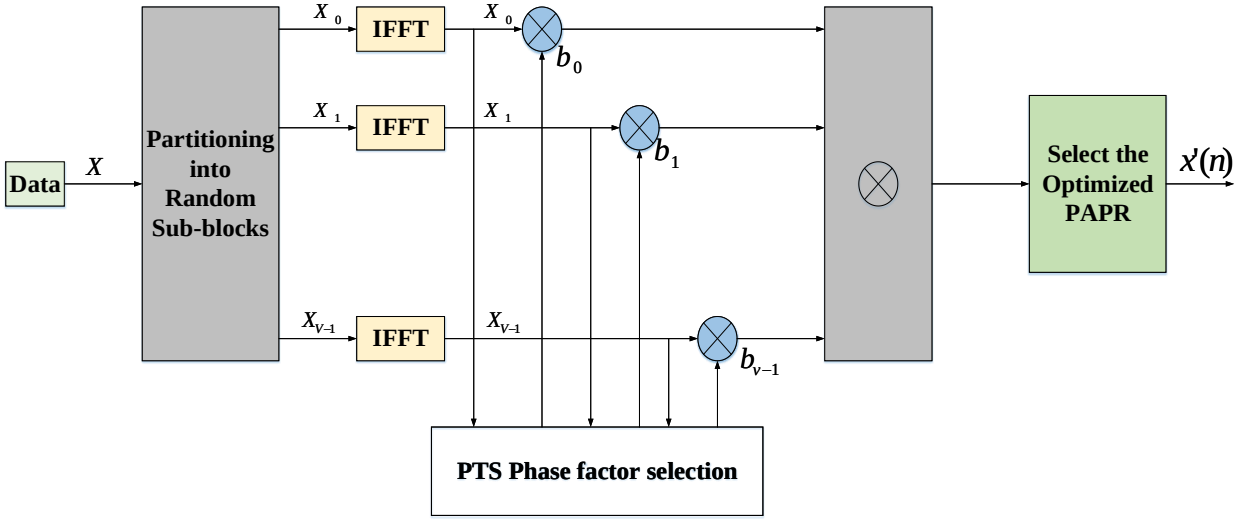


Figure 2.3: Diagram of the PTS Model(Taspinar *et al.*, 2011).

The phase factor is chosenas given in equation (2.8) such that the PAPR can be minimized

$$\left[\tilde{b}^1,...\tilde{b}^s\right]=\underset{[b^1,...,b^s]}{\arg\ \min}\left(\max_{n=0,1,...,N-1}\left|\sum_{s=1}^{S}b^s x^s[n]\right|\right) \tag{2.10}$$

Therefore, the time domain signal with the lowest PAPR vector is expressed as follows:

$$\tilde{X}=\sum_{s=1}^{S}\tilde{b}^v X^v \tag{2.11}$$

In order to reduce the search complexity of the signal, the phase factor $\left\{\tilde{X}=\sum_{s=1}^{S}\tilde{b}^s X^s\right\}$ selection is limited to a set of certain elements as follows:

$$b=\left\{e^{j2\pi i/\mathrm{W}}\mid i=0,1,...,W-1\right\} \tag{2.12}$$

In the phase factor optimization, since the phase factor of the first subblocks is usually taken as $b_0=1$, there are W^{S-1} alternative *b* combinations, where $b=\left[b_0, b_1, b_2,..., b_{s-1}\right]$ and *W* is the number of phase factors. The *b*, b_s values are as follows(Taspinar *et al.*, 2011):

$$b_s=\begin{cases}\{\pm 1\}, & if\quad W=2\\ \{\pm 1,\pm j\}, & if\quad W=4\end{cases} \tag{2.13}$$

As stated earlier, several researchers have proposed a meta-heuristic (such as: BFO, PSO and ABC) based PTS technique for PAPR reduction in OFDM. This is due to the promising advantages (such as: Ease of implementation, robustness, fast convergence, etc.) of these meta-heuristic algorithms. In order to provide a clear argument for the proposed research, detail explanation of some of the meta-heuristic algorithm employed for the same purpose, which are in similar class (Swarm) with the proposed modified AFSA based PTS technique for PAPR reduction are presented.

2.2.2 BFO based PTS for PAPR Reduction

Bacterial foraging optimization algorithm is a new bionic optimization algorithm, which was proposed, based on foraging behaviour of E. coli found in human intestine (Passino, 2002). Foraging theory is based on the assumption that animals search for and obtain nutrients in a way that maximizes their energy intake *E* per unit time T spent during foraging. Decision-making in foraging is a control strategy for organism guidance. In Manjith & Suganthi, (2013)BFO, was proposed to optimized the best phase factor from W^{M-1} combinations, where M is the number of sub-blocks and W is the allowed phase factor. In the BFO the food source (number of bacterial) is made equivalent to the phase factor as follows (Manjith & Suganthi, 2013):

$$b = \left\{ b_{i1}, b_{i2}, b_{i3}, ..., b_{i(\mathrm{W}_{\mathrm{M}-1})} \right\} \tag{2.14}$$

where $i = 1, ..., W^{M-1}$. The objective is to find the minimum of fitness $P\left(b_i\right)$ which is the best phase factor combination for which PAPR values is minimum.

2.2.3 ABC based PTS for PAPR Reduction

ABC is a meta-heuristic optimization algorithm which was proposed in (Karaboga, 2005) using the foraging behaviours of honeybee.In the ABC algorithm, employed bees, onlooker bees, and scout bees are tasked with finding optimum food sources, and first the food source positions are generated randomly. Based on this, the position of the food source is made equivalent to phase factor (vector) in the PAPR reduction as follows (Taspinar *et al.*, 2011):

$$b = \left\{ b_{i1}, b_{i2}, b_{i3}, ..., b_{i(\mathrm{V}-1)} \right\} \tag{2.15}$$

where $i = 1, 2, ..., SN$ and SN denotes the population size of the colony, which compose of the employed bees or the onlooker. As associated with ABC, the employed bees look for a new food source within the neighbourhood of the previous source. If the nectar amount of the new source is higher than the previous one, the new source is memorized as a possible optimum solution(Ozturk *et al.*, 2015).

This research will propose a modified AFSA based PTS technique for PAPR reduction in OFDM, based on the behaviours of AFSA described in the following subsection.

2.2.4AFSA based PTS for PAPR Reduction

Artificial Fish Swarm Algorithm (AFSA) is an optimization algorithm which was inspired by the intelligent behaviours of schoolof fish(Peng, 2011). The AFSA has demonstrated some importantcharacteristic such as high precision, robustness, ease of implementation, insensitive to initial parameters, etc.(Mu'azu *et al.*, 2015). The individual behaviour of fish is to hunt for food, which has made it difficult for the algorithm to jump into global minimum individually. This leads to several disadvantages such as blindness of search space, poor convergence speed, etc.(Mu'azu *et al.*, 2015).As a way of addressing this shortcomings, an idea based on the best individual found so far was proposed with the aim of addressing some of the stated shortcomings above and guiding the evolution of the algorithm.The modified AFSA was used as an optimization algorithm in the PTS technique for PAPR reduction. The threebasic behaviours of fish (preying, swarming and chasing) on which AFSA algorithm is inspired are discussed as follows.

2.2.4.1 Preying

Generally, the fish perceives the region with more food in water by vision, sense and/or communication with neighbouring fishes and moves quickly towards this

region(AwadEl-Bayoumy *et al.*, 2013). Suppose the current state of artificial fish is X_i, theartificial fish selects aState X_j randomly within its visual distance such that(Wang & Li, 2015):

$$X_j = X_i + rand(0,1) \times visual \tag{2.16}$$

If the objective function $f(X_j) < f(X_i)$ in the minimization problem, it goes forward a step in the following direction(Mu'azu *et al.*, 2015):

$$X_i^{(t+1)} = X_i^{(t)} + rand(0,1) \times step \times \frac{X_j^{(t)} - X_i^{(t)}}{\left\| X_j^{(t)} - X_i^{(t)} \right\|} \tag{2.17}$$

$$\left\| X_j^{(t)} - X_i^{(t)} \right\| = \left| \sqrt{\left(X_j^{(t)}\right)^2 - \left(X_i^{(t)}\right)^2} \right| \tag{2.18}$$

Equation (2.18) is the Euclidean distance between artificial fish j and artificial fish i. If $f(X_j) < f(X_i)$, the artificial fish selects another state randomly again using equation (2.16).If the artificial fish cannot meet the requirement in a given time, it moves one step in the following direction(Mu'azu *et al.*, 2015)

$$X_j^{(t+1)} = X_i^t + rand(0,1) \times step \tag{2.19}$$

Note $rand(0,1)$ is a random number generator between mean of 0 and standard deviation of 1. At this point, the best individual which gives the best fitness will be memorized. This will be used to guide the evolution of individuals in the next stage.

2.2.4.2 Swarming

Swarming is a group behaviour of fishes executed to avoid danger and ensure or guarantee their existence. Suppose the current state of fish is X_i and nf is the number

of fellow within the visual distance. Assuming this visual distance is not crowded, that is (Gao *et al.*, 2010):

$$V = \left\{ X_i \mid d_{ij} \le visual \right\},\ nf \ne 0 \tag{2.20}$$

Let X_c be the centre position and Y_c then

$$X_c = \sum_j^{nf} X_j \Big/ nf \tag{2.21}$$

And

$$Y_c = f\left(X_c\right) \tag{2.22}$$

If $nf \times Y_c < \delta \times Y_i$ and $Y_c < Y_i$, the artificial fish moves one step forward towards the companion centre positions as follows(Gao *et al.*, 2013):

$$X_i^{(t+1)} = X_i^{(t)} + rand(0,1) \times step \times \frac{X_c^{(t)} - X_i^{(t)}}{\left\| X_c^{(t)} - X_t^{(t)} \right\|} \tag{2.23}$$

If this is not advantageous then, it executes the preying behaviour. The crowd factor limits the scale of swarms, and more fishesonly cluster at the best area (Mu'azu *et al.*, 2015), which ensures that they move to an optimum location in a wide field.

2.2.4.3 Chasing

When a fish finds food, neighbouring fish(s) will trail and reach the food quickly. Suppose the current state of the artificial fish is X_i and X_m is the best artificial fish individual within the visual distance, the fitness associated with the best individual is:

$$Y_m = f\left(X_m\right) \tag{2.24}$$

If $Y_m < Y_i \; and \; nf \times Y_m < \delta \times Y_i$ theAF moves one step towards X_m in the following direction (Mu'azu *et al.*, 2015).

$$X_i^{(t+1)} = X_i^{(t)} + rand(0,1) \times step \times \frac{X_m^{(t)} - X_i^{(t)}}{\left\| X_m^{(t)} - X_t^{(t)} \right\|} \qquad (2.25)$$

If this movement is not advantageous, the AF execute the preying behaviour. The flow chart of the standard AFSA Algorithm is shown in Figure 2.4(Mu'azu *et al.*, 2015):

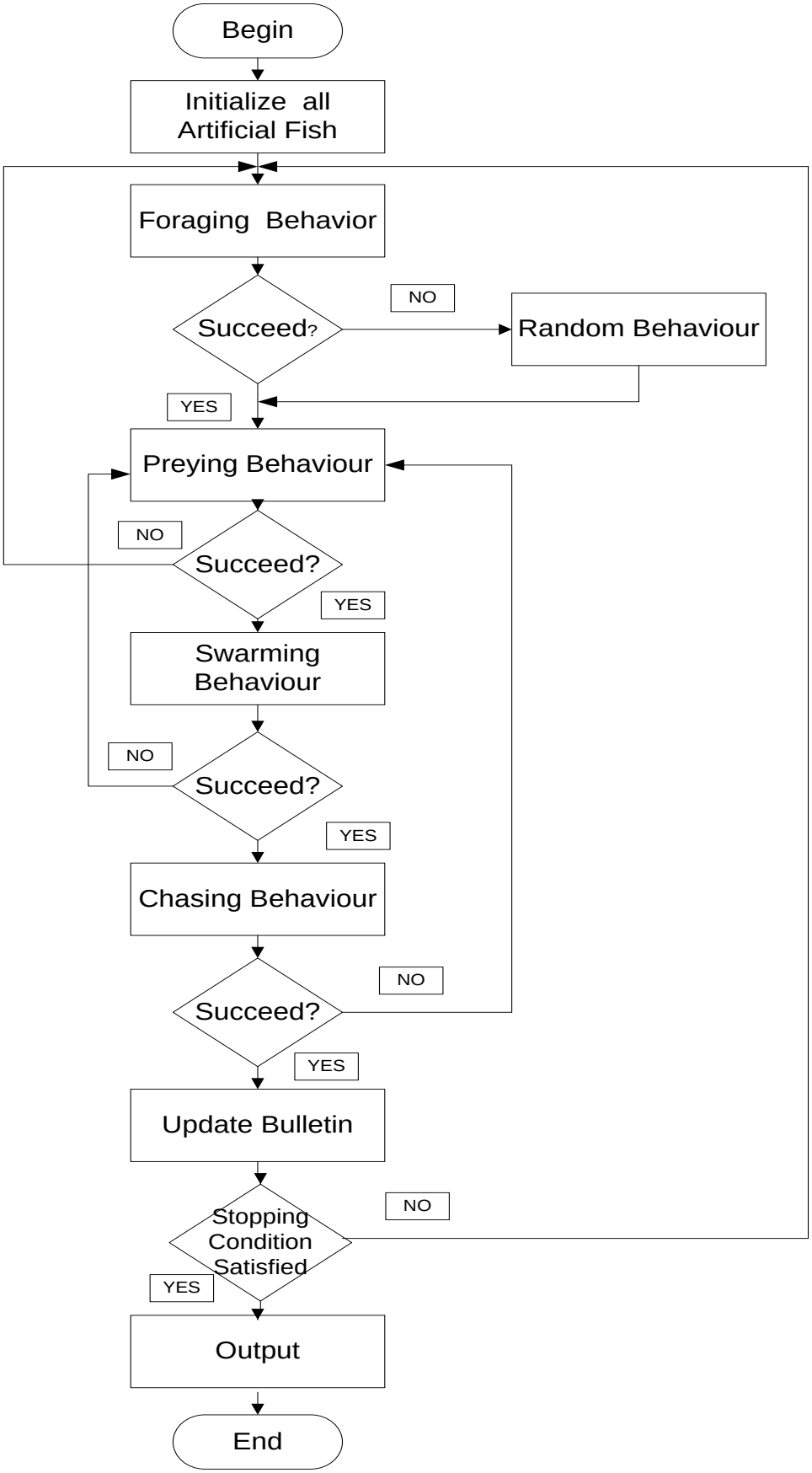


Figure 2.4: Flowchart implementation of the standard AFSA (Mu'azu *et al.*, 2015).

2.3 Review of Similar Works

In this section, relevant literatures directly related to this work are presented and reviewed to establish their respective problems. These literatures include the previous research works using classical method and meta-heuristic optimization techniques such as ABC, PSO, GA, etc.

Giannopoulos & Paliouras, (2009)implemented a low-complexity technique for retrieving the weighting factors associated with PTS PAPR reduction technique. The predefined values of pilot tones were used to explore all the permissible combination of weighting factors in order to identify the right phase factor combination to be employed by the transmitter. Simulation results showed that the proposed decoder required no additional pilot tones or explicit transmission of side information, therefore, no data rate loss was implied. However, the problem of weighting factor selection due to the multiplicative nature of PTS on the transmitted symbol still persisted becausethe method took a whilefor the right factor combination to be employed. Also when the number of sub carriers increases, the range of predefined values would increase andthis would increase the complexity of the system.

Wang *et al.*, (2010)proposed a method based on modified Artificial Bee Colony Partial Transmit Sequence (ABC-PTS) techniqueto search for the better combination of phase factors. The ABC based PTS techniquesignificantly reduced the computational complexity for larger PTS subblocks and offered lower peak-to-average power ratio at the same time. Simulation result showed that the ABC-PTS technique was an efficient method to achieve significant PAPR reduction. However, this work selected a predefined phase factor of $[-1, 1]^{M}$ or $[-1, 1, j, -j]^{M}$ which limited its solution because

the best phase factor combination which gave the minimal PAPR reduction would be outside this predefined values when the number of sub carriers increases.

Palanivelan & Anand, (2010) implemented a scheme based on Relaxed Greedy Algorithm (RGA) to reduce Peak to Average Power Ratio (PAPR) in Orthogonal Frequency Division Multiplexing (OFDM) systems. The resultant signals hada very large PAPR which could significantly impact the power efficiency and performance of a High Power Amplifier (HPA). A simple transformation on Sub Optimum Partial Transmit Sequence (SOPTS) combined with RGA was performed. Simulation results showed that PAPR reduction of upto 5dB could be obtained and further side information need not be transmitted to the receiver. To further evaluate the PAPR reduction, they compared their proposed scheme with the SOPTS scheme based on Orthogonal Greedy Algorithm (OGA). The results showed that the proposed scheme offered better PAPR reduction than the OGA basedSOPTS.However, the local solution associated with RGA due to limited guiding parameters and because they usually did not operate exhaustively on all data was a draw back for this method.

El Mouhib *et al.*, (2011)implemented a new suboptimal technique for the reduction of the PAPR by combining two suitable methods for Multiple Input Multiple Output (MIMO) OFDM systems. The first method was based on Boolean Particle Swarm intelligence Optimization (BPSO) algorithm applied to Partial Transmit Sequence (PTS) technique and the second was the Space Time Bloc Coding (STBC). The BPSO-PTS technique provided better performance and it was promoted as an uncomplicated way for PAPR reduction. In this technique, the transmitted sequence was selected by minimizing the maximum PAPR over all transmission antennas. The simulations and the BER performance demonstrated that more inertia weight and phase weighting factor obtained better PAPR reduction performance without bringing much higher complexity.

Their results showed that the added BPSO/PTS method to orthogonal space time bloc coding minimized computational complexity cost, as well as the PAPR, and gave a better optimal PTS performance in comparison with the conventional methods. However, the combination of BPSO and STBC led to anincrease in the computation time and complexity, whichlead to loss of information before the right phase factor is selected.

Ouqour *et al.*, (2012)proposed an Active Constellation Extension-Projection Onto Convex Sets (ACE-POCS) combined with the Particle Swarm Optimization (PSO) and Space Time Bloc Coding (STBC) for PAPR reduction. The ACE-POCS technique which was applied independently on each transmit antenna showed its effectiveness in reducingPAPR but converged slowly. To address this convergence problem, the PSO was introduced. Simulation and BER performance showed that the PSO-ACE-POCS method added to STBC minimized the PAPR with a fast convergence in comparison with the ACE-POCS method applied to STBC. However, the combination of this techniques increased the computational complexity of the system.

Salehinejad & Talebi, (2012)proposed an approach for peak-to-average power ratio reduction based on Global Harmony Search Partial Transmit Sequence (GHS-PTS) scheme. In the GHS-PTS, the data block to be transmitted is partitioned into disjointed subblocks, which were combined using phase factors to minimize PAPR. Due to the exhaustive search over all combinations of allowed phase factors associated with PTS, the GHS was employed because of its fast implementation and simplicity. Simulation result showed that a significant reduction in PAPR was achieved. However, choosing the harmony search acceptance rate that gives the right phase factor when the number of sub carriers is increased is time consuming, thus computation time is at risk of being compromised.

Taspinar & Yildirim, (2013) implemented an efficient peak-to-average power ratio reduction technique using Artificial Bee Colony (ABC) algorithm in Wavelet Packet Modulation (WPM). The foraging behaviours of ABC were employed for optimal selection of phase factor associated with PTS based PAPR reduction. The performance of the ABC algorithm for 6th Daubechies wavelets was compared with the original WPM for different Daubechies wavelets, random search PTS for 6th Daubechies wavelets and optimum PTS by computer simulations. Results showed that the proposed technique attained a suboptimal solution. However, evaluating the performance only on 6^{th} Daubechies is not sufficient for an optimal conclusion.

Yu *et al.*, (2013)proposed a modified Artificial Bee Colony-Partial Transmit Sequence (ABC-PTS)technique for peak-to-average power ratio reduction in multi input multi output orthogonal frequency division multiplexing. They introduced the global best idea of particle swarm optimization algorithm and the ABC updating equation was modified with the introduction of a learning factor to consider the balance between the ability of exploration and exploitation. Simulation results showed that the proposed approach had more PAPR reduction capability than the traditional ABC-PTS algorithm with the same time consumed, while having lower bit error rate. The problem of this work was thatthe computational complexity associated with phase factor selection in PTS was not reduced by this method.

Chen *et al.*, (2014)implemented a harmony search-based Tone Reservation (TR) technique to reduce the Peak-to-Average Power Ratio (PAPR) of an Orthogonal Frequency Division Multiplexing (OFDM) signal. In the TR scheme, a small number of unused subcarriers called Peak Reduction Carriers (PRCs) were reserved to reduce the PAPR and the goal of the scheme was to find the optimal values of the PRCs that minimized the PAPR of the transmitted OFDM signal. Simulation results showed that

the TR based on HS algorithm achieved a good PAPR reduction. However, the technique required an exhaustive search overall combinations of allowed PRC set, which resulted in a delay in convergence and high computational complexity.

Zhou *et al.*, (2014)implemented a Modified Elite Chaotic Artificial Fish Swarm Algorithm (MECAFSA)PTS technique for PAPR reduction in OFDM systems. In this approach, each artificial fish is equivalent to a weighting factor sequence which was encoded into a vector. An elite set which recorded the best AFSA in position with the highest food concentration set as the elite record. Base on this, the elite list was updated. The behaviours of AFSA was prioritized with the chasing behaviours assigned the highest priority, then the swarming behaviour and the preying behaviour. Simulation results indicated that the proposed technique was valid with an improved performance over SLM and Quantum Evolutionary Algorithm (QEA) PTS based technique. However, the method did not consider the constant effect of the AFSA parameters and the elite information were not used to influence the subsequent generation of AFSA.

Luo *et al.*, (2015) proposed two improved selective mapping methods without explicit Side Information (SI). This method included the Euclidean Distance SeLected Mapping (ED-SLM) and the SeLective Mapping (SLM) method. In the Proposed ED-SLM method, signals were transmitted without side information which was scrambled by special initial phase sequences and at the receiver.A Euclidean Phase distance Detection (EPD) method was used to detect the SI and complete the demodulation. In their proposed SLM method, the signals were transformed by Hadamard matrix to reduce peak-to-average power ratio. Then the row vectors of Hadamard matrix were used as phase sequences and superimposed on the data signals. The theory and simulation results showed that the two improved SLM methods performed better in PAPR and BER reduction than the conventional SLM method.This method had limitations because

of the phase factor overlapping associated with matrix superimpositioncaused by the non-linear nature of the OFDM signals.

Bharathi & Gangatharan, (2015)implemented a new low complexity transform which combined the fast Walsh Hadamard Transform (WHT) and Fast Hartley Transform (FHT) into a single fast orthonormal transform for OFDM across Additive White Gaussian Noise (AWGN) channel model. The new transform was developed through the sparse matrices method in OFDM system, which was capable of reducing Peak-to-Average Power Ratio (PAPR) of the transmitted symbols with better Bit Error Rate (BER) performance degradation at a reasonable reduced complexity. The system performance was verified via simulations. When compared with the FHT method, the proposed OFDM signal could be generated by FHT via WHT with lower PAPR and reduced computational complexity. But their proposedmethod had the same BER performance as FHT. However, the problem of weighting factor selected due to the multiplicative nature of PTS on the transmitted symbol still persisted.

It is evident from the literature thatvarious techniques for reducing peak-to-average power ratio in OFDM systems have been given significant research attention. However, continuous improvement on this field is required to reduce PAPR to as minimal as possible. This has made researchers to focus their attention on the PTS technique based onthe promising characteristics of meta-heuristics optimization techniques, such as PSO, HSA, GA, AFSA, ABC, etc. employed for phase factor selection that gives a minimal PAPR.These meta-heuristic algorithms are regeneration based, which implies that proper guiding parametersare required for them to perform optimally.In this research work, a modified AFSAalgorithm was employed for PTS based phase factor selection in an OFDM system and the main guiding parameter for the algorithm isa

feedback of the best information obtained during the generation of AFSA, which was used to increase the diversification of the search space.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter presents the step by step procedure employed for the successful implementation of the research work. Detail discussion of the Partial Transmit Sequence (PTS) technique, Artificial Fish Swarm Algorithm (AFSA) implementation and its proposed modification are presented.

3.2 Materials used for the Research Work

The materials used for this research work included; MATLAB R2015a communication/optimization toolbox, an HP Laptop and literature materials.

3.3 Methodology

The methodology adopted for this research work involved replicating the standard AFSA algorithm and developing the modified AFSA algorithm. Subsequently, MATLAB R2015a communication/optimization toolbox was used to implement both algorithms in a PTS technique for PAPR reduction and the steps employed are outlined below:

i. Initialization of the number of artificial fish (population), search dimension, visual distance, step size, and crowd factor parameters of AFSA and replication of the:
    i. Preying
    ii. Swarming
    iii. Chasing, behaviours of AFSA and introduction of a modification to guide the evolution of the algorithm.

ii. Initialization of the number of subcarriers, number of sub blocks, oversampling factor, phase factor and number of antenna parameters for OFDM simulation and setting up the partial transmit sequence OFDM model.

iii. Applying the modified AFSA in item (i) for phase factor optimization in the system model developed in item (ii).

iv. Evaluation of the performance of the developed model using Bit Error Rate (BER) and Complementary Cumulative Density Function (CCDF) as performance metrics.

v. Validation by comparing the results obtained using the modified AFSA-PTS model with the results obtained byZhou*et al.*, (2014).

3.4 Modified AFSA based PTS Scheme

The artificial fish swarm algorithm which simulate the foraging behaviour of school fish was employed for the optimum phase factor selection. Since in the AFSA algorithm, the preying, swarming and chasing behaviour were responsible for finding the optimum randomly deployed food sources. Therefore, the random partitioning method was adopted in this research. In the PAPR reduction problem, an artificial fish corresponds to a phase factor vector $b_i = [b_{i1}, b_{12}, ...b_{i(V-1)}]$ which is synonymous to the position of food in the solution search space. Assuming the current position of fish is b_i, the preying behaviour of AFSA based on the phase factor determination is given as follows:

$$b_i^{(t+1)} = b_i + rand \times step \times \frac{b_j - b_i}{\left\| b_j - b_i \right\|} \tag{3.1}$$

Similarly, the swarming and chasing behaviour of AFSA based on the phase factor notation are presented as follows:

$$b_i^{(t+1)} = b_i + \phi_i \times step \times \frac{b_c - b_i}{\|b_c - b_i\|} \tag{3.2}$$

$$b_i^{(t+1)} = b_i + \phi_i \times step \times \frac{b_{\min} - b_i}{\|b_{\min} - b_i\|} \tag{3.3}$$

where;

$b_i^{(t+1)}$ is the new phase (new food source)

b_j is the current position

b_i is the solution within the neighbourhood of b_j

b_c is the centre position of the food source (phase factor)

$b_{\min}$ is the best phase factor found so far within the visual distance.

In order to address some of the challenges of standard AFSA which were highlighted in chapter two, the best information obtained during the generation of AFSA was used to increase the diversification of the search space. This is with the aim of addressing the imbalance between exploration and exploitation and improve the solution searching capability of the AFSA. This is formulated as follows:

$$b_{new} = b_i + \beta \times \kappa \times \left(b_{best} - \lambda\right) \tag{3.4}$$

where:

β is a random number generator with a mean of one (1) and standard deviation of zero (0).

κ is the step size parameter

b_{best} is the best individual found so far.

λ is the weighted Euclidean position which depends on the behaviour evaluating.

For example, if preying is the current behaviour under evaluation, then

$$\lambda = \frac{b_j - b_i}{\left\| b_j - b_i \right\|} \tag{3.5}$$

if swarming is the behaviour under evaluation, then:

$$\lambda = \frac{b_c - b_i}{\left\| b_c - b_i \right\|} \tag{3.6}$$

if chasing is the behaviour under evaluation then

$$\lambda = \frac{b_{\min} - b_i}{\left\| b_{\min} - b_i \right\|} \tag{3.7}$$

Note:All other information and parameters of the artificial fish swarm algorithm are as discussed in subsection 2.2.4 of chapter two.Figure 3.1 shows the modified AFSA based PTS algorithm for peak to average power reduction.

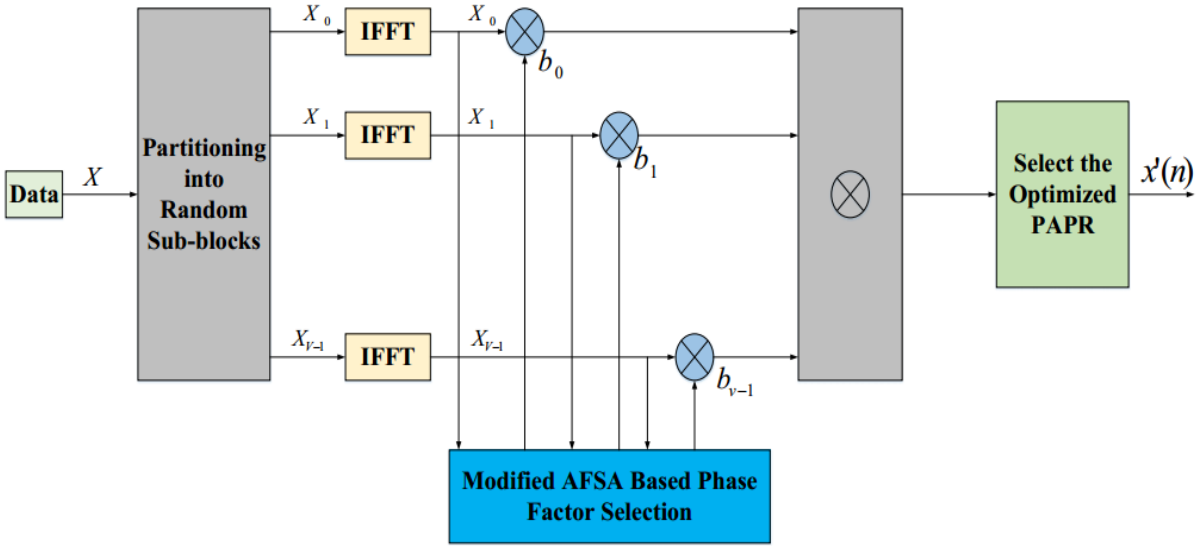


Figure 3.1: Diagram of the Modified AFSA based PTS Model

The flowchart for the implementation of the developed modified artificial fish swarm algorithm based partial transmit sequence is given in Figure 3.2.

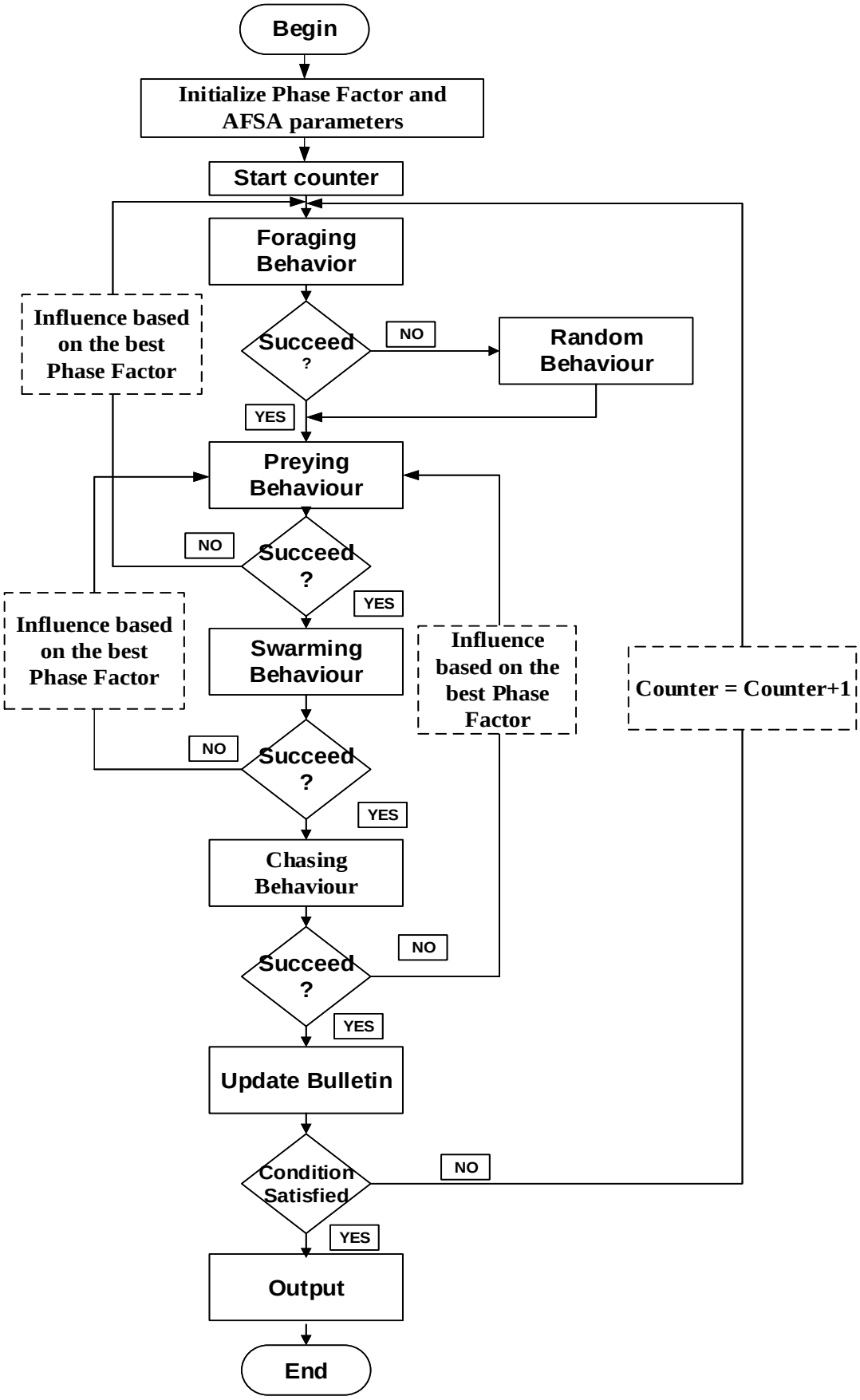


Figure 3.2: Flow chart Implementation of the modified AFSA.

At each stage of Figure 3.2 (preying, swarming, and chasing behaviour) of the algorithm, the best individual's information (phase factor) stored in the memory is employed to influence the regeneration of the algorithm which is not the case with the standard AFSA. In other words, preceding iterations in the modified AFSA is dependent and guided by the best result obtained in the previous iteration, whereas for the standard AFSA, the preceding result is compared with the previous result and the best is stored in the memory. Hence, themodified AFSA algorithm is used to model the PTS based PAPR reduction technique for this work, though a comparison is done with the standard AFSA.

3.5 Partial Transmit Sequence Technique for PAPR Reduction

In order to implement the partial transmit scheme, the OFDM sequence was divided into multiple subsequence and each subsequence was multiplied by difference weights until an optimum value was obtained. From Figure 2.3, the data stream (information) in frequency domain *X* was separated into *V* non-overlapping sub-blocks and each sub-block vectors has the same size *N*. Therefore, every subblock contain *N/V* nonzero elements and every other part is set to zero. Even though different partitioning methods have been proposed in literature, in this study the random partitioning method that could improve PAPR reduction and also obeys the random principle of AFSA was adopted. Subsequently, the sub-blocks are assumed to have the same size as given in the following equations:

$$\hat{X} = \sum_{v=1}^{V} b_v X_v \tag{3.8}$$

$$b_v = e^{j\varphi_v}\left(\varphi_v \in [0,2\pi]\right)\{v = 1,2,...,V\} \tag{3.9}$$

Where; b_v is the phase factor, X_v is the input data and v is the size of the input data

Equation (3.9) is the weighting factor used for phase rotation. The signal is converted into time domain by applying the IFFT operation on X_v by modifying Equation (3.9) as follows:

$$\hat{x} = IFFT(\hat{X}) = \sum_{v=1}^{V} b_v IFFT(X_v) = \sum_{v=1}^{V} b_v X_v \tag{3.10}$$

In order to select a suitable optimum phase factor combination

$$b = [b_1, b_2, ..., b_v] \tag{3.11}$$

the following objective function is employed:

$$b = [b_1, b_2, ..., b_v] = \arg\min_{(b_1, b_2, ..b_v)} \left(\max_{1 \le n \le N} \left| \sum_{v=1}^{V} b_v x_v \right|^2 \right) \tag{3.12}$$

Equation (3.12) $\arg\min(...)$ is the judgment condition that output the minimum value of the objective function. Therefore, the PAPR of the OFDM signal can be determined. As stated earlier, the transmitted signal of a continuous-time complex OFDM is given as:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_v e^{j 2\pi f_v t}, \qquad 0 \le t < NT \tag{3.13}$$

The size of the input data vector

$$X = [X_0, X_1, ..., X_{N-1}] \tag{3.14}$$

correspond to the size of the artificial fish swarm and the number of subcarriers *N*correspond to the population of fish. Each symbol is assigned to one subcarrier at a frequency of

$$f_v = v \Delta f \qquad 0 \le v \le N-1 \tag{3.15}$$

where subcarrier spacing

$$\Delta f = 1/NT \tag{3.16}$$

and *T* is the symbol period of one OFDM signal. Since the PTS is required for discrete-time signals, Equation (3.13) is re-written as

$$x(n) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi vn/LN}, 0 \le n < LN \tag{3.17}$$

where L is the oversampling factor and the OFDM signal is oversampled when the value of L is 8. The PAPR of the discrete-time signal is expressed as

$$PAPR(x) = \frac{\max_{0 \le n \le LN-1} \left\{ |x(n)|^2 \right\}}{E\left\{ |x(n)|^2 \right\}} \tag{3.18}$$

where the function $E\{\ldots\}$ denotes the expected value of the OFDM signal.

It should be observed from Equation (3.12) that the PAPR reduction performance and computational complexity of the PTS algorithm is closely related to the sub-block partition and the searching nature of the weighting or phase factor selection. In this research, a suboptimum technique alongside the AFSA algorithm is developed.

The main steps of the modified AFSA based PTS are highlighted as follows:

i. Initialize the phase vector b_i (i.e. population of Fish) and initialize all the parameters if AFSA (search dimension, visual, step, crowd, iteration)
ii. Randomly generate the positions of fish.
iii. Evaluate the fitness of each phase vector.
iv. Evaluating preying behaviour
v. If (iv) is better than (iii), then go to (vi).
vi. Evaluate swarming behaviour
vii. If (vi) is better than (iv) then implement (viii) else retain (iv).
viii. Implement chasing behaviour
ix. Retain the best between (iv), (vi) and (viii).
x. Evaluate the final fitness
xi. Memorize the solution of the best phase factor
xii. Until termination criterial is reached.

The model parameters used for the successful implementation of this research work are presented in Table 3.1:

Table 3.1: Model Parameters used.

Parameters	**Units**
Number of iteration	100
Number of sub carriers	32, 128, 256
Maximum Number of Symbols	10^3
Number of Overlapping Sub Block (L)	8
Modulation Type	QPSK
Guard Interleave	8, 32, 64
Population of Fish	32, 128, 256
SNR (Width Interval of 1)	15 (0-14)
Visual distance	0.7
Step size	0.2

It is important to note that the choice of the parameters presented in Table 3.1 is based on consultation of literature and the work of Zhou *et al,* (2014), which was used to validate this research. Parameters presented were adopted from this work and varied based on the simulation and performance of the developed modified AFSA-PTS technique.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the results obtained using the modified artificial fish swarm algorithm and the standardAFSA algorithm are presented and discussed. Results obtained are also compared with the work of Zhou*et al.* (2014), for validation.

4.2 Generated Signal Power

In carrying out this research work, Matlab was used to simulate the signal power with 250 as the total number of symbols as shown in Figure 4.1.

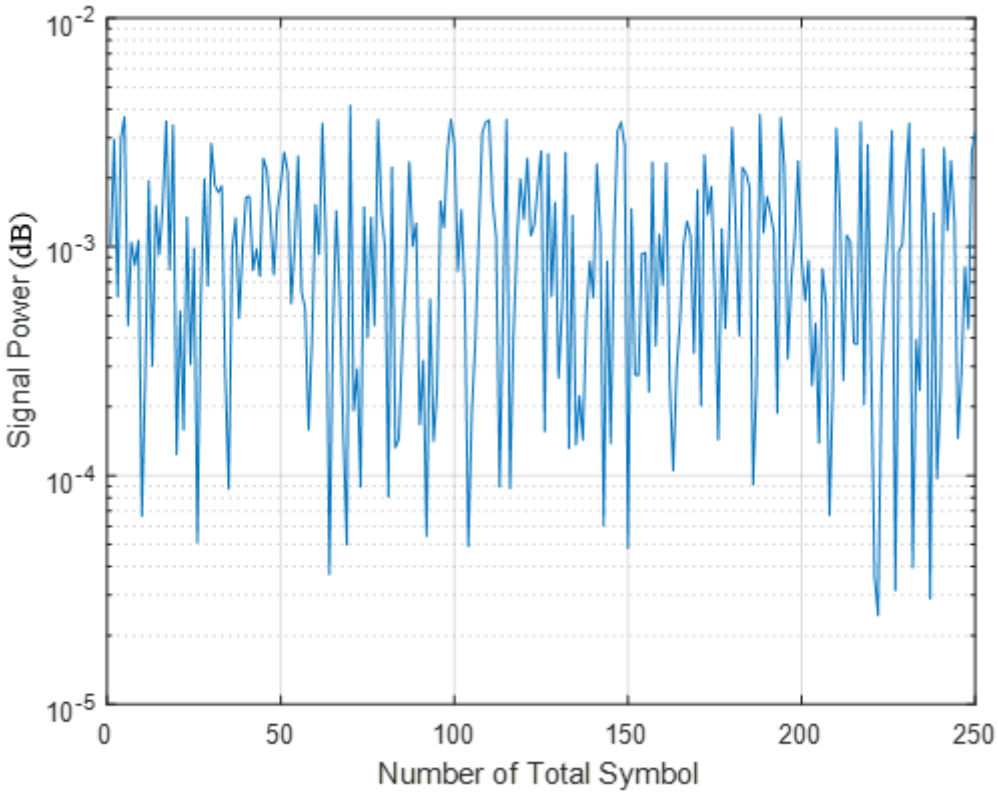


Figure 4.1: OFDM Generated Signal Power

Figure 4.1 show the power of the input orthogonal frequency division multiplexing signal generated at the input whose peak amplitude square (which is the peak power)

divided by the RMS value squared (which is average power) needs to be reduced to limit nonlinear signal distortion.

4.3 PAPR Reduction using Modified and Standard AFSA based PTS

To evaluate the performance of the developed modified AFSA-PTS technique in comparison with the standard AFSA-PTS technique and the original signal, the Complementary Cumulative Distribution Function (CCDF) was used to evaluate the merits of the techniques.

The simulation results obtained using the model parameters highlighted in Table 3.1 for the respective algorithms are shown in Figures 4.2, 4.4 and 4.6, with the performance of the modified AFSA-PTS (mAFSA-PTS) highlighted in blue, standard AFSA-PTS (sAFSA-PTS) highlighted in red and the original OFDM signal with no PTS highlighted in black. Also shown in Figures 4.3, 4.5 and 4.7, are the BER performance evaluation of the respective parameters. In the simulations, QPSK was adopted as the modulation scheme for the symbols, while the maximum number of iterations was set at 100. The population size for each simulation was equated to the number of subcarriers and the inputs symbol sequence is uniformly distributed among all the symbols.

Figure 4.2 show the CCDF result for the modified AFSA-PTS, standard AFSA-PTS and original signal, to select the phase weighting factor for the PAPR reduction with the phase weighting sequence length (L) of 8 and the number of subcarriers set at 32.

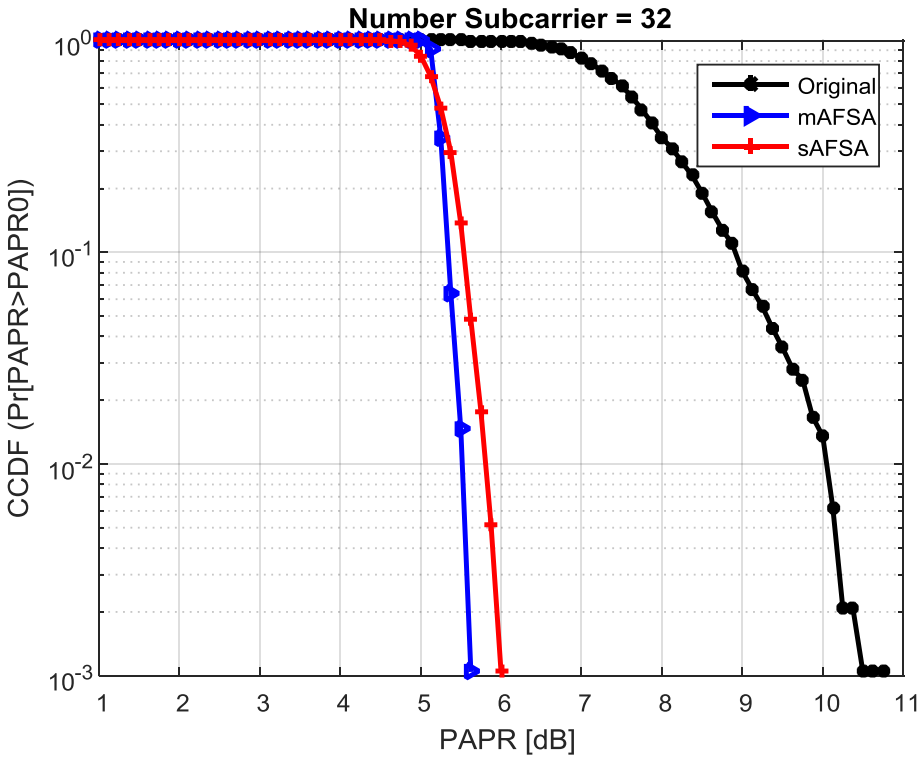


Figure 4.2: CCDF of the PAPR with L=8, No. of Subcarrier=32

The results from Figure 4.2 show PAPR for the mAFSA-PTS at 5.6 dB, sAFSA-PTS at 6.0 dB and the original signal at 10.5 dB. This shows the mAFSA-PTS yields a better result compared to the sAFSA-PTS and the original signal.

Figure 4.3 show the bit error rate performance of the OFDM system using both mAFSA-PTS and sAFSA-PTS for a total number of 32 subcarrier.

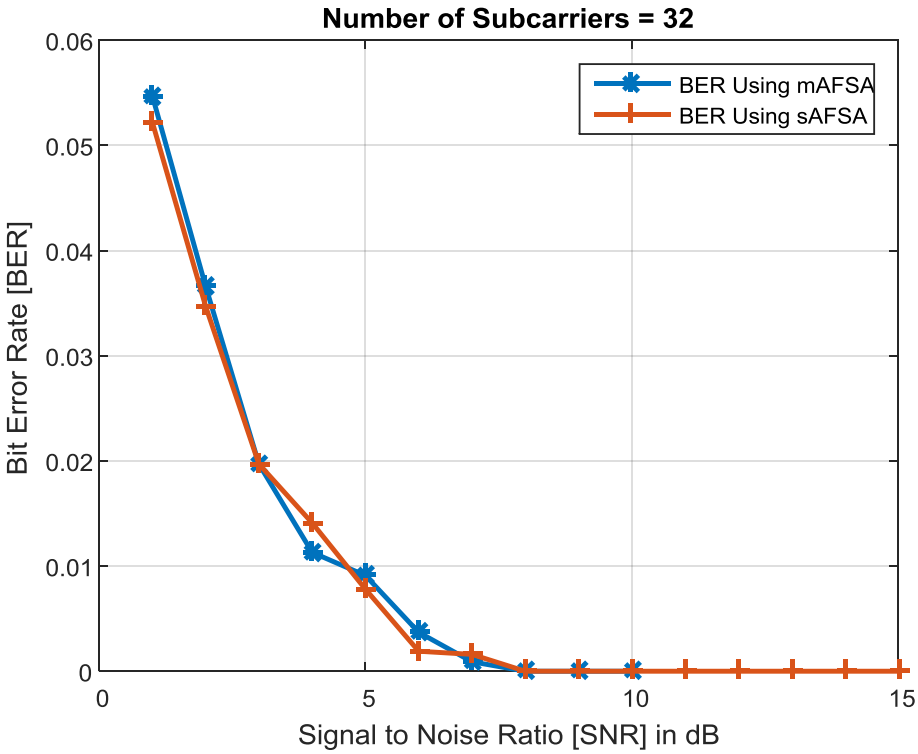


Figure 4.3: BER Performance with L=8, No. of Subcarrier=32

From Figure 4.3, the BER performance shows a relatively close result for both techniques and it can be observed that, the number of bit data affected by noise is highest at about 0.055 when the signal to noise ratio is 1dB. However, this value reduces drastically and remains constantat zero in both the modified and standard AFSA based PTS when the level ofthe Signal to Noise Ratio (SNR) increasesto about 8dB. This indicates that increase in SNR will have little or negligible effect on the OFDM data stream at 8dB SNR and above.

When the number of subcarriers is set to 128, Figure 4.4 show the CCDF result for the modified AFSA-PTS, standard AFSA-PTS and original signal to select the phase weighting factor for the PAPR reduction with the phase weighting sequence length (L) of 8.

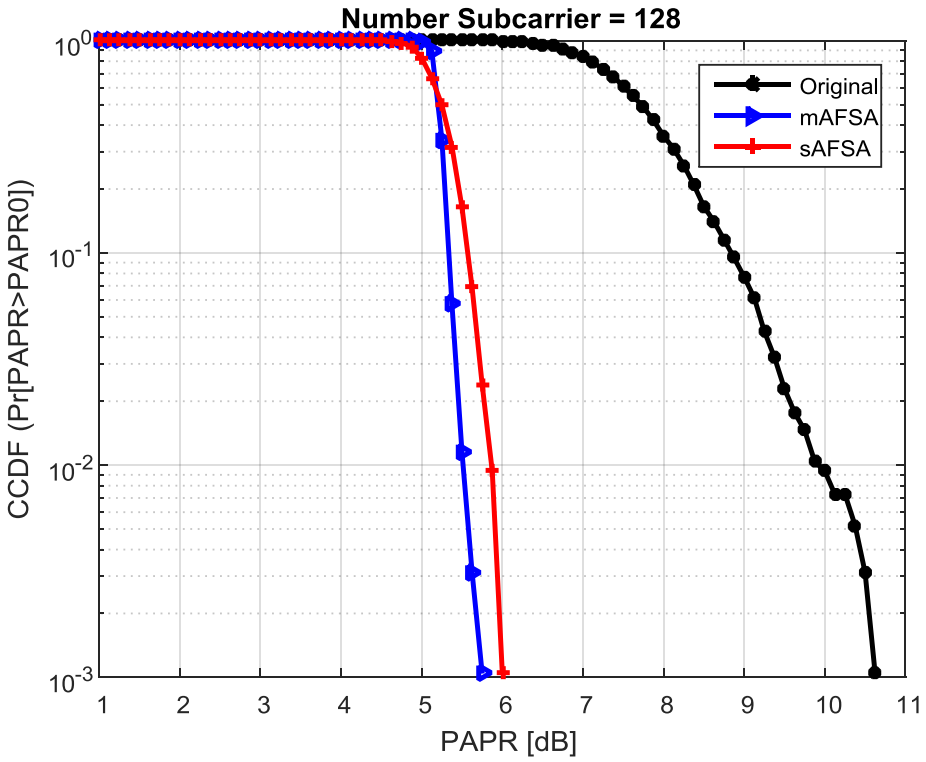


Figure 4.4: CCDF of the PAPR with L=8, No. of Subcarrier=128

As can be deduced from Figure 4.4, the results shows PAPR for the mAFSA-PTS at 5.8 dB, sAFSA-PTS at 6.0 dB and the original signal at 10.6 dB. This shows the modified AFSA-PTS yields a better result compared with the sAFSA-PTS and the original signal.

Figure 4.5 show the bit error rate performance of the OFDM system using both mAFSA-PTS and sAFSA-PTS for a total number of 128 subcarrier.

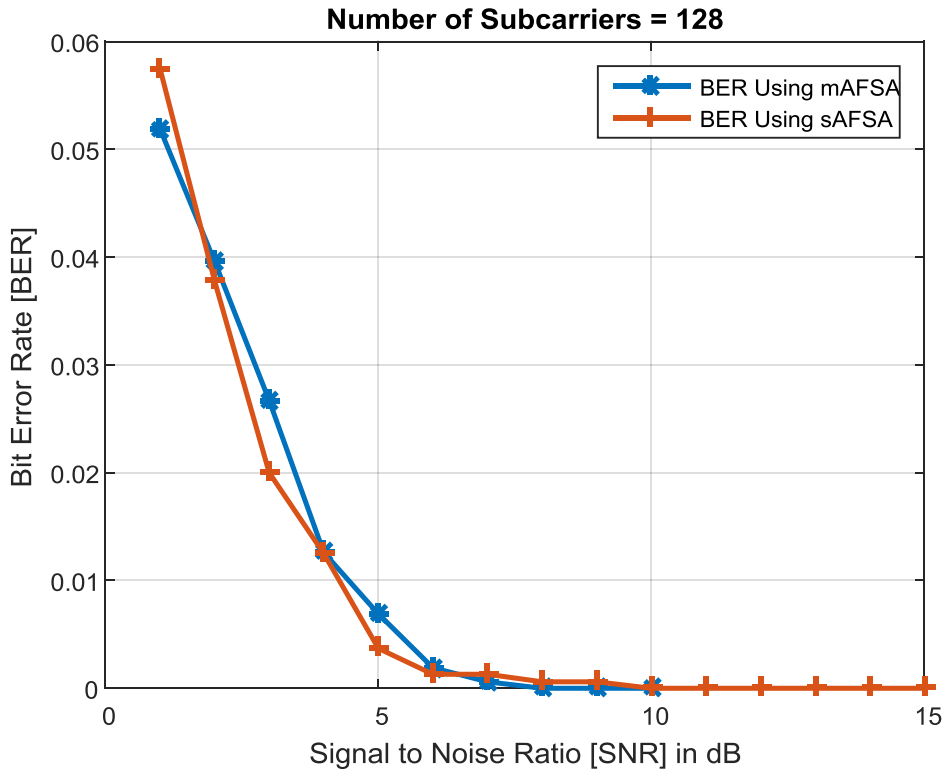


Figure 4.5: BER Performance with L=8, No. of Subcarrier=128

It can be observed from Figure 4.5 that, the number of bit data affected by noise is highest at about 0.052 for mAFSA and 0.058 for sAFSA, when the signal to noise ratio is about 1dB. However, this value reduces drastically and remains constant at zero when the signal to noise ratio is 8dB for mAFSA and 10dB for sAFSA. This indicate that increase in noise ratio will have little or negligible effect on the OFDM data stream at 8dB SNR for mAFSA and 10dB SNR for sAFSA. The 2dB difference is an indication of early convergence for the mAFSA-PTS technique in relation to signal to noise ratio.

Figure 4.6 show the CCDF result for the modified AFSA-PTS, standard AFSA-PTS and the original signal to select the phase weighting factor for the PAPR reduction with the phase weighting sequence length (L) of 8 and the number of subcarriers set at 256.

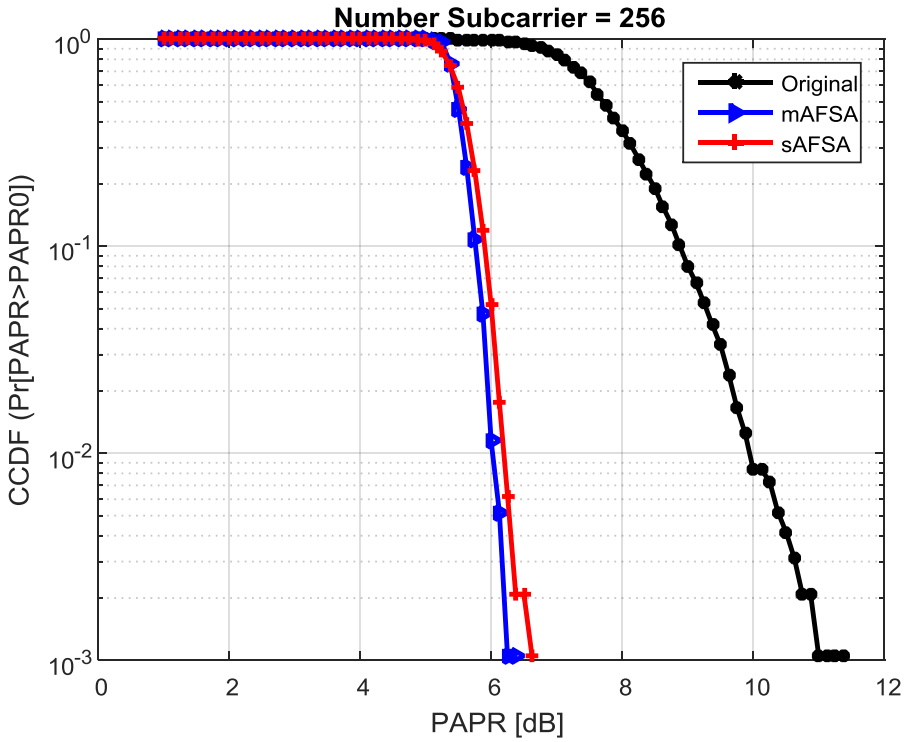


Figure 4.6: CCDF of the PAPR with L=8, No. of Subcarrier=256

From Figure 4.6, the results shows PAPR for the mAFSA-PTS at 6.2 dB, sAFSA-PTS at 6.4 dB and the original signal at 11.0 dB. This shows the modified AFSA-PTS yields a better result compared with the sAFSA-PTS and the original signal.

Figure 4.7 show the bit error rate performance of the OFDM system using both mAFSA-PTS and sAFSA-PTS for a total number of 256 subcarrier.

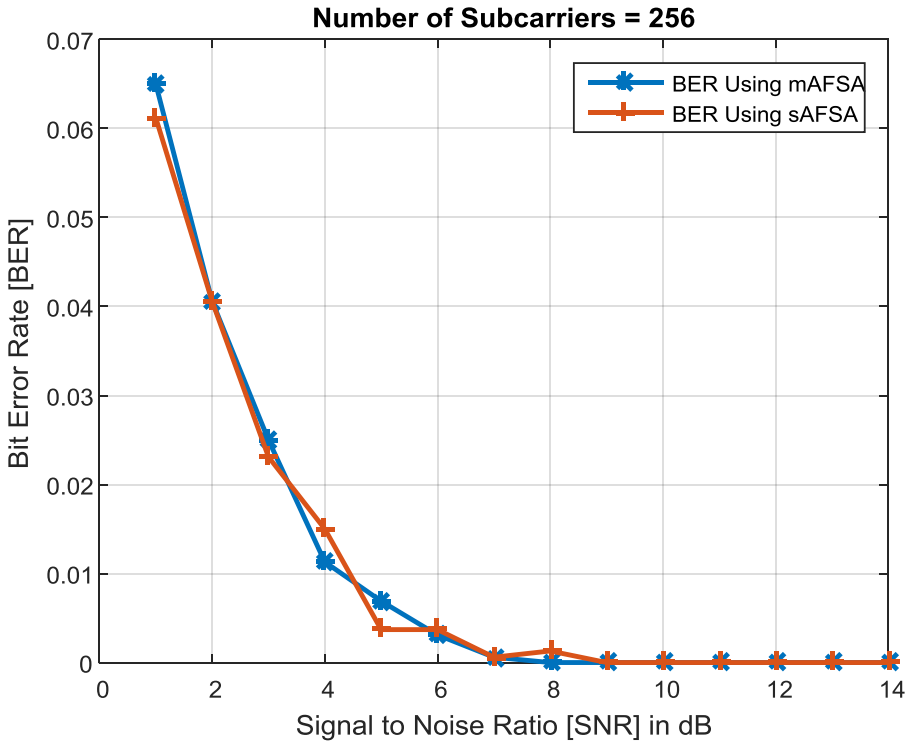


Figure 4.7: BER performance with L=8, No. of Subcarrier=256

From Figure 4.7, the BER performance shows a relatively close results for both techniques and it can be observed that, the number of bit data affected by noise is highest at about 0.064 when the signal to noise ratio is 1dB. However, this value reduces drastically and remain constant at zero in both the modified and standard AFSA based PTS when the number of signal to noise ratio increases up to about 7dB. This indicate that increase in noise will have little or negligible effect on the OFDM data stream at 7dB SNR and above.

For all three number of subcarriers evaluated, the PAPR reduction as shown in Figures 4.2, 4.4 and 4.6, mAFSA-PTS is better than the sAFSA-PTS and the original signal. However it can also be deduced thatboth AFSA-PTS technique have significant reduction in PAPR as against the original signal.Hence, this result demonstrates the effectiveness of the modified AFSA-PTS technique.

4.4 Validation

The simulation result for the CCDF of the PAPR for 128 sub carriers (Figure 4.4) is tabulated in Table 4.1. Also in Table 4.2 is the tabular deduction of the result obtained by Zhou*et al* (2014), for the CCDF of the PAPR for 128 sub carriers.

Table 4.1: PAPRo Tabular Result for mAFSA, sAFSA and Original signal (no. of subcarriers=128).

SIMULATION PARAMETERS	**mAFSA $PAPR_O$ (dB)**	**sAFSA $PAPR_O$ (dB)**	**Original signal $PAPR_O$ (dB)**
No. of subcarriers=128, Phase weighting sequence Length=8	5.8	6.0	10.6

Table 4.2: PAPRo Tabular Result for MECAFSA-PTS, QEA-PTS, SLM-PTS and Original signal, deduced from Zhou *et al* (2014), (no. of subcarriers=128).

SIMULATION PARAMETERS	**MECAFSA-PTS $PAPR_O$ (dB)**	**QEA-PTS $PAPR_O$ (dB)**	**SLM-PTS $PAPR_O$ (dB)**	**Original signal $PAPR_O$ (dB)**
No. of subcarriers=128, Phase weighting sequence Length=8	5.9	7.0	7.4	10.0

Comparing the results in Tables 4.1 and 4.2, mAFSA-PTS has a PAPR of 5.8dB while MECAFSA-PTS, QEA-PTS and SLM-PTS have a PAPR of 5.9dB, 7.0dB, and 7.4dB respectively. Therefore this shows mAFSA-PTS has a slightly better PAPR performance when compared with MECAFSA-PTS and a significant improved PAPR

performancewhen compared with results for QEA-PTS and SLM-PTS. This affirms the notion that mAFSA-PTS as developed is an effective technique in PAPR reduction and helped improve PAPR.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

This research presented the development of a modified AFSA-PTS technique for PAPR reduction in OFDM systems. The developed method was implemented in MATLAB R2015a and the following results are obtained:

i. The modified AFSA has a better PAPR reduction than the standard AFSA with a percentage improvement of 6.67% over the standard AFSA when the number of subcarriers is 32. The modified AFSA also produce a percentage improvement of 3.33% and 3.13% over the standard AFSA when the number of subcarriers were 128 and 256 respectively.

ii. Both the modified AFSA and the standard AFSA algorithms performed efficiently in reducing the PAPR when compared with the original signal, with a percentage reduction of 46.67% and 42.86% respectively when the number of subcarriers is 32. Also, the modified AFSA-PTS produce a percentage reduction of 45.28% while the standard AFSA-PTS produce a percentage reduction of 43.40% when the number of subcarriers is 128. Similarly, when the number of subcarriers is 256, the modified AFSA-PTS and standard AFSA-PTS produce a PAPR percentage reduction of 43.64% and 41.82% respectively.

iii. Validation indicates that the modified AFSA-PTStechnique is efficient with an improved performance of 1.69% over the MECAFSA-PTS technique proposed in the work of Zhou *et al* (2014).

5.2 Conclusions

In this research work the development of a modified Artificial Fish Swarm Algorithm (AFSA) based Partial Transmit Sequence (PTS) technique for Peak to Average Power Ratio (PAPR) reduction in Orthogonal Frequency Division Multiplexing (OFDM) systems is presented with the replication of the standard AFSA and its use in PTS technique. Due to the ease at which the standard AFSA falls into local minima, this research developed a modified AFSA using the global best information obtained from the previous generations and this was applied in the PTS technique for PAPR reduction with the following conclusions drawn;

i. The developed modified AFSA algorithm was used for phase factor selection in the PTS based PAPR reduction technique in OFDM.
ii. The performance of the modified technique was evaluated and results showed that the modified method was effective with significant reduction in PAPR when compared with the original signal, and an improved PAPR reduction when compared with the standard AFSA PTS technique.
iii. The modified AFSA was able to reduce PAPR thereby improving Bit Error Rate (BER) performance degradation and eliminating non-linear distortion effects to achieve power efficiency of the high-power amplifier.

5.3 Significant Contributions

Though several research works have been carried out with the aim of reducing PAPR in OFDM systems, the contributions of this work include:

i. The research was able to develop a modified Artificial Fish Swarm Algorithm (AFSA) based PTS technique for PAPR reduction in OFDM system that performed efficiently in reducing the PAPR with a percentage reduction of

46.67%, 45.28% and 43.64% when compared with the PAPR of the original signal with the number of subcarriers as 32, 128, and 256 respectively.

ii. The developed modified AFSA had a better PAPR reduction than the standard AFSA with a percentage improvement of 6.67%, 3.33%, and 3.13% when the number of subcarriers is 32, 128 and 256 respectively. This show an improvement in performance of the AFSA algorithm with the introduction of the modification implemented in the research work.

iii. The modified AFSA and the standard AFSA algorithms performed efficiently in reducing the PAPR while comparing with the original signal, with a percentage reduction of 46.67% and 42.86% respectively when the number of subcarriers is 32. Also, both algorithm had a respective PAPR percentage reduction of 45.28% and 43.40% when the number of subcarriers is 128. Similarly, when the number of subcarriers is 256, the modified AFSA and standard AFSA produced a PAPR percentage reduction of 43.64% and 41.82% respectively when compared with the original signal.

5.4 Recommendations.

Even though the aim of the research which is to develop a modified artificial fish swarm algorithm-based partial transmit sequence technique for peak to average power ratio reduction has been achieved, the following areas for further research are recommended for consideration:

i. The performance of the proposed method can be evaluated by comparing with similar PAPR reduction techniques such as Tone Injection, Tone Rejection, etc.

ii. The developed modified AFSA algorithm can be applied in other research areas such as image processing, power system engineering, etc.

REFERENCES

Baro, M., & Ilow, J. (2008). *PAPR reduction in OFDM using wavelet packet pre-processing.* Paper presented at the 2008 5th IEEE Consumer Communications and Networking Conference, CCNC 2008.

Bharathi Raja, N., & Gangatharan, N. (2015). A new low complexity transform for peak power reduction in discrete hartley transform based multicarrier OFDM system. *International Review on Computers and Software, 10*(6), 552-557.

Bi, Y., Meng, L., & Zhang, G. (2012). *A novel LOS/NLOS channel learning approach based on PSO algorithm.* Paper presented at the IET Conference Publications.

Chen, J. S., Hung, H. L., & Huang, Y. F. (2014) Harmony search algorithm based nearly optimal peak reduction tone set selection for PAPR reduction in OFDM system. *Vol. 8398 LNAI. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (pp. 342-351).

Cho, Y. S., Yang, W. Y., Kim, J., & Kang, C.-G. (2010). *Mimo-Ofdm Wireless Communications With Matlab* (Vol. 1). Singapore: Publisher, John Wiley & Sons (Asia) Pte Ltd.

Cuteanu, E. V., & Isar, D. (2012). *Hybrid PAPR reduction scheme using Walsh Hadamard precoding and signal companding.* Paper presented at the 2012 10th International Symposium on Electronics and Telecommunications, ISETC 2012 - Conference Proceedings.

Daoud, O., & Alani, O. (2009). Peak-to-Average Power Ratio reduction technique for MIMO/OFDM systems. *International Journal of Mobile Communications, 7*(6), 632-645. doi: 10.1504/IJMC.2009.025535

El Mouhib, K., Oquour, A., Jabrane, Y., Said, B. A. E., & Ait Ouahman, A. (2011). PAPR reduction using BPSO/PTS and STBC in MIMO OFDM system. *Journal of Computer Science, 7*(4), 454-458. doi: 10.3844/jcssp.2011.454.458

Gangwar, A., & Bhardwaj, M. (2012). An overview: Peak to average power ratio in OFDM system & its effect. *International Journal of Communication and Computer Technologies, 1*(2), 22-25.

Gao, X. Z., Wu, Y., Wang, X., Zenger, K., & Huang, X. (2013). A cultural Artificial Fish-swarm Algorithm for optimization. *ICIC Express Letters, Part B: Applications, 4*(1), 231-236.

Gao, X. Z., Wu, Y., Zenger, K., & Huang, X. (2010). *A knowledge-based Artificial Fish-swarm Algorithm.* Paper presented at the 2010 13th IEEE International Conference on Computational Science and Engineering, CSE 2010, Hong Kong.

Giannopoulos, T., & Paliouras, V. (2009). A low-complexity PTS-based PAPR reduction technique for OFDM signals without transmission of side information. *Journal of Signal Processing Systems, 56*(2-3), 141-153. doi: 10.1007/s11265-008-0238-y

Jaya, T., Margaret Suganthi, V., & Gopinathan, E. (2015). Reduction of papr in orthogonal frequency division multiplexing using optimal search partial transmit sequence technique. *ARPN Journal of Engineering and Applied Sciences, 10*(13), 5478-5482.

Karaboga, D. (2005). An idea based on honey bee swarm for numerical optimization: Technical report-tr06, Erciyes university, engineering faculty, computer engineering department.

Krongold, B. S., & Jones, D. L. (2003). PAR reduction in OFDM via active constellation extension. *Broadcasting, IEEE Transactions on, 49*(3), 258-268.

Li, C.-P., Wang, S.-H., & Wang, C.-L. (2010). Novel low-complexity SLM schemes for PAPR reduction in OFDM systems. *Signal Processing, IEEE Transactions on, 58*(5), 2916-2921.

Liang, H., Liao, H. Y., Chen, H., & Cheng, C. H. (2011). *A modified constellation extension scheme with error correction capability for peak-to-average power ratio reduction in OFDM systems.* Paper presented at the 7th International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM 2011.

Liang, H., Lin, Z., Chen, H., & Yang, C. Y. (2010). *A modified genetic algorithm PTS technique with error correction for PAPR reduction in OFDM systems.* Paper presented at the ISITA/ISSSTA 2010 - 2010 International Symposium on Information Theory and Its Applications.

Luo, R., Li, R., Dang, Y., Yang, J., & Liu, W. (2015). Two improved SLM methods for PAPR and BER reduction in OFDM-ROF systems. *Optical Fiber Technology, 21*, 26-33. doi: 10.1016/j.yofte.2014.07.007

Manjith, R., & Suganthi, M. (2013). A Sub-Optimal Pts Algorithm Based On Bacterial Foraging Optimization Technique For Papr Reduction In Mimo-Ofdm System. *Journal of Theoretical & Applied Information Technology, 57*(2).

Mohanty, B., & Ramavath, S. (2015). *A companding technique for PAPR reduction in DWT OFDM systems.* Paper presented at the Proceedings of 2014 IEEE International Conference on Advanced Communication, Control and Computing Technologies, ICACCCT 2014.

Mu'azu, M. B., Salawudeen, A. T., Sikiru, T. H., Muhammad, A., & Abdu., A. I. (2015). weighted Artificial Fish Swarm Algorithm with Adaptive Behaviour Based Linear Controller Design for Nonlinear Inverted Pendulum. *Jounal of Engineering Research JER, 20*(1), 1-12.

Naeiny, M. F., Jahromi, A. J., & Marvasti, F. (2010). Modified Active Constellation Extension for PAPR Reduction of Space-Frequency Block Coded OFDM Systems. *Electrical Engineering, 17*(2), 196-204.

Ouqour, A., Louliej, A., Jabrane, Y., Es Said, B. A., & Ouahman, A. A. (2012). Peak-to-average power ratio reduction using active constellation extension-projection onto convex sets combined with particle swarm optimization added to space time bloc coding in multiple input multiple output-orthogonal frequency division multiplexing system. *Journal of Computer Science, 8*(12), 2017-2024. doi: 10.3844/jcssp.2012.1780.1787

Palanivelan, M., & Anand, S. (2010). *RGA based approach for PAPR reduction in OFDM systems.* Paper presented at the Proceedings - 2010 3rd IEEE International Conference on Computer Science and Information Technology, ICCSIT 2010.

Passino, K. M. (2002). Biomimicry of bacterial foraging for distributed optimization and control. *Control Systems, IEEE, 22*(3), 52-67.

Peng, Y. (2011). An improved artificial fish swarm algorithm for optimal operation of cascade reservoirs. *Journal of computers, 6*(4), 740-746.

Sahoo, S., & Patra, S. K. (2015). *VHDL implementation of circularly shifted PTS technique for PAPR reduction in OFDM.* Paper presented at the Proceedings of 2014 IEEE International Conference on Advanced Communication, Control and Computing Technologies, ICACCCT 2014.

Salehinejad, H., & Talebi, S. (2012). PAPR reduction of OFDM signals by novel global harmony search in PTS scheme. *International Journal of Digital Multimedia Broadcasting, 2012*. doi: 10.1155/2012/940849

Shigei, N., Araki, K., & Miyajima, H. (2014) Effective selection and mutation in genetic algorithm for PAPR reduction of OFDM signal. *Vol. 273. Advances in Intelligent Systems and Computing* (pp. 61-73).

Shyam P., Reddy., D., Sudha, V., & Sriramkumar, D. (2014). *Low complexity PAPR reduction in OFDM using both selective mapping and clipping methods.* Paper presented at the International Conference on Communication and Signal Processing, ICCSP 2014 - Proceedings.

Soliman, N. F., Hassan, E. S., Shaalan, A. H. A., Fouad, M. M., El-Khamy, S. E., Albagory, Y., El-Bendary, M. A. M., Al-Hanafy, W., El-Rabaie, E. S. M., Dessouky, M. I., El-Dolil, S. A., Alshebeili, S. A., & El-Samie, F. E. A. (2015). Efficient Image Communication in PAPR Distortion Cases. *Wireless Personal Communications, 83*(4), 2773-2834. doi: 10.1007/s11277-015-2568-y

Suyama, S., Adachi, H., Suzuki, H., & Fukawa, K. (2009). *PAPR reduction methods for eigenmode MIMO-OFDM transmission.* Paper presented at the IEEE Vehicular Technology Conference.

Taspinar, N., Karaboga, D., Yildirim, M., & Akay, B. (2011). PAPR reduction using artificial bee colony algorithm in OFDM systems. *Turk J Electr Eng Comput Sci, 19*(1), 47-58.

Taspinar, N., & Yildirim, M. (2013). Peak-to-Average Power Ratio Reduction using Artificial Bee Colony Algorithm in Wavelet Packet Modulation. *Journal of Advanced in Computer Networks, 1*(2), 265-269.

Venkatachalam, S., & Manigandan, T. (2015). PAPR reduction and performance analysis of alamouti MIMO-OFDM systems using slantlet based P-SLM scheme. *International Journal of Applied Engineering Research, 10*(13), 33013-33017.

Wang, Y., Chen, W., & Tellambura, C. (2010). A PAPR reduction method based on artificial bee colony algorithm for OFDM signals. *IEEE Transactions on Wireless Communications, 9*(10), 2994-2999. doi: 10.1109/TWC.2010.081610.100047

Wang, Y., & Li, L. (2015). An Improved Intelligent Algorithm Based On The Group Search Algorithm And The Artificial Fish Swarm Algorithm. *Int. J. Optim. Civil Eng, 5*(1), 37-52.

Wang, Y., & Luo, Z. (2011). Optimized iterative clipping and filtering for PAPR reduction of OFDM signals. *Communications, IEEE Transactions on, 59*(1), 33-37.

Wen, J. H., Lee, S. H., & Cheng, C. H. (2009). SLM-based PAPR reduction method using partial data circulation and side information insertion in OFDM systems. *International Journal of Communication Systems, 22*(1), 87-100. doi: 10.1002/dac.960

Wunder, G., Fischer, R. F., Boche, H., Litsyn, S., & No, J.-S. (2012). The PAPR problem in OFDM transmission: New directions for a long-lasting problem. *arXiv preprint arXiv:1212.2865*.

Xiaowen, L., Qianjun, F., Jie, Y., (2011). *A Modified Phase Transmit Sequences Approach to Reduce PAPR in LTE System.* Paper presented at the Proceedings of 2011 International Conference on Computer Science and Information Technology (ICCSIT 2011).

Yu, X., Li, S., Zhu, Z., & Zhang, T. (2013). An improved artificial bee colony-partial transmit sequence algorithm for PAPR reduction in OFDM systems. *International Journal of Wireless and Mobile Computing, 6*(5), 473-480. doi: 10.1504/IJWMC.2013.057395

Zhao, Y., Wang, T., Tao, R., Shi, P. F., & Jiang, Z. G. (2014). Peak to Average Power Ratio reduction with low computational complexity in FrFT-OFDM system. *Dianzi Yu Xinxi Xuebao/Journal of Electronics and Information Technology, 36*(1), 246-249. doi: 10.3724/SP.J.1146.2013.00323

Zheng, J. Q., & Wang, Y. J. (2013) A PAPR reduction method for hexagonal constellation-based OFDM signals. *Vol. 397-400. Applied Mechanics and Materials* (pp. 2287-2290).

Zhou, J., Dutkiewicz, E., Liu, R. P., Huang, X., Fang, G., & Liu, Y. (2014). *Modified elite chaotic artificial fish swarm algorithm for PAPR reduction in OFDM systems.* Paper presented at the Communications and Information Technologies (ISCIT), 2014 14th International Symposium on.

Appendix A

mFile of the Modified AFSA

```
function AFSA
%*********************************************
clear all
clc
N=input('Please how many Number of Artificial Fish(N) do you want?:  ');
clc
D=input('What Dimension (D) do you want for each Artificial Fish?:  ');
clc
visual=input('What should be the Visual Distance of the Artificial fishes?:  ');
clc
step=input('Please select the step size of the artificial Fish.:  ');
clc
zig=input('Please enter the Crowd Factor of the Artificial Fish.:  ');
clc
try_num=input('Please enter the number of trials an Artificial fish: ');
clc
%fitness=input('Select the test function:\nPress 1 to Select Ackley\nPress 2 to Select
CM\nPress 3 to Select DeJongf4\nPress 4 to Select Expfun\nPress 5 to Select
Griewank\nPress 6 to Select Hyperelliptic\nPress 7 to Select LM1\nPress 8 to Select
LM2\nPress 9 to Select Neumaier3\nPress 10 to Select Rastrigin\nPress 11 to Select
Rosenbrock\nPress 12 to Select Sal\nPress 13 to Select Schwefel\nPress 14 to Select
chaffer\nPress 15 to Select Sphere\nPress 16 to Select Bukin\nPress 17 to Select
Elteejayy\nPress 17 to Select PID TUNING.:  ');
clc
FISHS=input('PLEASE ENTER THE INITIAL FISH MATRIX OR \nPRESS ZERO
(0)FOR MATLAB TO CREATE THEM\nFISH:= ');
clc
Itr = input('PLEASE ENTER THE NUMBER OF ITERATIONS: ');
global Xmin Xcentre population
% Generate the artificial fishes which is the same as the Food
% concenteration
tic
if FISHS==0
pop=rand(N,D);
pop=sort(pop);
else
   pop=FISHS;
end
popi=pop;%Initial positions of the AF and start with preying conditions
PTS_AFSA
return
fitpopi=PTS_AFSA(fitness,popi);
for i=1:N
Try=0;
Itr_max=Itr;
iteration = 0;
```

```
while Try<try_num
   iteration = iteration+1;
   Try=Try+1;
   popj(i,(1:D))=popi(i,(1:D))+rand*visual;%randomly selected position
   fitpopj(i,1)=PTS_AFSA(fitness,popj(i,(1:D)));
if fitpopj(i,1)<fitpopi(i,1)
%Execute preying
   popi(i,(1:D))=popi(i,(1:D))+rand*step*(popj(i,(1:D))-
popi(i,(1:D)))/sum((abs(popj(i,(1:D)).^2-popi(i,(1:D)).^2)).^0.5);
   Try=try_num;
end
visual=ceil(visual*(Itr_max-iteration)/Itr_max);
step=ceil(step*(Itr_max-iteration)/Itr_max);
try_num=ceil(try_num*(Itr_max-iteration)/Itr_max);

end
if fitpopj(i,1)>fitpopi(i,1)
popi(i,(1:D))=popi(i,(1:D))+rand*step;%Execute if preying fails
end
end
%start Swarming
popii=pop;
fitpopii=PTS_AFSA(fitness,popii);
popk=popii+rand*visual;% represent next positions of AF.
for hh=1:N
for h=1:N
   Xcentre=zeros(1,D);
   nf=0;
if sum(abs(popk(h,:).^2-popii(h,:).^2).^0.5)<=visual %Conditions for  number of
fellows btw visual distance
      nf=nf+1;
      B=popk(h,:);
      Xcentre=Xcentre+B;
end

end
Xcentre=Xcentre/nf;
Ycentre=PTS_AFSA(fitness,Xcentre)
if nf*Ycentre<zig*fitpopii(hh)
if Ycentre<fitpopii(hh)
      popii(hh,:)=popii(hh,:)+rand*step*(Xcentre-popii(hh,:))/sum((abs(Xcentre.^2-
popii(hh,:).^2)).^0.5);%Uncrowded area
else
clear i;
for i=1:N
Try=0;
Itr_max=Itr;
iteration=0;
while Try<try_num
   iteration = iteration+1;
```

```
    Try=Try+1;
    popk(i,(1:D))=popii(i,(1:D))+rand*visual;
    fitpopk(i,1)=PTS_AFSA(fitness,popk(i,(1:D)));
if fitpopk(i,1)<fitpopii(i,1)
    popii(i,(1:D))=popii(i,(1:D))+rand*step*(popk(i,(1:D))-
popii(i,(1:D)))/sum((abs(popk(i,(1:D)).^2-popii(i,(1:D)).^2)).^0.5);%Execute Swarming
    Try=try_num;
end
    visual=ceil(visual*(Itr_max-iteration)/Itr_max);
    step=ceil(step*(Itr_max-iteration)/Itr_max);
    try_num=ceil(try_num*(Itr_max-iteration)/Itr_max);
end
if fitpopk(i,1)>fitpopii(i,1)
popii(i,(1:D))=popii(i,(1:D))+rand*step;
end
end
end
end
end

%Start Chasing
popiii=pop;
fitpopiii=PTS_AFSA(fitness,popii);
popl=popiii+rand*visual;
clear ihhh
for hh=1:N
for h=1:N
    Xmin=[];
    nf=0;
if  sum(abs(popl(h,:).^2-popiii(hh,:).^2).^0.5)<=visual
        nf=nf+1;
        Xmin=[Xmin;popl(h,:)];
end
end
clear h;
if nf~=0
for h=1:nf-1
if  sum(abs(popl(h+1,:).^2-popiii(h+1,:).^2).^0.5)<sum((abs(popl(h,:).^2-
popiii(h,:).^2)).^0.5)
        Xmin=Xmin(h+1,:);
else
         Xmin=Xmin(h,:); %represent the best artificial fish  individual withing visual
distance.
end
end
end
Ymin=PTS_AFSA(fitness,Xmin);
if nf*Ymin<zig*fitpopiii(hh)
if Ymin<fitpopiii(hh)
```

```
        popiii(hh,:)=popiii(hh,:)+rand*step*(Xmin-popiii(hh,:))/sum((abs(Xmin.^2-
popiii(hh,:).^2)).^0.5)
else
clear i;
for i=1:N
Try=0;
Itr_max=Itr;
iteration=0;
while Try<try_num
    iteration=iteration+1;
    Try=Try+1;
    popl(i,(1:D))=popiii(i,(1:D))+rand*visual;
    fitpopl(i,1)=PTS_AFSA(fitness,popl(i,(1:D)));
if fitpopl(i,1)<fitpopiii(i,1)
    popiii(i,(1:D))=popiii(i,(1:D))+rand*step*(popl(i,(1:D))-
popiii(i,(1:D)))/sum((abs(popl(i,(1:D)).^2-popiii(i,(1:D)).^2)).^0.5);
    Try=try_num;
end
    visual=ceil(visual*(Itr_max-iteration)/Itr_max);
    step=ceil(step*(Itr_max-iteration)/Itr_max);
    try_num=ceil(try_num*(Itr_max-iteration)/Itr_max);
end
if fitpopl(i,1)>fitpopiii(i,1)
popiii(i,(1:D))=popiii(i,(1:D))+rand*step;
end
end
end
end
end
%Determing which behavior yield the best solution
population=[];
for Fish=1:N
for property=1:3
if property==1
            Best=popi(Fish,:);
end
if property==2
if PTS_AFSA(fitness,Best)>PTS_AFSA(fitness,popii(Fish,:))
                Best=popii(Fish,:);
end
end
if property==3
if PTS_AFSA(fitness,Best)>PTS_AFSA(fitness,popiii(Fish,:))
                Best=popiii(Fish,:);
end
end
end
    population=[population;Best];
end
fitpop=PTS_AFSA(fitness,population);
```

```
BEST_FITNESS=min(fitpop);
```

Appendix B

mFil: MATLAB Program for the PTS objective Function

```
function [ccdf papr=PTS_AFSA(N, X)
clear all
close all
clc
tic;
%++++++++++++++++++++++++++Declear the common
variables++++++++++++++++++++++++++++++
global nSymbol;
global M0;
global Super;
%global pjn
global tdatatmp;
global PAPR_f1;
global PAPR_f9;
global PAPR_fs;
MAX_nSymbol=960;%Maximum  number of Symbol
V=8 ;   % Number of Overlapping  subblocks
nloop=100;          % Number of iteration
M=32;   % Number of subcarriers/Number of subchannels
N=500;
M0=1;
SNR= 0:14;          % signal to noise ratio vector in dB
Rate0= zeros(1, length(SNR)); % initializing bit error rate
Guard_Interval = M/4;% Guard interval length

disp('Running');
for nSymbol=1:MAX_nSymbol,
%++++++++++++++++++      ++++++++++++++++++++
   progress=fix(100*(nSymbol./MAX_nSymbol));
   clc;
   fprintf('Computation in Progress>>>>\n',nSymbol,MAX_nSymbol,progress);
%++++++++++++++++  Deifined the input data
%++++++++++++++++  and the Modulation Scheme  +++++++++++++++
   datain=randint(1,N);
   QPSKdata=qpsk(datain);
%+************************************************
%++++ Implement the ifft
   ifftin=QPSKdata;
   Do=ifft(ifftin,[],2);
%+++++
   Signal_Power = abs(Do.^2);
   Peak_Power = max(Signal_Power,[],2);
   Mean_Power = mean(Signal_Power,2);
   PAPR_Orignal(nSymbol) = 10*log10(Peak_Power./Mean_Power);
   [ACE_data9,D9]=ACE9(V,QPSKdata);                %++++  ACE-PAPR·
   Signal_Power9 = abs(ACE_data9.^2);
```

```
    Peak_Power9 = max(Signal_Power9,[],2);
    Mean_Power9 = mean(Signal_Power9,2);
    PAPR_9(nSymbol) = 10*log10(Peak_Power9./Mean_Power9);
%++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++
%************************ACE-SGP**********************
    [ACE_datas,Ds]=ACE0(V,QPSKdata);
    Signal_Powers = abs(ACE_datas.^2);
    Peak_Powers = max(Signal_Powers,[],2);
    Mean_Powers = mean(Signal_Powers,2);
    PAPR_s(nSymbol) = 10*log10(Peak_Powers./Mean_Powers);
if M0==1                                %
        Super=zeros(1,M*length(QPSKdata));
        datains=zeros(1,M*N);
end
        datains(((M0-1)*N+1):(M0*N))=datain;
        Super(((M0-1)*length(QPSKdata)+1):(M0*length(QPSKdata)))=QPSKdata;
        M0=M0+1;
if M0==M+1
        M0=1;

        [SACE_data9,Df9]=ACE9(V,Super);
        [SACE_datas,Dfs]=ACE0(V,Super);
        SIFFTdata9=reshape(SACE_data9,M,N./2);
        x=1;
for x=1:1:M
            Signal_Powerf9 = abs(SIFFTdata9(x,:).^2);
            Peak_Powerf9 = max(Signal_Powerf9,[],2);
            Mean_Powerf9 = mean(Signal_Powerf9,2);
            PAPR_f9(nSymbol-M+x) = 10*log10(Peak_Powerf9./Mean_Powerf9);

end
end
end
%++++++++++++++++++++++++CCDF++++++++++++++++++++++++++++++++
disp('--------------------------------')
[ccdfo,PAPRo] = CCDF_fzm(PAPR_Orignal,1,14);
[ccdf9,PAPR9] = CCDF_fzm(PAPR_9,1,14);
[ccdff9,PAPRf9] = CCDF_fzm(PAPR_f9,1,14);
disp('--------------------------------')
figure
semilogy(PAPR9,ccdf9,'-b>','LineWidth',2,'MarkerSize',5);
xlabel('PAPR0 [dB]');
ylabel('CCDF (Pr[PAPR>PAPR0])');
legend('PAPAR using mAFSA')
grid on
figure
semilogy(PAPRo,ccdfo,'-k*','LineWidth',2,'MarkerSize',5);
hold on
semilogy(PAPR9,ccdf9,'-b>','LineWidth',2,'MarkerSize',5);
```

```
hold on
semilogy(PAPRf9,ccdff9,'-r+','LineWidth',2,'MarkerSize',5);
% axis([1 14  1e-004 1e000]) ;
legend('Original','mAFSA','sAFSA');
% title('PAPR Reduction');
xlabel('PAPR [dB]');
ylabel('CCDF (Pr[PAPR>PAPR0])');
grid on;
title('Number Subcarrier = 32')
% if N>16;
figure
semilogy(Signal_Powerf9)
xlabel('Number of Total Symbol')
ylabel('Signal Power')
grid on
%end
q=M0+1;             % Modulation level
for ebn0 = 1 : length(SNR)
   ebn0;
for i = 1 : nloop
%% Transmitter
      %% Data generation
         Data_In = randint(M,1,q);
      %% Modualtion
         Data_Mod = qammod(Data_In,q);
      %% IFFT
         Data_IFFT = ifft(Data_Mod,M);
      %% Guard interval insertion
         Data_Guard = [Data_IFFT(M- Guard_Interval + 1 : M);Data_IFFT];
      %% P/S conversion
      [a b]=size(Data_Guard);
      Data_Tx=reshape(Data_Guard,a*b,1);
%% Channel Effect
      %% AWGN
      Data_Noise = awgn(Data_Tx,ebn0,'measured');
%% Receiver
      %% S/P conversion
      Data_Rx=reshape(Data_Noise,a,b);
      %% Guard interval removal
      Data_Removeal_Gaurd  = Data_Rx(Guard_Interval+1:M+Guard_Interval);
      %% FFT
       Data_FFT   = fft(Data_Removeal_Gaurd,M);
      %% Demodualtion
      Data_Out   = qamdemod(Data_FFT,q);
%% BER
%
      [nErr rate0] = symerr(Data_Out,Data_In);
      Rate0(ebn0)= Rate0(ebn0) + rate0;
end
      Rate0(ebn0)= Rate0(ebn0)/nloop;
```

```
end
X=Rate0
hold on
f1=figure(4);
set(f1,'color',[1 1 1]);
hold on
semilogy(SNR,Rate0,'k-*','LineWidth',2)
xlabel('Signal to Noise Ratio [SNR] in dB');
ylabel('Bit Error Rate [BER]')
grid on
toc
disp('End of Simulation');
```

Appendix C

mFile of the QPSK Modulation

```
function dout=qpsk(din)

%++++++++++++++++++++++++variables++++++++++++++++++++++++++++
% din
% dout
%++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

din2=1-2*din;
din_temp=reshape(din2,2,length(din)/2);
for i=1:length(din)/2,
   dout(i)=din_temp(1,i)+j*din_temp(2,i);
end
```