Sudan University of Science and Technology
College of Graduate Studies

Performance Enhancement in Digital Mobile Satellite Using SC-FDMA with MIMO

تحسين الأداء في المحمول الرقمي للاقمار الصناعية بإستخدام المدخلات المتعددة والمخرجات المتعددة مع أحادي الحامل لتقسيم التردد للوصول المتعدد

Thesis Submitted in Partial Fulfilment of the Requirements of the Degree of M.Sc.in Electronic Engineering (Communications)

By:

Amr Mohamed Musa Mohamed

Supervisor:

Prof. Rashid Abdrlhaleem Saeed

July 2019

الآية

بسم الله الرحمن الرحيم

قال تعالى:

قَالُواْ سُبۡحَانَكَ لَا عِلۡمَ لَنَآ إِلَّا مَا عَلَّمۡتَنَآۖ إِنَّكَ أَنتَ ٱلۡعَلِيمُ ٱلۡحَكِيمُ

سورة البقرة (32)

Dedication

This research paper is lovingly dedicated to our respective parents who have been our constant source of inspiration. They have given us the drive and discipline to tackle any task with enthusiasm and determination. Without their love and support this research would not have been made possible. I also dedicate this research paper to my subject teacher who never failed to teach and guide me, to my family who supports me in everything and most of all to the Almighty God who gives me strength and good health while doing this.

Acknowledgment

Thank you to all of those who have helped listened and encouraged me throughout this study.

I am indebted to my supervisor **Prof. Rashid A. Saeed** whose guidance, advice and patience has been immeasurable.

Finally I thank my family, without whom this thesis would not have been started or completed! Your encouragement and support has never faltered; thank you.

Abstract

Single carrier frequency division multiple accessing (SC-FDMA) technique is one of the good generation modulation techniques for uplink transmission in wireless communication system. It promises to deliver high throughput, low bit error rate, high spectral efficiency with low peak to average power ratio (PAPR) than the orthogonal frequency division multiple accessing (OFDMA) technique. In this thesis mathematical modelling and Matlab simulation are carried out to obtain PAPR performance for different modulation formats and number of subcarriers for SC-FDMA technique. The methodology use complete digital MIMO demonstrator, the first of its kind, allows in-depth verification and optimization of the MIMO techniques applied to satellite broadcasting networks. Moreover, the demonstrator allows complementing and confirming the theoretical and our simulation-based. It is shown that dual polarization MIMO diversity is able to provide remarkable gains in terms of satellite/terrestrial transmit power reduction and/or capacity increase compared to more conventional non MIMO solutions. It is also demonstrated that the adoption of a relatively simple spatial multiplexing MIMO technique represents the best way to grasp these gains.

المستخلص

تقنية أحادي الحامل لتقسيم التردد للوصول المتعدد هي تشكيل جيل المستقبل لنقل الإرسال في نظام الاتصالات اللاسلكية .وتقوم بتوفير معدل نقل عالي و معدل أخطاء قليل في البيانات وكذلك كفاءة طيفية عالية مع انخفاض نسبة ذروة القدرة إلى القدرة المتوسطة مقارنة بتقنية أحادي الحامل لتقسيم التردد للوصول المتعدد في هذه البحث النماذج الرياضية تم تنفيذها بواسطة النمذجة ومحاكاة بإستخدام الماتلاب للحصول عليها أداء نسبة ذروة القدرة إلى القدرة المتوسطة لتنسيقات التشكيل المختلفة و عدد الموجات الحاملة الفرعية لتقنية أحادي الحامل لتقسيم التردد للوصول المتعدد .

وكذلك تم أستخدام تقنية المدخلات المتعددة والمخرجات المتعددة ، التحقق المتعمق والتحسين الأمثل على شبكات البث عبر الاقمار الصناعية . علاوة على ذلك تسمح هذا التقنية بتكملة وتأكيد النتائج النظرية أو المحاكاة المبنية حتى الآن. وقد تبين أن الاستقطاب الثنائي المدخلات المتعددة والمخرجات المتعددة للتنوع قادر على توفير مكاسب ملحوظة من حيث الحد من قدرة الإرسال عبر الأقمار الصناعية / الأرضية و / أو زيادة السعة مقارنة مع حلول المدخلات المتعددة والمخرجات المتعددة غير التقليدية. كما يتبين أن اعتماد تقنية المدخلات المتعددة والمخرجات المتعددة متعددة الإرسال البسيطة نسبيًا يمثل أفضل طريقة لفهم هذه المكاسب.

CONTENTS

Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

SNR	Signal to Noise Ratio
SC-FDMA	Single carrier frequency division multiple access
MIMO	Multiple Inputs and Multiple Outputs
PAPR	power average peak ratio
OFDMA	Orthogonal frequency-division multiple access
GEO	geostationary satellite
LEO	low Earth orbit
MEO	medium Earth orbit
LANs	local area networks
WANs	wide area networks
PCN	Personal Communications Network
PCS	Personal Communications Service
CDMA	Code-Division Multiple Access
GSM	Global System for Mobile communication
SC	Single Carrier
SNIR	Signal to interference plus noise ratio
DPPB	dual polarization per beam
CCDF	complementary distribution function
IFDMA	intermittent frequency division multiple access
LFDMA	localized frequency division multiple access
DVB-SH	Digital Video Broadcasting Satellite to Hand-held
AFD-DFE	Adaptive Frequency Domain Decision Feedback Equalize
DFE	Decision Feedback Equalize
LMS	land mobile satellite)
MQAM	M-ary quadrature amplitude modulation
ML	maximum likelihood
MISO	multiple-input single-output
SISO	single-input single-output
TTI	Transmission Time Interval
FFT	Fast Fourier transform
LB	long blocks
SCME	Spatial Channel Model Extension
QAM	quadrature amplitude modulation
QPSK	Quadrature Phase Shift Keying
CP	Cyclic Prefix

CHAPTER ONE
INTRADUCTION

CHAPTER ONE

INTRADUCTION

1.1 Introduction

Multiple-input and multiple-output or MIMO is a method for multiplying the capacity of a radio link using multiple transmit and receive antennas to exploit multipath propagation.

Optimization of the MIMO techniques applied to Digital Mobile Satellite. Single Carrier Frequency Division Multiple Access (SC-FDMA) is a promising technique for high data rate uplink communication and has been adopted by 3GPP for it next generation, main advantage of OFDM, as is for SC-FDMA, is its robustness against multipath signal propagation, which makes it suitable for broadband systems. SC-FDMA brings additional benefit of low peak-to-average power ratio (PAPR) compared to OFDM making it suitable for uplink transmission by user-terminals.

1.2 Problem Statement

Reduce the size of the device by reducing battery size while preserving battery life increase, exactly to reducing the peak-average-power-ratio (PAPR).

1.3 Proposed Solution

Using SC-FDMA with MIMO to reducing the peak-average-power-ratio (PAPR) in Uplink Mobile Digital Satellite.

1.4 Aim and Objectives

Enhancement power loss in Mobile Satellite Digital by Using SC-FDMA with MIMO.

Using SC-FDMA in MIMO for reduce co-channel interference and increase SNIR. Reduce energy reflected in reducing the size of the device (handheld).

1.5 Methodology

The methodology is divided to four parts.

- Modeling is done by using the mathematical equations of the OFDMA and MIMO.
- The design is done by drawing the figures of component to OFDMA and MIMO. Describe digital signal and illustrates architectural composition for Digital Mobile Satellite.
- Simulation is done by analysis results from the figures of each signal with OFDMA-MIMO and without. By Using matlab simulation and Simulation in PAPR.
- Verification process is done by comparing between the theoretical results and Simulation results and makes sure the process reducing the PAPR.

1.6 Thesis Outline

This thesis contains of five chapters and is organized as follows:

- Chapter one: is discussed the research preface, problem statement, objectives, and the Methodology.
- Chapter two: is discussed literature review which is divided into background and related works.
- Chapter three: is represent mathematical model of the design is done by drawing the figures of component to OFDMA and MIMO. Describe digital signal and illustrates architectural composition for Digital Mobile Satellite and the important parameters that have been used in this research are clearly stated in this Chapter.
- Chapter four: is discussed the analysis results.
- Chapter five: is discussed the conclusions for the whole research, it also provides suggestion for future recommendation where the proposed system can be modified to enable the simulation to be more practical and continuously.

CHAPTER TWO
LITERATURE REVIEW

CHAPTER TWO

BACKGROUND ANF LITERATURE REVIEW

2.1 Overview

This chapter constituting of two parts, first part is background to covers the Digital Mobile Satellite, PAPR , SC-FDMA ,MIMO and study matlab application which is used in the research. Part two is related works.

2.2Background

Every satellite application achieves its effectiveness by building on the strengths of the satellite link. A satellite is capable of performing as a microwave repeater for Earth stations that are located within its coverage area, determined by the altitude of the satellite and the design of its antenna system. The arrangement of three basic orbit configurations is shown in Figure 2.1. A GEO satellite can cover nearly onethird of the Earth's surface, with the exception of the Polar Regions. This includes more than 99% of the world's population and economic activity.

The low Earth orbit (LEO) and medium Earth orbit (MEO) approaches require more satellites to achieve this level of coverage. Due to the fact that non-GEO satellites move in relation to the surface of the Earth, a full complement of satellite (called a constellation) must be operating to provide continuous, unbroken service. The trade-off her is that the GEO satellites, being more distant, incur a longer path length to Earth stations, while the LEO systems promise short paths not unlike those of terrestrial systems[1].

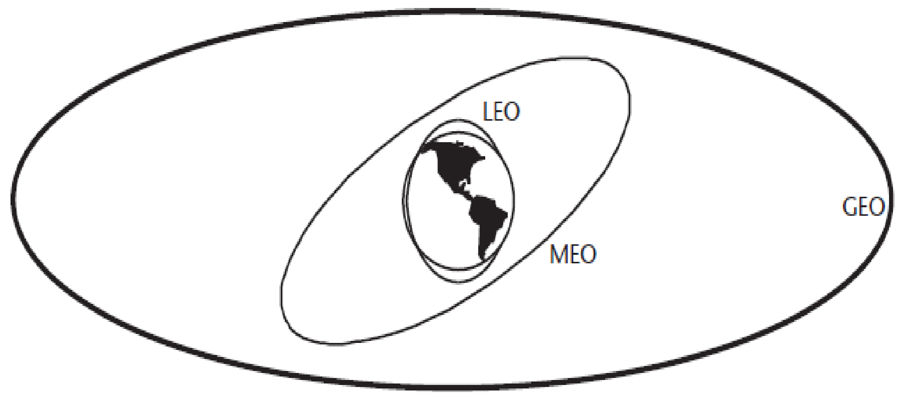


Figure 2.1 The **three most popular orbits for communication.**

2.3 Peak to Average Power Ratio for uplink satellite link

The Peak to Average Power Ratio (PAPR) is currently viewed as an important implementation issue in communication systems. Specifically, for wireless cellular systems the price of the mobile unit is required to remain low. This means that a limited PAPR can be supported. Orthogonal Frequency Division Multiplexing (OFDM) and Single Carrier (SC) are the prominent candidates for the next generation of wireless communications physical layer standards. PAPR was considered extensively for OFDM and much attention was given to the issue by academy and industry.

PAPR as a function of bandwidth efficiency for OFDM and SC modulation techniques is considered. It is shown that high PAPR for both types of modulation technique appears as a result of high bandwidth efficiency demand, regardless of the modulation technique used. This property is not unique to OFDM [2].

2.4 Single Carrier Frequency Division Multiple Access

Single carrier frequency division multiple access (SCFDMA), which utilizes single carrier modulation and frequency domain equalization is a technique that has similar performance and essentially the same overall complexity as those of OFDMA system. One prominent advantage over OFDMA is that the SC-FDMA signal has lower PAPR because of its inherent single carrier structure. SC-FDMA has drawn great attention as an attractive alternative to OFDMA, especially in the uplink communications where lower PAPR greatly benefits the mobile terminal in terms of transmit power efficiency [3].

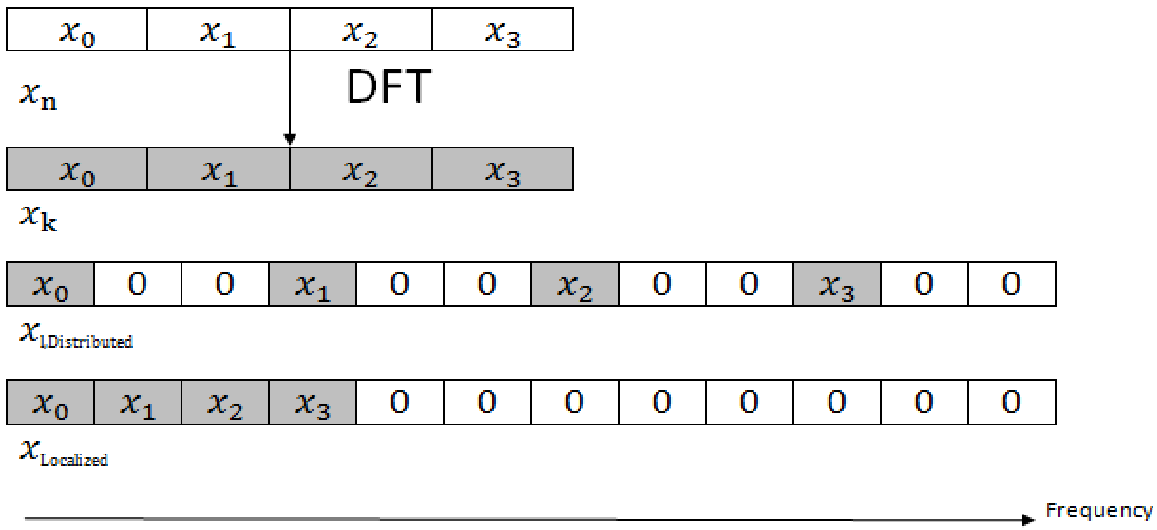
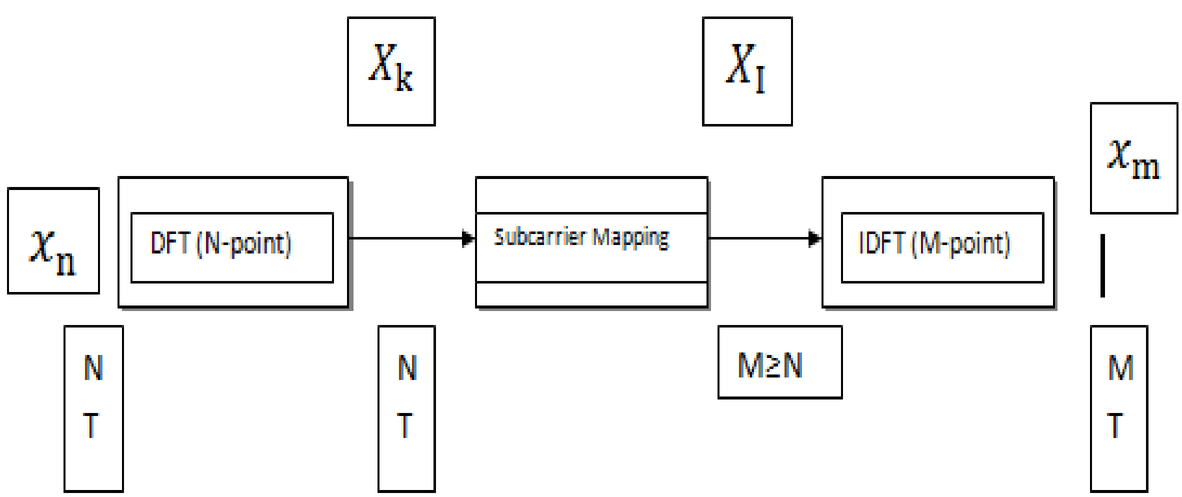


Figure2.2 SC-FDMA transmits symbols in the frequency domain.

SC-FDMA transmit symbols in the frequency domain for N = 4 subcarriers per user, Q = 3 users, and M = 12 subcarriers in the system. X l, Distributed denotes transmit symbols for distributed subcarrier mapping scheme and X l, Localized denotes transmit symbols for localized subcarrier mapping scheme.

$$x_k = \sum_{n=0}^{N-1} x_n e^{-j\frac{2\pi}{N}nk} \qquad (2\text{-}1)$$

Equation (2-1) to explain Direct forurier transform(DFT) .



N, M: number of data symbols T: symbol durations

Figure2.3 SC-FDMA transmits symbols. There are *M* total number of carriers, among which *N* (< *M*) subcarriers are occupied by the input data.

2.5 Multiple Inputs and Multiple Outputs

A channel may be affected by fading and this will impact the signal to noise ratio. In turn this will impact the error rate, assuming digital data is being transmitted. The principle of diversity is to provide the receiver with multiple versions of the same signal. If these can be made to be affected in different ways by the signal path, the probability that they will all be affected at the same time is considerably reduced. Accordingly, diversity helps to stabilize a link and improves performance, reducing error rate.
Several different diversity modes are available and provide a number of advantages:

- Time diversity: Using time diversity, a message may be transmitted at different times, e.g. using different timeslots and channel coding.
- Frequency diversity: This form of diversity uses different frequencies. It may be in the form of using different channels, or technologies such as spread spectrum / OFDM.
- Space diversity: Space diversity used in the broadest sense of the definition is used as the basis for MIMO. It uses antennas located in different positions to take advantage of the different radio paths that exist in a typical terrestrial environment.

MIMO is effectively a radio antenna technology as it uses multiple antennas at the transmitter and receiver to enable a variety of signal One of the core ideas behind MIMO wireless systems space-time signal processing in which time (the natural dimension of digital communication data) is complemented with the spatial dimension inherent in the use of multiple spatially distributed antennas, i.e. the use of multiple antennas located at different points. Accordingly MIMO wireless systems can be viewed as a logical extension to the smart antennas that have been used for many years to improve wireless.
It is found between a transmitter and a receiver, the signal can take many paths. Additionally by moving the antennas even a small distance the paths used will change. The variety of paths available occurs as a result of the number of objects that appear to the side or even in the direct path between the transmitter and receiver. Previously these multiple paths only served to introduce interference. By using MIMO, these additional paths can be used to advantage. They can be used to provide additional robustness to the radio link by improving the signal to noise ratio, or by increasing the link data capacity.
The two main formats for MIMO are given below:

2.5.1 Spatial diversity

Spatial diversity used in this narrower sense often refers to transmit and receive diversity. These two methodologies are used to provide improvements in the signal to noise ratio and they are characterized by improving the reliability of the system with respect to the various forms of fading.

In a m by n channel with rich scattering, there are $min\{m,n\}$ degrees of Freedom. In a MIMO channel with rich scattering:

$$maximum\ diversity\ = mn \quad (2\text{-}2)$$

$$degrees\ of\ freedom\ = min\{m,n\} \quad (2\text{-}3)$$

The name of the game in space-time coding is to design schemes which Exploit as much of both these resources as possible.

2.5.2 Spatial multiplexing

This form of MIMO is used to provide additional data capacity by utilizing the different paths to carry additional traffic, i.e. increasing the data throughput capability.

As a result of the use multiple antennas, MIMO wireless technology is able to considerably increase the capacity of a given channel while still obeying Shannon's law. By increasing the number of receive and transmit antennas it is possible to linearly increase the throughput of the channel with every pair of antennas added to the system. This makes MIMO wireless technology one of the most important wireless techniques to be employed in recent years. As spectral bandwidth is becoming an ever more valuable commodity for radio communications systems, techniques are needed to use the available bandwidth more effectively. MIMO wireless technology is one of these techniques.

Paths to carry the data, choosing separate paths for each antenna to enable multiple signal paths to be used.

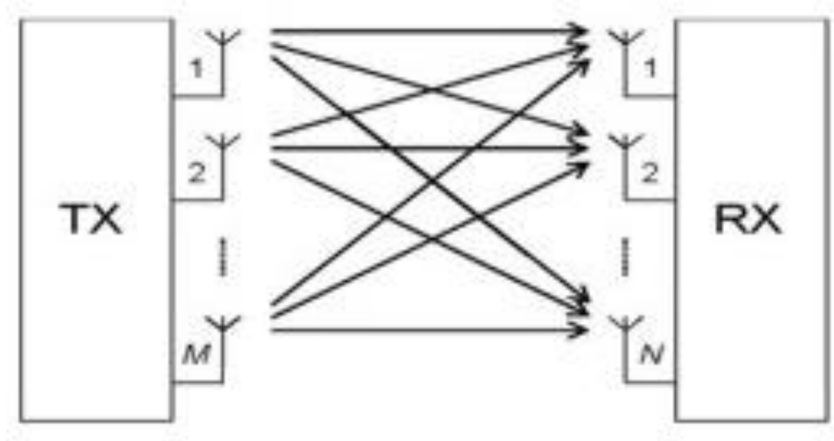


Figure2.4 MIMO system

r^*_{max} Is the largest multiplexing gain achievable in the channel
$d^*_{max} = d^*(0)$ Is the largest diversity gain achievable
For a $m \times n$ MIMO channel, it is not difficult to show:

$$r^*_{max} = min\{m, n\} \quad (2\text{-}4)$$

$$d^*_{max} = mn \quad (2\text{-}5)$$

2.6 Related Works

Confirmed that the MIMO technique provides sizeable gains in power efficiency gain.

In [4] Practical MIMO in mobile satellite broadcasting, gain increases with the reduction of the antenna cross-polar isolation and the time interleave duration, while reduces with increasing co-channel interference (using dual polarization per beam (DPPB)).

In [5] extensive set of laboratory measurement results for existing stochastic satellite and hybrid MIMO ,but It is shown that dual polarization MIMO diversity is able to provide remarkable gains in terms of satellite/terrestrial transmit power reduction and/or capacity increase compared to more conventional non MIMO solutions.

In [6] Use SC-FDMA Systems in Uplink the proposed algorithm achieves significant performance improvement in terms of packet timeout rate, goodput, power consumption, and fairness.

In [7] PAPR analysis is used for SC-FDMA signals with pulse formation. We analytically derive SC-FDMA signals for the date range and digitally compare the PAPR properties using the complementary distribution function (CCDF) in PAPR. The results showed that SC-FDMA signals already had lower PAPR than OFDMA signals. In a typical SC-FDMA comparison, localized FDMA (LFDMA) contains higher PAPR than intermittent FDMA (IFDMA) but PAPR is somewhat lower than OFDMA. It is also noted that pulse formation increases PAPR.

In [8] a set of conclusions is drawn from our results that describe the effect of the upper configuration diagrams on the BER and the probability of error for both OFDMA and SC-FDMA. The power spectral density of the multiple access technologies (OFDMA and SC-FDMA) is calculated and the result shows that OFDMA has a high spectral density. The modulation schemes also have a significant impact on PAPR for OFDMA and SC-FDMA to increase the higher-order configurations of PAPR in SC-FDMA and reduce PAPR in OFDMA. However, the total value of the PAPR ratio is the minimum in SC-FDMA for all modulation schemes. The results of calculating the power spectral density support the observations contained in PAPR.

In [9] the physical layer relies on an improved version of the Digital Video Broadcasting Satellite to Hand-held (DVB-SH) standard that utilizes dual-polarization (MIMO) output technology. This MIMO, the first of its kind, allows for in-depth verification and improvement of MIMO technologies applied to satellite broadcasting networks. Moreover, this protester can complete and confirm theoretical or simulation-based results published to date. The diversity of MIMO is shown to be able to yield significant gains with respect to the reduction of satellite / terrestrial transmission capacity and / or amplification compared to conventional solutions other than MIMO. The adoption of the MIMO method for simple spatial multiplexing has also been shown to be the best way to understand these gains.

In [10] expand our formula to include multi-input multiple-input SC-FDMA (MIMO) systems where we show that Adaptive Frequency Domain Decision Feedback Equalize (AFD-DFE) has a significant reduction in computational complexity when compared with an adaptive Decision Feedback Equalize (DFE) in the frequency band. Finally, large-scale simulations are performed to demonstrate our proposed (AFD-DFE) durability to offset Doppler frequency and high frequency carrier.

CHAPTER THREE
METHODOLOGY

CHAPTER THREE

METHODOLOGY

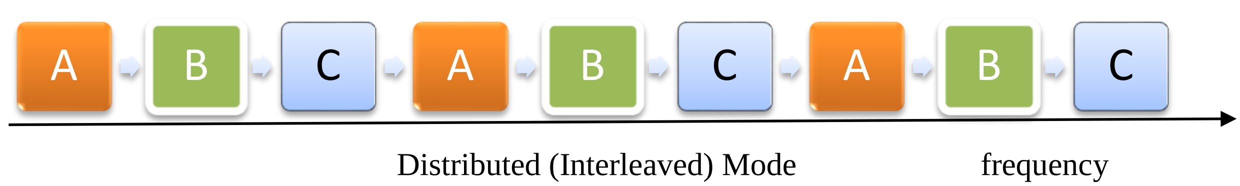
3.1 Overview

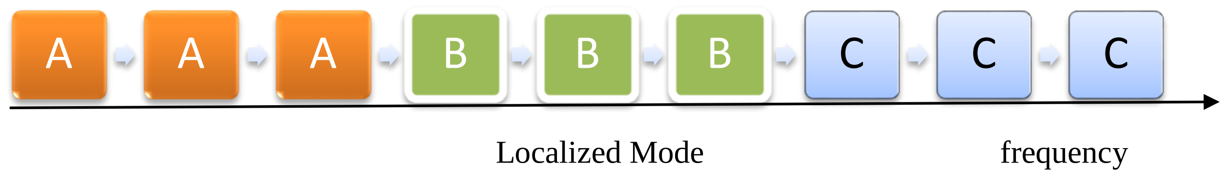
This chapter describes the details explanation of the methodology that has been used in this research. Chapter three is one of the important parts that act as the guidelines in order to accomplish the research. The most important aspect during the methodology stage is the design of transmitter Using SC-FDMA with MIMO system for analysis and simulation process at Compare without using that. A theoretical model of transmitter Using SC-FDMA with MIMO system for analysis was developed. The part I of the development represents the general system is mathematic model and part II block diagrams for transmitter Using SC-FDMA with MIMO system. I will discuss calculations and design for each SC-FDMA and MIMO on alone. The parameters that have been used in this research are clearly stated.

3.2 Single Carrier Frequency Division Multiple Access (SC-FDMA)

3.2.1 Mathematical Models of SC-FDMA

The Number of sub-carriers allocated per user It is assumed to be M. In the SC-FDMA method, N-point DFT Used for propagation, DFT output is set to Sub-carriers of IDFT. The effect of PAPR reduction depends on the method of assigning the sub-carriers to each party. Two different approaches are used to assign sub-carriers between users, DFDMA (FDMA distributed) and LFDMA (FDMA localized) as shown in figure 3.1. In DFDMA, N DFT Outputs are distributed on a full scale of M Sub-tankers with zeros are filled with unused sub-carriers in N-M. But in LFDMA, DFT outputs are allocated to a consecutive N Sub-carriers are filled in sub-carriers M and the remainder Zeros. If DFT outputs are distributed in DFDMA Uniformly with equal distance and then referred to as Interleaved FDMA (IFDMA).





A, B, C Terminals

Figure3.1 DFDMA and LFDMA subcarrier assignment modes

Figure 3.1 illustrates the subcarrier allocation in the DFDMA and LFDMA with M =3, N = 12 and X = 4, where X = N/M is called the bandwidth spreading factor. Input data is DFT-spread to generate S[k] signals in frequency domain as given in equation (3-1).

$$S_k = \sum_{k=0}^{N-1} S'[k]\, e^{-j2\pi mk/M} \quad (3\text{-}1)$$

These are allocated as depicted in equation (3-2).

$$S'[k] = \begin{cases} S\left[\frac{k}{X}\right], & k = X.n_1,\ n_1=1,2,3,\dots,N-1 \\ 0, & otherwise \end{cases} \quad (3\text{-}2)$$

The IFFT output sequence s'[m] with m = N. x + l for x = 0, 1, 2, ………, X-1 and n = 0, 1, 2, ………. , N-1 can be expressed as shown in equation (3-3).

$$s'[m] = \frac{1}{X}\sum_{n_1=0}^{N-I} S[n] \quad (3\text{-}3)$$

This is a repetition of the original input signal scaled in the time domain. For the IFDMA where the subcarrier mapping starts with the rth subcarrier (r = 0, 1, 2, …X-1), the DFT spread symbol is expressed as in equation (3-4).

$$S'(k) = \begin{cases} S\left[\frac{k-r}{X}\right], k = X.n_1 + r, n_1 = 0,1,2,3, \ , N-1 \\ 0\,, \end{cases} \quad (3\text{-}4)$$

In this case the corresponding IFFT output sequence, {s'[m]}, is given by equation (3-5).

$$s[m] = \frac{1}{X}.e^{\frac{j2\pi m}{M^r}}.S[n] \quad (3\text{-}5)$$

When it is compared with equation (3-3), it is evident that the frequency shift of subcarrier allocation starting point by r subcarriers gives a phase rotation of $e^{\frac{j2\pi m}{M^r}}$ in IFDMA mapping. For LFDMA mapping, the IFFT input signal $S'(k)$ at the transmitter is expressed as in equation (3-6).

$$S'(k) = \begin{cases} S[k], k = 0,1,2,\dots,N-1 \\ 0\ \ k = N, N+1,\dots,M-1 \end{cases} \quad (3\text{-}6)$$

The IFFT sequence $s'[n]$with m= X.n + x for x = 0,1,2,….X-1 is expressed as in equation (3-7).

$$s'[m] = \frac{1}{X}\frac{1}{N}\sum_{k=0}^{M-1} S[k]e^{j2\pi k\frac{Xn+x}{XN}} \quad (3\text{-}7)$$

When x= 0, equation (3-7) is represented as in equation (3-8).

$$s'[m] = \frac{1}{X}s[n] \quad (3\text{-}8)$$

But in the case of x ≠ 0, it is represented as in equation (3-9).

$$S[k] = \sum_{p=0}^{N-1} S[p]e -^{j2\pi k\frac{p}{M}} \quad (3\text{-}9)$$

Then equation (3-7) changes and is represented by equation (3-10).

$$s'[m] = \frac{1}{X}e^{J\pi\frac{(N-1)x-Xn}{XN}} . \sum_{p=0}^{M-1} \frac{\sin\left(\pi\frac{x}{X}\right)}{N\sin\left(\pi.\frac{Xn+x}{XN}-\pi\frac{p}{N}\right)} . \left(e^{J\pi\frac{p}{N}} s[p]\right) \quad (3\text{-}10)$$

It can be observed from equations (3-8) and (3-10), that the time-domain LFDMA signal becomes the 1/X-scaled copies of the input sequence at the multiples of X in the time domain. Other values are calculated by adding all the input sequences with the different complex-weight factor. Time-domain signals when the DFT-spreading technique for IFDMA and LFDMA is applied with N = 12, M= 3, and X = 4, where s'IFDMA[n] and s'LFDMA[n] are expressed by equations (3-5) and (3-10), respectively.

3.2.2 Design of SC-FDMA

Figure 3.2 shows the flow of the link level simulation for SC-FDMA. In the simulations, we consider interleaved FDMA (IFDMA), which is a distributed subcarrier mapping scheme, and localized FDMA (LFDMA) with static scheduling (i.e., no channel-dependent scheduling or subband hopping).

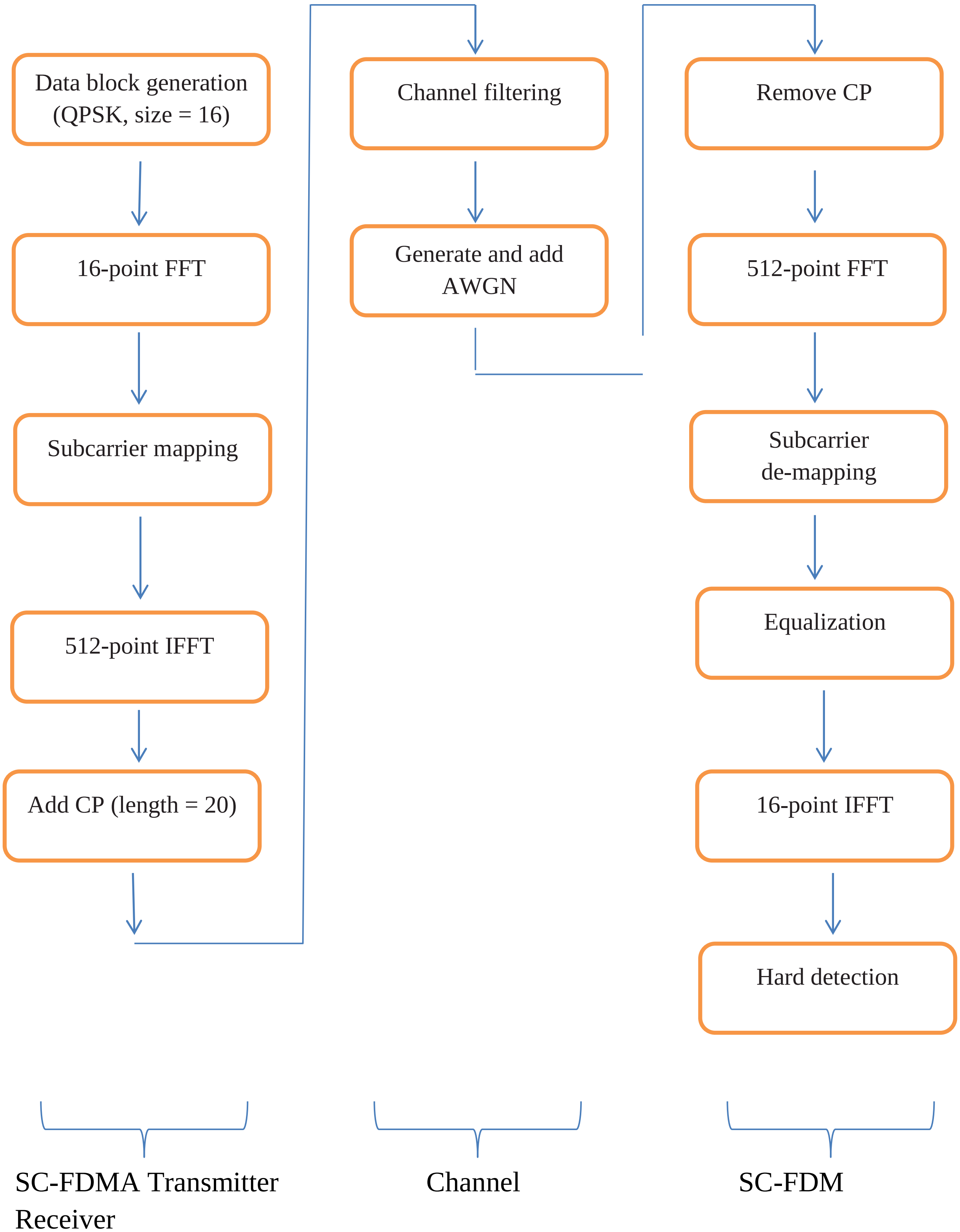


Figure3.2 Block diagram of SC-FDMA link level simulator

3.3 Multiple Inputs and Multiple Outputs (MIMO)

3.3.1 Mathematical Models of MIMO

We assume a dual circular polarization (RHCP/LHCP) MIMO system with = 2 transmit and M_R = 2 receive antennas (polarizations) suffering quasi-static flat land mobile satellite (LMS) fading that remains constant for a block length of at least T = 2 symbol periods. The generic input-output relationship over T symbol periods is given by

$$Y = HS + N \quad \text{(3-11)}$$

Where S is the $M_T \times T$ transmit codeword matrix with elements from a codebook consisting of symbols drawn from an M-ary quadrature amplitude modulation (MQAM) alphabet and obeying the power constraint $\leq T \cdot P$, where P is the total transmit power per symbol period. The rows of S represent signals transmitted in orthogonal polarizations, while its columns represent consecutive symbol periods. Moreover, H is the $M_R \times M_T$ complex channel matrix generated according to, N is the $M_R \times T$ noise matrix of complex Gaussian elements with variance N_0, and Y is the $M_R \times T$ complex matrix of received signals. At the receiving side, a generic exhaustive search decoder is employed realizing maximum likelihood (ML) decoding according to arg $\min_S \|Y - HS\|F$, where $\| \cdot \|F$ denotes the Frobenius norm of a matrix

3.3.2 Design of MIMO

The transmission over a general MIMO communication channel with n_T transmit and n_R receive dimensions can be described with the baseband signal model
As depicted in Figure 3.3 and equation (3-11), where $S \in \mathbb{C}^{n_T*1}$ is the transmitted vector, $H \in \mathbb{C}^{n_T*n_R}$ is the channel matrix $Y \in \mathbb{C}^{n_R*1}$ is the received vector, and $N \in \mathbb{C}^{n_R*1}$ denotes the noise.
A multicarrier MIMO channel can be similarly described, either explicitly for the N carriers as

$$Y_k = H_k S_k + N_k \qquad 1 \leq k \leq N \quad \text{(3-12)}$$

Or implicitly as in (11) by defining the block-diagonal equivalent matrix
$H = diag(\{H_k\})$. When $n_T = 1$, the MIMO channel reduces to a single-input multiple output (SIMO) channel (e.g., with multiple antennas only at the receiver). Similarly, when $n_R = 1$, the MIMO channel reduces to a multiple-input single-output (MISO) (e.g., with multiple antennas only at the transmitter). When both $n_T = 1$ and $n_R = 1$, the MIMO channel simplifies to a simple scalar or single-input single-output (SISO) channel.

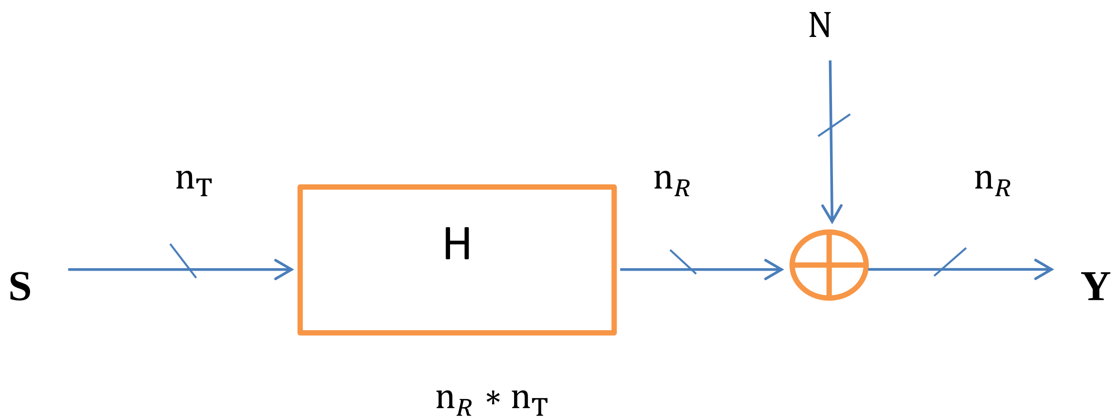


Figure3.3 Scheme of a MIMO channel

3.4 Peak-to-Average Power Ratio Simulation of SC-FDMA

3.4.1 Mathematical Models of PAPR

Peak-to-average-power ratio (PAPR) is a performance measurement that is indicative of the power efficiency of the transmitter. In the case of an ideal linear power amplifier where we achieve linear amplification up to the saturation point, we reach the maximum power efficiency when the amplifier is operating at the saturation point. A positive PAPR in dB means that we need a power backoff to operate in the linear region of the power amplifier. We can express the theoretical relationship between PAPR [dB] and transmit power efficiency as follows

$$\eta = \eta_{max}.10^{-\frac{PAPR}{20}} \qquad (3\text{-}13)$$

Where η is the power efficiency and η_{max} is the maximum power efficiency. A salient advantage of SC-FDMA over OFDMA is the lower PAPR because of its inherent single carrier structure. The lower PAPR is greatly beneficial in the uplink communications where the mobile terminal is the transmitter. As time domain samples of the SCFDMA modulated signals are different depending on the subcarrier mapping scheme and we can expect different PAPR characteristics for different subcarrier mapping schemes.

It is a measure used to calculate the fluctuations in the envelope of signals the average power and peak power for a given sample { x_m} of an OFDM system is given by equation (3-14) and (3-15) respectively.

$$P_{av} = \frac{1}{F_s}\sum_{n=0}^{F_s-1} X_m^2 \quad (3\text{-}14)$$

$$P_{peak} = max_m\{X_m^2\} \quad (3\text{-}15)$$

It is defined as the ratio of maximum (peak) power to average power of the signal as given by equation (3-16).

$$PAPR = \frac{P_{peak}}{P_{av}} \quad (3\text{-}16)$$

3.4.2 Simulation of PAPR

Figure 3.4 show the flow of the PAPR simulations for SCFDMA.

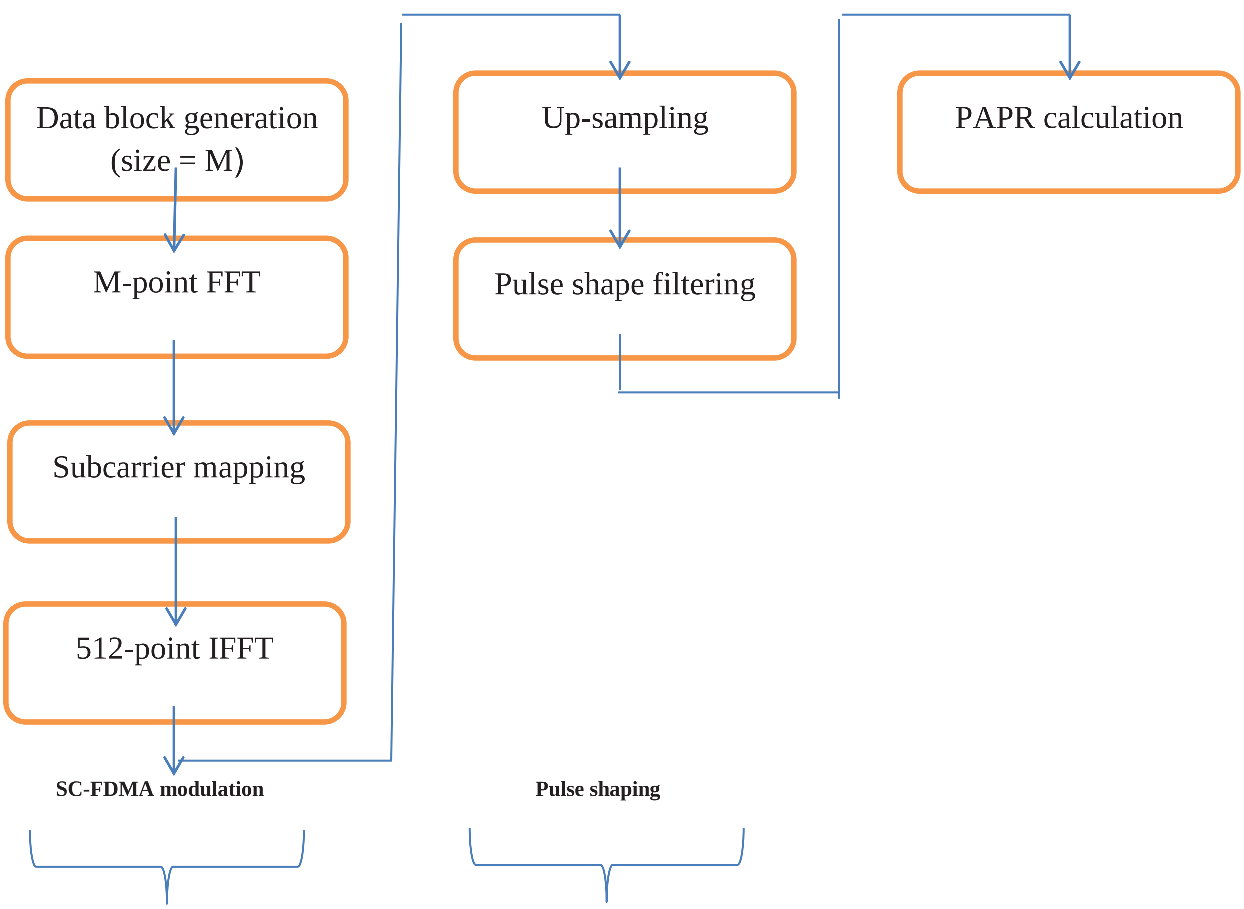


Figure3.4 Block diagram of PAPR simulator for SC-FDMA

CHAPTER FOUR
RESULTS AND DISCUSSION

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Overview

This chapter contains the process of analysis of the signal using SC-FDMA compared to using OFDMA and shows the difference between them in the improvement of performance as well as the use of MIMO Whether or not and how this affects the signal.

4.2 Simulation of SC-FDMA

The particular system setup for Single Carrier Frequency Division Multiple Access, simulation parameter for SC-FDMA.

Table 4.1 Simulation parameters for Single Carrier Frequency Division Multiple Access (SC-FDMA)

transmission bandwidth	5 MHz
symbol rate	7.68 million symbols/sec
TTI length	0.5 $msec$
number of blocks per TTI	6 long blocks (LB)
number of occupied subcarriers per LB	128
FFT block size	512
Cyclic Prefix (CP) length	32 symbols
subcarrier mapping	static distributed
pulse shaping	time domain squared-root raised-cosine filter (roll-off factor = 0.22) with 2× oversampling
channel model	3GPP SCME C (Spatial Channel Model Extension C) quasi-static Rayleigh fading with mobile speed of 3 km/h [11] – we assume the channel is constant during the duration of a block
antenna configurations	2 transmit and 2 receive antennas
data modulation	16-QAM for 1st stream and QPSK for 2nd stream
channel coding	1/3-rate turbo code

4.3 Simulation of MIMO

We base the simulation setup on mobile satellite uplink and we use the following simulation parameters and assumptions.

Table 4.2 Simulation parameters for Multiple Inputs and Multiple Outputs (MIMO)

Satellite mobile phones carrier frequency	2.0 GHz
Transmission bandwidth	5 MHz
Symbol rate	7.68 million symbols/sec
TTI length	0.5 $\boldsymbol{msec}$
Number of blocks per TTI	6 long blocks (LB)
Number of occupied subcarriers per LB	128
FFT block size	512
Cyclic Prefix (CP) length	32 symbols
Subcarrier mapping	static distributed
Pulse shaping	time domain squared-root raised-cosine filter (roll-off factor = 0.22) with 2× oversampling
Channel model	3GPP SCME C (Spatial Channel Model Extension C) quasi-static Rayleigh fading with mobile speed of 3 km/h [11] – we assume the channel is constant during the duration of a block
Antenna configurations	2 transmit and 2 receive antennas
Data modulation	16-QAM for 1st stream and QPSK for 2nd stream
channel coding	1/3-rate turbo code

4.4 PAPR of OFDMA Signal

Matlab simulations have been performed and the obtained PAPR value is shown in Figure 4.1. At 0.01 % of CCDF the PAPR value obtained are 9.4 dB for number of subcarriers N = 512.

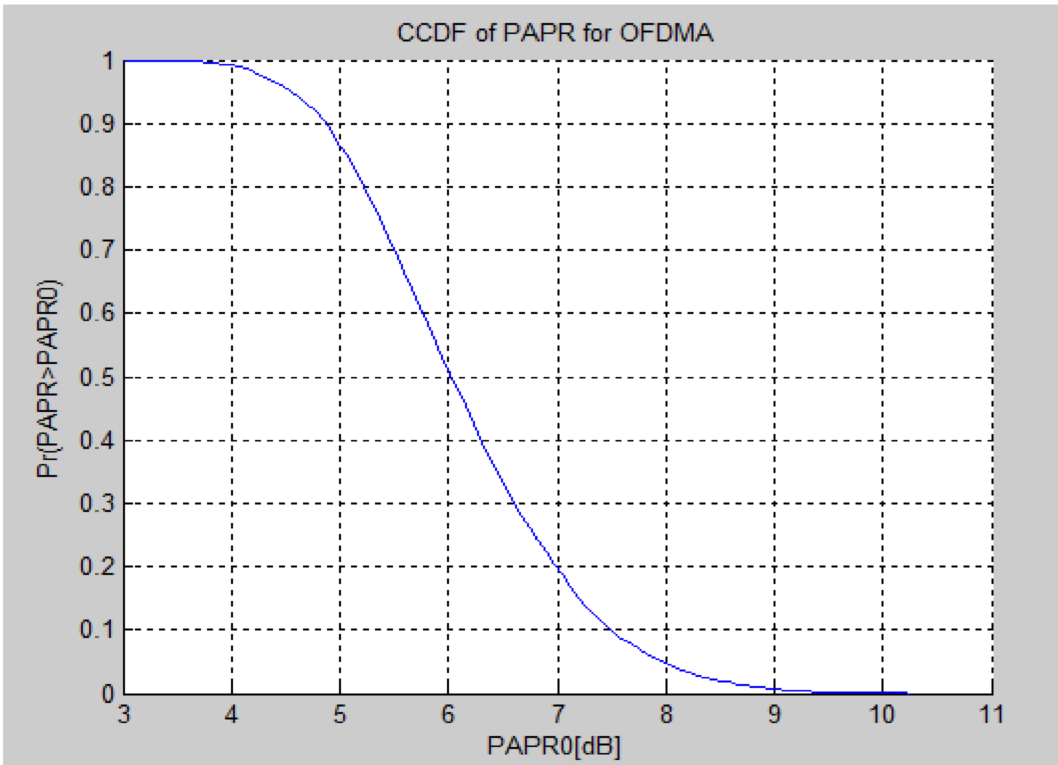


Figure 4.1 CCDF of PAPR for OFDMA

The main reason of high PAPR value is that OFDM modulated signal follows Rayleigh distribution. The higher PAPR is also caused by the higher amplitude of the first side lobe of the sinc shaped pulses. If the amplitude of first side lobe is reduced with the help of pulse shaping filters, the value of PAPR can be effectively reduced.

4.5 PAPR of SC-FDMA Signal

Mathematical modeling and Matlab simulations of equation (10) are done to obtain the PAPR value single carrier FDMA signal. The results obtained are depicted in Figure 4.2.

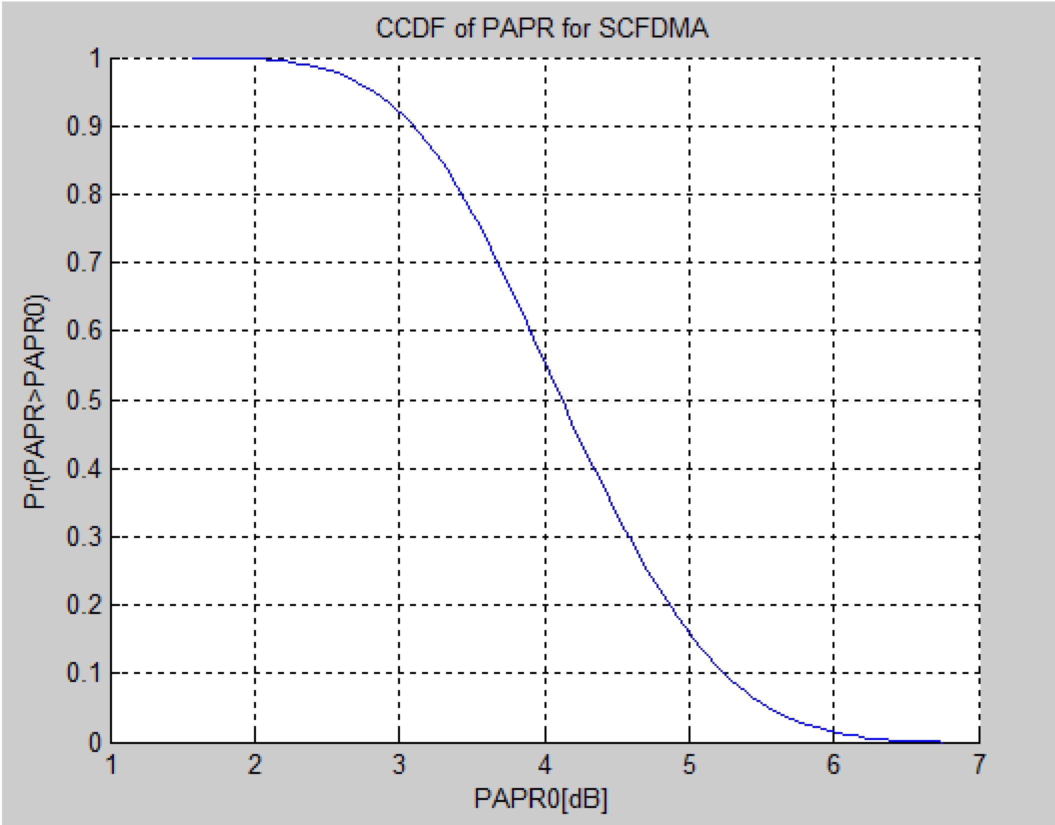


Figure 4.2 CCDF of PAPR for SCFDMA

It can be observed from figure 4.1 that for N = 512 Subcarriers the PAPR values at 0.01% of CCDF are 6.5dB.

4.6 Comparison of CCDF of PAPR for SCFDMA and OFDMA

PAPR of using Complementary Cumulative Distribution Function,

The probability that PAPR (1) is higher than a certain PAPR (1) value PAPR0 (Pr {PAPR (1)>PAPR0}), figure 4.3 indicates the comparative values of PAPR for SCFDMA at 0.01 % of CCDF value. It is clearly indicated that PAPR is highest for OFDMA.

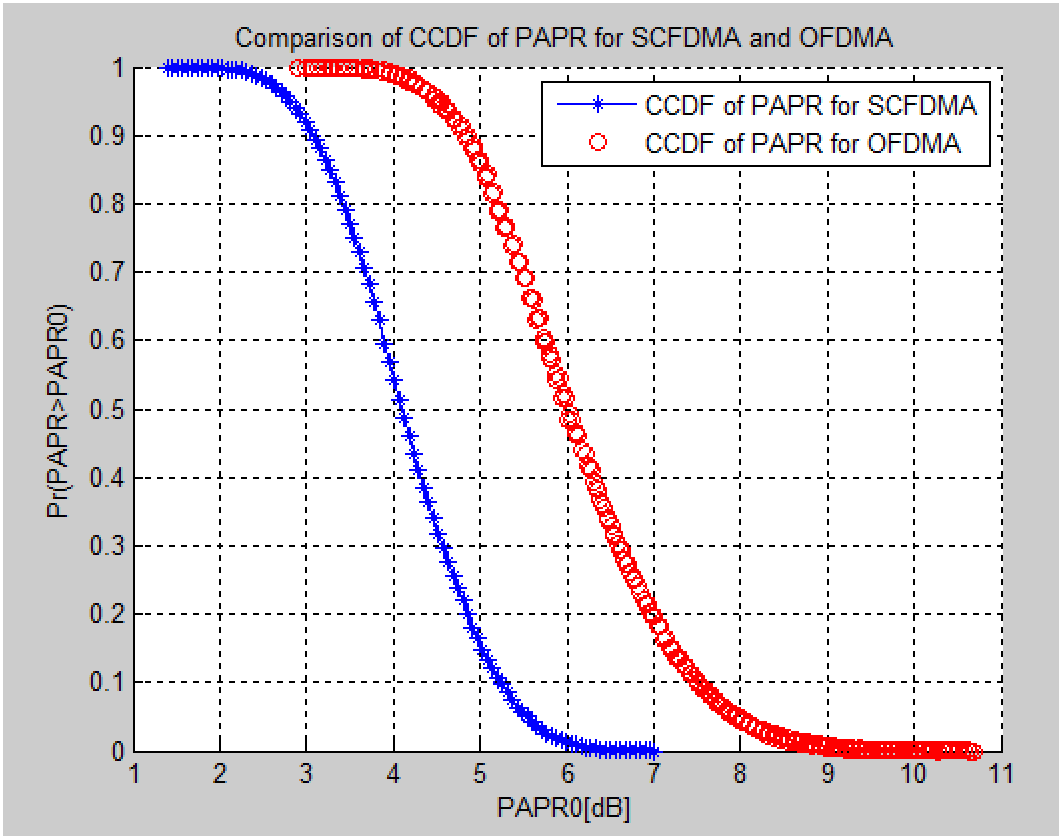


Figure 4.3 Comparison of CCDF of PAPR for SCFDMA and OFDMA

The recommended SC-FDMA technique for uplink wireless transmission. SC-FDMA is a modified version of the SC/FDE system similar as OFDMA is that of the OFDM technique. SC-FDMA has better PAPR performance with high throughput, low bit error rate and high spectral efficiency.

4.7 SNR without MIMO Signal

Matlab simulations have been performed and the obtained SNR value is shown in figure 4.4. At 18 dB of SNR the Capacity value obtained are 5bit/s/Hz.

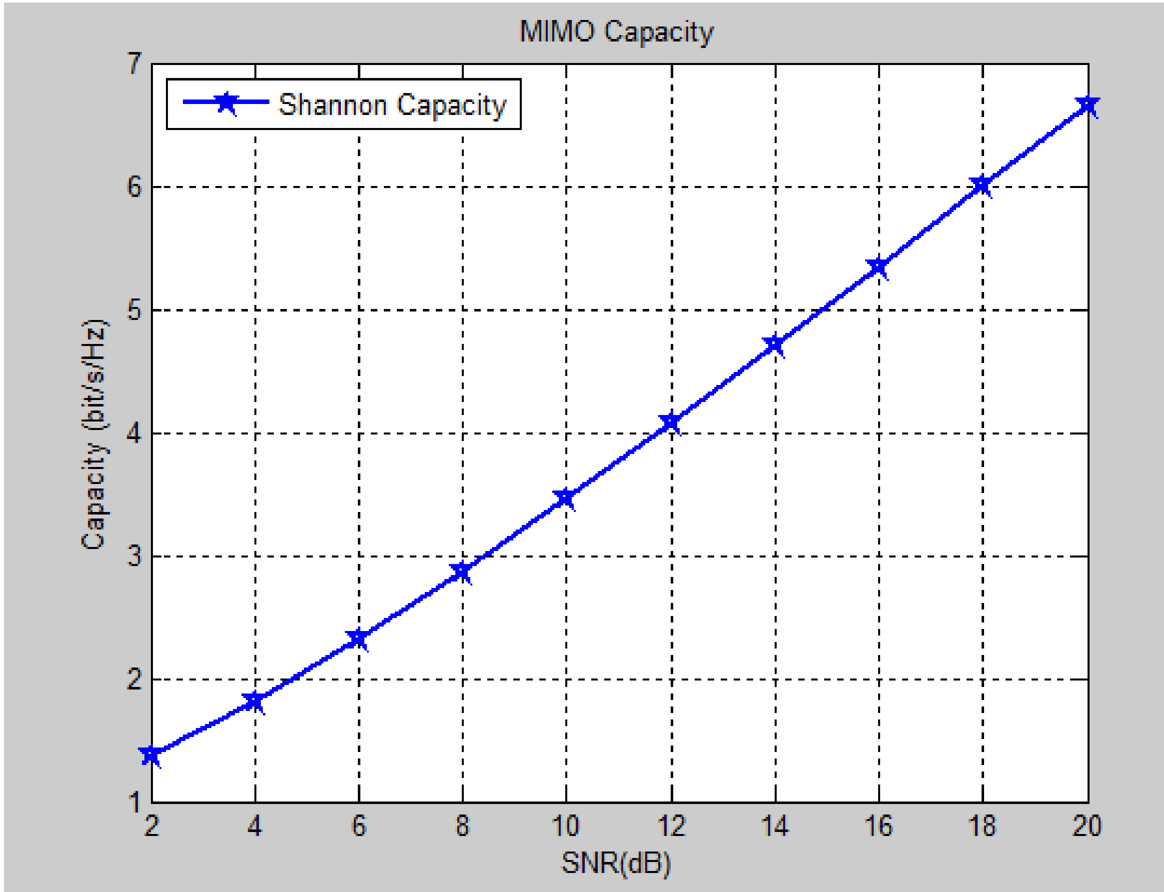


Figure 4.4 SNR without MIMO Signal

4.8 SNR with MIMO Signal

Matlab simulations have been performed and the obtained SNR value is shown in figure 4.5. At 18 dB of SNR the Capacity value obtained are 10 bit/s/Hz, 15 bit/s/Hz, 21 bit/s/Hz for 2*2 MIMO, 3*3MIMO, 4*4 MIMO Respectively.

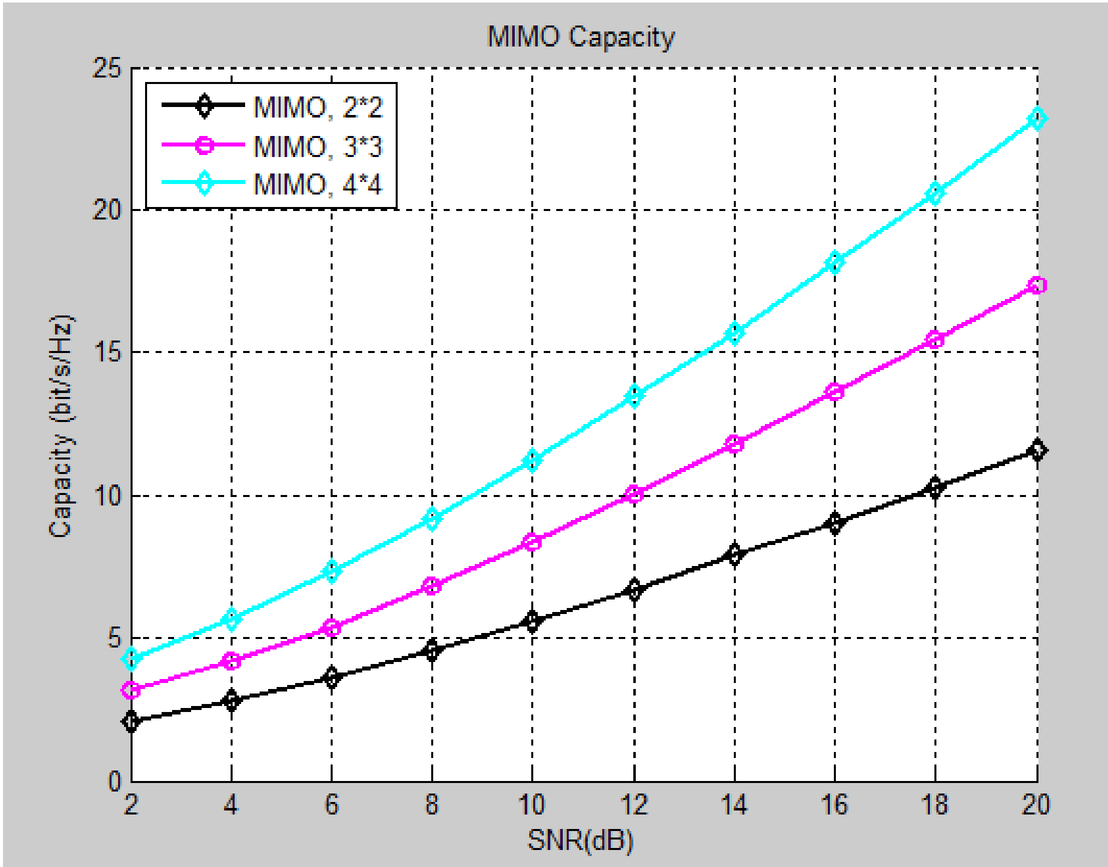


Figure 4.5 SNR with MIMO Signal

4.9 Comparison of SNR for MIMO and without MIMO

Figure 4.6 indicates the comparative values of SNR for MIMO at 18 dB of SNR value. It is clearly indicated that is capacity highest for 4*4MIMO.

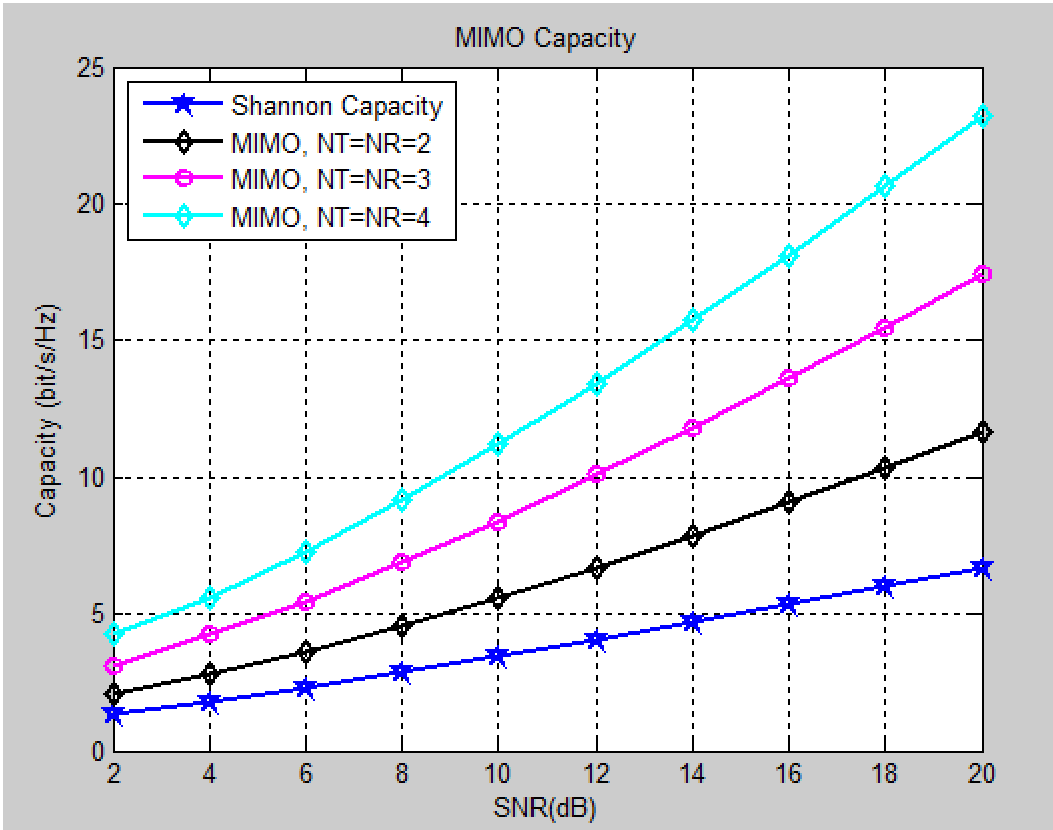


Figure 4.6 Comparison of SNR for MIMO and without MIMO

Recommended MIMO technology for wireless transmission of the uplink. MIMO has better performance than high-capacity SNR The optimization also increases as we use multiple MIMO matrices. In other words, the higher the rank of the matrix, the greater the signal rate relative to the noise, so 3*3 MIMO better than 2*2 MIMO and so on.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this thesis, we analyzed the PAPR of SC-FDMA signals for single and multiple antenna transmissions using numerical simulations. . Another noticeable fact is that pulse shaping increases PAPR. A pulse-shaping filter should be designed carefully in order to reduce the PAPR without degrading the system performance.

And provides a detailed presentation of MIMO SCFDMA system and comparison of data transfer Accuracy with OFDMA system and with frequency Field Equation System (FDE). The ultimate goal this project was completed by proposing a full workflow to improve the performance of the required BER Process the baseband signal. This flow of work consisted basically three steps: literary study, research Analysis of MIMO data transfer, and a Low MIMO SC-FDMA BER system using MATLAB. A soft decoding The MIMO detector is fine decoding with reasonable complexity it has been applied to the encrypted SC-FDMA MIMO system, which greatly enhanced the bit error rate performance. The BER and the probability of error are parsed by changing the SNR. Proposed BER performance Detection system is close to detecting ML during Reduce the complexity of large volume Constellation sizes. The above results appear clearly it has found lower SNR values for MIMO Detection devices compared to other detector systems.

5.2 Recommendations

After completing this research there are still some open issues can be considered for future researches which include:

- It is possible to use the techniques used in advance in the ground mobile for use in the mobile space, as well as the experience of any new technology in the use of another.
- In order to improve the performance of the signal, it is possible to work on the transmitter method, i.e. to improve the performance of the antennas It is also possible to change signal technique

References

[1] Ricardo De Gaudenzi, MIMO for Mobile Satellite Digital Broadcasting, TRANSACTIONS ON VEHICULAR COMMUNICATIONS, IEEE· JANUARY 2015

[2] Kanglian Zhao, Wenfeng Li, Polarized modulation scheme for mobile satellite MIMO broadcasting Bin Zuo, Naitong Zhang Wireless Symposium (IWS), IEEE, 2015.

[3] Massimo Bertinelli, MIMO over Satellite, IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 13, NO. 1, 2011.

[4] Naveed Iqbal, Naofal Al-Dhahir, Adaptive Frequency-Domain RLS DFE for Uplink MIMO SC-FDMA, IEEE, 2015,

[5] J. Jalden, B. Ottersten, "On the complexity of sphere decoding in digital communications," IEEE Trans. Signal Process., vol. 53, no. 4, pp. 1474-1484, 2005.

[6] A.J. Paulraj, D.A. Gore, R.U. Nabar, H. Bolcskei, "An overview of MIMO communications - A key to gigabit wireless," in Proc. IEEE, vol. 92, no. 2, pp. 198-218, 2004.

[7] Hyung G. Myung ,Junsung Lim, David J. Goodman. "PEAK-TO-AVERAGE POWER RATIO OF SINGLE CARRIER FDMA SIGNALS WITH PULSE SHAPING," IEEE, 2006.

[8] Abdul Samad Shaikh ,Khatri Chandan Kumar, "Performance Evaluation of LTE Physical Layer Using SC-FDMA & OFDMA, " Blekinge Institute of Technology ,November 2010.

[9] Riccardo De Gaudenzi , Ari Hulkkonen , M. Bertinelli , "MIMO for Mobile Satellite Digital Broadcasting: From Theory to Practice, "IEEE TRANSACTIONS ON VEHICULAR COMMUNICATIONS , ANUARY 2015

[10] Naveed Iqbal, Naofal Al-Dhahir, Azzedine Zerguine, Abdelmalek Zidouri, "Adaptive Frequency-Domain RLS DFE for Uplink MIMO SC-FDMA ," IEEE,2013.

[11] D. Porrat, "Information theory of wideband communications," IEEE Commun. Surveys Tuts, vol. 9, no. 2, pp. 2-16, 2007.

[12] T. Marzetta, B. Hochwald, "Capacity of a mobile multiple-antenna communication link in Rayleigh flat fading," IEEE Trans. Inf. Theory, vol. 45, no. 1, pp. 139-157, 1999.

[13] H. Weingarten, Y. Steinberg, S. Shamai, "The capacity region of the gaussian MIMO broadcast channel," IEEE Trans. Inf. Theory, vol. 52, no. 9, pp. 3936-3964, 2006.

[14] B. Hassibi, M. Sharif, "Fundamental limits in MIMO broadcast channels," IEEE J. Sel. Areas Commun., vol. 25, no. 7, pp. 1333-1344, 2007.

[15] S. Hirakawa, N. Sato, and H. Kikuchi, "Broadcasting satellite services for mobile recption," *Proceedings of the IEEE*, vol. 94, no. 1, pp. 327– 332, Jan. 2006.

[16] U.D. Deep, B.R. Petersen and J. Meng, "A Smart Microcontroller-Based Iridium Satellite-Communication Architecture for a Remote Renewable Energy Source," IEEE Tran. On Power Delivery, 2009.

[17] K. Raghunath and A. Chockalingam, "SC-FDMA versus OFDMA: Sensitivity to Large Carrier Frequency and Timing Offsets on the Uplink," *IEEE Global Telecommunications Conference (GLOBECOM)*,pp. 1–6, Nov. 2009.

[18] S. Alamouti, “A simple transmit diversity technique for wireless communications,” *IEEE Journal on Selected Areas in Communications*, vol. 16, no. 8, pp. 1451–1458, 1998.
[19] M. Di Renzo, H. Haas, and P. M. Grant, “Spatial modulation for multiple-antenna wireless systems: A survey,” *IEEE Communications Magazine*, vol. 49, no. 12, pp. 182–191, Dec. 2011.
[20] Jerry D. Gibson, “The Communications Handbook, CRC Press, second edition , April 29, 2002.

Appendix A – Simulation Code

Matlab Simulation Codes for SC-FDMA and OFDMA (PAPR)

```
%=========================================
% This is the PAPR simulator for SC-FDMA.
%=========================================
function paprSCFDMA()
dataType = ’Q-PSK’; % Modulation format.
totalSubcarriers = 512; % Number of total subcarriers.
numSymbols = 16; % Data block size.
Q = totalSubcarriers/numSymbols; % Bandwidth spreading
factor of IFDMA
Q tilda = 31; % Bandwidth spreading factor of DFDMA.
Q tilda < Q.
subcarrierMapping = ’IFDMA’; % Subcarrier mapping scheme.
pulseShaping = 1; % Whether to do pulse shaping or not.
filterType = ’rc’; % Type of pulse shaping filter.
rolloffFactor = 0.0999999999; % Rolloff factor for
the raised-cosine filter.
% To prevent divide-by-zero, for example, use
% 0.099999999 instead of 0.1.
Fs = 5e6; % System bandwidth.
Ts = 1/Fs; % System sampling rate.
Nos = 4; % Oversampling factor.
if filterType == ’rc’ % Raised-cosine filter.
psFilter = rcPulse(Ts, Nos, rolloffFactor);
elseif filterType == ’rr’ % Root raised-cosine filter.
psFilter = rrcPulse(Ts, Nos, rolloffFactor);
end
numRuns = 1e4; % Number of iterations.
papr = zeros(1,numRuns); % Initialize the PAPR results.
for n = 1:numRuns,
% Generate random data.
if dataType == ’Q-PSK’
tmp = round(rand(numSymbols,2));
tmp = tmp∗2 - 1;
data = (tmp(:,1) + j∗tmp(:,2))/sqrt(2);
elseif dataType == ’16QAM’
dataSet = [-3+3i -1+3i 1+3i 3+3i . . .
-3+i -1+i 1+i 3+i . . .
```

```
-3-i -1-i 1-i 3-i . . .
-3-3i -1-3i 1-3i 3-3i];
dataSet = dataSet/sqrt(mean(abs(dataSet).ˆ2));
tmp = ceil(rand(numSymbols,1)∗16);
for k = 1:numSymbols,
if tmp(k) == 0
tmp(k) = 1;
end
data(k) = dataSet(tmp(k));
end
data = data.’;
end
% Convert data to frequency domain.
X = fft(data);
% Initialize the subcarriers.
Y = zeros(totalSubcarriers,1);
% Subcarrier mapping.
if subcarrierMapping == ’IFDMA’
Y(1:Q:totalSubcarriers) = X;
elseif subcarrierMapping == ’LFDMA’
Y(1:numSymbols) = X;
elseif subcarrierMapping == ’DFDMA’
Y(1:Q tilda:Q tilda∗numSymbols) = X;
end
% Convert data back to time domain.
y = ifft(Y);
% Perform pulse shaping.
if pulseShaping == 1
% Up-sample the symbols.
y oversampled(1:Nos:Nos∗totalSubcarriers) = y;
% Perform filtering.
y result = filter(psFilter, 1, y oversampled);
else
y result = y;
end
% Calculate the PAPR.
papr(n) = 10∗log10(max(abs(y result).ˆ2)/
mean(abs(y result).ˆ2));
end
% Plot CCDF.
[N,X] = hist(papr, 100);
semilogy(X,1-cumsum(N)/max(cumsum(N)),’b’)
```

```
% Save data.
save paprSCFDMA
%=======================================
% This is the PAPR simulator for OFDMA.
%=======================================
function paprOFDMA()
dataType = ’Q-PSK’; % Modulation format.
totalSubcarriers = 512; % Number of total subcarriers.
numSymbols = 16; % Data block size.
Fs = 5e6; % System bandwidth.
Ts = 1/Fs; % System sampling rate.
Nos = 4; % Oversampling factor.
Nsub = totalSubcarriers;
Fsub = [0:Nsub-1]∗Fs/Nsub; % Subcarrier spacing.
numRuns = 1e4; % Number of runs.
papr = zeros(1,numRuns); % Initialize the PAPR results.
for n = 1:numRuns,
% Generate random data.
if dataType == ’Q-PSK’
tmp = round(rand(numSymbols,2));
tmp = tmp∗2 - 1;
data = (tmp(:,1) + j∗tmp(:,2))/sqrt(2);
elseif dataType == ’16QAM’
dataSet = [-3+3i -1+3i 1+3i 3+3i . . .
-3+i -1+i 1+i 3+i . . .
-3-i -1-i 1-i 3-i . . .
-3-3i -1-3i 1-3i 3-3i];
dataSet = dataSet/sqrt(mean(abs(dataSet).ˆ2));
tmp = ceil(rand(numSymbols,1)∗16);
for k = 1:numSymbols,
if tmp(k) == 0
tmp(k) = 1;
end
data(k) = dataSet(tmp(k));
end
data = data.’;
end
% Time range of the OFDM symbol.
t = [0:Ts/Nos:Nsub∗Ts];
% OFDM modulation.
y = 0;
for k = 1:numSymbols,
```

```
y= y + data(k)∗exp(j∗2∗pi∗Fsub(k)∗t);
end
% Calculate PAPR.
papr(n) = 10∗log10(max(abs(y).ˆ2)/mean(abs(y).ˆ2));
end
% Plot CCDF.
[N,X] = hist(papr, 100);
semilogy(X,1-cumsum(N)/max(cumsum(N)),'b')
% Save data.
save paprOFDMA

%This code shows the capacity of MIMO system:
%=======================================
% This is the SNR  simulator for MIMO .
%=======================================
clear all
clc
%Shannon capacity
snr=0;
for i = 1:10
snr = snr +2;
c=(log(1+10^(snr/10)))/log(2);
x(i)=snr;
y(i)=c;
end
figure
plot(x,y,'bp-','LineWidth',1.5)
hold on
 % capacity of MIMO Link with NR=2, NT=2
NR=2;
rand('state',456321)
snr=0;
for i=1:10;
snr=snr+2;
for j=1:10000;
c(j)=(NR*log(1+(10^(snr/10))*abs(normrnd(0,1)))/log(2));
end
yy(i)=mean(c);
xx(i)=snr;
end
plot(xx,yy,'kd-','LineWidth',1.5)
 % capacity of MIMO Link with NR=3, NT=3
```

```
NR=3;
rand('state',456321)
snr=0;
for i=1:10;
snr=snr+2;
for j=1:10000;
c(j)=(NR*log(1+(10^(snr/10))*abs(normrnd(0,1)))/log(2));
end
yy(i)=mean(c);
xx(i)=snr;
end
plot(xx,yy,'mo-','LineWidth',1.5)
 % capacity of MIMO Link with NR=4, NT=4
NR=4;
rand('state',456321)
snr=0;
for i=1:10;
snr=snr+2;
for j=1:10000;
c(j)=(NR*log(1+(10^(snr/10))*abs(normrnd(0,1)))/log(2));
end
yy(i)=mean(c);
xx(i)=snr;
end
plot(xx,yy,'cd-','LineWidth',1.5)
xlabel('SNR(dB)')
ylabel('Capacity (bit/s/Hz)')
grid on
legend('Shannon Capacity','MIMO, 2*2','MIMO, 3*3','MIMO, 4*4',2)
title('MIMO Capacity')
```