T.C.

ALTINBAS UNIVERSITY

Electrical and Computer Engineering

MINIMUM ERROR DESIGN OF SOFTWARE DEFINED RADIO TRANSCEIVER MODEL USING MATLAB

Mohammed Waleed Majeed Al-Dulaimi

Master Thesis

Supervisor

Prof. Dr. Osman Nuri UCAN

Istanbul (2019)

MINIMUM ERROR DESIGN OF SOFTWARE DEFINED RADIO TRANSCEIVER MODEL USING MATLAB

by

Mohammed Waleed Majeed Al-Dulaimi

Electrical and Computer Engineering

Submitted to the Graduate School of Science and Engineering

in partial fulfillment of the requirements for the degree of

Master of Science

ALTINBAS UNIVERSITY

2019

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. Majid S. Naghmash
Co-Supervisor

Prof. Dr. Osman Nuri UCAN
Supervisor

Examining Committee Members (first name belongs to the chairperson of the jury and the second name belongs to supervisor)

Prof. Dr. Osman Nuri UCAN	School of Engineering and Natural Sciences, Altinbas University	___________________
Assoc. Prof. Dr. Oğuz BAYAT	School of Engineering and Natural Sciences, Altinbas University	___________________
Academic Title Name SURNAME	Faculty, University	___________________

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Çağatay AYDIN
Head of Department

Approval Date of Graduate School of
Science and Engineering: ____/____/____

Asst. Prof. Dr. Oğuz BAYAT
Director

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Mohammed Waleed Majeed Al-Dulaimi

DEDICATION

To my beloved family (My dad, mom, brothers and sister), to my teachers in the past, present and future. To my Prof. Dr. Osman Nuri UCAN, to my Asst. Prof. Dr. Majid S. Naghmash, to my friends and to all those who truly believed in me and never let me down throughout the way.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude Prof. Dr. Osman Nuri UCAN for all the knowledge and support he provided during my study for the Master Degree and throughout the work to complete this thesis. You have made my dream come true.

ABSTRACT

MINIMUM ERROR DESIGN OF SOFTWARE DEFINED RADIO TRANSCEIVER MODEL USING MATLAB

Al-Dulaimi, Mohammed Waleed

M.S., Electrical and Computer Engineering, Altınbaş University,

Supervisor: Prof. Dr. Osman Nuri UCAN

Co-Supervisor: Asst. Prof. Dr. Majid S. Naghmash

Date: April /2019

Pages:53

This thesis presents the design and simulation of minimum error software defined radio (SDR) transceiver model using MATLAB is presents. The SDR has come out as priority topic of research since it wills replace for traditional implementation on wireless mobile systems. The SDR techniques have to be used which is particularly in gathering the fast growth of communication systems and user demands as well as the industry of mobile functionality. The under sampling theory is used to receive the carrier sampled and performs different standards using 64-QAM modulation scheme. Different channel performance was evaluated and investigates to show the effect of noise and provide low error rate. In modern communication systems, the adoption with more complicated coding and modulation scheme become more important without need to change any component of mobile device. Therefore, the current generation of mobile systems was developed to be more effective and popular in the market with new generation. The implementation results of proposed model shows promising performance to support the current mobile generation and could accelerate to new technology with fast rate and small size device as well as low power consumption. In addition, low bit error rate have been provided in this model.

Keywords: SDR, 64-QAM, Low BER, MATLAB

ÖZET

MATLAB KULLANAN MINIMUM HATA YAZILIMI TANIMLI RADYO (SDR) ALICI-VERICI MODELININ TASARIMI VE SIMÜLASYONU

Al-Dulaimi, Mohammed Waleed

M.S., Elektrik ve Bilgisayar Mühendisliği, Altınbaş Üniversitesi,

Tez Danışman: Prof. Dr. Osman Nuri UCAN

Danışman: Asst. Prof. Dr. Majid S. Naghmash

Tarih: Nisan/2019

Sayfalar: 53

Bu yazıda MATLAB kullanan minimum hata yazılımı tanımlı radyo (SDR) alıcı-verici modelinin tasarımı ve simülasyonu sunulmaktadır. SDR, kablosuz mobil sistemlerdeki geleneksel uygulamaların yerini alacağı için öncelikli araştırma konusu olarak ortaya çıkmıştır. Özellikle iletişim sistemlerinin ve kullanıcı taleplerinin yanı sıra mobil işlevsellik endüstrisindeki hızlı büyümeyi toplamak için kullanılan SDR teknikleri kullanılmalıdır. Aşağıdaki örnekleme teorisi, örneklenen taşıyıcıyı almak için kullanılır ve 64-QAM modülasyon şeması kullanılarak farklı standartlar gerçekleştirir. Gürültünün etkisini göstermek ve düşük hata oranı sağlamak için farklı kanal performansı değerlendirilmiş ve araştırılmıştır. Modern iletişim sistemlerinde, daha karmaşık kodlama ve modülasyon şeması ile benimseme, mobil cihazın herhangi bir bileşenini değiştirmeye gerek kalmadan daha önemli hale geldi. Bu nedenle, mevcut nesil mobil sistemler kuşağı, yeni nesil ile piyasada daha etkili ve popüler olacak şekilde geliştirilmiştir. Önerilen modelin uygulama sonuçları, mevcut mobil üretimi desteklemek için ümit vaat eden bir performans göstermektedir ve düşük güç tüketimi ile birlikte hızlı ve küçük boyutlu cihazlarla yeni teknolojiyi hızlandırabilir. Ek olarak, bu modelde düşük bit hata oranı sağlanmıştır.

Anahtar Kelimeler: SDR, 64-QAM, Düşük BER, MATLAB

TABLE OF CONTENTS

LIST OF TABLES

Pages

LIST OF FIGURES

Pages

LIST OF ABBREVIATIONS

SDR: Software Defined Radio

GSM: Global System for Mobile

FIR: Finite Impulse Response

RRC: Root Raised Cosin

CIC: Cascaded Integrator–Comb

IF: Intermediate Frequency

MP: Multi-Processor

SR: Software Radio

QAM: Quadrature Amplitude Modulation

ISI: Intersymbol Interference

FPGA: Field-Programmable Gate Array

DSA: Dynamic Spectrum Access

1. INTRODUCTION

1.1 GENERAL OVERVIEW

The software defined radio techniques is a process of implement the baseband and intermediate frequency band sections by mean of software [1]. The current technology of communication systems is developed to provide the ability of implement a complex communication system and comprising many waveforms with different frequencies [2]. The basic concept of SDR technology is to achieve s software as close to antenna to solve the hardware problems under software idea [3]. The SDR techniques have implement the baseband and intermediate frequency transmitter and receiver sections of mobile communications [4]. The SDR concept permits for digital communication to adopt more modulation and coding schemes to meet the user demand in mobile communications [5]. Early 1991, Mitola has define the SDR for a plan to build a GSM base station to combine the digital receivers and controlled the jammers in communication systems for software radio (SR) transceivers [6]. This idea has developed for first time in US army under speaks easy paper to use programmable processing and emulate ten radios frequency band within 2 to 2000MHz [7]. The advantage of SDR is to offer more flexibility in wireless mobile communication systems for extensive range of claims and cellular GSM systems [8]. In bounded applications of mobile communication, the FPGA is used because the reconfigurable of its components has efficient reliability [9]. In addition, the FPGA present an opening utilizing hardware and software simulation to expand high performance for unusual application under excluding processor in software functions [10, 11]. Many other researchers have been proposed their work in SDR transceiver such as [12, 13]. Figure 1 shows the functional block diagrams of SDR parts for transmitter and receiver in mobile communication systems.

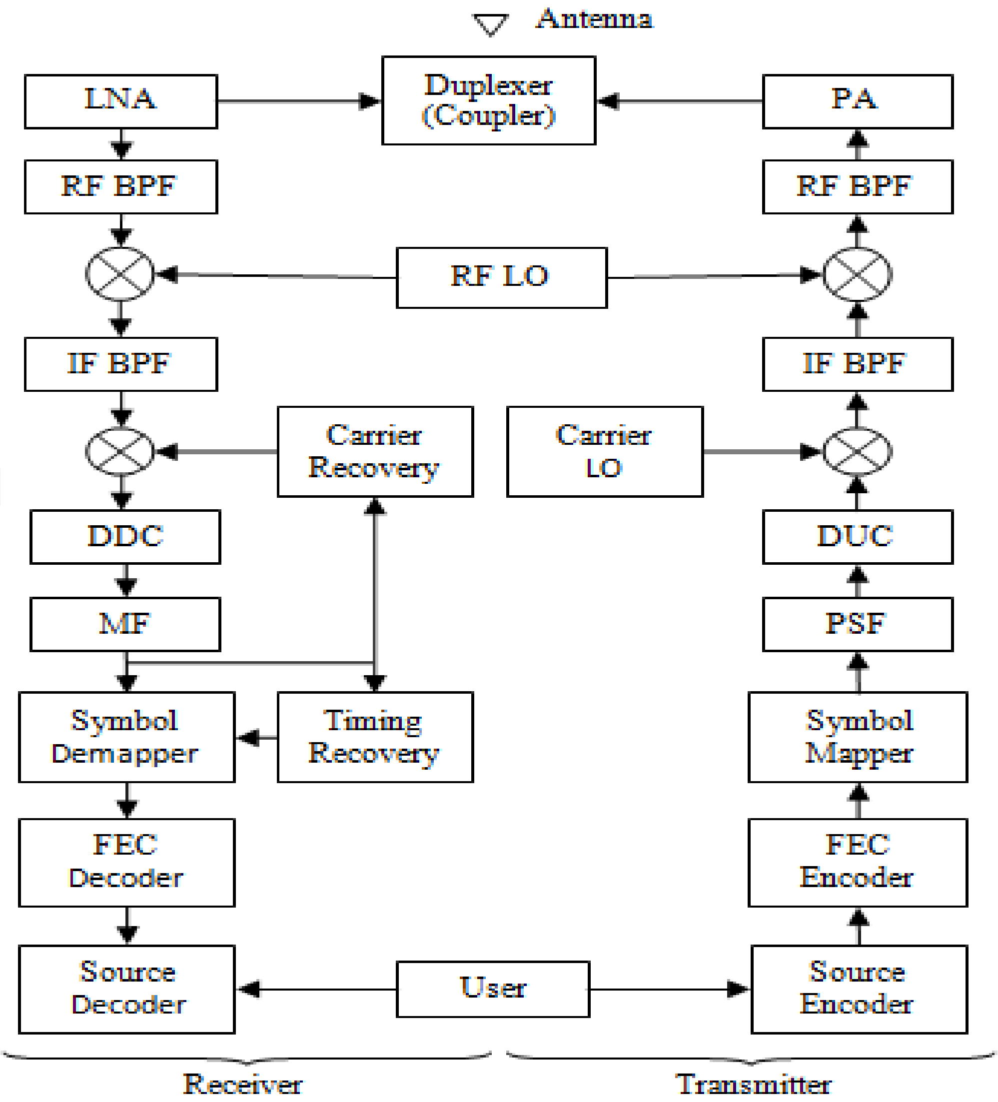


Figure 1.1: Software Defined Radio system

1.2 PROBLEM STATEMENT

Many of the research presented on the design of SDR transceiver applications to improve the efficiency of this model. However there are still some limitations in these designs. The error in the model response is still high. This error is undesirable and will distort the incoming signals with unjustified power consumption.

At present, we need a small device, low power, high quality, and height compatibility together with considerable standards. into this, the design of SDR transceiver have to be optimized in terms error between transmit and received waveforms.

1.3 OBJECTIVE AND SCOPE OF THE RESEARCH

When drawing software-defined radio (SDR), and the following aims were defined:
The objectives for the research work were to apply and evaluate software-defined radio applications (SDRs) to a multi-homogeneous reference processor architecture.

1. objective behind this is to define a strong and flexible structure that is sufficiently capable of handling the physical layer for signal processing requirements of wireless communication systems.
2. for an extension to computational power and flexibility, another design criteria (such as energy and energy efficiency) have also been observed. Power and power consumption is critical when handling applications that target battery-powered devices. In fact, energy and energy enjoy absolutely stable budgets and both layers of software and hardware must be optimized as much as possible and effective collaboration with every other.

1.**4 THESIS OUTLINE**

Chapter 1: This chapter contains introduction, motivation, problem statement, objectives and thesis outline

Chapter 2: This chapter includes the literature review and related work

Chapter 3: This chapter includes practical design of proposed model

Chapter 4: The discussion of results is presents in this chapter

Chapter 5: In this chapter, the conclusion and future work is present

2. LITERATURE REVIEW

2.1 INTRODUCTION

Simply as SDR that is defined as "the radio in whose all or some of the physical layer functions are a specific program" by means of an SDR forum [14]. In real time that means this is the structure is so flexible that SDR can be configured to adapt to waveforms and various wireless standards, operating methods, bandwidths, and frequency bands [15]. Also, the maximum that important process in SDR technology for Software Defined Radio is the data rate transformation section. That is the sampling speed for the measure of the signal contained in the SDR receiver [16]. The first idea of by Mitola, (1995) the technology of the Software, Defined Radio was inserted. It has also been detected as a radio that can handle or process the multi-phase signal of the subsystem as described [17]. Mitola is used in the field of multiple signal processing and he has been working as such in this subject very well since 1991. investigation of the Steinbrech's was deeper and clearer in an idea and then came out to strengthen the system [18]. An idea on SDRs was shared at the first conference that took place in Europe at the time in May 1997. Of the algorithms can also be Modern techniques designed from many under the radio technology definition program using MATLAB software [19].

2.2 FRAMEWORK

The SDR core idea is to replace most the analog signal processing in transceivers with the digital signal processing to provide flexibility through reprogramming or re-configuration.

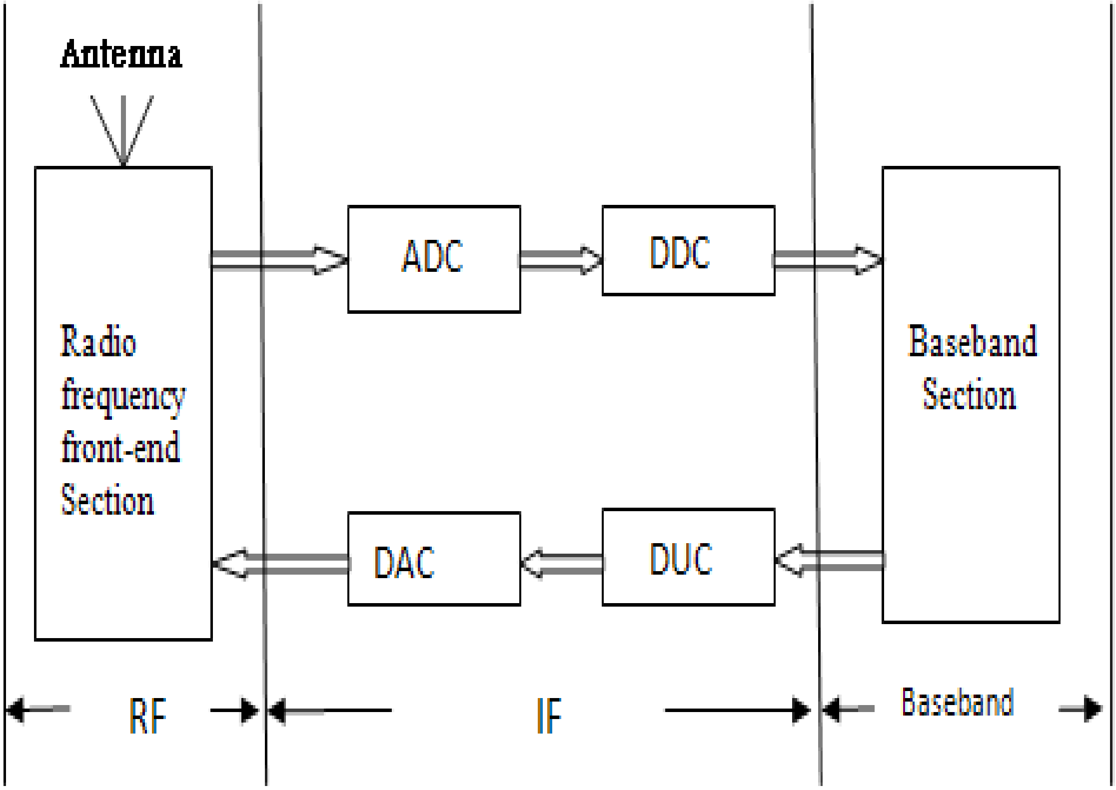


Figure 2.1: Practical Structural of SDR System for Wireless Communication

2.3 RELATED WORK

Modeling of Reusable Sampling Receptors and Basic Base for Software-Defined Broadcasting [20].

For the first time, a historical review of classical sources has been made and differences between all samples have been compared. The second time, I have been deeply reviewing the study of the processing tools used that have been used for discrete-time signals to be clearly working of all tools. Next, two receivers were compared, from [21] and [22].

To a second, a form was created in Simulink. The front part includes a receiver and the model has a receiver and transmitter. In the model that was tested, showing its behavior graphically became easy after using the basic BPSK modification. Since the case use modulation is independent, it is also possible to test and use other configurations. For this, the file can be used in the future as a base for the construction of different receivers for other purposes as well as for testing [23].

Since SDRs are becoming more common, many companies and institutions have developed front end computers and software to help develop radios.

Of the front-end devices still to date were USRP device boards. Also, for the development of SDR, there are also several programming packages available for development, as well as GNU Radio, Open Source OSSIE, Simulink and Open Source Lab (SDR) presentations . The researchers also developed the many criteria for radios, after using the most relevant developmental tools [24].

The primary domain processing application had been implemented. The program based was on, Radio GNU based, a free source toolkit together with a rich collection from signal processing countenance. The design uses the CCSDS frame layout with the front-end error emendation and the BPSK switch. A downlink implementation was characterized by the Costas Loop loop, which represents any frequency range in the midst of the transmitter and receiver. The upward link application was furthermore implemented for the comprehensive test [25].

Communications Architecture (SCA) Implementation transceiver specific radio-specific software (SDR) is designed using open source software: as a basic software program embedded (OSSIE). SDR design requires both the IEEE 802.11a standard (WLAN 5GHz) and the C ++ and CORBA software tools available to implement physical transmission and reception layers. A gradual development model has been chosen, for this job, which consists and consists of three stages: Develop, Design and Verify. This model and feature was of an ever-increasing nature, from earlier versions of the system that allow the developer to learn. A total of 23 components using OSSIE require the implementation of the IEEE 802.11a physical layer and 31 serial I / O transponders, 12 different functions, the receiver with 18 components, 20 serials, and 12 different functions. Verification and validation of the transmitter and receiver layers are also completed successfully according to IEEE test cases [26].

The has been achieved the elasticity of the radio system out of the connotation of software-defined radios (SDRs). The as a fertile road into effectively carry out SDR stage the action focuses within used multi-processor (MP) architectures.

In actuality, a stage instituted during MP architectures were ambidextrous into delivering raise showing together with a high point from the flexibility. In addition, the homogeneous MP stage can reduce layout and in verification of the costs Moreover supply raise scalability to the expression from software or hardware. In addition, the framework provides homogeneous MP minimal calculate qualifications of than non-homogeneous solutions. High, flexible, high-performance, energy-efficient and energy-efficient telecommunications algorithms have been implemented.

A suggested reference stage, Fine silica, was a homogeneous MP framework Component from a 3x3 network from conversion nodes (PNs), push through a network hierarchy (NoC) [27].

This work was motivated by the development of a test for software-specific radio programs (SDR) for Dynamic Spectrum Access (DSA). Pursuit used the today that works start by means of providing that basic fact on software-defined radio technology, contrasting and comparing between structures and common test tests. In addition, the planning of the low-cost, flexible SDR test had been developed [28].

14-bit dual-channel generator/radio system defined by software on a digital converter. Multi-stage adaptations and stages are designed to operate two analog circuit adapters to 800 MHz per second (MSPs) and two digital to analog switches in 1600 MSP from a 25-MSPS software interface and implemented. Throughout the system, quadratic processing was used, and a collection of low-grade and high-quality mixers was implemented to allow for frequency translation across the first Nyquist range of transformers. Many reconstruction candidate designs have been investigated for the transmitter side, and have been implemented cheaply by using the programmable [29].

To contribute progressively to the enhance of SDRs of a nanoscale communication system employ open source systems and programs. The Oliveri (2011) platform developed agile SDR devices that can be placed on the CubeSat 1U. The device for the SDR system, developed as the Space Space Microsystem Innovations and Applications (COSMIAC) CubeSat FPGA [30], was developed.

The On the DSP-based algorithms, the main focus was, an approach is also known as "Dirty RF" signal processing techniques to reduce nonlinear interference. The Digital Alleviation Algorithm designed using radio frequency measurements, real-time operation and large-scale simulations were verified. an advanced baseband behavioral model was Has been developed to correspond to the structures of the receiver of direct conversion as soon as possible, thus taking into account all distortions generated in the radio frequency and baseband [31].

This technology used to develop by software defined radio (SDR) to enhance traditional radiometer with that of radiometer that had on par performance. In addition to showing an SDR-based radiation scale that can achieve similar performance, A conventional radiometer, in terms of stability and sensitivity, The intrinsic capacity of SDR technology has been shown to permit the application of functions beyond what is normally provided by a conventional radiation scale.

In addition, SDR technology, by reducing costs and increasing investment capacity, may become an attractive means of extending access to radiometric measurement to the public research community[32].

The applications of SDR had been implemented to remove configuration, configuration and other processing to signal a digital source signal using software modules running on a personal computer or another capable device. With the processing of software signals, we have implemented highly configurable and flexible DSP systems[33].

A range of proposals is presented to verify the design and implementation of wireless protocol programming. This provides a design solution that is well suited to the SDR requirements. Through this model design is provided to be a good solution that meets the requirements of the SDR, take this approach focuses on the characteristics and optimization - evaluation and applications from all aspects of the implementation of the design based on the characteristics of wireless communication protocols[34].

The use of the packet collision resolution method is then a way to improve packet decoding. After that the resolution has been reached by the concept collision mechanism by facilitating the way to cancel the package signal developed in this work. He also made improvements at the time of the future to be responsible for allowing the developed future to be cognitive [35].

This includes a sophisticated low-cost microwave interface that can be remodeled and portable for biomedical imaging. As well as to reduce cost, and the radio allocated to the program (SDR) is a brilliant concept that allows the formation of a microwave biomedical interface through flexible working parameters [36].

Also, multi-use RF applications and software consisting of many GNU radio instruments can be used for signal processing and implementation [37].

The work involves creating a model developer for software-defined radio broadcasting. SIMULINK has been used and the IEEE 802.11 and Bluetooth standards have been implemented. The purpose was to create and configure protocols that are not compatible with

WLAN and Bluetooth standards and show their functionality. It also includes the implementation of the IEEE 802.11a standard used in the wireless network and is also used in basic protocols for Bluetooth. Text for IEEE 802.11a standard of different transmitter conditions [38].

By means of the differences in the rectangular QAM code, a new method was introduced to add safety in various digital communication systems. This was also verified by constellations with variable mappings. Each code was assigned a different phase level and to a level within each, A jump in the scheme of constellations and not to affect the rules used for gray encryption and is to remain on the teams and one adjacent code.

This is achieved by changing the constellation assignments where each code is assigned to a different level and level in a constellation chart at each variation (jump) without breaking the gray coding rules, ie, only one difference is maintained between adjacent symbols [39].

Was implemented for learning to practice radio communication based on an SDR-based workstation that was able to receive and infer radio transmissions and presents. Results obtained and learning abilities were also identified by working together with new devices of this type [40].

New model of SDR transceiver has been suggested by [41] to verify the basic

functionality and validate their usefulness under specific conditions. The major aspect of SDR including advantage, disadvantage and architecture of this technique has been proposed by [42]. The implementation of SDR ground receiver station which converts the analog signal to digital baseband signal representation has been projected by [43]. They sent the received baseband signal to the host computer to provide demodulation process and decoding the incoming signals in order to extract the transmitted data. The design of SDR transceiver using open source SCA embedded kit has been introduced by [44]. The implementation and design of a high-performance, flexible, an energy-efficient for the algorithm for the wireless communications systems has been introduced by [45]. The design and implementation of SDR system with two channel and 4-bits digital generator has published by [46]. The implementation and evaluation of 2x2 MIMO channel sounder of SDR using FPGA board to support different sounding sequence has been proposed by[47]

3. SIMULATION OF PROPOSED MODEL

3.1 INTRODUCTION

This chapter contain, design of software-defined radio SDR transceiver using MATLAB Simulink block set and running the model under AWGN channel effect.

3.2 PROPOSED SDR SIMULINK MODEL

To facilitate and examine the performance of proposed SDR model, the IF and baseband sections of mobile transceiver has been designed and simulated using communication block set in MATLAB as showing in Figure 3.1. In the transmitter part, the modulation, pulse shaping and up sampling filters is designed according to GSM system requirements illustrated in Table 3.1. The receiver section of GSM system under SDR techniques which is consists of down sampling and demodulation scheme has been comprised to provide signal recovery of incoming waveforms.

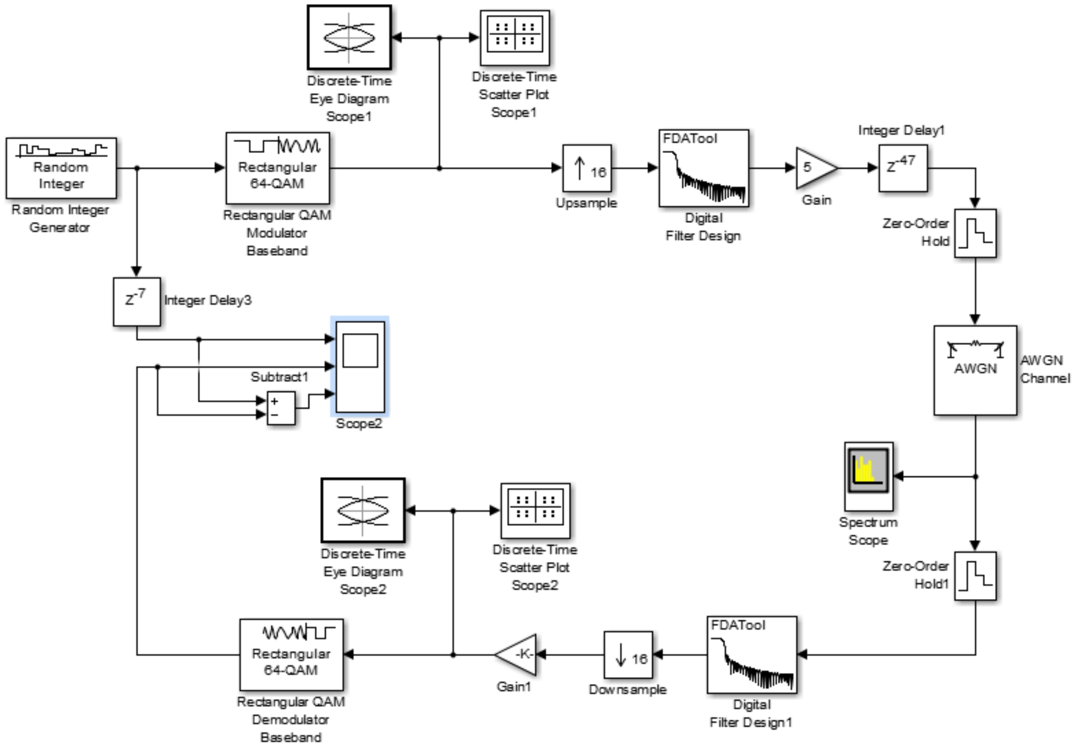


Figure 3.1: Proposed SDR Model

Table 3.1: Model Specifications

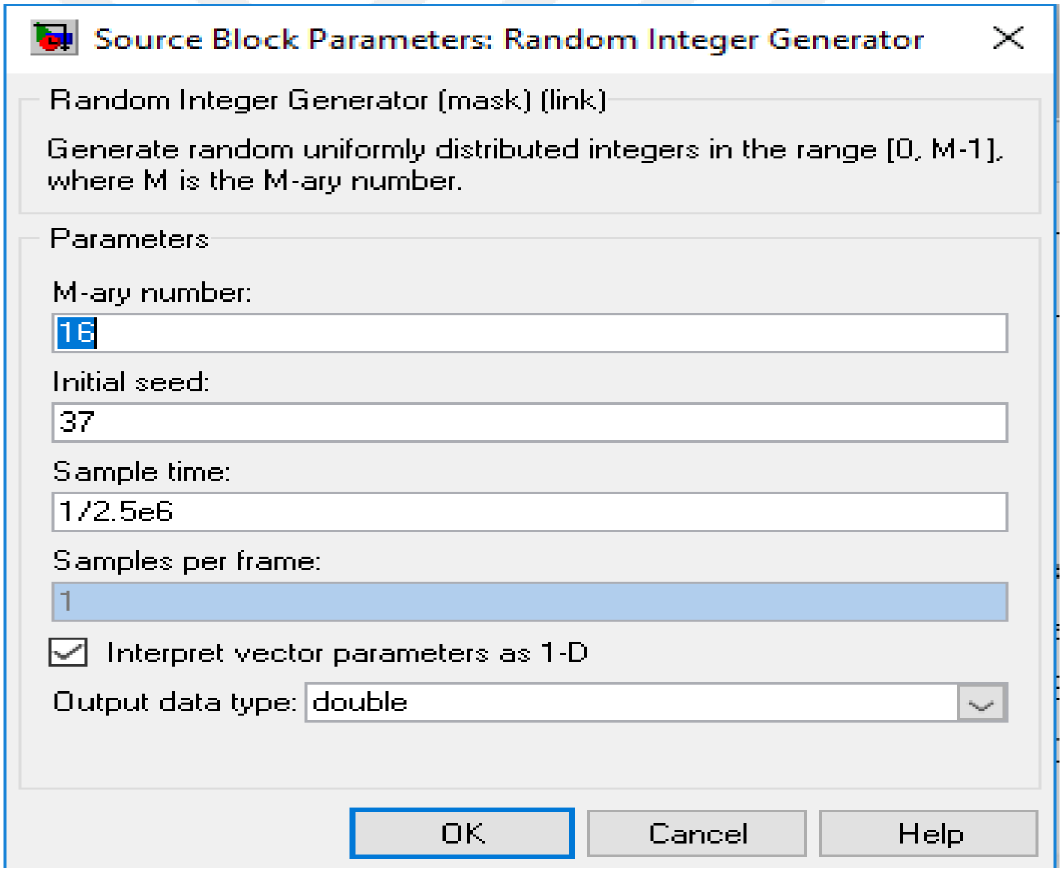
Modulation Scheme	64-QAM
The Rate of Symbol	2.5 MSPs
The Factor of Interpolator and Decimation	16
Noise Effect	AWGN
Sample Rate of Receiver Filter	60 MHz

3.3 DESIGN OF TRANSMITTER SECTION

The transmitter part of SDR model in the baseband and IF frequency contains the signal generator from the random integer generator blocks. That sample allows you to create random integers. Randomity comes from, for atmospheric noise, that for such purposes that best than the pseudo-random number algorithms commonly used in computer programs. Figure 3.2 shows the random integer generator. Create integers distributed regularly in the range [0, M, 1] where M is the M-ary number. The generated signal has modulated by the 64-QAM modulator with 2.5 Msps Figure 3.3 shows the rectangular 64-QAM modulator baseband. Adjusts the input signal using the rectangle modulation method.

The M-ary number must be a numerical force of two. The entry can be either a bit or an integer. The constellation can be ordered by setting a binary, gray mapping, or user-defined mapping.

For the sample-based bits input, must the width must be equal that number of the bits per code. In the frame-based input, the entry must be an integer column multiplied by the number of bits per code. For an integer based on samples, the input number must be a number. For frame-based integer input, the input must be a column vector. The QAM Modulator modulates the M-ary spatial configuration with a rectangular grid constellation. The output is represented as the base range of the included signal. The pair close to of points in the constellation is separated by the otminimum distance parameter value. The modulated signal is converted by a factor of 16 and pulse-shaped by the RRC filter.



Source Block Parameters: Random Integer Generator

Random Integer Generator (mask) (link)

Generate random uniformly distributed integers in the range [0, M-1], where M is the M-ary number.

Parameters

M-ary number: 16

Initial seed: 37

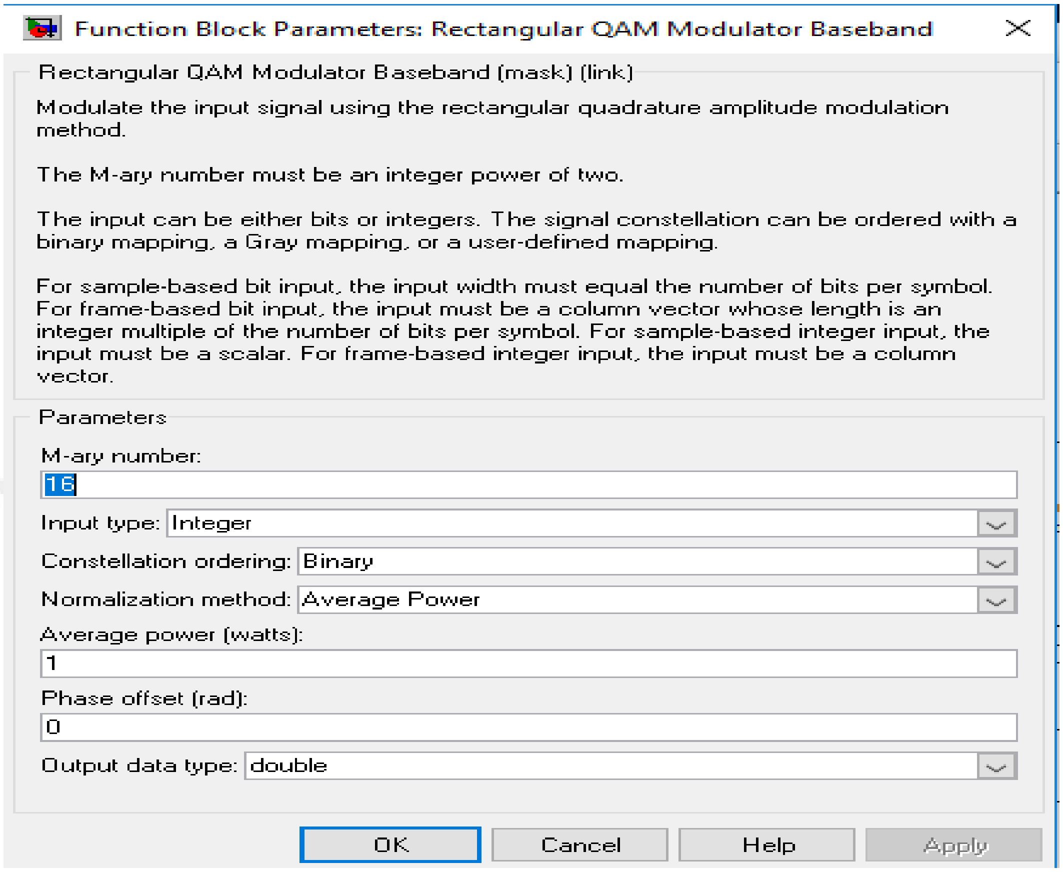
Sample time: 1/2.5e6

Samples per frame: 1

☑ Interpret vector parameters as 1-D

Output data type: double

Figure 3.2: Random Integer Generator



Function Block Parameters: Rectangular QAM Modulator Baseband

Rectangular QAM Modulator Baseband (mask) (link)

Modulate the input signal using the rectangular quadrature amplitude modulation method.

The M-ary number must be an integer power of two.

The input can be either bits or integers. The signal constellation can be ordered with a binary mapping, a Gray mapping, or a user-defined mapping.

For sample-based bit input, the input width must equal the number of bits per symbol. For frame-based bit input, the input must be a column vector whose length is an integer multiple of the number of bits per symbol. For sample-based integer input, the input must be a scalar. For frame-based integer input, the input must be a column vector.

Parameters

M-ary number: 16

Input type: Integer

Constellation ordering: Binary

Normalization method: Average Power

Average power (watts): 1

Phase offset (rad): 0

Output data type: double

Figure 3.3: Rectangular 64-QAM Modulator Baseband

To modify the speed of sample signal, the sample rate of existing signal could be increased by mean of interpolation process. The interpolation are comprises the generation of continuous curve via conventional samples. To obtain the interpolation sequence, this curve will sample at new sample rate by a factor of M, M-1. The increasing technique at sampling frequency Fs should be calculated according to the flowing formula:

$$f_s = f_{new} = M f_{old} \qquad (3.1)$$

In the suggested model, the QAM signal is interpolated by 16 to generate a new sample rate. The new sample rate after interpolation is calculated to get 60 Msps.

The inherent loss of M will be generated due to interpolation process. The inherent loss has been overcome by add gain stage in the system design to provide unity gain along with old sequence and new one. The pulse shaping filter type FIR with Kaiser Window has been used in the transmitter part. The requirement of RRC filter is illustrated in Table 3.2.

Table 3.2: Root Raised Cosine Filter Requirements

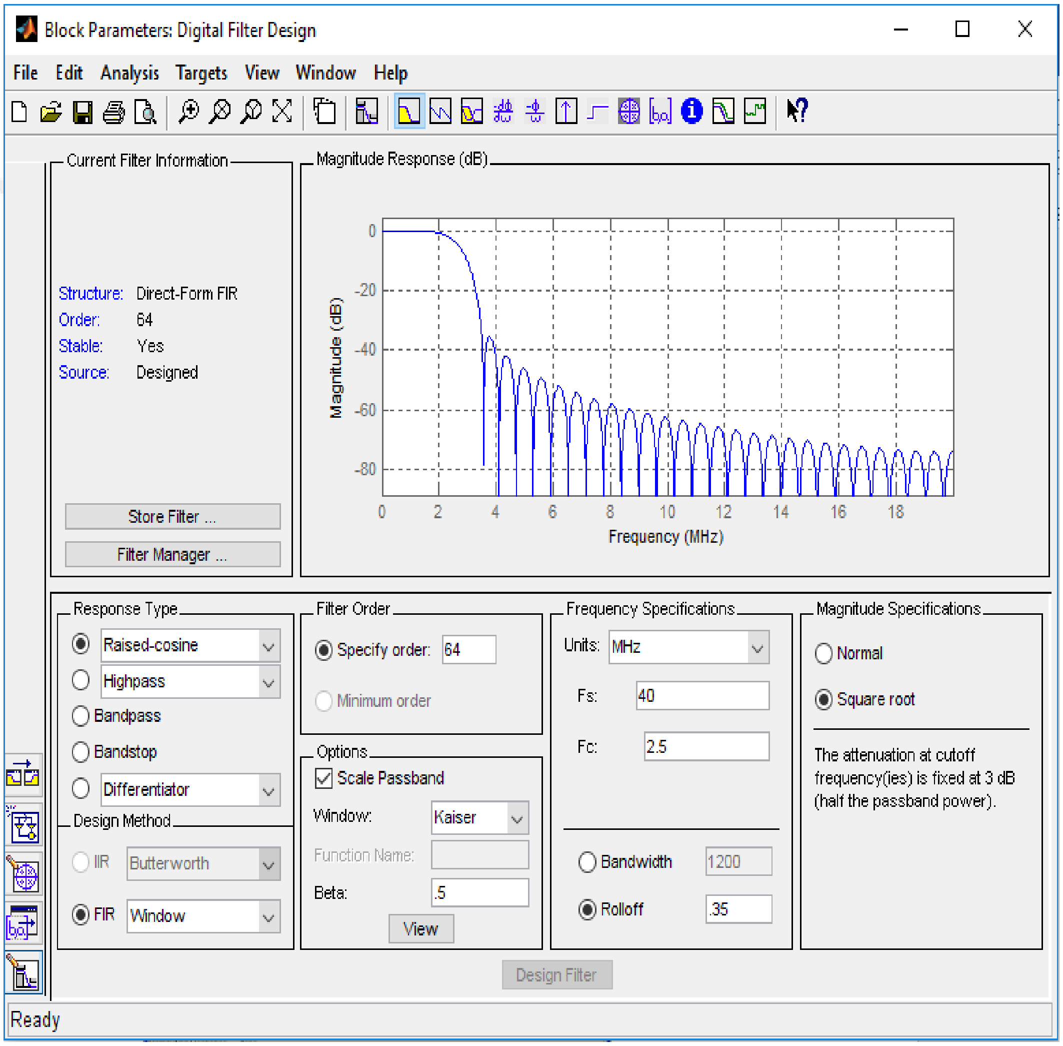
Centre Frequency f_{centre}	2.5 MHz
The Sampling Speed	60 MHz
Attenuation of Stop Band Rejoin	-50 dB
β $(roll\,off\ factor)$	0.35
The Response of Phase	Linear
Solidity Grade	Stable

The response of RRC filter contains three frequency points such as Nyquist, stop band and pass band area [48]. These points could be calculated as follow:

$$f_{stot} = (1+\beta)f_{center} = (1+0.35)X\ 2.5MHz = 3.375MHz \tag{3.2}$$

$$f_{pass} = (1-\beta)f_{center} = (1-0.35)X\ 2.5MHz = 1.625MHz \tag{3.3}$$

Figure 3.4 shows the magnitude response of RRC filter and Figure 3.5 shows the impulse response of RRC filter which is indicate that the filter is none distorted and stable in all band.



Structure: Direct-Form FIR
Order: 64
Stable: Yes
Source: Designed

Response Type
● Raised-cosine
○ Highpass
○ Bandpass
○ Bandstop
○ Differentiator

Design Method
○ IIR Butterworth
● FIR Window

Filter Order
● Specify order: 64
○ Minimum order

Options
☑ Scale Passband
Window: Kaiser
Function Name:
Beta: .5

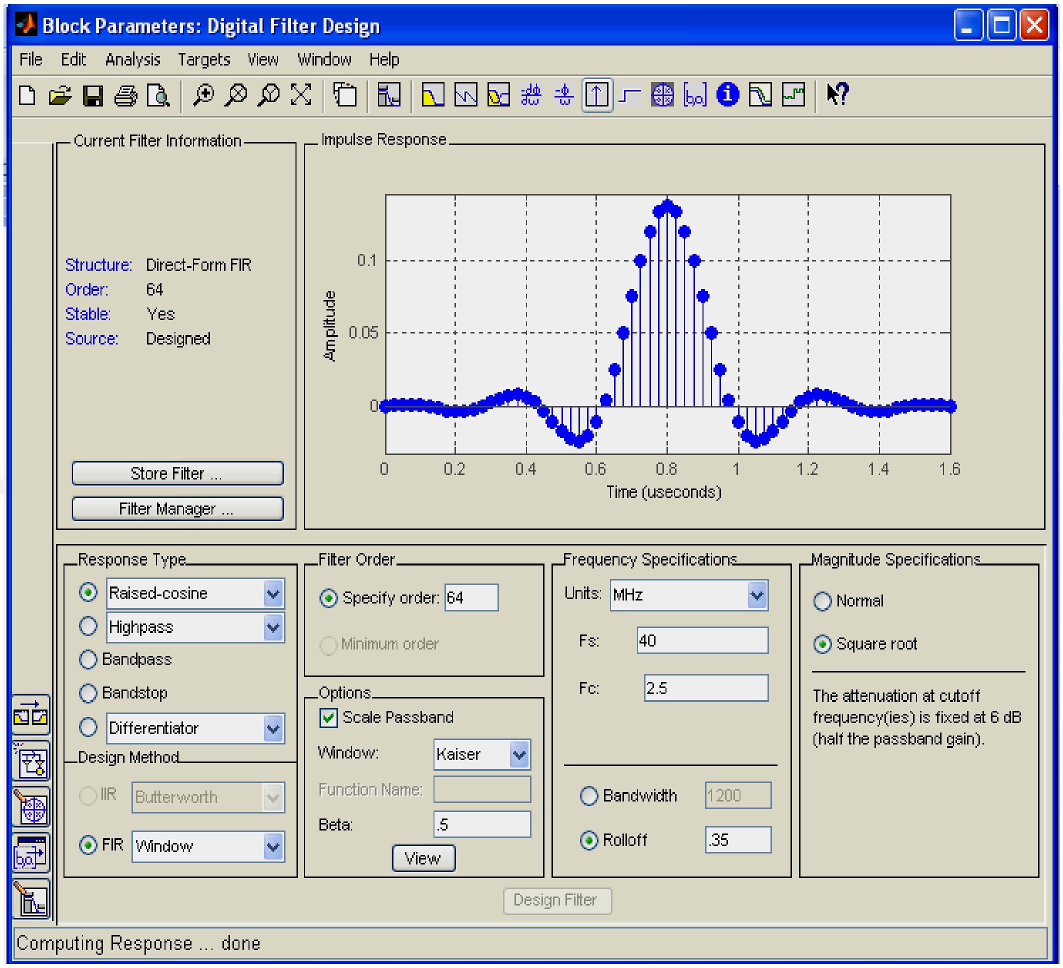
Frequency Specifications
Units: MHz
Fs: 40
Fc: 2.5
○ Bandwidth 1200
● Rolloff .35

Magnitude Specifications
○ Normal
● Square root

The attenuation at cutoff frequency(ies) is fixed at 3 dB (half the passband power).

Ready

Figure 3.4: RRC Magnitude Response



Structure: Direct-Form FIR
Order: 64
Stable: Yes
Source: Designed

● Raised-cosine
○ Highpass
○ Bandpass
○ Bandstop
○ Differentiator

○ IIR Butterworth
● FIR Window

● Specify order: 64
○ Minimum order

☑ Scale Passband
Window: Kaiser
Function Name:
Beta: .5

Units: MHz
Fs: 40
Fc: 2.5
○ Bandwidth 1200
● Rolloff .35

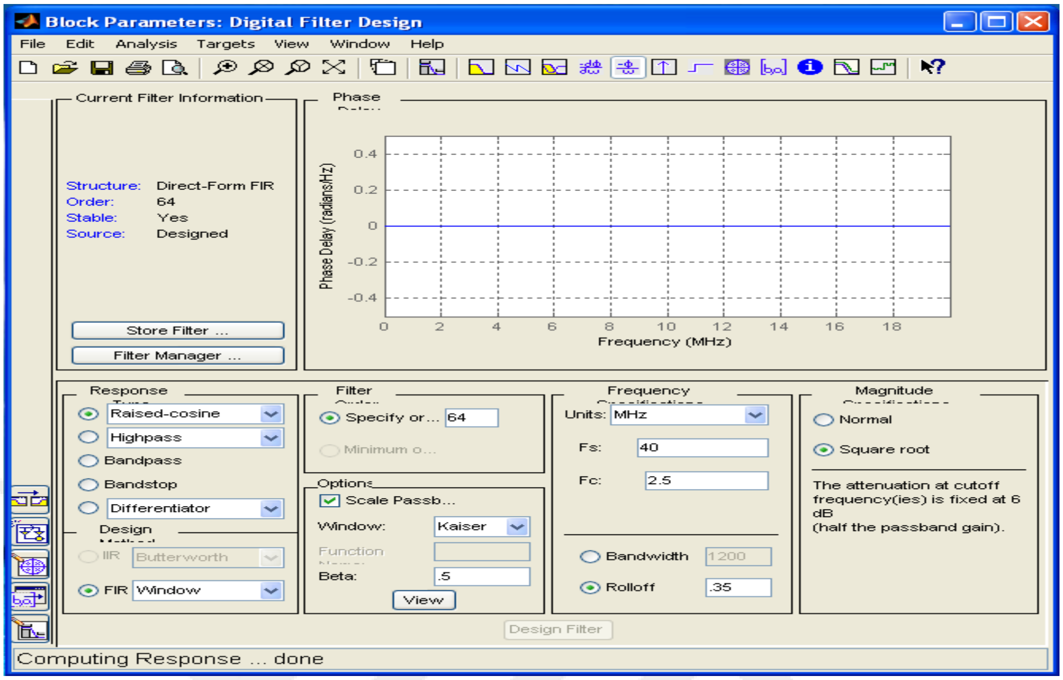
○ Normal
● Square root

The attenuation at cutoff frequency(ies) is fixed at 6 dB (half the passband gain).

Computing Response ... done

Figure 3.5: Impulse Response of RRC Filter

Figure 3.6 show the phase delay response of the RRC transmitter filter and Figure 3.7show the Group delay response of the RRC transmitter filter. In the interesting band which indicates linearity of group delay and constant response. The linearity of phase response refers to the state of a straight line along with the function of frequencies. This means no distortion or delay in filter response.



Structure: Direct-Form FIR
Order: 64
Stable: Yes
Source: Designed

● Raised-cosine

● FIR Window

● Specify or... 64

☑ Scale Passb...

Window: Kaiser

Beta: .5

Units: MHz

Fs: 40

Fc: 2.5

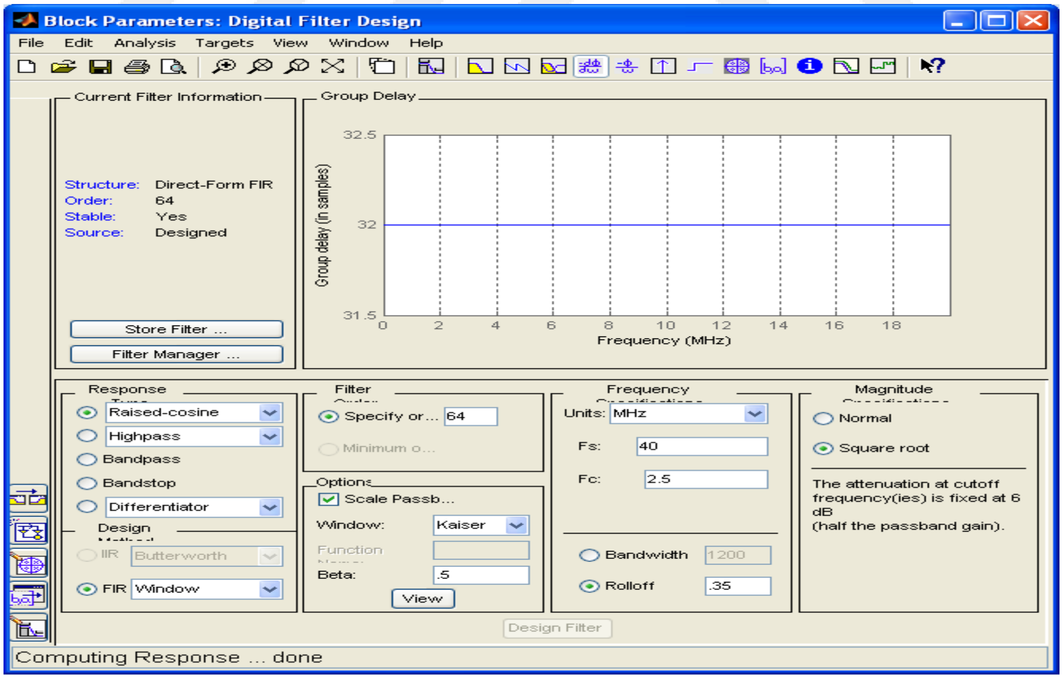
● Rolloff .35

● Square root

The attenuation at cutoff frequency(ies) is fixed at 6 dB (half the passband gain).

Computing Response ... done

Figure 3.6: Phase Delay of RRC Transmitter Filter Response



Structure: Direct-Form FIR
Order: 64
Stable: Yes
Source: Designed

● Raised-cosine

● FIR Window

● Specify or... 64

☑ Scale Passb...

Window: Kaiser

Beta: .5

Units: MHz

Fs: 40

Fc: 2.5

● Rolloff .35

● Square root

The attenuation at cutoff frequency(ies) is fixed at 6 dB (half the passband gain).

Computing Response ... done

Figure 3.7: Group Delay of RRC Transmitter Filter Response

Figure 3.8 illustrates the spectrum of the original signal under AWGN channel effect with 2.5 dB. Adds white Gaussian noise channel an AWGN for the signal that passes through it. The digital efficiency of feedforward mitigation successfully had been verified in the AWGN channels through RF laboratory measurements and simulations connections with cables. Nothing changes In principle, in a mitigation architecture if the level for the input signals varying due to the realistic radio channel manifesting all wave propagation phenomena, namely diffraction, reflection, shadowing, and scattering.

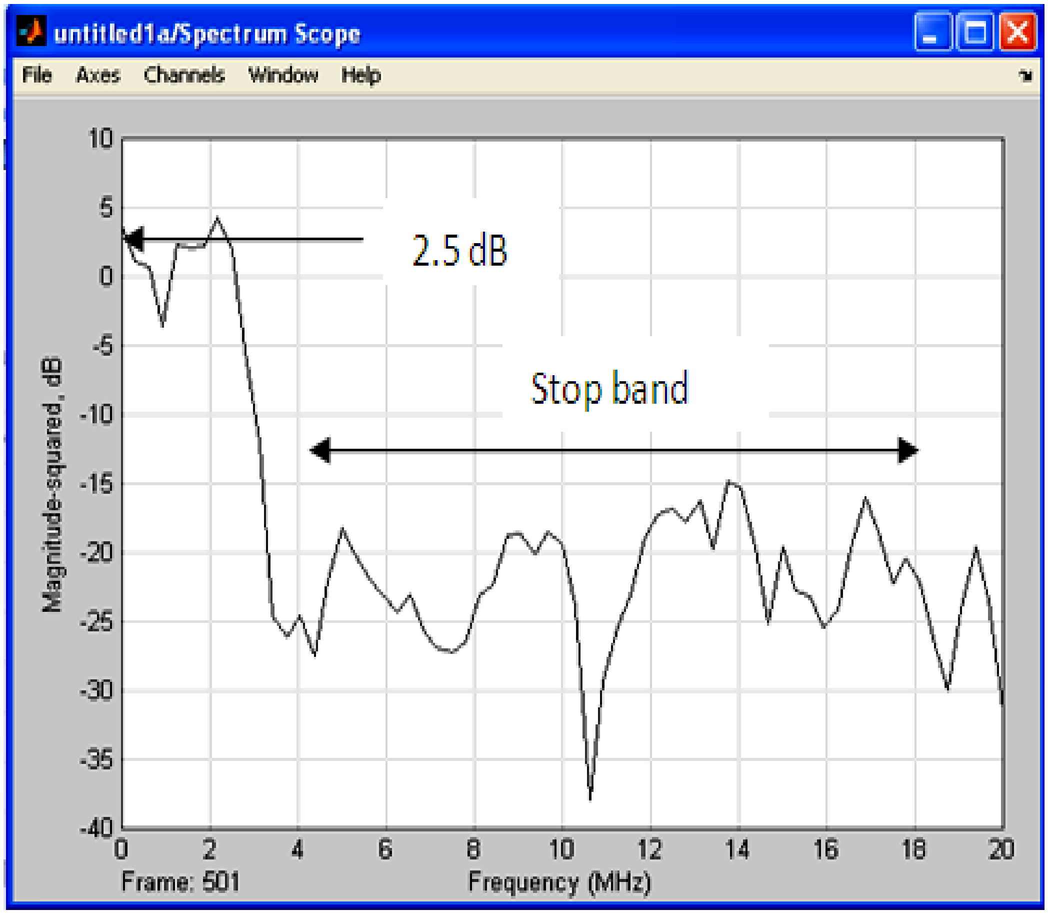
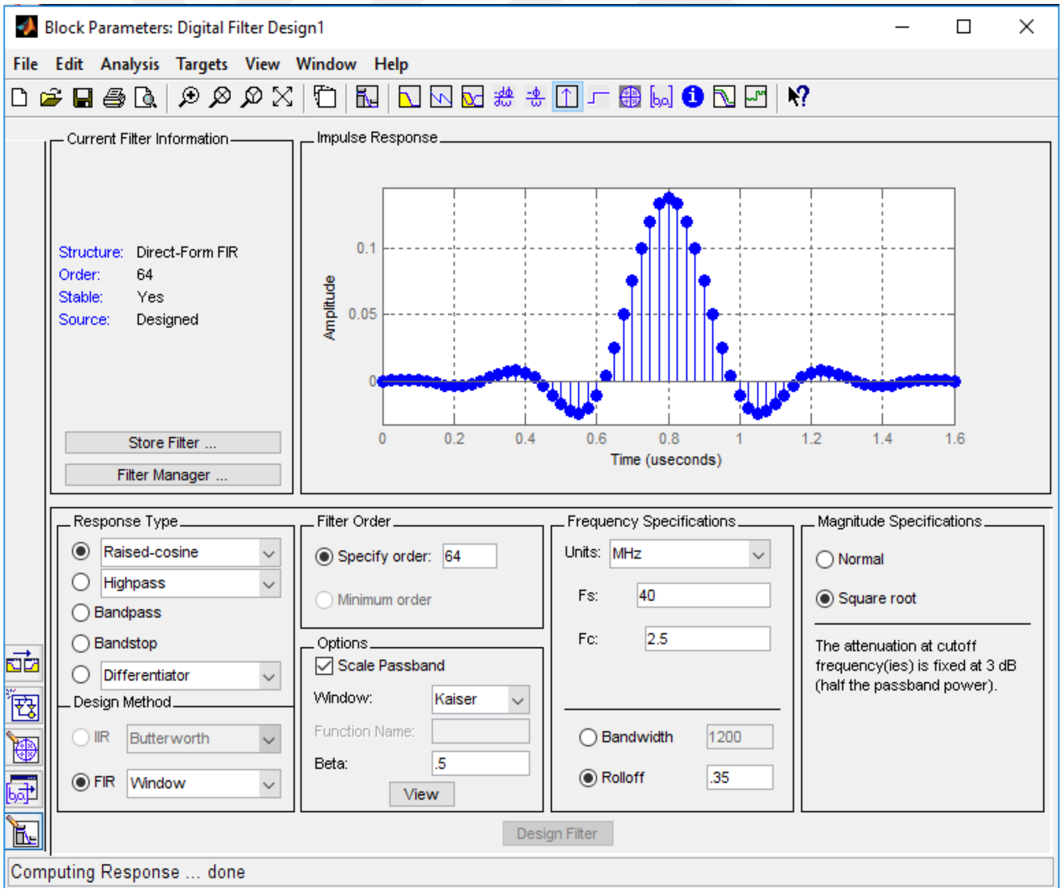


Figure 3.8: Original Baseband Signal

3.4 DESIGN OF RECEIVER SECTION

The receiver part of SDR model in the baseband and IF frequency. The incoming signal to the receiver section is contaminated by noise and decimated to IF after AWGN channel. This signal is processed with SNR under 20 dB. By using RRC filter, the received signal is pulse shaped with 60 MHz sample rate and decimated by 16. Figure 3.9 shows impulse amplitude response of received RRC filter. This processing introduce inherent amplitude which is balanced by add gain stage to provide unity gain. The processing mitigation, demodulation as well as the GSM, and implemented had been in MATLAB the existing using the toolbox for GSM sim that was compliant full with the GSM standard.



Structure: Direct-Form FIR
Order: 64
Stable: Yes
Source: Designed

Response Type
● Raised-cosine
○ Highpass
○ Bandpass
○ Bandstop
○ Differentiator

Design Method
○ IIR Butterworth
● FIR Window

Filter Order
● Specify order: 64
○ Minimum order

Options
☑ Scale Passband
Window: Kaiser
Function Name:
Beta: .5

Frequency Specifications
Units: MHz
Fs: 40
Fc: 2.5
○ Bandwidth 1200
● Rolloff .35

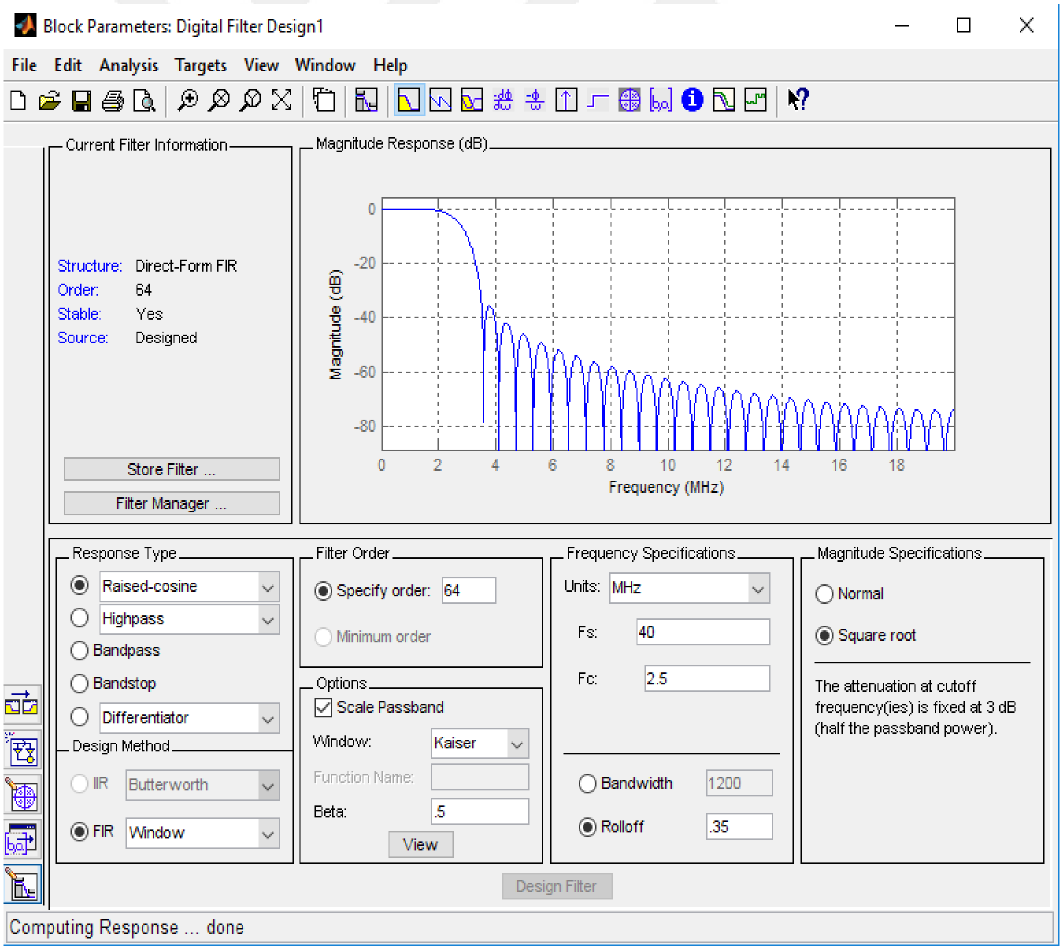
Magnitude Specifications
○ Normal
● Square root

The attenuation at cutoff frequency(ies) is fixed at 3 dB (half the passband power).

Computing Response ... done

. **Figure 3.9:** Impulse Response of Received RRC Filter

Figure 3.10 shows frequency response of received RRC filter. The processing of the signal, the RRC filter, sometimes known as the SRC filter, is used as a transmitter and receiver for the digital communications system to perform identical filtering. This helps to minimize interference of intersymbol (ISI). The combined response to two of these filters is the cosine filter response. It gets its name from the fact that the frequency response. For a minimum of ISI (Intersymbol Interference), the total response of the transmitter filter, channel response, while receiver filter must meet the Nyquist ISI standards. The Raised-cosine filtering is the most popular filter response that meets this standard. Half of this filtration is performed on the transmission side and the half on the receiving side. On the receiving side, the channel response can also be considered, if accurately estimated, so that the overall response is a Raised-cosine filter.



Structure: Direct-Form FIR
Order: 64
Stable: Yes
Source: Designed

● Raised-cosine
○ Highpass
○ Bandpass
○ Bandstop
○ Differentiator

○ IIR Butterworth
● FIR Window

● Specify order: 64
○ Minimum order

☑ Scale Passband
Window: Kaiser
Function Name:
Beta: .5

Units: MHz
Fs: 40
Fc: 2.5
○ Bandwidth 1200
● Rolloff .35

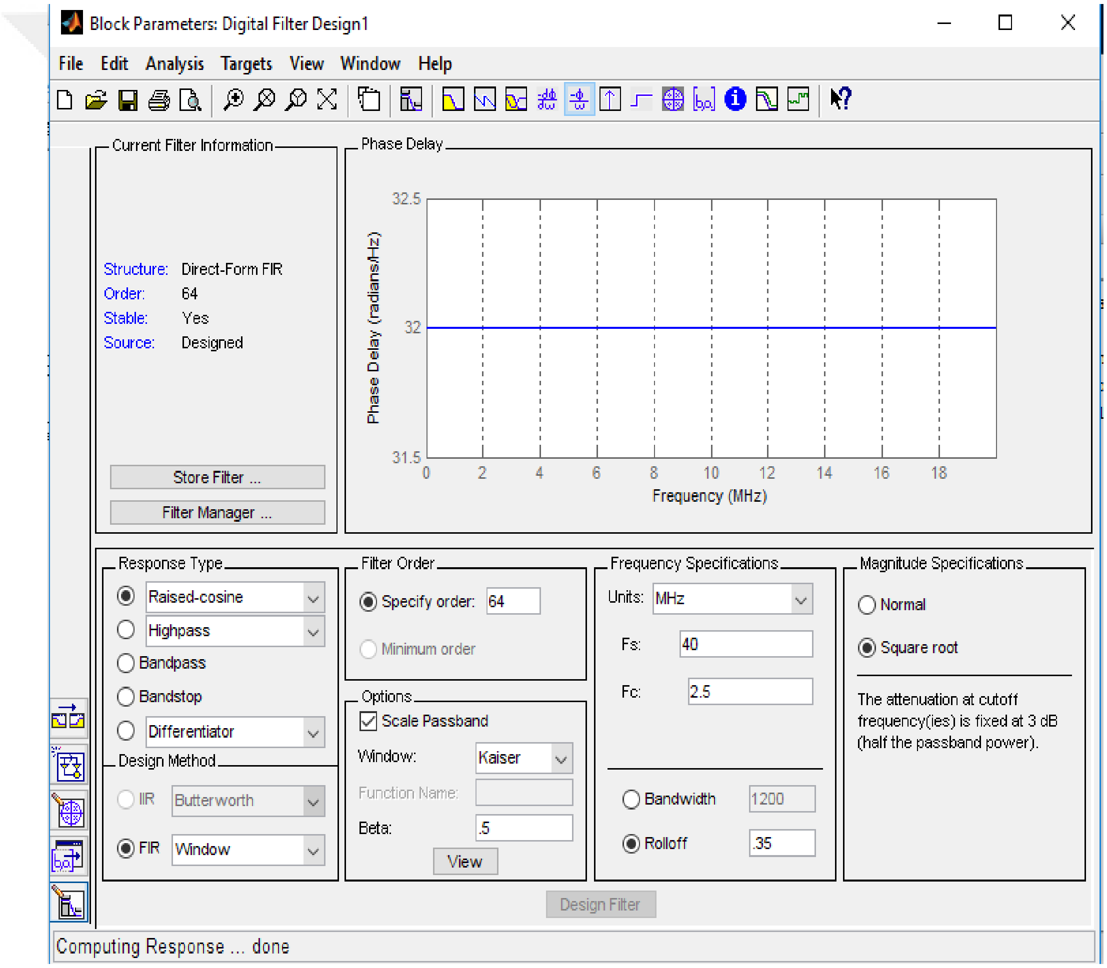
○ Normal
● Square root

The attenuation at cutoff frequency(ies) is fixed at 3 dB (half the passband power).

Computing Response ... done

Figure 3.10: Frequency Response of Received RRC Filter

Figure 3.11 show the phase delay response of the RRC receive filter and Figure 3.12 show the Group delay response of the RRC receive filter in the interest band which indicate linearity of group delay and constant response. The linearity of phase response refers to state of straight line along with function of frequencies. This means no distortion or delay in filter response.



Structure: Direct-Form FIR
Order: 64
Stable: Yes
Source: Designed

Response Type
● Raised-cosine
○ Highpass
○ Bandpass
○ Bandstop
○ Differentiator

Design Method
○ IIR Butterworth
● FIR Window

Filter Order
● Specify order: 64
○ Minimum order

Options
☑ Scale Passband
Window: Kaiser
Function Name:
Beta: .5

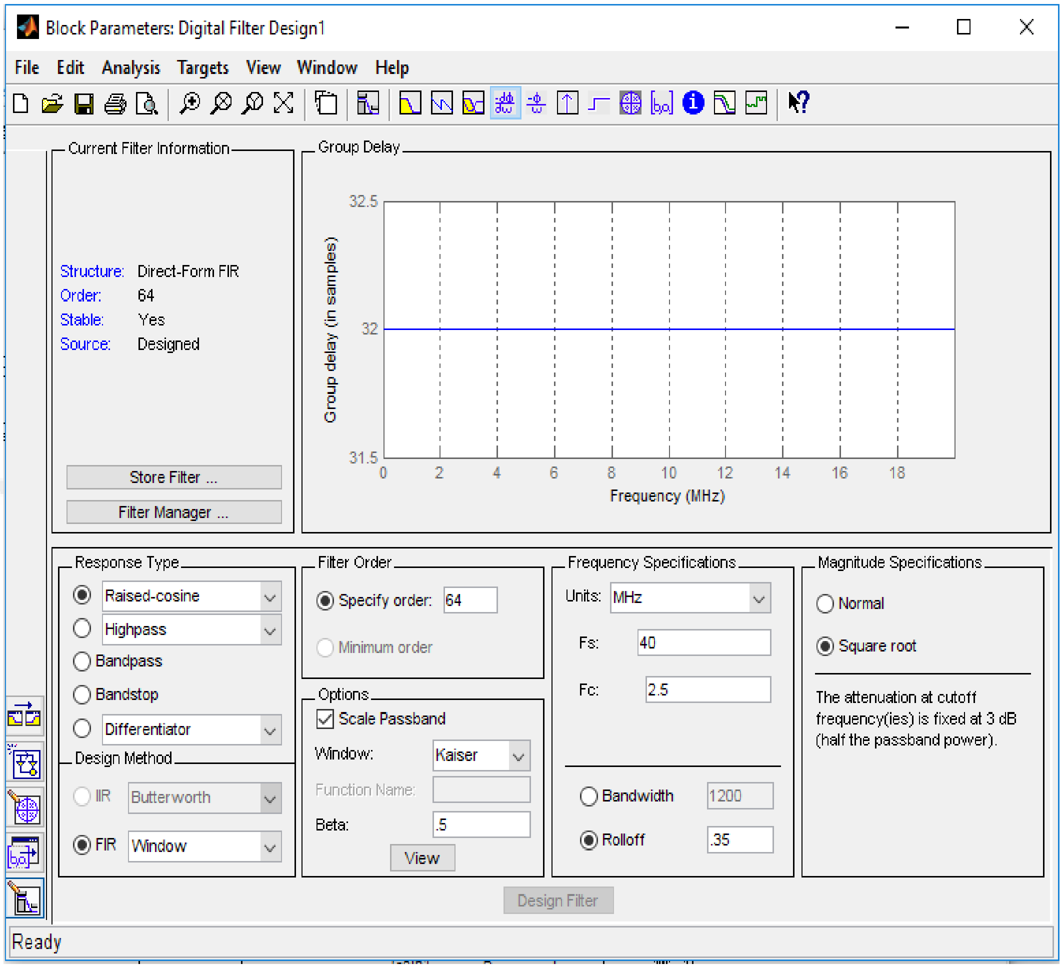
Frequency Specifications
Units: MHz
Fs: 40
Fc: 2.5
○ Bandwidth 1200
● Rolloff .35

Magnitude Specifications
○ Normal
● Square root

The attenuation at cutoff frequency(ies) is fixed at 3 dB (half the passband power).

Computing Response ... done

Figure 3.11: Phase Delay of RRC Receive Filter Response



Structure: Direct-Form FIR
Order: 64
Stable: Yes
Source: Designed

● Raised-cosine
○ Highpass
○ Bandpass
○ Bandstop
○ Differentiator

○ IIR Butterworth
● FIR Window

● Specify order: 64
○ Minimum order

☑ Scale Passband
Window: Kaiser
Function Name:
Beta: .5

Units: MHz
Fs: 40
Fc: 2.5
○ Bandwidth 1200
● Rolloff .35

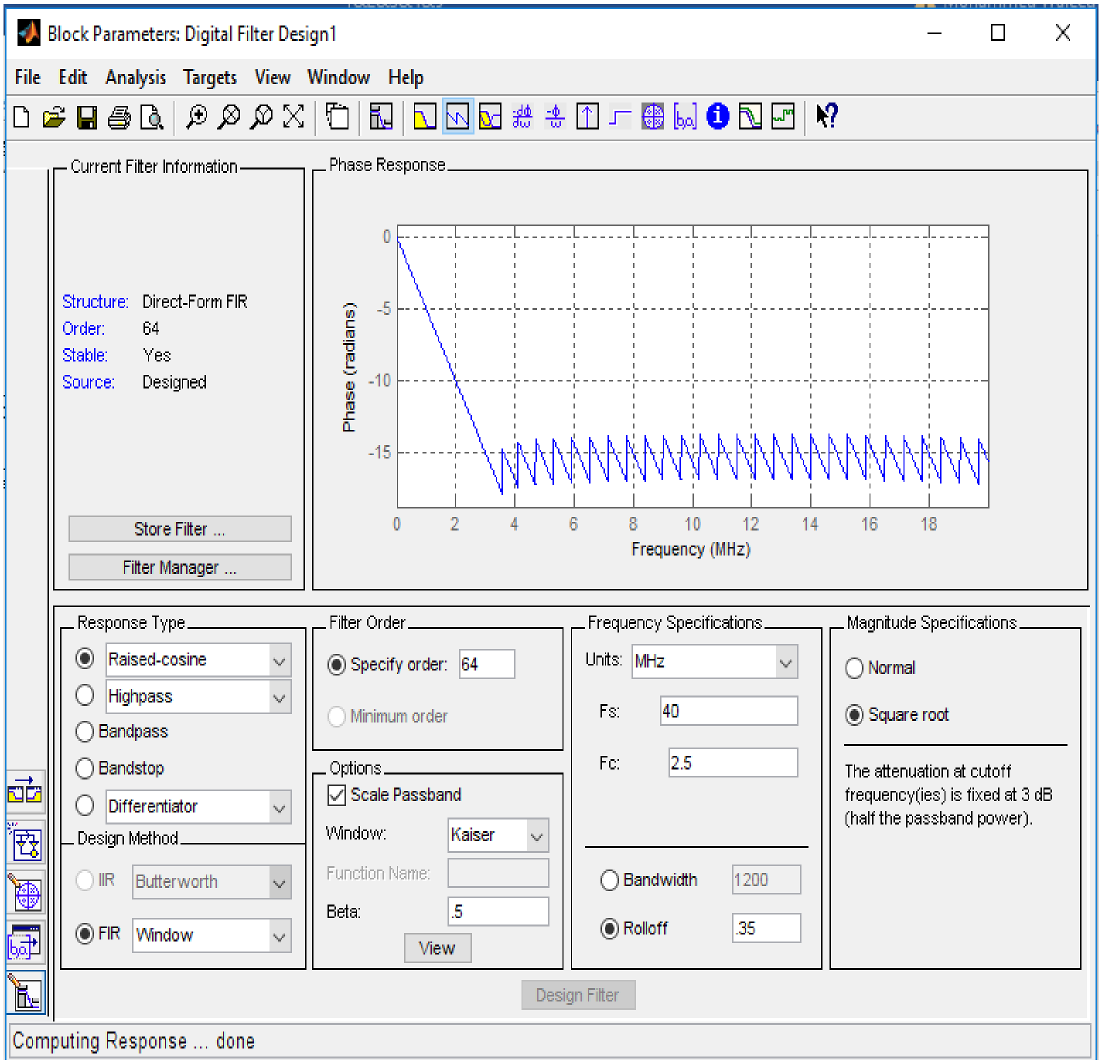
○ Normal
● Square root

The attenuation at cutoff frequency(ies) is fixed at 3 dB (half the passband power).

Figure 3.12: Group Delay of RRC Receive Filter Response

This algorithm that Using, frequency FIR filter, that represented while phase response can be by the lowest number of non-zero transactions. Therefore, reduce the computational complexity required to get the filter output.

The filter raised cosine anterior camshaft provides a large transition width and attenuation in the low downtime compared to the filter spiders in the size response. The Gaussian phase response of the filter is more linear in the range of traffic compared to the RRC filter. Figure 3.13 shows the phase response 64-QAM baseband of received waveforms.



Structure: Direct-Form FIR
Order: 64
Stable: Yes
Source: Designed

● Raised-cosine
○ Highpass
○ Bandpass
○ Bandstop
○ Differentiator

○ IIR Butterworth
● FIR Window

● Specify order: 64
○ Minimum order

☑ Scale Passband
Window: Kaiser
Function Name:
Beta: .5

Units: MHz
Fs: 40
Fc: 2.5
○ Bandwidth 1200
● Rolloff .35

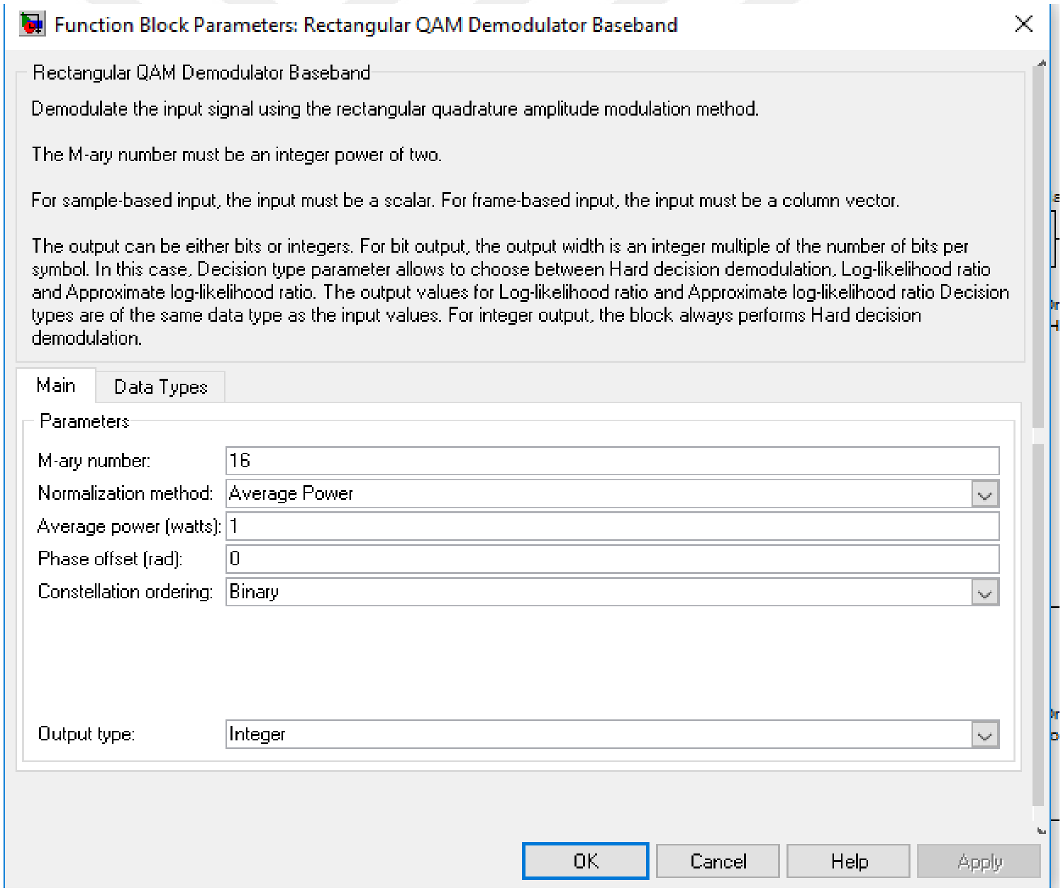
○ Normal
● Square root

The attenuation at cutoff frequency(ies) is fixed at 3 dB (half the passband power).

Computing Response ... done

Figure 3.13: Phase Response of RRC Receive Filter

Demodulate remove the input signal formation using the modulation rectangle method. The M-ary number must be a numerical force of two. To the sample-based inputs, the number of input must be a number. Into window-based input, the entry must be the vector of the column. The output can be either bit or integer. For bit output, the output width is multiple integer numbers of bits for each code. In this case, the decision type parameter allows you to choose between removing difficult decision making. Figure 3.14 shows the rectangular 64-QAM demodulator baseband of received waveforms.



Function Block Parameters: Rectangular QAM Demodulator Baseband

Rectangular QAM Demodulator Baseband

Demodulate the input signal using the rectangular quadrature amplitude modulation method.

The M-ary number must be an integer power of two.

For sample-based input, the input must be a scalar. For frame-based input, the input must be a column vector.

The output can be either bits or integers. For bit output, the output width is an integer multiple of the number of bits per symbol. In this case, Decision type parameter allows to choose between Hard decision demodulation, Log-likelihood ratio and Approximate log-likelihood ratio. The output values for Log-likelihood ratio and Approximate log-likelihood ratio Decision types are of the same data type as the input values. For integer output, the block always performs Hard decision demodulation.

Parameters

M-ary number: 16

Normalization method: Average Power

Average power (watts): 1

Phase offset (rad): 0

Constellation ordering: Binary

Output type: Integer

Figure 3.14: Rectangular 64-QAM Demodulator Baseband

4. RESULTS AND DISCUSSION

4.1 RESULTS

The outcome of this model is to introduce the mobile transceiver to work with any frequency band which could be tuned down to many frequency bands. The frequency spectrum problem shortage under consumption could be overcome by mean of cognitive radio in SDR core. The development of this model consider as save of amount of time in the design and testing. The 64-QAM transceiver has been successfully designed and simulated based SDR platforms. The maximum likelihood detection methods are simulated and working in appropriate way to minimize the error between transmits and received waveforms. The suggested SDR model show efficient performance to support current and future mobile generation. Figure 4.1 shows the eye diagram of 64-QAM baseband signal and the constellation diagram is illustrated in Figure 4.2 Subsequently, the modulated signal is converted by a factor of 16 and pulse-shaped by the RRC filter.

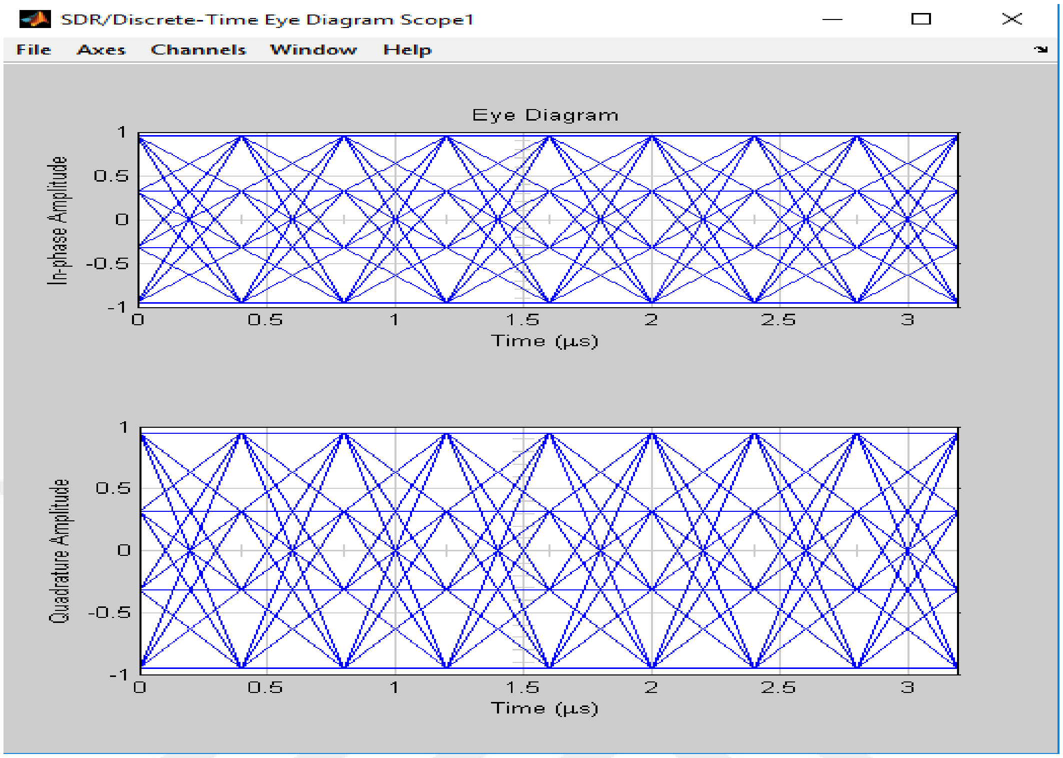


Figure 4.1: 64-QAM Eye Diagram of Transmit Signal

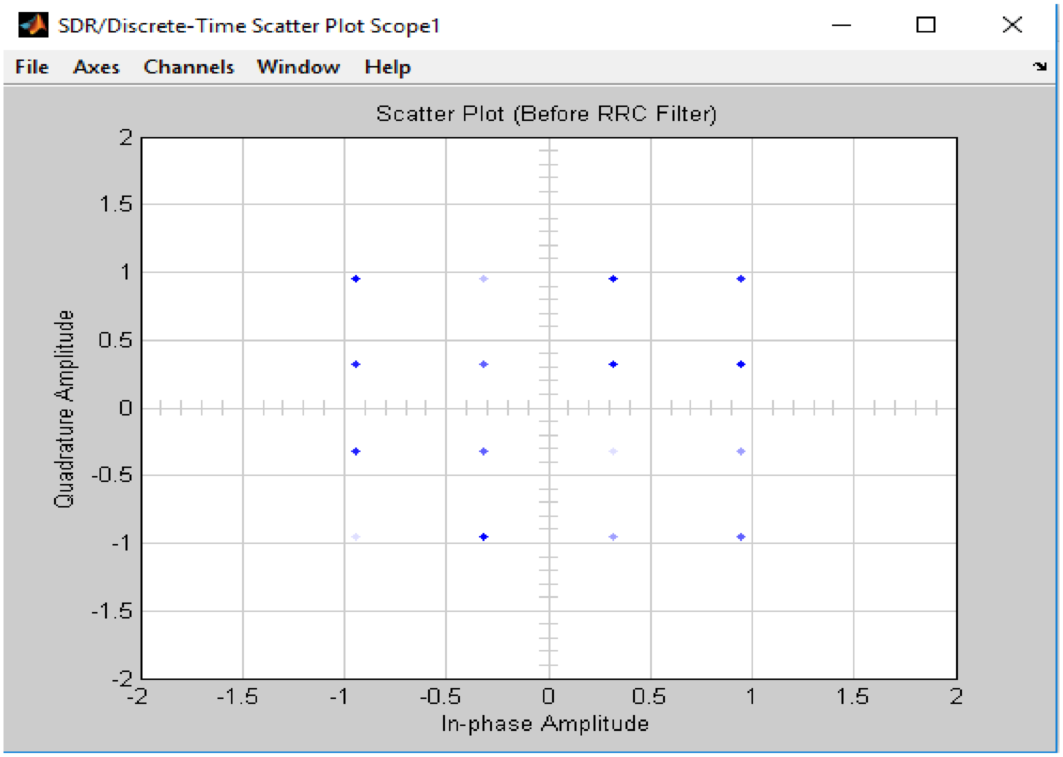


Figure 4.2: 64-QAM Constellation Diagram of Transmit Signal

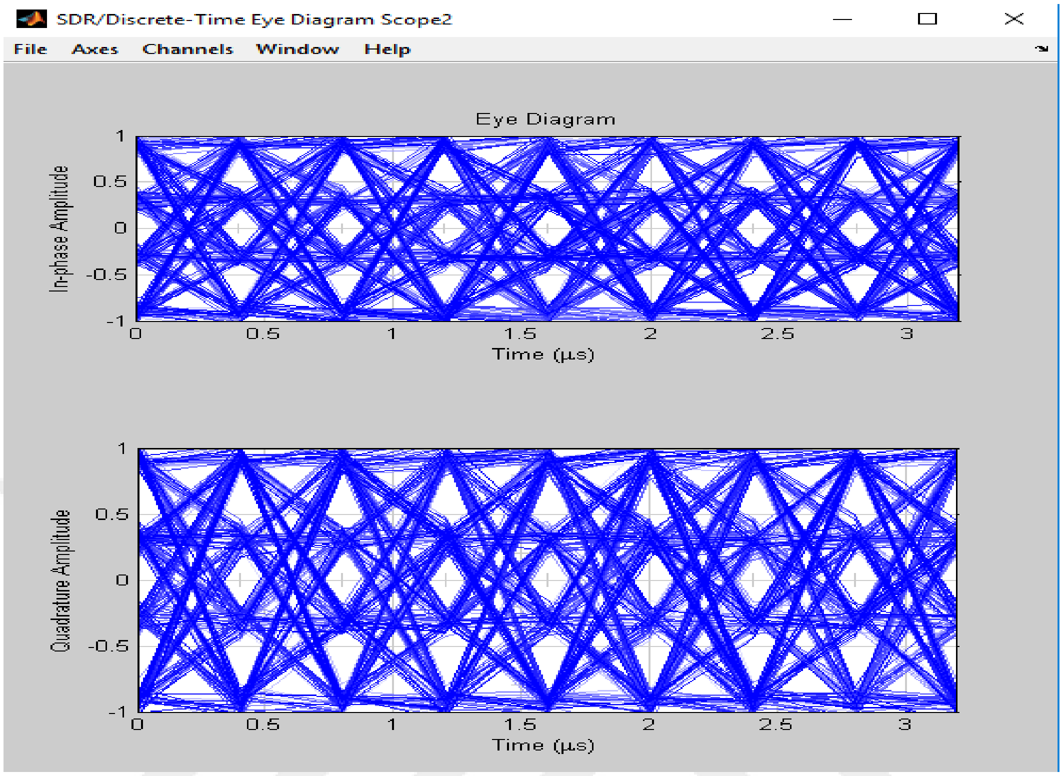


Figure 4.3: Received Eye Diagram With at 30 dB

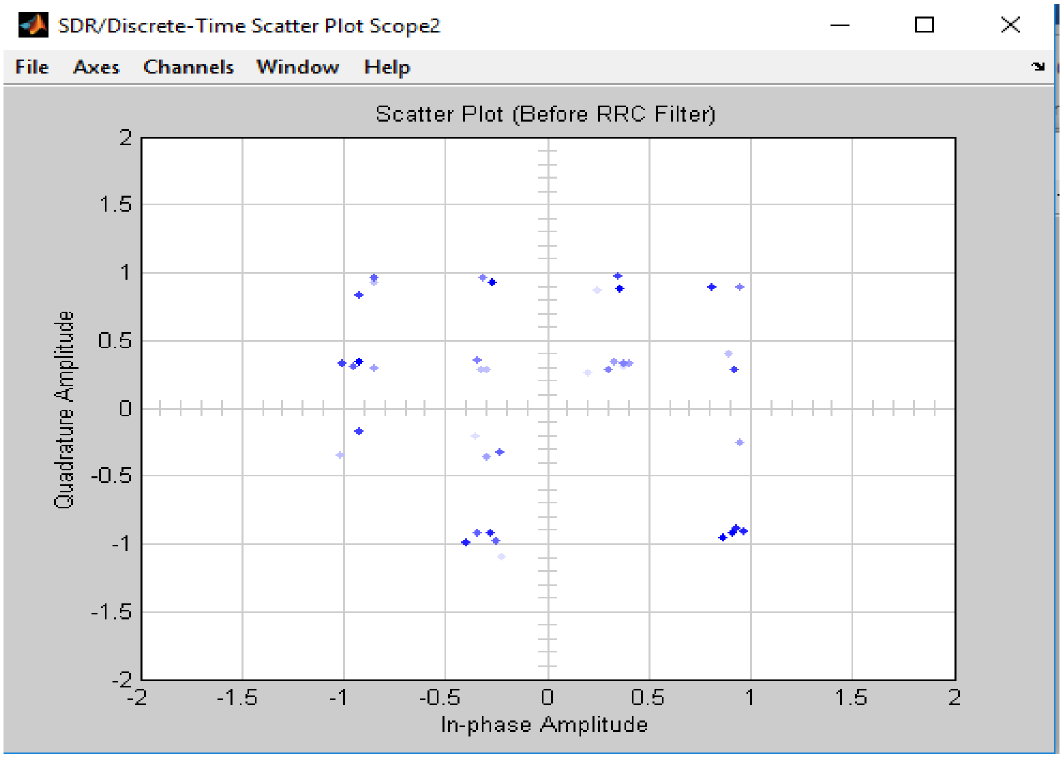


Figure 4.4: Received Signal Constellation Plot

Figure 4.3 and Figure 4.4 illustrate the eye and constellation diagrams of received waveforms.The noise associated with received signal is clearing appear with SNR of 20 dB. If the SNR increased to 30 dB, the margin of noise is start to be close out and eye diagrams become better. When the SNR decrease to 10 dB, the received eye diagrams look more distorted which is mean that the noise is proportional with SNR. Hence, less transmission error will introduce when the eye diagrams reveals less distortion as illustrated in Figure 4.3 and figure 4.4. Then, the received signals are filtered and fine gained to recover them into refine signals in the IQ channel. The final stage in the receiver part is the synchronization and down sampled process by a factor of 16 to become baseband symbol with 2.5 mega baud. The demodulated signals has compared with transmitted signals to confirm the functionality of the suggested model.

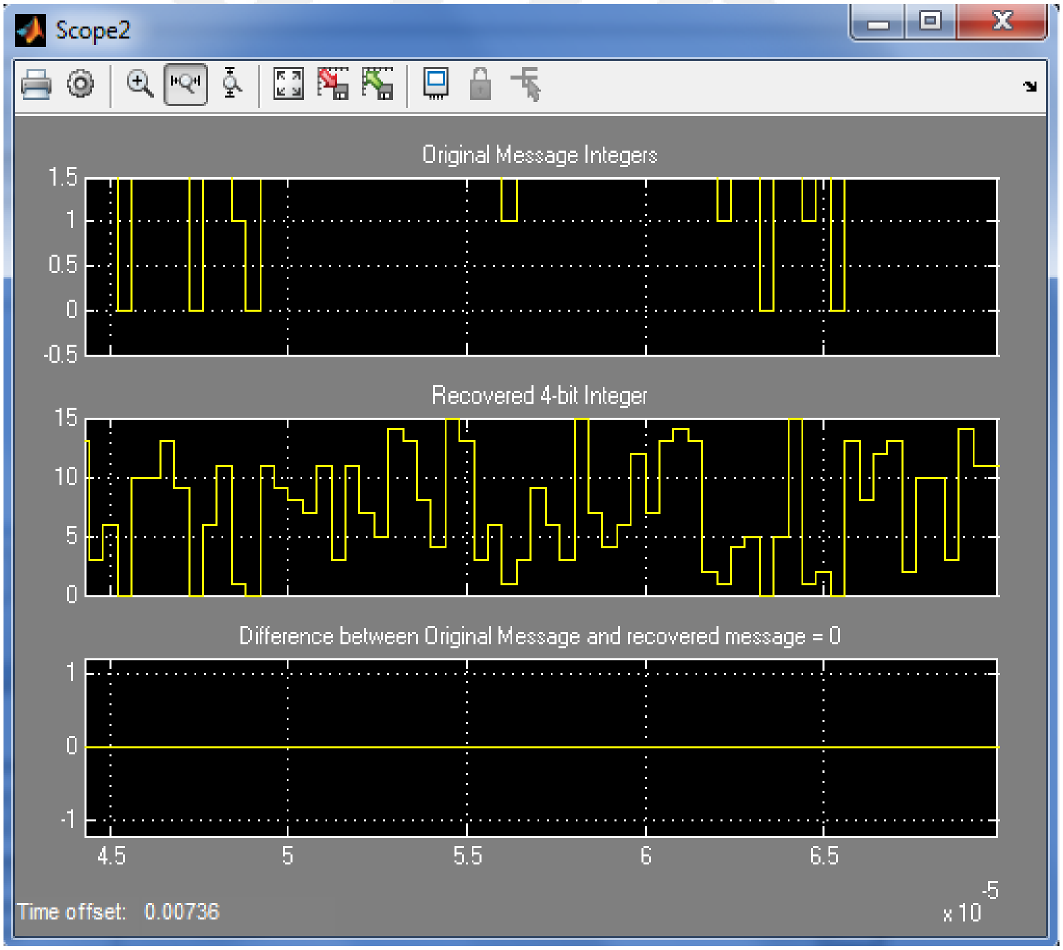


Figure 4. 5: Different Between Transmit and Received Signal

The error between transmit and received waveforms is zero due to accurate design and efficient synchronization between transmitter and receiver. Figure 4.5 shows zero difference between original waveforms and receiver output waveforms.

4.2 RESULTS DISCUSSION

The first step was done to simulate and the design SDR. by used blocks set a MATLAB SIMULINK. The results were presented, analyzed and presented at schematic drawings of the constellation and eye of modified signals and demodulation. These schemas describe the processing step of the transmitted and receiving signal in the form of a pulse and the effect of channel distortion in the system. Algorithms were chosen such that the errors are reduced while maintaining resource efficiency. The Implementation results of SDR Model show that the designed model produces minimum error between Transmit and receive signals. The use of 64-QAM scheme is better than other scheme in SDR Technology.

It has been shown that the constellation points of the receiver center point are distorted and become separate when the noise in the channel increases. As is the case, however, they are immersed clear and around the midpoint when the SNR increases. We concluded that this means with increased channel noise that the error increases.

The exact synchronization between the sender and the receiver is improved by retrieving the timing. Exemplify the important trouble for the originality of the original signal is the synchronization between the 64-QAM transmission and the 64-QAM receiver. insomuch as the arbitrary bit string is used for pseudo-noise, the generality outstanding option is to retrieve the synchronization timing. To minimize the complexity of synchronization, use this technique. That synchronization achieves the maximum likelihood from a filtered signal to finding the best time for the sample, after adjusting and expanding the important SNR. As shown in the constellation and eye schemes, the output of the receiver becomes similar to the transmitted signal schemes.

Wavelength input and output of the transmitter and receiver model. The IQ signals received and their granules are then filtered to become improved IQ signals. Then, to convert them to IQs baseband in the primary range (2.5 MB), the signals are synchronized and sampled by 16. The configuration, the recovered integer is compared from 6 bits (2.5 megabaud) with the sender's input to confirm all system functions, after demodulation. It turns out that the original message sent a 6-bit integer and received an integer 6-bit output that the difference between them is zero. The results showed that the synchronization timing of the SDR model for the transmitter and receiver met the timing qualifications of the model. In addition, optimal synchronization was achieved.

5. CONCLUSION AND SUGGESTIONS FOR FUTURE WORKS

5.1 CONCLUSION

This thesis presents the design and simulation of minimum error software defined radio model based on 64-QAM scheme. The outcome of this model is to introduce the mobile transceiver to work with any frequency band which could be tuned down to many frequency bands. The frequency spectrum problem shortage under consumption could be overcome by mean of cognitive radio in SDR core. The development of this model consider as save of amount of time in the design and testing. The 64-QAM transceiver has been successfully designed and simulated based SDR platforms. The maximum likelihood detection methods are simulated and working in appropriate way to minimize the error between transmits and received waveforms. The suggested SDR model show efficient performance to support current and future mobile generation

5.2 SUGGESTIONS FOR FUTURE WORKS

In view of the design and study of the software-defined radio model identified in the program, for future work in this area the following recommendations are proposed.

1. The SDR design can be better tuned to provide better performance with different channel effects

2. In that thesis knowledge of the software-defined radio that has been accomplished, is not totally complete. The has been implemented form the wireless communication system only in the IF and baseband steps. Further research may also focus on the overall implementation of the radio communications system in the radio specified in the program.

3. The channel is also a white Gaussian noise added only. In the configuration into carefully simulate real-life systems, Doppler shift, multipath fade, phase error, etc., for the channel can be inserted.

REFERENCES

[1] Dr. Sabah Nassir Hussein and Raghad Saad Majeed, "DESIGN AND FPGA IMPLEMENTATION OF WIRELESS BASEBAND MODEM FOR WIMAX SYSTEM BASED ON SDR", Journal of engineering and devilopment Vol.19, No. 06, November 2015.

[2] Shreevani. C, et al., " Design and Implementation of SDR Transceiver Architecture on FPGA", *INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING National Conference on Advanced Innovation in Engineering and Technology (NCAIET-2015)*

[3] Rehan Muzammil, et al., " Design and Implementation of 16-QAM Transceiver using Near-Maximum-Likelihood Detection for Software Defined Radio", symposium on computer and informatics Conference Paper pp. 159-164, March 2012

[4] G.Padmavathi, et al., " Design and Implementation of Software Defined Radio", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering *(An ISO 3297: 2007 Certified Organization)* Vol. 5, Issue 5, May 2016

[5] Vishnu. G, Karthik. P and Fathima Jabeen "VLSI Implementation of Software defined radio using Optimized Quadrature Direct Digital Frequency Synthesizer on FPGA", Second International Symposium on Computer Vision and the Internet (VisionNet'15) Procedia, Computer Science 58 : 414 – 421,2015.

[6] Divya Jain, Sandhya Gautam, Teena Sakla, "Implementation of Digital QPSK Modulator by Using VHDL/MATLAB", International Journal of Engineering and Technology, 2010.

[7] Wenmiao Song, Qiongqiong Yao, "Design and implement of QPSK modem based on FPGA", 3rd IEEE International Conference on Computer Science and Information Technology (ICCSIT),2010.

[8] Zlydareva, O.; Sacchi, C.; ―Multi-Standard WIMAX/UMTS System Framework Based on SDR‖, Aerospace Conference, 1-8 March 2008, Big Sky, Montana, USA. IEEE, pp. 1-13.

[9] Noseworthy, Joshua; Kulp, James, ―Standard Interfaces for FPGA Components‖, IEEE Military Communications Conference, 2007, MILCOM 2007 Oct, 29-31, Orlando, Florida, USA, pp. 1-5.

[10] Alluri, V.B., Heath , J.R.; Lhamon, M., ―A New Multichannel, Coherent Amplitude Modulated, Time-Division Multiplexed, Software-Defined Radio Receiver Architecture, and Field-Programmabale-Gate-Array Technology Implementation‖, IEEE Transactions on Signal Processing, VOL. 58, Issue: 10, 2010, pp. 5369-5384.

[11] Schuster, T.; Bruna, D.N.; Bougard, B.; Derudder, V.; Hoffmann, A.; Van der Perre, L., ―Subword-Parallel VLIW Architecture Exploration for Multimode Software Defined Radio‖, IEEE Workshop on Signal Processing Systems Design and Implementation, SIPS'06, 2-4 OCT 2006, Banff Park Lodge, Banff,AB, Canada. pp. 351 – 356.

[12] R. W. Stewart, L. Crockett, D. Atkinson, K. Barlee, D. Crawford, I. Chalmers, M. McLernon, and E. Sozer, "A low-cost desktop software defined radio design environment using matlab, simulink, and the rtlsdr," IEEE Communications Magazine, vol. 53, no. 9, pp. 64–71, 2015.

[13] R. W. Stewart, K. W. Barlee, D. S. Atkinson, and L. H. Crockett, Software Defined Radio using MATLAB & Simulink and the RTL-SDR. Strathclyde Academic Media, 2015.

[14] M. Sruthi, M. Abirami, A. Manikkoth, R. Gandhiraj, and K. Soman, "Low cost digital transceiver design for software defined radio using rtl-sdr," in Automation, Computing, Communication, Control and Compressed Sensing (iMac4s), 2013 International Multi-Conference on. IEEE, 2013, pp. 852–855.

[15] M. Petrova, A. Achtzehn, and P. Máhónen, "System-oriented communications engineering curriculum: teaching design concepts with sdr platforms," IEEE Communications Magazine, vol. 52, no. 5, pp. 202– 209, 2014.

[16] S. G. Bilén, A. M. Wyglinski, C. R. Anderson, T. Cooklev, C. Dietrich, B. Farhang-Boroujeny, J. V. Urbina, S. H. Edwards, and J. H. Reed, “Software-defined radio: a new paradigm for integrated curriculum delivery,” IEEE Communications Magazine, vol. 52, no. 5, pp. 184–193, 2014.

[17] S. B. Junior, V. C. de Oliveira, and G. B. Junior, “Software defined radio implementation of a qpsk modulator/demodulator in an extensive hardware platform based on fpgas xilinx zynq,” Journal of Computer Science, vol. 11, no. 4, p. 598, 2015.

[18] R. M. Ferreira, A. Shahpari, F. P. Guiomar, S. B. Amado, M. Drummond, J. D. Reis, A. N. Pinto, and A. L. Teixeira, “Hardware optimization for carrier recovery based on mth power schemes,” in Optical Fiber Communications Conference and Exhibition (OFC), 2016. IEEE, 2016, pp. 1–3.

[19] N. J. Gaurihar, I. R. Khadse, T. S. Ghonade, A. Borkar, A. Singh, and M. M. Patil, “Design and implementation of ldpc codes and turbo codes using fpga,” 2016.

[20] D. Kuswidiastuti, S. Suwadi, T. Suryani, and D. Elvia, “Implementation and performance analysis of convolution codeon warp (wireless open access research platform),” JAVA Journal of Electrical and Electronics Engineering, vol. 13, no. 1, 2016.

[21] Shen, D.H., Chien-Meen Hwang, Lusignan, B.B. and Wooley, B.A. ―A 900-MHz RF Front-End with Integrated Discrete-Time Filtering.‖ IEEE Journal of Solid-State Circuits. 31.12 (December 1996): 1945-1954.

[22] Staszewski, R.B., Muhammad, K., Leipold, D., Chih-Ming Hung, Yo-Chuol Ho, Wallberg, J.L., Fernando, C., Maggio, K., Staszewski, R., Jung, T., Jinseok Koh, John, S., Irene Yuanying Deng, Sarda, V., Moreira-Tamayo, O., Mayega, V., Katz, R., Friedman, O., Eliezer, O.E., de-Obaldia, E. and Balsara, P.T. ―All-Digital TX Frequency Synthesizer and Discrete-Time Receiver for Bluetooth Radio in 130-nm CMOS.‖ IEEE Journal of Solid-State Circuits. 39.12 (December 2004): 2278-2291.

[23] A. G. Konshina, P. V. Dubovskii, and R. G. Efremov, “Structure and Dynamics of Cardiotoxins,” *Curr. Protein Pept. Sci.*, vol. 13, no. 6, pp. 570–584, 2012.

[24] J. Melorose, R. Perroy, and S. Careas, “Studies in Software-Defined Radio System Implementation,” *Statew. Agric. L. Use Baseline 2015*, vol. 8, no. 33, pp. 1–40, 2015.

[25] A. Løfaldli, “Design of ground station receiver for Kongsberg Satellite Services based on Software Defined Radio,” *NTNU Nor. Univ. Sci. Technol.*, vol. 1159, p. 46, 2016.

[26] J. M. Urrea, “Software Defined Radio Design for an Ieee 802.11a Transceiver Using Open Source Software Communications Architecture (Sca) Implementation::Embedded (Ossie).,” *Public Policy*, no. Mar, p. 89, 2006.

[27] Roberto Airoldi, “Design and Implementation of Software Defined Radios on a Homogeneous Multi- Processor Architecture,” *Tampere Univ. Technol.*, vol. 1136, p. 54, 2013.

[28] David A. Clendenen, “A Software defined Radio Testbed for Research in Dynamic Spectrum Access,” *Purdue Univ.*, vol. 13, no. May, pp. 1–67, 2012.

[29] D. Björklund, “Implementation of a Software-Defined Radio Transceiver on High-Speed Digitizer/Generator SDR14,” *Linköpings Univ.*, vol. 581, p. 96, 2012.

[30] N. D. Gadkari, “Development of a Nanosatellite Software Defined Radio Communications System in Partial Fulfillment of the Requirements for the,” *TORONTO, ONTARIO*, no. May, p. 112, 2015.

[31] D.-I. M. Grimm, “Dirty RF Signal Processing for Mitigation of Receiver Front-end Non-linearity Dissertation,” *Ilmenau*, vol. 13, p. 220, 2013.

[32] M. E. Nelson, P. H. Jones, J. Basart, and B. K. Hornbuckle, “Implementation and evaluation of a software defined radio based radiometer,” *Iowa State Univ.*, vol. 15053, p. 109, 2016.

[33] K. Watermeyer, “Design of a hardware platform for narrow-band Software Defined Radio applications,” *Forum Am. Bar Assoc.*, vol. 23, no. January, pp. 1–104, 2007.

[34] Y. Lin, “Realizing Software Defined Radio–A Study in Designing Mobile Supercomputers,” *Design*, p. 164, 2008.

[36] Zhang, H., Li, L., Wu, K. “ 24 GHz software-defined radar system for automotive applications”, *Proceeding in European Conference on Wireless Technologies*, Munich, Germany, pp.138–141, 2007 .

[37] Jayaseelan Marimuthu, K.S. Bialkowski and A. Abbosh, “Software-Defined Radar for Medical Imaging,” *IEEE Trans. Microwave Theory and Techn.* vol. 64, no. 2, pp. 643-652, Feb. 2016.

[38] A. S. K. Vasudevan, B. S. R C., and Z. C. Alex, “Software Defined Radio Implementation (With simulation & analysis),” *Int. J. Comput. Appl.*, vol. 4, no. 8, August, pp. 21–27, 2010.

[39] G. Padmavathi, M. Chaarmeli, A. Brrindha, and A. M. Jayasri, “Design and Implementation of Software,” *Int. J. Adv. Res. Electr. Electron. Instrum. Eng.*, vol. 5, no. 5,May, pp. 4387–4392, 2016.

[40] J. M. Nuñez Ortuño and C. Mascareñas Pérez-Iñigo, “Software Defined Radio (Sdr) on Radiocommunications Teaching,” *INTED2016 Proc.*, vol. 1, pp. 1094–1100, 2016.

[41] N. M. Zawawi, M. F. Ain, S. I. S. Hassan, M. A. Zakariya, C. Y. Hui, and R. Hussin, “Implementing WCDMA digital up converter in FPGA,” in *2008 IEEE International RF and Microwave Conference*, 2008, pp. 91–95.

[42] S. Mahboob, “FPGA Implementation ofDigital Up/Down Convertor for WCDMA System,” *Advanced Communication Technology (ICACT), 2010 The 12th International Conference on, Volume: 1*, 2010. .

[43] M. O. S. Omara, “Efficient design of Dual Digital Up Converter for WCDMA and CDMA2000 using system generator,” *Proc. - 2013 Int. Conf. Comput. Electr. Electron. Eng. ’Research Makes a Differ. ICCEEE 2013*, pp. 140–143, 2013.

[44] H C Sirnivasaiah Shivaraj Sajjan, “IMPLEMENTATION OF DIGITAL UP-DOWN CONVERTOR FOR WCDMA SYSTEMS,” *International Journal of Ethics in Engineering & Management Education 2348-4748, Volume 1, Issue 5, May2014*, 2014. .

[45] M. R. G. Swathi, “Design of a Multi-Standard DUC Based FIR Filter Using VLSI Architecture,” *International Journal of Scientific Engineering and Research (IJSER)*, 2015. .

[46] X. Cai, M. Zhou, and X. Huang, “Model-Based Design for Software Defined Radio on an FPGA,” *IEEE Access*, vol. 5, pp. 8276–8283, 2017.

[47] B. D. Rami Akeela, “Software-defined Radios: Architecture, State-of-the-art, and Challenges,” *INTERNET OF THINGS RESEARCH LAB, DEPARTMENT OF COMPUTER ENGINEERING, SANTA CLARA UNIVERSITY, USA — MARCH 2018*, 2018.

[48] M. W. Al-dulaimi, “Minimum Error Design of Software Defined Radio Transceiver Model Using MATLAB MATLAB kullanan minimum hata yazılımı tanımlı radyo (SDR) al ıcı - verici modelinin tasarımı ve simülasyonu,” *AURUM J. Eng. Syst. Archit.*, vol. 2, no. 2, pp. 1–12, 2019.