Implementation of OFDM System Using Software Defined Radio

A Dissertation Submitted in Partial Fulfillment of the Requirement for the Award of the Degree of

MASTER OF ENGINEERING

in

Wireless Communication

Submitted By

Pritpal Kaur

801563019

Under Supervision of

Dr. Hem Dutt Joshi

Assistant Professor, ECED

ELECTRONICS AND COMMUNICATION ENGINEERING DEPARTMENT

THAPAR UNIVERSITY, PATIALA, PUNJAB

JULY, 2017

DECLARATION

I, Pritpal Kaur hereby declare that the work presented in this thesis entitled "Implementation of OFDM system using Software Defined Radio" in partial fulfillment of the requirement for the award of degree of Master of Engineering in Wireless Communication submitted at Electronics and Communication Engineering Department, Thapar University, Patiala is an authentic record of work carried out by me under the supervision of Dr. Hem Dutt Joshi (Assistant Professor, ECED, Thapar University) from 2015 to 2017. The matter presented in this thesis has not been submitted either in part or full to any other university or institute for the award of any other degree.

Date: 14/sep/17

Pritpal

(Pritpal Kaur)

(801563019)

It is certified that the above statement made by the candidate is correct to the best of knowledge and belief.

Date: 14/sep/17

Joshi

(Dr. Hem Dutt Joshi)

(Assistant Professor)

Scanned by CamScanner

ACKNOWLEDGEMENT

First and foremost, thanks are due to God-the most merciful and most-beneficent to whom I relate any success in achieving any work in my life.

It gives me the greatest pleasure to express my deepest-attitude and warmest-thanks to Dr. Hem Dutt Joshi, Assistant Professor, Electronics and Communications Department, Thapar University, Patiala, for kind supervision, patient guidance and valuable suggestions and support-throughout this report. I am truly very fortunate to have the opportunity to work with him. I found this guidance to be extremely-valuable.

I am also thankful to Dr. Alpana Agarwal, Head of ECED &Program Coordinator Dr. Ashutosh Kumar Singh. I would like to thank entire faculty members and staff of Electronics and Communication Engineering Department who devoted their valuable time and helped me in all possible ways towards successful completion of this work. I am also grateful to all the friends and colleagues who supported me throughout. I thank all those who have contributed directly or indirectly to this work.

Last but not least, I would like to thank my parents for their years of unyielding love and for constant support and encouragement. They have always wanted the best for me and I admire their determination and sacrifice.

ABSTRACT

As the technologies grow quickly and the devices and computers become cost-effective and powerful, tracks of research seam to allow a group of new researchers the chance to use and perform experiments on the technologies that were only available to a few people. This is the scenario for wireless communications system technologies.

Now-a-days, computers are being used for the signal processing tasks which were previously done by dedicated devices. Inexpensive computers which we use in our day-to-day lives at home are capable of doing the important computation that these dedicated devices are performing. Software Defined Radio (SDR) is similar to this kind of stuff.

The transformation of the signal processing over some dedicated device into software run by a common PC opens up great potentials at very reasonable price. With the help of the SDR, we can now examine and modify every value of the given communication system.

By doing research on this topic, command on both wireless communication systems and SDR can be gained. With this objective in my mind, I tried to implement the wireless communication system. Because of the enormous advantages of OFDM (Orthogonal Frequency Division Multiplexing), it was selected for implementation. The purpose of this is to analyze the performance of orthogonal frequency division multiplexing using C700 platform of software defined radio. In this paper focused on image transmission in OFDM and test that image using software defined radio (C700 platform). In this paper considers the different aspects specific to the image as data and also provides essential steps to address them. Comparison of different modulation schemes according to the parameters of SNR, BER, percent error of pixels (received image) between the transmitted and received image of the proposed system.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

OFDM	*Orthogonal Frequency Division Multiplexing*
SDR	*Software Defined Radio*
DSL	*Digital Subscriber Line*
LTE	*Long term evolution*
ISI	*Inter symbol Interference*
ICI	*Inter carrier Interference*
PAPR	*Peak to average power ratio*
TC-OFDM	*Turbo code orthogonal frequency division multiplexing*
BPSK	*Binary phase shift keying*
QPSK	*Quadratre phase shift keying*
QAM	*Quadrature amplitude modulation*
MATLAB	*Matrix Laboratory*
ETSI	*European Telecommunication Standard Institute's*
BER	*Bit error rate*

CHAPTER 1

INTRODUCTION

Nowadays, rapid advancements in wireless technologies are in demand, necessitating the design of smaller and more sophisticated technologies that support a wide range of standards. A Software Defined Radio is a very financial and economic solution that provides highly reconfigurable platform. Coping to the challenging task of multimodal standard processing and adaptability to future technologies like LTE is a core function of these designs [1]. Due to this advantage these platforms show a great scope not only in upcoming industrial arena but also for future academic advancements.

Day by day demand for broadband access is increasing at a fast rate, and at the same time is not limited to areas that already have an existing high quality infrastructure. For instance, developing countries and rural areas may not have the existing telecom infrastructure or the existing connections, typically over copper, to meet the requirements of Digital Subscriber Line (DSL) technology.

Even, it is expected that users will require more bandwidth on the move. While current technologies can meet this demand, the useful range is limited. This limitation opens up opportunities for technologies such as Orthogonal Frequency Division Multiplexing.

The main ambition of most upcoming wireless communications techniques is to get highest results in the given bandwidth with minimum amount of errors. Orthogonal Frequency Division Multiplexing (OFDM) is a very often applied modulation approach. A high speed continuous data stream is divided into more parallel ones which can be slower. These slower data streams serve as input data source for parallel modulators. The modulator output is summed and the superposition of the modulated signals is transmitted. The realization of modulation is performed in the frequency domain and the principal of the Fourier transform is utilized. This modulation approach is utilized very often these days. We can find it in Wi-Fi systems, in the system for terrestrial Digital Video Broadcasting, LTE and others [2]

1.1 OFDM

OFDM is a parallel transmission system in which complex data is transmitted on multiple orthogonal carrier frequencies. Therefore, it is also known as digital multi-carrier modulation scheme. In this system, the data is carried by closely spaced orthogonal sub-carriers.

OFDM works on the basic principle of dividing of a high rate stream of data into streams of lower rate that are to be transmitted over a number of sub-carriers cumulatively. Now, with the increase in the duration that a symbol takes for parallel subcarriers having lower rate, the rate of dispersion caused in the time domain goes down. Inter symbol interference is effectively removed by including guard time in all such symbols [3].

1.1.1 OFDM Advantages

a) Immunity to selective fading: it bears resistance to frequency selective fading than any single carrier system do, because it splits the entire channel into various signals of a narrowband that get affected individually as flat fading sub-channels.Resilience to interference: Interference appears only in a limited span of bandwidth and thus protecting other sub-channels. Thus the chances of losing all the data and information are ruled out [4].

b) Spectrum efficiency: Efficient use of the available spectrum is a very crucial advantage of the OFDM systems as they utilize close- spaced overlapping subcarriers

c) Resilient to “INTER SYMBOL INTERFERENCE”: The low data rate on each of the sub-channel leads to a high magnitude of resiliency to inter-symbol and inter-frame interference [4].

1.1.2 OFDM Disadvantages:

(a) High peak to average power ratio: An OFDM signal has comparatively high PAPR than single carrier communication system. This affects the RF amplifier efficiency

(b) Sensitive to carrier offset and drift: carrier frequency offset and drift have an impact on the OFDM whereas single carrier frequencies show less sensitivity [4].

1.1.3 Limitations of OFDM:

Understated are the few limitations that an OFDM may offer:

1. Exhibition of a very high „Peak to Average Power Ratio‟(PAPR**)**

2. High degree of sensitivity to frequency errors (Transmitter & Receiver offset**)**

3. There is an Inter carrier Interference (ICI) that prevails between the subcarriers

1.1.4 Applications of OFDM

I. OFDM is a technique, used in many digital communication systems like:

1. Digital Television (DTV)

2. Digital Audio Broadcasting (DAB)

3. Terrestrial Digital Video Broadcasting (DVB-T)

4. Digital Subscriber Line (DSL)

5. Broadband Internet Access

6. Standards -Wireless local area networks (WLANs)

7. Standards-Wireless metropolitan area networks (WMANs)

8. Communications via mobile [6].

II OFDM designs and skills are used in:

1. American National Standards Institute's (ANSI)
2. Asymmetric Digital Subscriber Line (ADSL)
3. High-bit-rate Digital Subscriber Line (HDSL), and
4. Very-high-speed Digital Subscriber Line (VDSL) standards and in the European Telecommunication Standard Institute's (ETSI)

1.2 Software Defined Radio

1.2.1 Definition

SDR is a concept which has come in limelight since the last decade of the twentieth century. The ambition of Software Defined Radio is to develop a system which can be used to work with multiple radios functioning at various parameters. Not only this but also it can regulate to any array and any other modulation design by using a prevailing software along with programmable hardware.

C700 is a modular SDR (Software Defined Radio) platform. It allows system designers and researchers to build their own test beds in a practical way which employing a variety of standard modules that comprise all functionalities required to architect a communication system.

SDR is a class of reconfigurable, reprogrammable and upgradable radios whose physical layer characteristics can be significantly modified via software changes. Another definition for Software Defined Radio is to combine both hard and soft system techniques and render the whole system much more flexible and convenient for wireless infrastructure [10] .SDR helps to construct a method for resourceful and safe elucidation to the crisis of edifying multimode, multiband and multi functional wireless communication devices.

1.2.2 COMPONENTS OF SDR

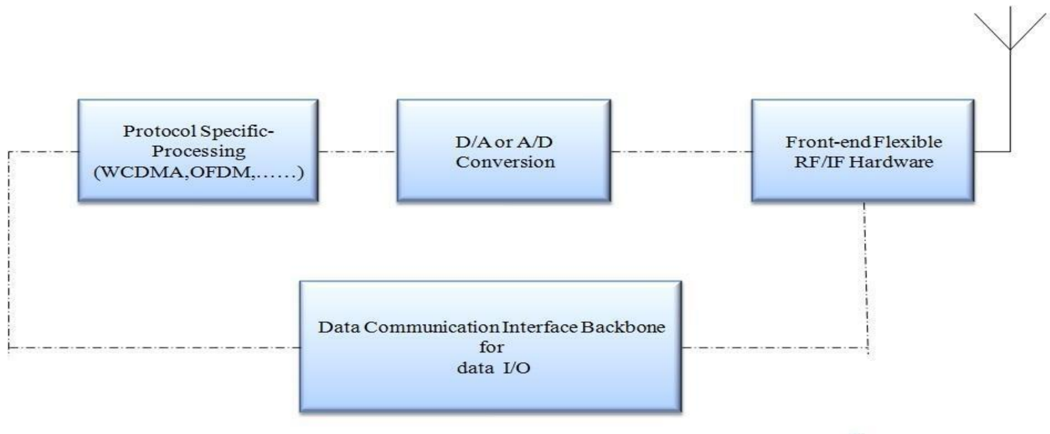


Figure 1.1 SDR Components [7]

1.2.3 C700 Applications

In Research and Education of:

1. Multichannel applications like MIMO , massive MIMO, and other wireless technologies
2. FMCW and similar Radars
3. UWB applications
4. Laboratory Vector Signal Generator/Analyzer
5. Wireless researches for Life science, medical, bio etc.
6. Radio Monitoring
7. Radio positioning and Localization
8. DPD (Digital pre-distortion) Researches
9. Multi-channel phase coherent; Direction Finders, Passive Radars
10. Phased array antenna measurements and study

11. Ad-hoc Networks
12. Several other complex radio systems
13. Passive RADAR
14. Production and ATE(Automatic Test Equipment)

1.2.4 Advantages of SDR

1. It has variety of high speed PC interfaces.
2. Internal processing power.
3. Lower price for primitive applications.
4. It has high performance.
5. Measurement capabilities.
6. Cost effective

1.2.5 Disadvantages of SDR

1. Lack of versatility.
2. Limited RF end performance.
3. In adequate phase coherence capabilities(MIMO, Passive RADAR)
4. Complex set up for multichannel applications.
5. It is not primarily designed for education purposes.
6. Time consuming and daunting in some applications.

1.3 STRUCTURE OF THESIS

The thesis is prepared as stated below: -

In chapter 1 it provides an insight to all the topics those are related to the research work. Then, gives the advantages and disadvantages, limitations, applications of OFDM and software defined radio. In chapter 2 it provides the Literature review. In this chapter, various literature work done by some dedicated researchers is discussed and some of Gaps in the study and thesis objectives that have been discussed in end of the chapter 2. In chapter 3 it provides the detailed study of OFDM system modeling. In chapter 4 it provides deep study of hardware modules of C700 software defined radio. Also include specifications of each module. In chapter 5 it provides a deep study of the software used for the thesis is done. It includes complete experimental set up of C700 platform and PC has been demonstrated in this chapter. In the chapter 6 results have been included in this chapter. Results based on the image transmission with the help of C700 are included in this chapter 5. Chapter7 includes the conclusion and Future scope points have been provided in the chapter. The lists of references are given at the end of the thesis.

CHAPTER 2

LITERATURE REVIEW

For commencing the thesis work, first of all we require to thoroughly examine different research documents provided by the courtesy of other research fellows. By studying the research papers, we can have an idea of what work has been done. Papers related to this work are selected and studied. Researched papers are described below:

J. Mitola (1992) [8] discuss that a software radio is a set of DSP based system consists of different blocks of communications systems like transmitter, channel model, receiver on a software platform. It includes a set of processors on which the software radio is hosted for real-time communications. The paper also compared the enabling hardware technologies to software radio requirements. The proposed applications of Software Radio are music, packet radio, telemetry and HD TV.

S. Venkatachalam et al. [9] dropped the research on, "Implementation of Orthogonal Frequency Division Multiplexing (OFDM) using Software Definable Radio (SDR) Platform", which displayed the fundamental concepts related to Software Defined Radio structural design was discussed. It also discusses the brief introduction of OFDM that is in communication done by wireless techniques. In this also discuss the various techniques for combat the inter symbol interference (ISI) that is a very habitual hindrance in wireless connections and communications. This research paper merely focuses on the achievement of OFDM transmitter in Software Radio.

N. Praba et al. [10] proposed the image transmission in OFDM using various modulation techniques (BPSK, QPSK, 16-PSK, 256PSK) is analyzed. In this paper channel is modeled using AWGN and amplitude clipping also introduced in the communication channel. Evaluation of different parameter of transmission such as BER, percentage noise of pixilated between the transmitted and acknowledged image is done to characterize performance of the system.

Snehal C.Mane and S.R. Chougule in [11] presented the image transmission over coded OFDM system with Low Density Parity Check Coding (LDPC) using SDR. They also discuss several techniques to eliminate the PAPR in OFDM system.

Ms. A K Jesna [12] presented the OFDM system model for transmitter and receiver. The source image at the transmitter coded to the binary format. Before transmitting through the AWGN channel, PAPR reduction techniques introduced in between the OFDM transmitter and OFDM receiver. Modulation techniques such as BPSK, QPSK and QAM are also discussed in this paper.

C Anjana et al. [13] proposed a method for the reduction of error rate and in this method used the channel estimation and synchronization techniques with the implementation of GNU radio. The BER plot of OFDM system was observed with channel estimation and without channel estimation. There was an improvement in the plot which used channel estimation and synchronization and channel equalization.

Hen-Geul Yeh et al. [14] display a Software Radio (SDR) system for wireless communication was also discussed. An example of Adaptable orthogonal frequency division multiplexing (OFDM) transceivers with respect to standards like IEEE 802.11 is also considered. For simplicity in OFDM baseband transceivers are implemented in to two equipped modes, they are BPSK and QPSK. The performance comparison between these straight loop method and loop method and also offered orthogonal frequency division multiplexing length against clock cycles (speed).

Ali el Moussati et al. [15] discuss the concept of the design and execution of wireless Turbo Code OFDM (TC-OFDM) on the Small Form Factor (SFF) based SDR provided by Texas Instruments. They have also shown simulation results and done performance analysis over AWGN and Rayleigh fading channel. They have shown that both ISI and ICI can be resolved using turbo codes. The overhead associated due to CP can also be decreased by these codes.

Arief Marwanto et al. [16] offered research in a multinational meet titled, "Experimental Study of OFDM Implementation Utilizing GNU Radio and USRP - SDR". The research paper here examines the feasibility via GNU Radio, the Universal Software Radio Peripheral (USRP) and an open source SDR implementation and also discuss the SDR hardware platform and also explain the two modulation techniques QPSK and BPSK in which OFDM radio signal is use to transmit and receive using software defined radio(SDR). Quality of Service (QOS) based on PRR has been investigated and analyzed.

Ryota Yoshizawa et al. [17] illustrated few obstacles and difficulties that may occur while using OFDM systems such as high PAPR naturally affects the power of the (PA) or power amplifier by reducing it. For addressing this trouble, various PAPR reduction techniques such as clipping and filtering (CAF) has been considered as the simplest method while it imposes severe nonlinear in-band distortion. In this paper also investigate the distortion less PAPR reduction methods s that is selected mapping (SLM) and trellis shaping (TS).

Brian Kelley [18] describes the different challenges of new generations in broadband SDR. The major dispute for upcoming generation software radio is to keep the system flexible while similarly, sustaining efficient algorithm for broadband communication and ease of programming. In this paper he focused mainly on OFDM transmitter and receiver styles due to their bandwidth scalability and their popularity.

Pallavi Sharma and Ameeta Seehra [19] present the transmission and reception of image over Rayleigh fading channel. In this paper grey level image has been transmitted using different system. They have used MIMO system with Alamouti coding. Comparison has been done in terms of image performance metrics on the basis of quality of images such as Quality index (Q-Index) and PSNR (Peak Signal to Noise Ratio).

S. N. Kulkarni and J.A. Desai [20] examine and evaluate the Bit Error Rate in occurrence of noises such as gaussian noise, rayleigh noise and rician noise. Main ambition of several communication system is to receive data with minimum errors. These errors reduce the performance of system. In this research paper focuses on the outcome of unlike type of noises in QPSK and 16 QAM modulation schemes under AWGN channel. The results obtained from the simulink models are used for the transmission of an image.

Naglaa F.Soliman et al. [21] proposed continuous picture broadcasting in excess of Coded OFDM with LDPC coding. In this paper, for improvising the outcome and efficiency of the OFDM systems, the researcher has utilized Trigonometric transformations. This scheme also affects the magnitude negatively, the PAPR that comes in the OFDM signals. It reduces the error resilience over AWGN channel. They have used SPIHT algorithm for the purpose of source coding of the data to be transmitted.

Joaquin Garcia et al. [22] discussed various wireless communication standards as IEEE standard 802.11, IEEE standard 802.16, Multi Carrier-CDMA, Digital Video Broadcasting (DVB), Wireless

USB etc. We know that Mitola brought the idea of "Software Defined Radio" that includes complete configurable DSP as Fast Fourier Transform; as a result Field programmable gate array has the ability to foster its multiple operations. In his research he brings out an FPGA execution, designing along with validation of an "Orthogonal Frequency Division Multiplexing" modulator of IEEE standard 802.11 a using a high level design tool.

CHAPTER 3

OFDM SYSTEM MODEL

Continually increasing requirement of this generation for higher rate of communication, higher mobility, and higher carrier frequency has turn out to be an extreme precedence. A variety of modulation techniques like multicarrier modulation that has increased in sort to meet up these demands, they are CDMA and OFDM. The idea of OFDM started back in 1966 [23].

The idea of Orthogonal Frequency Division Multiplexing was initially introduced in the 50"s. In the middle of 60s; some researchers introduced this idea in the papers. OFDM signaling was developed again and used in some military HF (High Frequency) radio communication systems and high speed modems[24] [25]. However in this field it cannot significantly develop. CCITT standards for fast speed modems they are based on transmission of a single carrier. Afterward they projected it for digital mobile systems [26] to lighten the equalization problem in channelization, boost up the robustness adjacent to the impulse noise.

3.1 The principle of OFDM transmission

It is a multicarrier transmission technique. In this technique, it divides the bandwidth into numerous carriers, each of carriers modulated by means of low rate data stream. OFDM is a frequency division multiplexing with orthogonal carrier. The various user access techniques are accomplished by subdividing the obtainable bandwidth into several channels. Then that are owed to the available client [23]. Many of the communication standards have accepted an OFDM as major scheme for modulation or say that technique for data transmission [27].

3.2 MODELLING OF OFDM

3.2.1 Transmitter Model

a) OFDM Frames:

Core of the OFDM source is the OFDM modulator; it modulates the source information stream frame by frame. The information would be modulated at once and it would not be divided in to frames, when the entire number of symbols in a information streams that is transmitted is smaller than the total of symbols transmitted per frame.

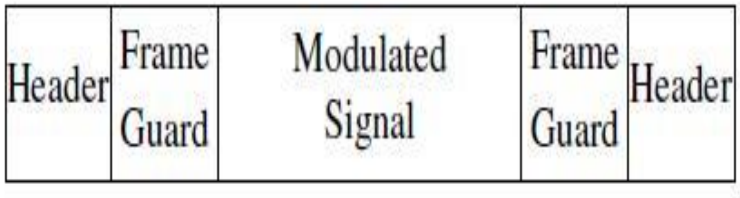


Figure 3.1 Modulated Signal (Single frames) [28]

Figure 3.1, shows that the two frame guards with all zero values and in a length of one symbol period are added to the both ends of the modulated time signal, when the data stream is not sufficiently long to be divided into multiple frames [28]

Figure 3.2 Modulated Signal (Multiple frames) [28]

Figure 3.2, shows that frame guard is inserted in among two neighboring frames and among mutual ends of the cascaded time signal. Couple of headers is padded to each end of the guard sequence of the frames.

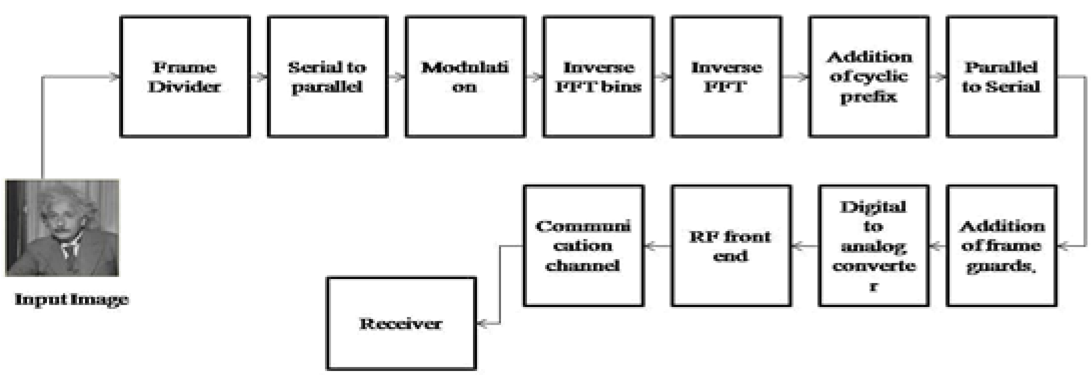


Figure 3.3 Block Diagram for OFDM transmission scheme [28]

b) OFDM Modulator

It is obvious that the amount of transmitting information is not equal to the number of the sub-carriers. For the conversion of the input information stream from serially toward parallels, the modulator have to be padded a number of zeros to the last part of the information stream. The information stream will fit into a 2-Dimentional matrix. A piece of column in the 2-Dimentional matrix corresponds to a carrier and each row corresponds to one symbol period.

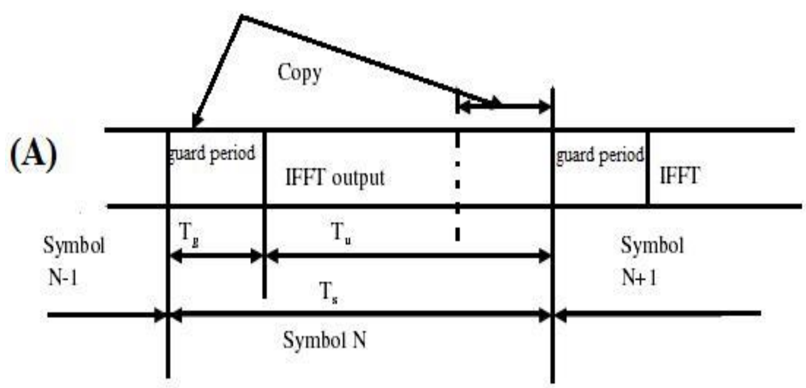
c) Inverse FFT:

Every line of column, the matrix signifies a carrier and values are accumulated to the columns of the Inverse FFT matrix where their resultant carriers have to remain. Their conjugate values are accumulating to the columns similar to the place of the conjugate carrier [29]. Alternative columns in the Inverse FFT matrix are situating to be zero.

To get the sending time signal matrix, IFFT of this matrix is taken. Only the real element of the Inverse FFT result is beneficial, the imaginary element is rejected.

d) Periodic Time Guard Insertion

As demodulating every symbol period of the acknowledged signal. The matrix after this can be called as modulated matrix. After converting this data into serial mode, a modulated time signal for one frame of data is generated.



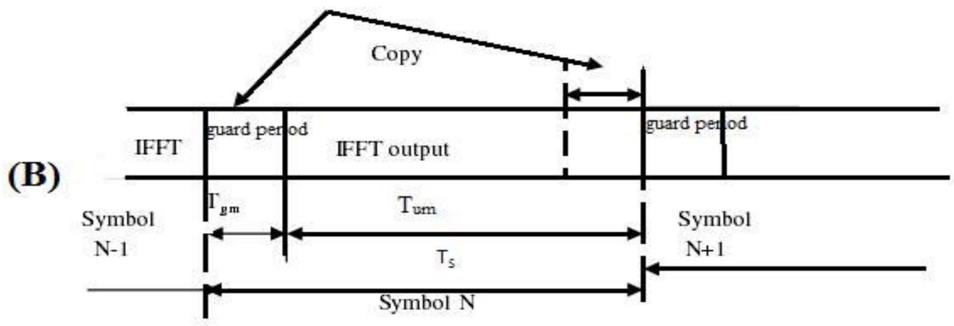


Figure 3.4 Time domain representation of conventional OFDM signal [29]

Figure (A) shows that, the guard periods fixes during all the frame of the data file of the image. Figure (B) it represents the time domain illustration of the new guard period where $T_g \geq T_{gm}$ and $T_u \geq T_{gm}$

- Communication Channel

AWGN channel has been considered in this study. The variance of noise σ is given as

$$\sigma = \frac{\sqrt{\text{Variance of the modulated signal}}}{\text{Linear SNR}} \qquad (3.1)$$

It has zero mean and standard deviation of AWGN channel equivalent to the square root of the variance of the modulated signal to the linear SNR (Signal to Noise ratio). Communication channel has two properties:

1. A variable clipping which is set by the user in MATLAB program.
2. Peak Power Clipping: - The Peak to Root Mean Square is the ratio of the transmitted signal before and after the channel [30].

3.2.2 Receiver Model

a) OFDM Demodulator:

At receiver, reverse process of modulator is performed. It demodulates the received data frame by frame unless the transmitted data has less number of symbols per frame [29].

b) Periodic Time Guard Removal:

A frame of discrete time signal converting from serial to parallel, a length of 25% of a symbol period is discarded from all rows. Thus the remaining is then a number of discrete signals. These discrete signals have the length of one symbol period and they are lined up in parallel.

c) FFT Time Signal to Spectral Space

Fast Fourier Transform (FFT) of the received time signal is taken. This results the spectrum of the received signal. The columns in the locations of carriers are extracted to retrieve the complex matrix of the received data.

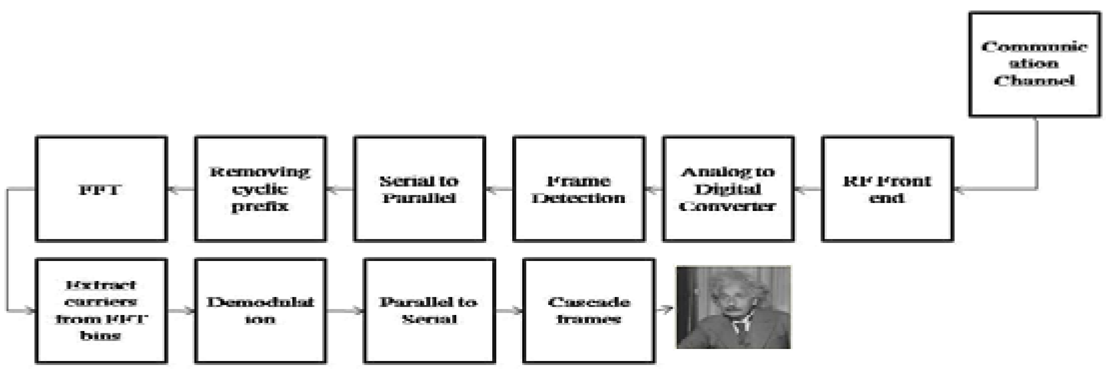


Figure 3.5 Block Diagram for OFDM reception scheme [29]

d) Demodulation:

The phase of each part in the complex matrix is converted into 0 to 360^0 and translates to one of the values within the symbol size. The differential operation is performing parallel on this new matrix to get back the demodulated information. This differential process manipulates the distinction between each two successive symbols in a column of the matrix.

At the end reference row is removed. To conclude the parallel to serial procedure is complete and demodulated information for frame is obtained.

CHAPTER 4

SOFTWARE DEFINED RADIO SYSTEM ARCHITECTURE

In this chapter we study the hardware modules of software defined radio. Also we include specifications of each module. With the help of C700 architecture, general purpose radio test bench can be implemented.

4.1 C700 System Architecture:

The C700 has designed in such a way so that it can be used to fulfill research needs and also as a basic platform to understand SDR. Its specifications are very efficient and best in education industry with small form factor and can be utilized as standalone product. Its architecture is divided in two module basic and innovative module as shown in Fig.4

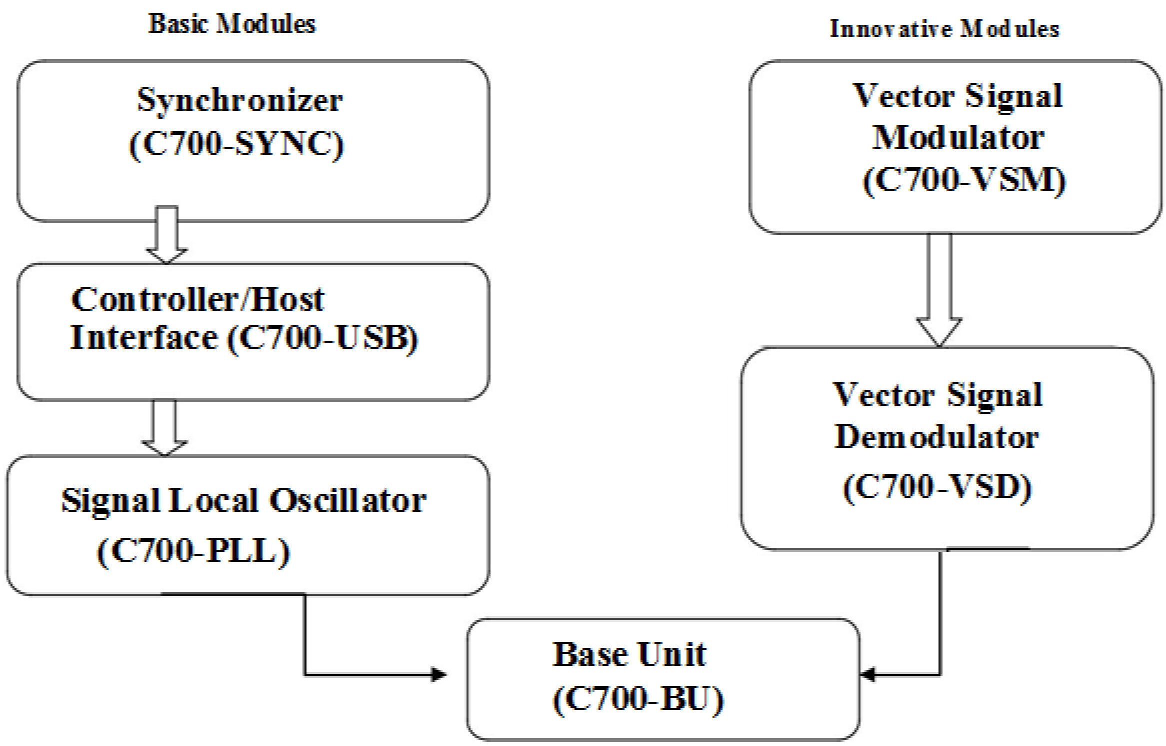


Figure 4.1 C700 Architecture [8]

1. C700 BASE UNIT(BU)

I. Mechanical fixation

II. Power management

III. Data communication, Synchronization

IV. LVDS(Low voltage differential signaling) signaling technique

V. Input power is 9 to 18 $V\ dc$

VI. Bus DC output is $+5V, +3.3V$

VII. System clock is 50 MHz

VIII. Within single chassis Bus speed is $700\ M\ bit/sec$

IX. Slots are 5 , 8 , 16 and 32 slots

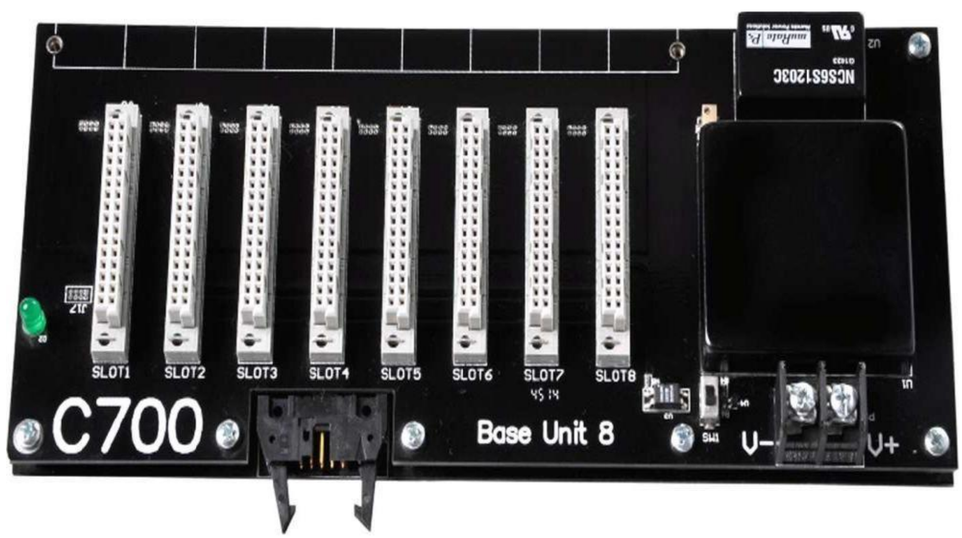


Figure 4.2 Base units [8]

2. C700 Basic module structure

Every C700 module comprises two detachable boards,

a) The system board: Controls system modules and it provides the internal communications.

b) The functional board: - It performs the following modules operation. Each module has its own FPGA (Altera EP3C10E144C7N)

i) FPGA handles the internal system communications & other user codes for data handling and processing.

ii) Modules H/W design is available as an open-source for alteration and reuse.

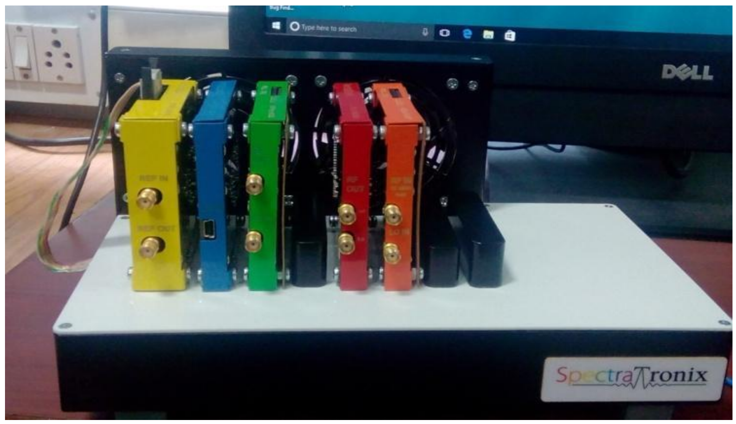


Figure 4.3 C700 platform

I. Synchronizer C700-SYNC

Clock, Timing, and internal system reference oscillator to synchronize multiple devices.

1) A 50 MHz reference clock for all modules of sdr.

2) High stable Internal reference OCXO is $< 1 \times 10 - 7$

3) External reference input and reference output:- 10 MHz

Figure 4.4 C700-SYNC

II. C700 Control Modules

C700-USB2 it controls the system by an external host.

Figure 4.5 C700- USB2

III. Local Oscillator C700-PLLx

1) High stable RF local oscillators
2) Reference frequency stability is $1 \times 10 - 7$
3) 0.1 to 6 GHz and Optional up to 18 GHz and $1GHz/ms$ Sweep Rate
4) 2 × LO(local oscillator) outputs
5) Phase noise is $-107\ dBc$
6) Switching time is 0.25 ms

Figure 4.6 C700-PLLx

3. C700 Innovative Modules

I. Vector Signal Modulator C700-VSM

1) It is RF Vector Signal Modulator/Generator
2) $0.4\ to\ 6\ GHz$
3) $37\ to\ -7\ dBm$:-RF Output Power
4) Real time bandwidth is $40\ MHz$
5) IQ resolution is $16\ bit$
6) Frequency Resolution is $1Hz$
7) Switching speed is $10\ \mu s$ within $320\ MHz$
8) Local oscillator input for phase coherent applications.

Figure 4.7 C700- VSM

II. Vector Signal Demodulator C700-VSD

1. RF Vector Signal Demodulator/Receiver and digitizer
2. $0.4\ to\ 6\ GHz$
3. Real time bandwidth is $40\ MHZ$
4. IQ resolution is $16\ bit$
5. frequency Resolution is $1 Hz$
6. Switching speed is $10\ us$ within $320\ MHz$
7. Level Accuracy should be $< 0.5 dB$ Typically $0.2 dB$
8. Image rejection is $> 40 dB$ and optional for $80 dB$
9. Local oscillator input for phase coherent applications

Figure 4.8 C700 –VSD

4.2 C700 System Specifications

Table 4.1 C700 Specifications [8]

Number of Modules Per Chassis	5,8,16 or 32
Frequency ranges	$10MHz\ to\ 18GHz$ It depends on the configuration
Frequency Accuracy	$1 * 10^{\wedge} - 7$
IQ Resolution	$16\ bits$
IQ Bandwidth(Real Time)	$40MHz$ for Transmitter and $40MHz$ for Receiver
Sampling Speed	50MSps
Phase Noise	$-107\ dBc$ ($1\ GHz$ for Carrier, $10\ KHz$ for Carrier Offset, 1 Hz for Measurement Bandwidth)
Level Accuracy	$< 0.5\ dB$ Transmitter and Receiver
Output Power	Refer to optional amplifier
RX Sensitivity	Refer to optional LNA's
Image Rejection	$> 40\ dB$ and optional for 80 dB

CHAPTER 5

OFDM SYSTEM IMPLEMENTATION USING SOFTWARE DEFINED RADIO

The system can be fully programmed and controlled right from design tool or system level simulation environment of choice. In addition a multitude of programming languages like VHDL, C, MATLAB and many others. These ideas could be implemented with the help of some sort of software and hardware. As the MATLAB software and C700 SDR kit was available in the research lab, so I decided to use this approach. For this approach the following hardware and software tools were required:

5.1. System Specifications

5.1.1 Software Specifications:

1. Processor Intel Core i3, Central Processing Unit 1.80 GHz
2. Random Access Memory-4 GHz
3. $64bit$ operating system
4. Supports Altera & Xilinx FPGAs & tools
5. Integrates with your design environment of choice: MATLAB (R2015a), Lab VIEW, G NU Radio etc
6. Install C700-USB2 driver: USB driver
7. C700 SDR general code for Transmitter and Receiver

5.1.2 Hardware Specifications:

Table 5.1 Hardware Specification [32]

Module	Description
C700-Orchestra	System chassis for 8 slot-base unit
C700-BU08	8 slot-base unit, 700 $Mbps$ bus speed, 50 MHz clock

C700-SYNCH1	C700 Synchronization module including the Synch cable
C700-USB2	USB2 communication module (system controller)
C700-PLL1e	System local oscillator module, 100 MHz 6 GHz 2 LO outputs, < -107 dBcphase noise @1 GHz, 10 KHz offset
C700-VSM1	Vector signal generator/modulator, 400 MHz 6GHz, 40MHz @ 16 bitresolution.
C700-VSD2	Vector signal receiver/demodulator and digitizer, 0.4 to 6 GHz, 40 MHz @ 16bit resolution.
C700-CAP	Dummy caps for communication bypass
Connection cables	1x USB Mini-B cable, 3x SMA (m-m) Cables.
Power Adapter	12dc AC/DC adapter

- RF Specification (Generator/Transmitter modules)

Table 5.2 Transmitter Specification [33]

Phase noise	$< -107dBc, 10\ KHz\ from\ 1\ GHz$ carrier
Amplitude accuracy	$< 0.5\ dB$ (Typical 0.2 dB)
Switching time	$< 10\ us$ (Within $\pm$ 160 MHz from LO frequency)
RF output power	$-37\ dBm\ to\ -7\ dBm\ over\ range -87\ dBm\ -7\ dBm$ (Optional amplifiers/attenuators available)

- RF Specification (Demodulator/Receiver modules)

Table 5.3 Receiver Specification [33]

Max. RF input level	$\leq 12\ dBm$
SFDR	$>\ 7\ 0\ dB$
Sensitivity	$< -90\ dBm$ (Optional low noise amplifiers available)
Amplitude accuracy	$< 0.5\ dB$ (Typical 0.2 dB)
Image rejection	$> 40\ dB$ (Optional 80 dB Refer to UDC modules specifications)

5.1.3 C700-FAN (System Fan Unit)

Figure 5.1 Fan Socket (Point A) [32]

Figure 5.2 C700-BU Sockets (Point B) [32]

5.1.4 C700 SDR Front Panel

Figure 5.3 C700 Front panel

5.1.5 C700 SDR LEDs Modules

When Initialize C700 System by turning it ON, notice that blue LED is flashing.
LEDs indication is mentioned in the following table:

Table 5.4 LED Status

LED	COLOR	STATUS
D1	Red	Powering ON
D2	Green	Sending
D3	Blue	Clock
D4	Green	Receiving

5.2 SYSTEM IMPLEMENTATION

The OFDM system implementation was done with the help of MATLAB and C700 SDR kit. OFDM system implementation was experimented in MATLAB and also codes were written for C700 SDR for transmitter and receiver section. USB2 drivers in the host PC were added and the module addresses of C700 had been set.

C700 SDR Experiment Set: Module Addresses of C700

VSM1='232F';

PLL1='12F';

VSD2='43F';

System Parameters:

Table 5.5 System parameter

Parameters	Values
Input Image Size	256×256(8-bit gray scale)
Inverse FFT size	64
Carriers	30
Modulation	BPSK,QPSK,QAM
Peak - Power -Clipping	9dB
Signal -To -Noise Ratio	5dB,15dB,30dB

5.3 C700 SDR Block diagram

The transmission and reception path of C700 SDR kit is shown in the figure 5.4

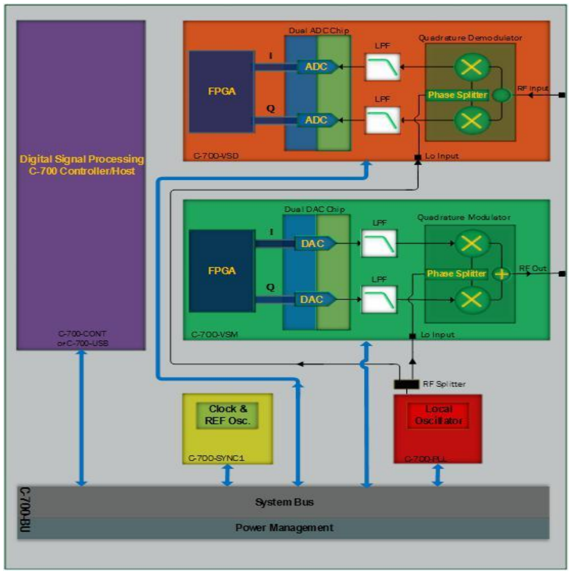


Figure 5.4 C700 logical structure 1TX path & 1RX path [32]

5.4 THE HOST PC WITH THE KIT-"INTERFACING"

Before installing the software for the functioning of C700 SDR, we need to install Matlab R2013 (a). After installing the MATLAB software, USB Drivers must be installed and added into the directory of the current MATLAB folder.

1. Mount C700-SYNC in the first slots, and mount other modules each one in any slot position.

2. C700-BU provides modules with data connection through a ring topology, so mount a bypass-cap in any non-used slots.

3. Connect C700-BU with its 12 supply, and turn it on.

4. Connect C700-USB2 to your PC using a USB cable.

5. Connect C700-SYNC to its synchronization cable.

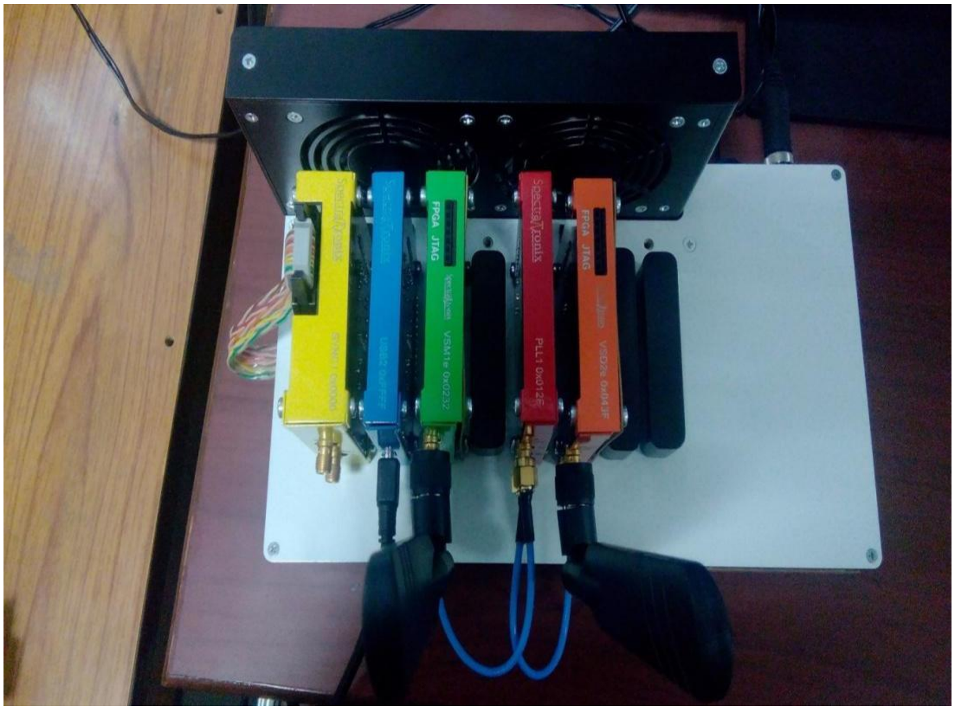


Figure 5.5 Connections of C700 Modules

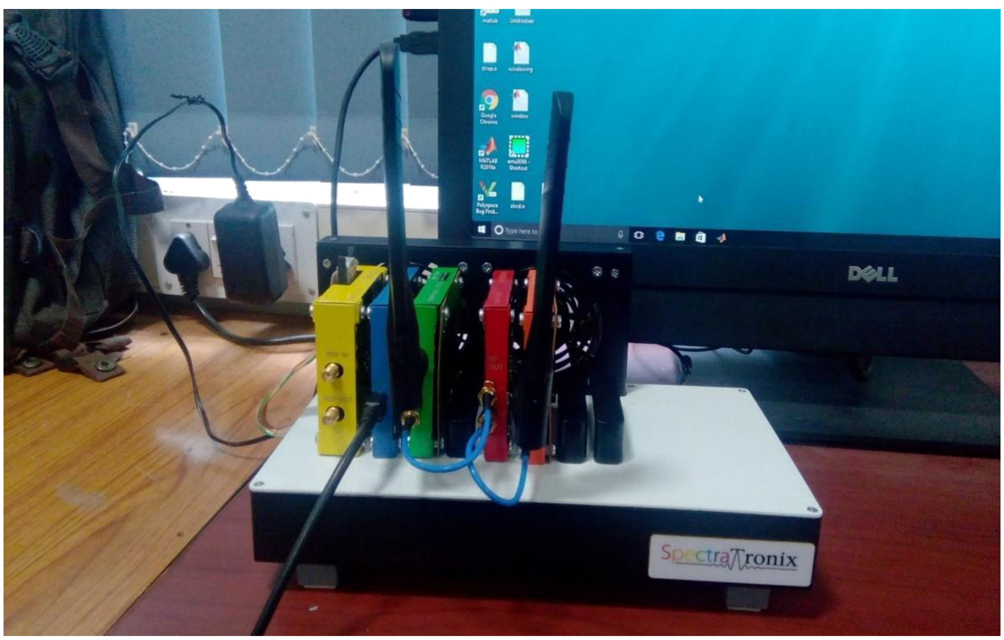


Figure 5.6 Connections of Front Panel

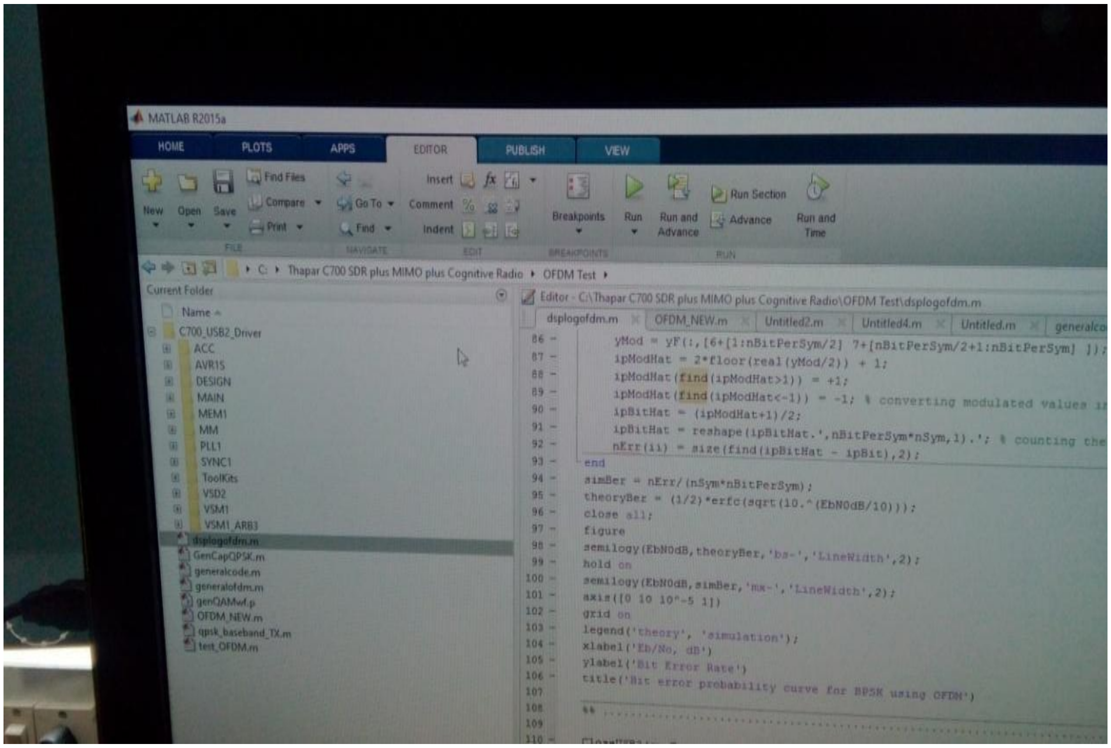


Figure 5.7 Installations of USB2 Drivers into MATLAB

6. Install C700-USB2 driver

7. Write a general MATLAB code of C700 SDR into transmitter and receiver side.

8. Using MATLAB, extract the compressed file“C700_USB2_Driver” in to the root directory of the current Matlab folder.

9. Select C700 modules according to your required prototype, tests bed or application.

10. Turn ON the programming switch, all the C700 LEDs begin flashing.

5.5 SYSTEM IMPLEMENTATION ON C700

To implement the system on the C700 software defined radio platform, we needed an interface between the hardware and the host computer. The OFDM system model was designed in Matlab and the USB2 driver software was installed for the interfacing with the hardware.

After all the steps, open MATLAB software. Now click on “Launch MATLAB.” MATLAB window will open. Now, add the USB2 drivers into the directory. The files of OFDM code and drivers both are added in the same directory of the MATLAB software.

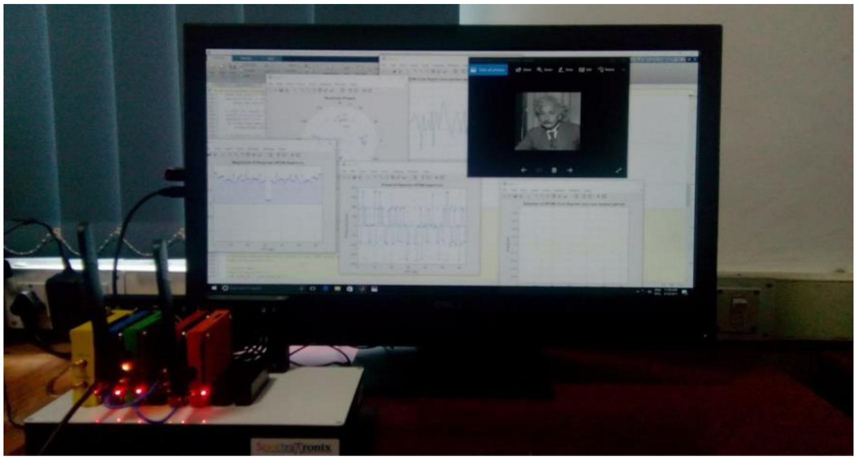


Figure 5.8 Complete Running setup of C700 platform

After setting up the connections and installing drivers, write the general MATLAB code of C700 software defined radio into OFDM transmitter and receiver side. Then turn ON the programming switch and click on the run button into the MATLAB software.

After that C700 LEDs will begin flashing. LED status is given below:

A. When red led is flashing, the status of the system is powering “ON” stage.
B. When green led is flashing, the data is being sent to the receiver.
C. When blue led is flashing, the status is showing “clock stage”.
D. When green led is flashing, the data is being received by the transmitter.

CHAPTER 6

RESULTS AND DISCUSSIONS

This chapter presents the results obtained by simulating and implementing the OFDM system into C700 SDR platform.

In the initial steps, the OFDM system was designed and the MATLAB code for image transmission for transmitter and receiver side was written. The whole system was designed along with the transmitter and receiver section. And also coding was written for transmitter and receiver section in terms of C700 SDR

6.1 OFDM Simulation using SDR with the configuration:

- INPUT IMAGE:

Input image is obtained, where ‘h’ stands for height of the image and ‘w’ stands for the width of image that is the form of matrix h by w. The width of image is in pixels. Then h by w matrix is reorganizing into a continuous data stream. The input image is 8 bit gray scale image, whose dimension is 256×256 and its word size is 8 bits per word. The input information will be then transformed in to the symbol size equivalent to the series of modulation. That modulation order is chosen by the user.

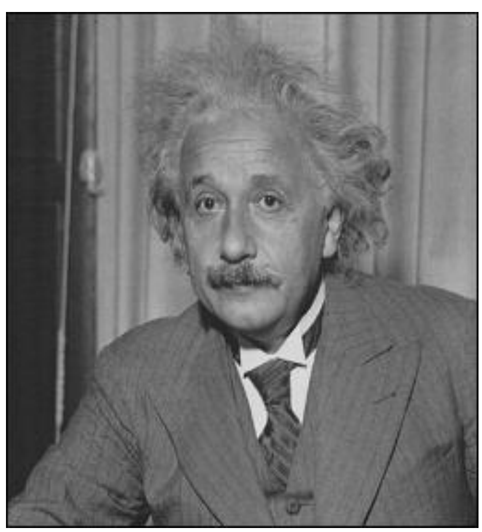


Figure 6.1 Original image

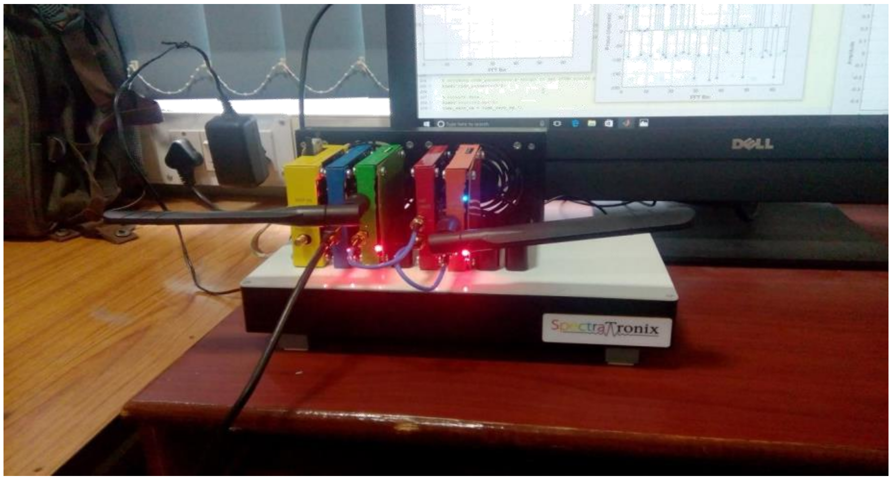


Figure 6.2 OFDM Simulation using C700

- Transmitter parameters

Table 6.1 Transmitter parameters of Modulation

Parameters	Values
Inverse FFT Size	64
Carriers	30
Modulation	BPSK,QPSK
Peak -Power -Clipping	9 dB
Signal-To-Noise Ratio	5-15 dB

Some graphs are plotted during the simulation:

- Transmitter plots/Modulation:

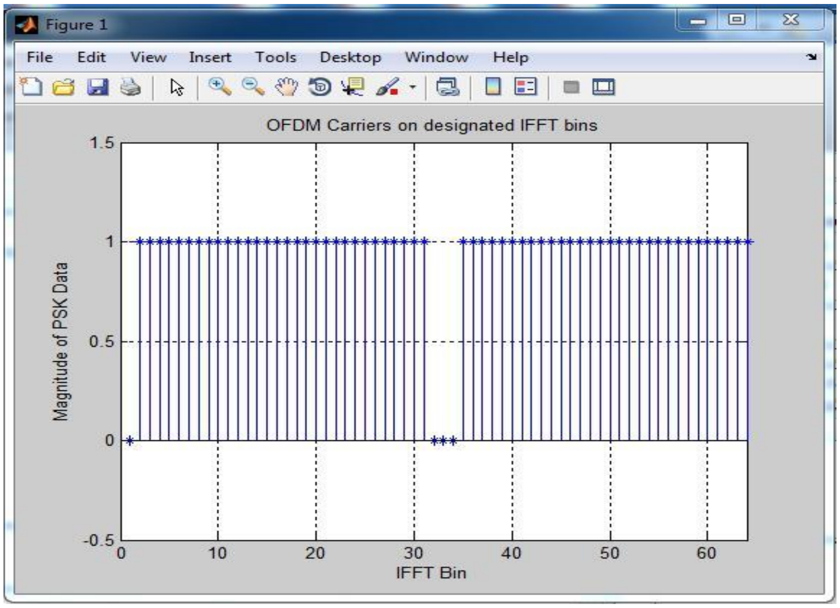


Figure 6.3 Magnitudes of OFDM carrier data on Inverse FFT bins

Figure 6.3 decides how the carriers and conjugate carriers are allocated into Inverse FFT bins, which is based on the size of Inverse FFT and the carriers, that are inserted by manually to the client.

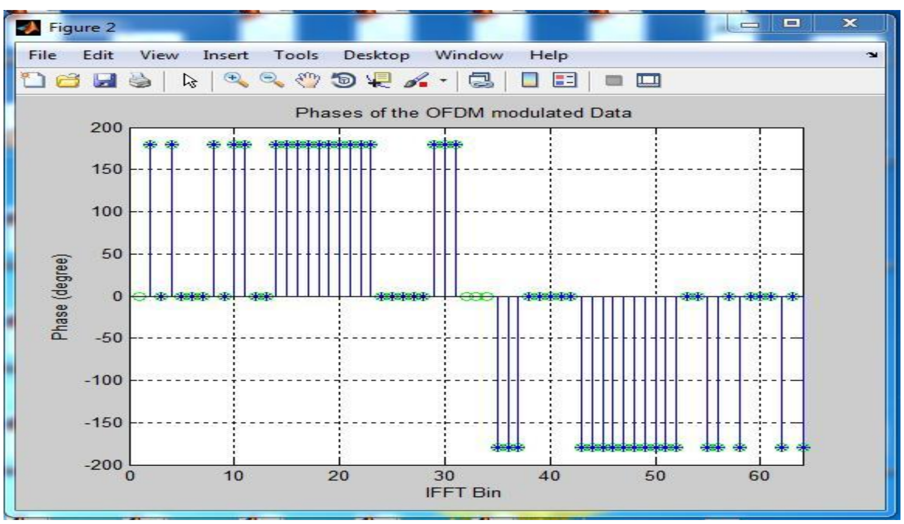


Figure 6.4 Phases translate from the data of OFDM

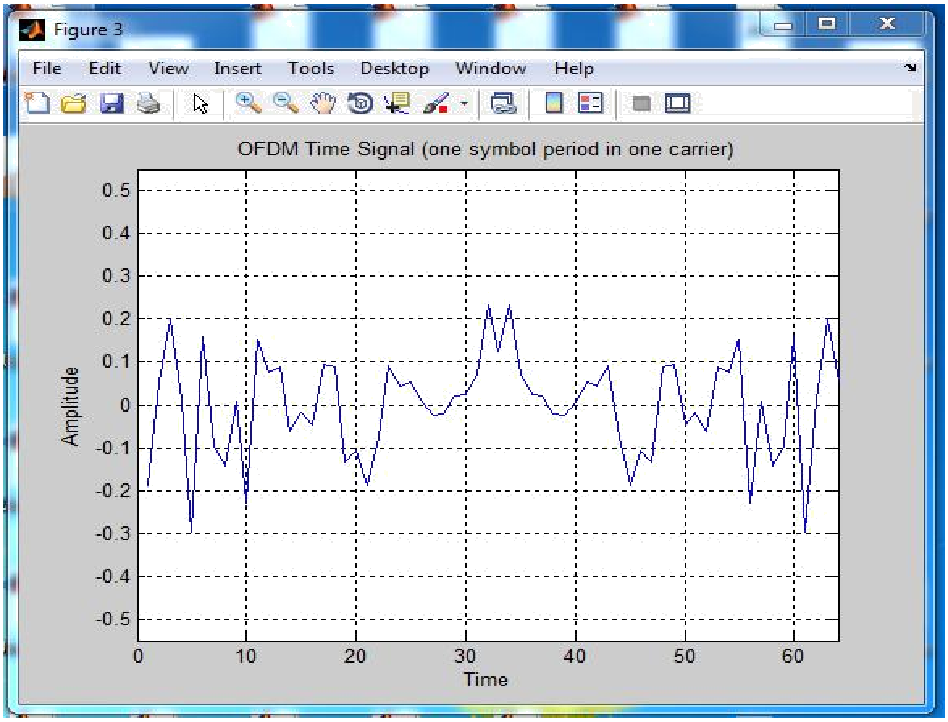


Figure 6.5 Modulated time signals for one carrier in one symbol period

Figure 6.4, 6.5 shows that the primary symbol period in the first data of frame.

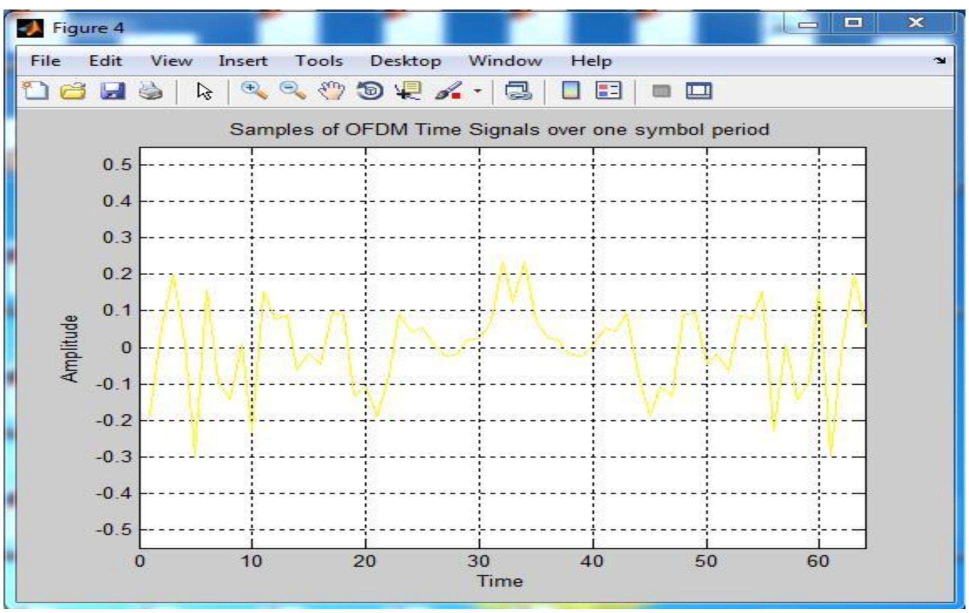


Figure 6.6 Modulated time signals for multiple carriers in one symbol period

Figure 6.5 shows the initial six symbol periods in the first frame.

- Receiver plots/Demodulation:

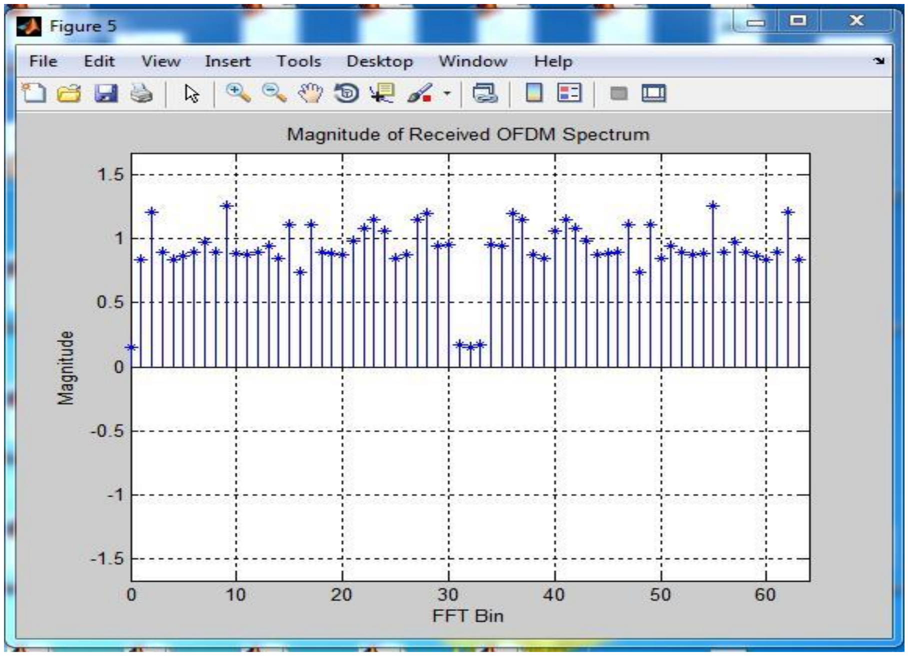


Figure 6.7 Magnitudes of the received spectrum of OFDM

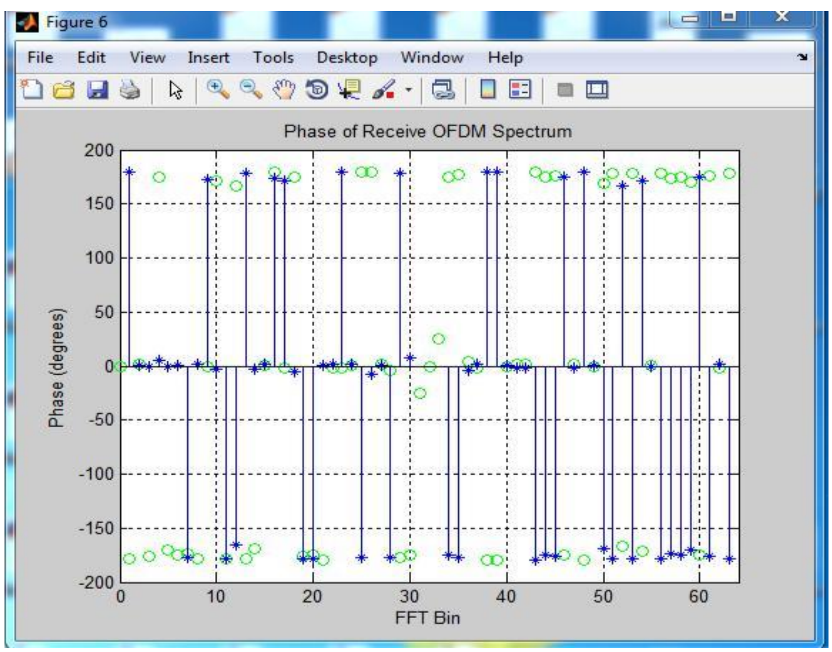


Figure 6.8 Phases of the received spectrum of OFDM

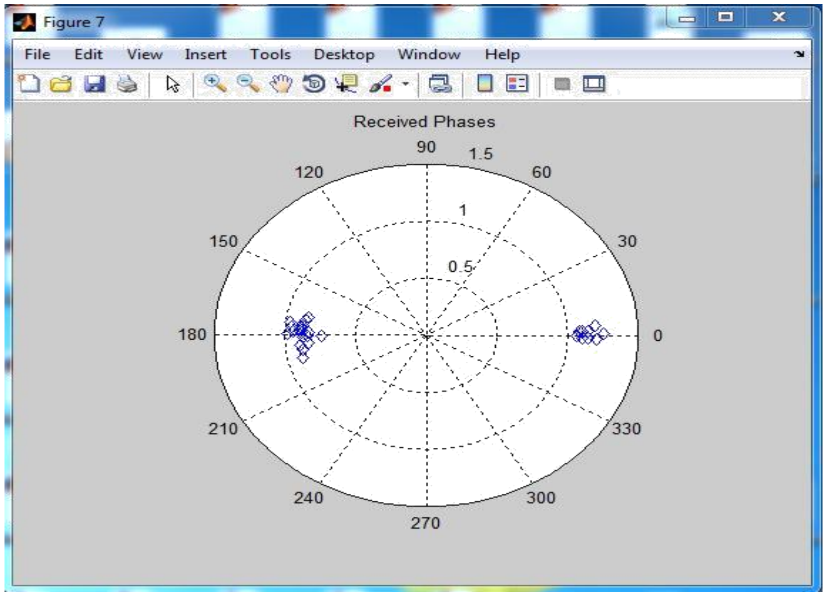


Figure 6.9 Polar plots of the received phases

However the figure 6.2 and final figures of the received data have superior possibility of getting inaccuracy due to erroneousness in the synchronization. A successful OFDM communication and response, in these plots display the sorting of phases that are received. Here, below shown the innovative image and the acknowledged images for different orders of modulations with different signal to noise ratio.

6.2 Performance of different modulation scheme

- For 5dB SNR

Table 6.2 Comparison of different modulations for 5dB SNR

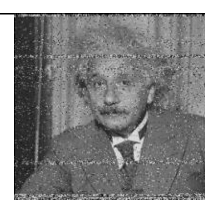
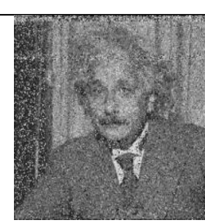
Modulation	SNR	BER	Received Image
BPSK	5dB	6.280%	
QPSK	5dB	24.50%	

Table 6.3 Average phase error for 5 dB

Modulation	SNR	Average Phase Error
BPSK	5dB	33.503(degree)
QPSK	5dB	33.586(degree)

Table 6.4 % Error of pixels for 5dB

Modulation	SNR	% Error of Pixels
BPSK	5dB	27.632%
QPSK	5dB	64.961%

- For 10dB SNR

Table 6.5 Comparison of different modulations for 10dB SNR

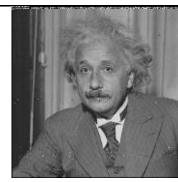
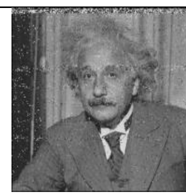
Modulation	SNR	BER	Received Image
BPSK	10dB	0.699%	
QPSK	10dB	6.2686%	

Table 6.6 Average phase error for 10 dB

Modulation	SNR	Average Phase Error
BPSK	10dB	16.018(degree)
QPSK	10dB	19.1985(degree)

Table 6.7 % Error of pixels for 10 dB

Modulation	SNR	% Error of Pixels
BPSK	10dB	1.739%
QPSK	10dB	17.3553%

- For 15dB

Table 6.8 Comparison of different modulations for 15dB SNR

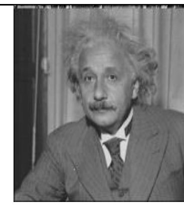
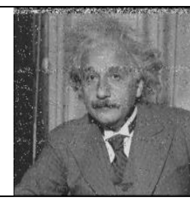
Modulation	SNR	BER	Received Image
BPSK	15dB	0.6137%	
QPSK	15dB	2.2895%	

Table 6.9 Average phase error for 15dB

Modulation	SNR	Average Phase Error
BPSK	15dB	9.344(degree)
QPSK	15dB	13.074(degree)

Table 6.10 % Error of pixels for 15dB

Modulation	SNR	% error of pixels
BPSK	15dB	1.2664%
QPSK	15dB	4.0603%

From the given result in tables shows the comparison of different modulation schemes with different signal to noise ratio. The BPSK, QPSK modulation techniques are used to transmit image using software defined radio. The same image is transmitted using BPSK, QPSK by using the different values of Signal to Noise Ratio (SNR). It can be seen that lesser the value of SNR, content of noise is more and quality of image is bad. For extremely noisy channels BPSK modulation is the best type of modulation for transmission of images in OFDM with lesser degree of BER, lesser phase errors, lesser percentage error of pixels and the quality of image is better than other modulation. In case of channels that are fairly noisy, QPSK modulation is the best for image transmission in OFDM as it gives higher data rate than BPSK.

CHAPTER 7

CONCLUDING REMARKS AND FUTURE SCOPE

New generations will be able to make a better world when they enjoy education. Software Defined Radio is a platform between theory and implementation. Its set up is quite simple and very easy to use. After studying the underlying theory, one can fully understand the goals and objectives behind their labs, enjoy implementing real life examples and eventually experience the happiness of realizing it.

CONCLUSION

There are so many advantages of the OFDM system. There exist some major disadvantages which must be removed for getting all the benefits. Hence, for overall improvement in the system performance, it is required to handle all the issues one by one. This thesis presented a brief review of OFDM system using SDR with their existing solutions. In this chapter, it can be concluded that this method of OFDM implementation on C700 platform is fairly easy with the help of C700 SDR and Matlab. The result shows that the BPSK modulation is better than other modulations with different signal to noise ratio but it is extremely noisy than the other modulations.

After analysation of the whole simulation it is noted that OFDM parameters for some combinations may fail for some trials. In contrast it also may succeed for repeated trails with the same parameters. On account of the spontaneous noise produced wirelessly through the antennas (which are situated on the C700 SDR platform) it may vary on each trial, and the problem behind this is due to the frame detector in the receiver of OFDM, because spontaneous noise enters into the receiver side. Future work is required to troubleshoot this matter and compose the frame detector at no cost of errors.

FUTURE SCOPE

1. In future work, we can try to investigate the effect on performance when applying ISI on any modulation, effect on performance when apply fading on any signal using GUI present in the C700 SDR. There are so many features in this software like- we can change manually roll off factor, modulation order, modulation type, bit order, filter type etc.
2. Other possible future works can be on carrying out the simulation process for an addition of data other than 8-bit word size of image data.