

ANALOG AND DIGITAL RECEIVER USING NI LABVIEW AND USRP SDR

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in Electronics and Communication Engineering

by

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(DEEMED TO BE UNIVERSITY)**

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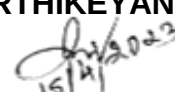
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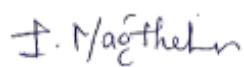
This is to certify that this Project Report is the bonafide work of SATHYA RUPA.S (39130405) and SHERIN.R (39130425) who carried out the project entitled “ANALOG AND DIGITAL RECEIVER USING NI LABVIEW AND USRP SDR” under my supervision from November 2022 to April 2023.


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DECLARATION

We SATHYA RUPA. S (39130405) and SHERIN. R (39130425) hereby declare that the Project Report entitled “ANALOG AND DIGITAL RECEIVER USING NI LABVIEW AND USRP SDR” done by us under the guidance of Dr.S.KARTHIKEYAN M.E.,Ph.D., Associate professor, Department of Electronics and Communication Engineering, SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Electronics and Communication Engineering.

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ABSTRACT

In this paper we discuss the recent trends in wireless communication system design using software designed radio (SDR). Software-defined radio (SDR) is a radio communication system where components that have been traditionally implemented in hardware are instead implemented by means of software on a personal computer or embedded system. A basic SDR system may consist of a personal computer equipped with a sound card, or other analog-to-digital converter, preceded by some form of RF front end. Significant amounts of signal processing are handed over to the general-purpose processor, rather than being done in special-purpose hardware. Such a design produces a radio which can receive and transmit widely different radio protocols based solely on the software used. Here the Universal Software Radio Peripheral (USRP) is used to design an analog and digital receiver in megahertz (MHZ) range. The signal in the megahertz range is received using the USRP board. This system is designed using NI LabVIEW software, a test and measurement development software. Using a SDR based receiver helps us to achieve very high level performance compared to the traditional receivers. This receiver can be implemented in applications that require the flexibility that enables them to be quickly reconfigured to support different standards, waveforms, and spectrum profiles. This flexibility is critical for military and commercial radio users who must be able to rapidly adapt their systems to changing operational requirements and threats. In the long term, software-defined radios are expected by proponents like the Wireless Innovation Forum to become the dominant technology in radio communications. SDRs, along with software defined antennas are the enablers of the cognitive radio.

KEYWORDS: Software-Defined Radio (SDR), Universal Software Radio Peripheral (USRP), NI LabVIEW, Wireless Communication

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LIST OF ABBREVIATIONS

ABBREVIATION	MEANING
SDR	Software Defined Radio
USRP	Universal Software Radio peripheral
LABVIEW	Laboratory Virtual Instrumentation Engineering Workbench
CR	Cognitive Radio
FM	Frequency Modulation
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
PSK	Phase Shift Keying
FSK	Frequency Shift Keying
OFDM	Orthogonal Frequency Division Multiplexing
BER	Bit Error Rate
CDMA	Code Division Multiple Access
UMTS	Universal Mobile Telecommunication System
GSM	Global System for Mobile Communication
WIFI	Wireless Fidelity
GPP	General Purpose Processor
DSP	Digital Signal Processor
FPGA	Field Programmable Gate Arrays
DDC	Digital Down Conversion
DUC	Digital Up Conversion
DAC	Digital to Analog Converter
ADC	Analog to Digital Converter
VISA	Virtual Instrument Software Architecture

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CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

The realm of technology is ever-changing. The way we communicate has been revolutionized by the advancement of new innovation in the telecommunication sector. One such innovation in communication sector is SDR (Software Defined Radio). A cognitive radio (CR) is a software-defined radio that is also capable of sensing its environment, track changes, and reacts upon its findings. Software radio is a revolution in radio design due to its ability to create radios that change on-the-fly, creating new choices for users. Software radio systems possess a substantial amount of flexibility, which provides the users and even the radio designers the options to create and employ advanced features deemed difficult by conventional radio systems. The universal software radio peripheral is designed to allow general-purpose computers to function as high-bandwidth software radios. The basic design philosophy behind the USRP has been to do all the waveform-specific processing, like modulation and demodulation, on the host CPU. Controlling a computer, with necessary hardware supports, to play with radios should be easier, interesting, and attractive. SDR is currently used to build radios that support multiple interface technologies (e.g., CDMA, GSM, and WiFi) with a single modem by reconfiguring it in software. SDR is also a modem technology and it ignores RF design issues. With the exponential growth in the ways and means by which people need to communicate - data communications, voice communications, video communications, broadcast messaging, command and control communications, emergency response communications, etc. - modifying radio devices easily and cost-effectively has become business critical. Software defined radio (SDR) technology brings the flexibility, cost efficiency and power to drive communications forward, with wide-reaching benefits realized by service providers and product developers through to end users. While traditional radio receivers are hard-wired to handle only specific bands and modes, software defined radios (SDR) leverage computer processors and software to perform most of the demodulation. This allows a small package of radio frequency (RF) sensing hardware to support a wide range of frequencies and the ability to listen into all modes of transmission [1].

1.2 SDR (SOFTWARE DEFINED RADIO)

An SDR system is a radio communication system where components that have typically been implemented in hardware (e.g., mixers, filters, amplifiers, modulators/demodulators, detectors) are instead implemented using software on a personal computer or other embedded computing devices. As a result, it transforms radio hardware problems into software problems. The fundamental characteristic of software radio is that software defines the transmitted waveforms and software demodulates the received waveforms. This is in contrast to most radios, in which the processing is done with either analog circuitry or analog circuitry combined with digital chips. Two decades ago, most radios had no software at all, and those that had it didn't do much with it. In a remarkably visionary article published in 1993, Joseph Mitola III envisioned a very different kind of radio: A mostly digital radio that could be reconfigured in fundamental ways just by changing the software code running on it. He dubbed this software-defined radio. The basic concept of the SDR software radio is that the radio can be totally configured or defined by the software so that a common platform can be used across a number of areas and the software used to change the configuration of the radio for the function required at a given time. There is also the possibility that it can then be re-configured as upgrades to standards arrive, or if it is required to meet another role, or if the scope of its operation is changed. One major initiative that uses the SDR, software defined radio, is a military venture known as the Joint Tactical Radio System, JTRS. Using this a single hardware platform could be used and it could communicate using one of a variety of waveforms simply by reloading or reconfiguring the software for the particular application required. This is a particularly attractive proposition, especially for coalition style operations where forces from different countries may operate together. Radios could be re-configured to enable communications to occur between troops from different countries, etc. The SDR software radio concept is equally applicable for the commercial world as well. One application may be for cellular base stations where standard upgrades frequently occur. By having a generic hardware platform, upgrades of standards can easily be incorporated. Migrations for example from UMTS to HSPA and on to LTE could be accommodated simply by uploading new software and reconfiguring it without any hardware changes, despite the fact that different modulation schemes and frequencies may be used. There are many opportunities for considering the use of the software defined radio, SDR, concept. As time progresses and the technology moves forward,

it will be possible to use the concept in new areas. Software-defined radio refers to technologies wherein these functionalities are performed by software modules running on field programmable gate arrays (FPGAs), digital signal processors (DSP), general-purpose processors (GPP), or a combination thereof. This enables programmability of both DDC/DUC and baseband processing blocks [14].

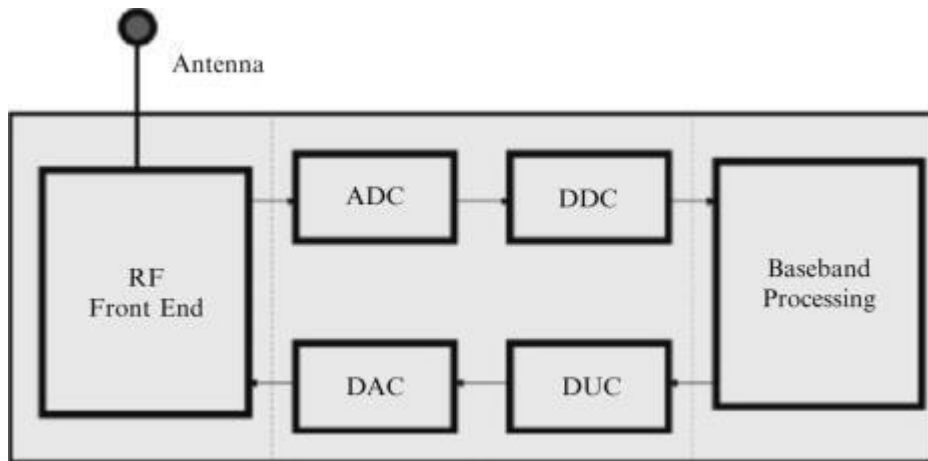


Fig 1.1 Block Diagram of Digital Radio

The block diagram of a generic digital radio as shown in the fig 1.1, consists of five sections, hence operation characteristics of the radio, such as coding, modulation type, and frequency band, can be changed at will, simply by loading a new software. Also, multiple radio devices using different modulations can be replaced by a single radio device that can perform the same task. SDR systems stand out for providing a high level of reconfigurability and trivial programmability: Users can implement custom functions using a graphical interface to create signal flow graphs. Although these features ensure flexibility in the design of hardware radios, they simultaneously constrain the throughput and provoke higher latency when processing a signal. SDR is based on a combination of a General-Purpose Processors (GPP) and a Digital Signal Processor (DSP). Therefore, a bus system is employed to transfer samples from the RF front-end to the GPP of the host computer, introducing latency that is not negligible. Furthermore, the computation of signal processing on the GPP results in low throughput due to the scheduling of buffers inside the operating system to compute incoming data. Another definition that seems to encompass the essence of the Software Defined radio, SDR is that it has a generic hardware platform on which software runs to provide functions including modulation and demodulation, filtering

(including bandwidth changes), and other functions such as frequency selection and if required frequency hopping. The benefits of SDR are compelling. For Radio Equipment Manufacturers and System Integrators, SDR Enables: A family of radio “products” to be implemented using a common platform architecture, allowing new products to be more quickly introduced into the market. Software to be reused across radio “products”, reducing development costs dramatically. Over-the-air or other remote reprogramming, allowing “bug fixes” to occur while a radio is in service, thus reducing the time and costs associated with operation and maintenance. It is not always feasible or practicable to develop a radio that incorporates all the features of a fully software defined radio. Some radios may only support a number of features associated with SDRs, whereas others may be fully software defined. In SDR, most of the signal processing, channel selection, tuning, modulation and demodulation are performed in digital domain through software. Thus, the ultimate goal of SDR is to move the Analog-to-Digital Converter (ADC) / Digital-to- Analog Converter (DAC) as close as possible to the antenna so that all signal processing can be done digitally via software. In order to give a broad appreciation of the level at which a radio may sit, the SDR Forum (now called the Wireless Innovation Forum, WINNF) has defined a number of tiers. These tiers can be explained in terms of what is configurable. Tier 0: A non-configurable hardware radio, i.e., one that cannot be changed by software. Tier 1: A software-controlled radio where limited functions are controllable. These may be power levels, interconnections, etc. but not mode or frequency. Tier 2: In this tier of software defined radio there is significant proportion of the radio is software configurable. Often the term software-controlled radio, SCR may be used. There is software control of parameters including frequency, modulation and waveform generation / detection, wide/narrow band operation, security, etc. The RF front end still remains hardware based and non-reconfigurable. Tier 3: The ideal software radio or ISR where the boundary between configurable and non-configurable elements exists very close to the antenna, and the “front end” is configurable. It could be said to have full programmability. Tier 4: The ultimate software radio or USR is a stage further on from the Ideal Software Radio, ISR. Not only does this form of software defined radio have full programmability, but it is also able to support a broad range of functions and frequencies at the same time. With many electronic items such as cell phones having many different radios and standards a software definable multifunction phone would fall into this category [17].

1.3 USRP (UNIVERSAL SOFTWARE RADIO PERIPHERAL)

NI Universal Software Radio Peripheral (USRP) devices are software defined radios used for RF applications. NI USRP transceivers can transmit and receive RF signals in several bands, and you can use them for applications in communications education and research. USRP hardware shown in fig 1.2 implements a direct conversion analog front end with high-speed analog-to-digital converters (ADCs) and digital-to-analog converters (DACs) featuring a fixed-personality FPGA for the digital down conversion (DDC) and digital up conversion (DUC) steps. The receiver chain begins with a highly sensitive analog front end that can receive very small signals and digitize them using direct down conversion to in-phase (I) and quadrature (Q) baseband signals. Down conversion is followed by high-speed analog-to-digital conversion and a DDC that reduces the sampling rate and packetizes I and Q for transmission to a host computer using Gigabit Ethernet for further processing. The transmitter chain starts with the host computer where I and Q are generated and transferred over the Ethernet cable to the USRP hardware. A DUC prepares the signals for the DAC after which I-Q mixing occurs to directly upconvert the signals to produce an RF frequency signal, which is then amplified and transmitted [18].



Fig 1.2 USRP Hardware

The USRP hardware driver (UHD) is the device driver provided by Ettus Research for use with the USRP product family. It supports Linux, MacOS, and Windows platforms. Several frameworks including GNU Radio, LabVIEW, MATLAB and Simulink use UHD. The functionality provided by UHD can also be accessed directly with the UHD API, which provides native support for C++. Any other language that can import C++ functions can also use UHD. This is accomplished in Python through SWIG, for example. UHD provides portability across the USRP product family. Applications developed for a specific USRP model will support other USRP models if proper

consideration is given to sample rates and other parameters. Most USRPs connect to a host computer through a high-speed link, which the host-based software uses to control the USRP hardware and transmit/receive data. Some USRP models also integrate the general functionality of a host computer with an embedded processor that allows the USRP device to operate in a stand-alone fashion. The USRP N200 and USRP N210 are high-performance USRP devices that provide higher dynamic range and higher bandwidth than the bus series. Using a Gigabit Ethernet interface, the devices in the Networked Series can transfer up to 50 MS/s of complex, baseband samples to/from the host. This series uses a dual, 14-bit, 100 MS/s ADC and dual 16-bit, 400 MS/s DAC. This series also provides a MIMO expansion port which can be used to synchronize two devices from this series. This is the recommended solution for MIMO systems. The X300 and X310 are third-generation USRPs that feature two full-duplex daughterboard slots and feature full 200 MS/s DACs and ADCs. As network interface, 10GBase over SFP+ allows full 200 MS/s on both channels in full-duplex operation. The N300, N310, N320 and N321 are current dual-channel models offering SFP+ connectivity, up to 200 MS/s and optionally sharing of local oscillators and TPM modules for verifiable software deployments. The original USRP, USRP2, USRP E1xx, USRP N2xx and X3xx families feature a modular architecture with interchangeable daughterboard modules that serve as the RF front end. Several classes of daughterboard modules exist: Receivers, Transmitters and Transceivers. Transmitter daughterboard modules can modulate an output signal to a higher frequency. Receiver daughterboard modules can acquire an RF signal and convert it to baseband. Transceiver daughterboard modules combine the functionality of a Transmitter and Receiver. The USRP B2xx and E3xx do not feature exchangeable daughterboards. The N3xx series has a JESD204B-attached daughterboard featuring the AD9371 frontend, but currently, no alternative daughterboards are commercially available. All products in Ettus Research Bus Series use a USB 2.0 or USB 3.0 interface to transfer samples to and from the host computer. The Embedded Series combines the same functionality of other USRP devices with an OMAP 3 embedded processor. The E310, released in November 2014, utilizes the Zynq SoC platform and the Analog Devices AD9361 RFIC for a very compact, embedded USRP. The devices in this family do not need to be connected to an external PC for operation. The Embedded Series is designed for applications that require stand-alone operation [9].

1.4 LABVIEW

LabVIEW is a graphical programming environment engineers use to develop automated research, validation, and production test systems. Laboratory Virtual Instrument Engineering Workbench (LabVIEW) is a system-design platform and development environment for a visual programming language from National Instruments. The programming paradigm used in LabVIEW, sometimes called G, is based on data availability. If there is enough data available to a sub VI or function, that sub VI or function will execute. Execution flow is determined by the structure of a graphical block diagram (the LabVIEW-source code) on which the programmer connects different function-nodes by drawing wires. These wires propagate variables and any node can execute as soon as all its input data become available. Since this might be the case for multiple nodes simultaneously, LabVIEW can execute inherently in parallel. Multi-processing and multi-threading hardware is exploited automatically by the built-in scheduler, which multiplexes multiple OS threads over the nodes ready for execution. LabVIEW integrates the creation of user interfaces (termed front panels) into the development cycle. LabVIEW programs-subroutines are termed virtual instruments (VIs). Each VI has three components: a block diagram, a front panel, and a connector pane. The last is used to represent the VI in the block diagrams of others, calling VIs. The front panel is built using controls and indicators. Controls are inputs: they allow a user to supply information to the VI. Indicators are outputs: they indicate, or display, the results based on the inputs given to the VI. The back panel, which is a block diagram, contains the graphical source code. All of the objects placed on the front panel will appear on the back panel as terminals. The back panel also contains structures and functions which perform operations on controls and supply data to indicators. The structures and functions are found on the Functions palette and can be placed on the back panel. Collectively controls, indicators, structures, and functions are referred to as nodes. Nodes are connected using wires, e.g., two controls and an indicator can be wired to the addition function so that the indicator displays the sum of the two controls. Thus, a virtual instrument can be run as either a program, with the front panel serving as a user interface, or, when dropped as a node onto the block diagram, the front panel defines the inputs and outputs for the node through the connector pane. This implies each VI can be easily tested before being embedded as a subroutine into a larger program. The Ch interpreter is a C/C++ interpreter that can be embedded in LabVIEW for scripting [7].

The graphical approach also allows nonprogrammers to build programs by dragging and dropping virtual representations of lab equipment with which they are already familiar. The LabVIEW programming environment, with the included examples and documentation, makes it simple to create small applications. This is a benefit on one side, but there is also a certain danger of underestimating the expertise needed for high-quality G programming. For complex algorithms or large-scale code, a programmer must possess extensive knowledge of the special LabVIEW syntax and the topology of its memory management. The most advanced LabVIEW development systems offer the ability to build stand-alone applications. Furthermore, it is possible to create distributed applications, which communicate by a client-server model, and are thus easier to implement due to the inherently parallel nature of G. LabVIEW can be used to perform a huge number of mathematical and logic functions, including, but certainly not limited to: basic arithmetic, if/then/elseif conditional statements, case statements, FFTs, filtering, PID control loops, etc. There are huge libraries of functions to pull from. You can also interface to code developed in other languages, through DLLs, .NET assemblies, and run-time interpreters (e.g., MATLAB), for example. Another somewhat unique capability that LabVIEW offers is real-time compilation and the ability to execute function blocks without requiring development of a test case. LabVIEW can run on any of these platforms: A Windows-based PC, A Windows-based PXI, An NI Compact RIO, An NI Single-Board RIO (including the NI SOM). LabVIEW includes extensive support for interfacing to devices such as instruments, cameras, and other devices. Users interface to hardware by either writing direct bus commands (USB, GPIB, Serial) or using high-level, device-specific drivers that provide native LabVIEW function nodes for controlling the device. LabVIEW includes built-in support for NI hardware platforms such as CompactDAQ and Compact RIO, with a large number of device-specific blocks for such hardware, the Measurement and Automation eXplorer (MAX) and Virtual Instrument Software Architecture (VISA) toolsets. National Instruments makes thousands of device drivers available for download on the NI Instrument Driver Network (IDNet). LabVIEW includes a compiler that produces native code for the CPU platform. The graphical code is converted into Dataflow Intermediate Representation, and then translated into chunks of executable machine code by a compiler based on LLVM. Run-time engine calls these chunks, allowing better performance. The LabVIEW syntax is strictly enforced during the editing process and compiled into the executable machine code when requested to run or upon saving single binary file [7].

CHAPTER 2

LITERATURE SURVEY

2.1 INFERENCES FROM LITERATURE SURVEY

Many people done projects on SDR based receivers and transmitters using different ways. Here we have collected some references. And we came up with a transceiver which transmits and receives signal using USRP and LabView. Here we listed some of the references related to SDR radio.

Trubin I S (2019) et al. presented a work on Simulation of System with Code Channel Division in the LabVIEW. Model of digital communication system with code channel division in LabVIEW is developed. During the development of the model, the focus was on performance and compatibility with the SDR (Soft Defined Radio) NI USRP-2920. The network level of the system is replaced by a source of random bits that form an analogue of speech frames. Using modelling in LabVIEW, the dependence of the probability of the appearance of distorted information frames at the output of the Viterbi decoder – FER (Frame Error Ratio) on the signal-to noise ratio (SNR) at the decoder input was obtained. In this work, the models of the transmitter and receiver of CDMA realized. The models implement all the basic operations performed on the signal, in accordance with the functional model of data transmission with code division of the channel. When developing individual modules of models, the main attention was paid to the speed and compatibility with the SDR platform NI USRP. The performance check of the developed models was carried out using NI USRP-2920. The network level of the system is replaced by a source of random bits that form an analogue of speech frames. To control the receiver model in LabVIEW, we developed a virtual instrument with a software interface. Using modelling in LabVIEW, the dependence of the probability of the appearance of distorted information frames at the output of the Viterbi FER (Frame Error Ratio) decoder on the signal-to-noise ratio (SNR) at the decoder input was obtained. The WCDMA receiver model allows you to select CPICH and CCPCH channels in a real signal received from a satellite. The purpose of this work was to develop a model of a digital communication system with code channel division (CDMA) in the LabVIEW environment compatible with the NI USRP SDR system [4] and test the performance of the model when receiving a real signal [7].

Ivan Ostroumov (2023) et al. presented a work on Software-Defined Transmitter to Support Automatic Dependent Surveillance-Broadcast. Aviation is a rapidly developed transportation system. Automatic Dependent Surveillance-Broadcast (ADS-B) is a key technology to support surveillance in the future air traffic system in which the number of airspace users is increased significantly due to the wide usage of new vehicle types. Airplane transponder of mode 1090ES is one of the most common implementations of ADS-B concept in the global market. Implementation of new types of airspace users required to reduce total equipment cost and minimize weight and size of onboard equipment with ensuring required level of flight safety. Therefore, in the paper we consider implementation of low-cost Software-Defined Transmitters to support ADS-B capability. Developed software is used for coding user data and generating the sequence of digital messages to support basic surveillance operations. Validation of developed software has been done on HackRF hardware and checked with the ground station based on RaspberryPI and RTL-SDR. ADS-B is going to be a key element of future air navigation system that supports the required level of flight safety for each airspace user. Modes 1090ES transponder is an important element of the system that supports whole air traffic management operation safely. However, the integration of new users, such as UAVs, paragliders, gliders, jet-suits, balloons, and others, into controlled airspace is required to research a new solution to structure and design ADS-B user-based transmitters. Proposed software structure minimizes the number of operations and makes it possible to be implemented with a help of a variety of available in the market low-cost software defined transmitters. Developed software for low-powered software-defined transmitters can be useful for testing, validation, and maintenance of SDRs that service ground networks of ADS-B ground stations. One of the important ways of further development is the integration of both software for generation ADS-B signals and software of GNSS signal receiver in one installation to use in various applications [6].

Xianjun Jiao (2020) et al. presented a work on open WIFI: a free and open-source IEEE802.11 SDR implementation on SoC. Open-source Software Defined Radio (SDR) project, such as srsLTE and Open-Air Interface (OAI), has been widely used for 4G/5G research. However, the SDR implementation of the IEEE802.11 (Wi-Fi) is still difficult. The Wi-Fi Short InterFrame Space (SIFS) requires acknowledgement (ACK) packet being sent out in $10\mu\text{s}/16\mu\text{s}$ (2.4GHz/5GHz) after receiving a packet successfully, thus

the Personal Computer (PC) based SDR architecture hardly can be used due to the latency ($\geq 100\mu\text{s}$) between PC and Radio Frequency (RF) front-end. Researchers have to do simulation, hack a commercial chip or buy an expensive reference design to test their ideas. To change this situation, we have developed an open-source full-stack IEEE802.11a/g/n SDR implementation — open WIFI. It is based on Xilinx Zynq System on-Chip (SoC) that includes Field Programmable Gate Array (FPGA) and ARM processor. With the low latency connection between FPGA and RF front-end, the most critical SIFS timing is achieved by implementing Physical layer (PHY) and low-level Media Access Control (low MAC) in FPGA. The corresponding driver is implemented in the embedded Linux running on the ARM processor. The driver instantiates Application Programming Interfaces (APIs) defined by Linux mac80211 subsystem, which is widely used for most SoftMAC Wi-Fi chips. Researchers could study and modify open WIFI easily thanks to the modular design. Compared to PC based SDR, the SoC is also a better choice for portable and embedded scenarios. An SoC based open-source full-stack IEEE802.11 SDR implementation is developed for the community. The module-based design can help implementing innovative ideas on different aspects of wireless system. The embedded design makes the project suitable for the scenario where power consumption and form factor are constrained [20].

Kushnure (2018) et al. presented a work on Implementation of FM Transceiver using Software Defined Radio (SDR). In this work we discuss about recent trends in wireless Communication system design using Software Defined Radio (SDR). Here the Universal Software Radio Peripheral (USRP) B200 board is used to design Frequency Modulation (FM) Transmitter and Receiver. The audio file transmitted from the USRP B200 board and it is received on the FM receiver of mobile phone as well as on the USRP B200 board. The system has been designed using the GNU Radio which is open-source software. In the demonstration the audio file is transmitted using Wideband Frequency Modulation (WBFM). The spectrum of FM is from 88 MHz to 108 MHz within this spectrum we can transmit and receive the FM signals. The results show that the audio file transmitted is received on the FM Receiver of Mobile Phone as well as USRP B200 Board Receiver. The spectrum received is just like the transmitted spectrum. Hence it is clear that one can implement other communication systems using SDR and analyse the performance [11].

Rahul Krishnan (2017) et al. presented a work on Software Defined Radio (SDR) Foundations, Technology Tradeoffs: A Survey. Software radio has emerged as a focus of both academic research and commercial development for future wireless systems. This paper briefly reviews the foundation concepts of the Software Radio. It then characterizes the tradeoffs among core software-radio technologies. Object oriented analysis leads to the definition of the radio reference platform and the related layered object-oriented architecture supporting simultaneous hardware and software evolution. Research issues inc. Industry-standard SDR architecture will shape the degree to which waveform plug-and-play is realizable for the wireless marketplace. The SDR Forum has made significant progress in defining such architecture. Research issues include better understanding of the computational properties of heterogeneous radio objects. Additional layering, tunneling, and virtual machines [29] extend the current architectures to a basis for the graceful evolution of SDR hardware and software components. As such architectures allow complexity [30] to increase rapidly, agent technology will be needed to integrate services in a context-sensitive way, further propelling this evolutionary process. Different process involved in SDR is implemented in digital on a DSP. In an N-element array, the channel isolation filters [16] extract channels for each of K users on each of N elements (K Users x N Elements). On the transmitter side baseband low speed digital interconnects are used, which are converted to high speed before the RF conversion. On the receiver side the analog signals are converted to digital with channel isolation in high-speed interconnects in the medium speed low Carrier to Interference Ratio (CIR) channels are selected. On the selected channels, interference cancellation, beam forming, CIR and soft decisions are implemented on Digital Signal Processors. Low speed digital interconnects are used by the end users [14].

Michael J Underhill (2018) et al. presented a work on Theory of Random Spurs and Spectrum-Collapse from SDR Phase-Noise and Carrier-Phase Measurements. The underlying processes causing random-spurs and spectrum-collapse for phase noise spectrum measurements are here investigated using low-cost SDR (Software-Defined Radio) signal processing techniques. Suitable windowing and long-record-averaging for the SDR FFT, with and without phase locking, provides a substantial cure. Metastability-theory is derived and found to explain long term persistence of spurs and collapse, and when they are likely to occur. For oscillator phase noise measurement, the dynamic-

range is limited by the noise figure of the SDR ADC and not by its number of bits, provided that sufficient oversampling is used. Micro-hertz phase noise can be measured up to one hundred times faster by measuring carrier phase-difference against a free-running stable reference source suitably tuned to the source under test. A novel method of signal compression promises ~ 20 to 30 dB increase of dynamic range for phase-noise measurement of oscillators. The target >150 dbc at 0.1 Hz offset, using a low-cost SDR, has so far been achieved. SDR techniques can much reduce if not eliminate the problems of random spurs and spectrum collapse in phase noise measurements. Metastability theory explains why these problems can persist for many measurement (FFT) frequency bin periods. But can be reduced by suitable filtering, sample selection and averaging techniques. SDR dynamic range can be extended by 20 dB or more by two oscillator carrier cancellation [12].

Ivanov D V (2021) et al. presented a work on Actualization of Parameters of Adaptive SDR equalizer of Wideband HF Radio Channels to Effectively Correct for Frequency Intramode Dispersion. State-of-the-art development of HF radio communication systems follows the idea of significant spreading the bandwidth of variable ionospheric radio channels. In this case, the topical scientific and technical problem is to overcome the negative effect of the frequency intramode dispersion of the medium. For this purpose, we tackled the problem of increasing the efficiency of the channel adaptive SDR-equalizer operating under the various geophysical conditions of the mid-latitude radio propagation path Cyprus-to-Yoshkar-Ola. The following operation modes of the SDR-equalizer were considered: periodic channel testing; estimating the SDR-equalizer parameters and training the SDR-equalizer. For experimental implementation of the testing mode, we developed a physical model of a communication HF signal with a wideband fast frequency hopping. There were experimentally determined: the minimum required bandwidth of the partial subchannel; the number of subchannels to correct for dispersion in 1 MHz channels. In addition to this, there are presented data on the influence of diurnal variations of the ionosphere on the SDR-equalizer parameters. Physical model of a wideband HF communication signal with fast frequency hopping based on the LFM CW signal was proposed. With the use of the model, we carried out experimental studies into the parameters of wideband channels with frequency intramode dispersion on the Cyprus-to Yoshkar-Ola radio path. They were used to actualize the parameters of the adaptive SDR-equalizer [5].

Jakub Kaderka T (2020) et al. presented a work on Time and sample rate synchronization of RTL-SDR using a GPS receiver. GPS receivers provide very precise Pulse Per Second (PPS) signal. A simple low-cost method of time synchronization for RTL-SDR receivers using such GPS time signal is described. The PPS signal is injected into an IF stage of the RTL-SDR and detected by correlation of an expected signal shape and the measured data. The accuracy of such pulse detection algorithm is in the worst case 5 samples or up to $2.1\ \mu\text{s}$ when using highest useful receiver sample rate of 2.4 MS/s. The algorithm can also be used to measure RTL-SDR oscillator offset with a very high precision for frequency corrections. The accuracy achieved is not enough for precise localization of ground targets, but it's sufficient enough to roughly estimate a location of an aircraft or a satellite. The method described allows to synchronize multiple RTLSDR receivers with accuracy up to $2.1\ \mu\text{s}$, or 5 samples. A simple algorithm based on replacing pulses that are too far from the expected value by median of the distance between pulses can improve a short-term accuracy approximately to 1 pulse, or $0.42\ \mu\text{s}$. When used for multilateration purposes (therefore synchronizing two distant receivers) the errors are summed together. The worst-case scenario gives error of $4.2\ \mu\text{s}$ which is equal to 1260 m of the position uncertainty per a pair of signal receivers. This error is big enough to render this method unusable for target localization on ground, but it's still sufficient for a rough estimation of aircraft or satellite positions. The modification to the hardware required is trivial and cheap off the shelf components can be used. A low price of this solution allows building of the TDOA systems in prices of several dozen dollars per receiver with enough accuracy to track airplane or satellite signals. Aside of the time synchronization, this method can be also used to measure the RTL-SDR oscillator error with high accuracy for precision calibration of the receiver. The results described in this article will be further used in development of an experimental satellite localization system [10].

Vincent Pignoly (2020) et al. presented a work on Fair comparison of hardware and software LDPC decoder implementations for SDR space links. LDPC codes are a family of error correcting codes used in most wireless and space communication standards such as CCSDS [1] and DVB [2] ones. Thanks to their high error correction features and their parallelism capabilities, different technical solutions nowadays enable their real-time implementations in Software Defined Radio (SDR) contexts. Indeed, even if Error Correction Code (ECC) decoders were previously implemented on dedicated

hardware targets (ASIC/FPGA), their real-time implementations on multi-core devices [3]-[5], is now possible. Software implementations currently provide high-throughput and low-latency features, scalability and also flexibility that makes them attractive for SDR systems. However, multi-core power consumption, throughput performance level and prices could be worse compared to ASIC/FPGA solutions for very high throughput SDR systems. In this paper, a fair comparison of multi-core and FPGA solutions for the development of a 10 Gbps communication system for space communications is detailed. In this paper, a fair comparison of LDPC decoder hardware and software implementations is done. For both kinds of solutions, state-of-the-art implementation were used. This study was conducted in the context of the development of a base station for 10 Gbps space communications. Experimental results demonstrate that both solutions achieved the throughput performance objective but with different features. Indeed, the development time of CPU based solution is shorter and its flexibility and reusability is higher. However, in current context, these advantages impact on the power consumption of the system that is about $30\times$ higher. Moreover, the CPU solution cost is about $1.5\times$ more expensive than FPGA one. This is the first completely fair comparison since the start of research on software ECC decoder implementations [19].

Salem Hassayoun (2020) et al. presented a work on SDR Bridge for a Secure Wireless Sensor Network (WSN). A software-defined Radio (SDR) is a wireless communication system whose main radio functionalities are implemented in software on an embedded system instead of hardware. The advantages of SDR include its wide range of frequency channels that have configurable bandwidths in addition to its support of multiple configurations and modulations. In this paper, an SDR bridge implemented within a wireless sensor network (WSN) is developed. The SDR bridge is inserted as a gateway between sensor nodes and the end-user receiver to add security to the overall network. For this study, LoRa link is chosen to ensure communication between the network components because of its low power consumption and its long range. Typically, the sensor nodes will send their data to the SDR bridge using LoRa modulation. The bridge will add a layer of security to the overall system by encrypting the signals sent within the bridge. Experimental results found during this study showed that the SDR Bridge allows successful interconnection of the sensor nodes and the end-user receiver. Also, the SDR Bridge prevented reception of the data by the user when data was encrypted unless the proper key was used. Encryption of the signal did not

have a significant effect on the QoS since the Packet Loss Ratio (PLR) of the link was around 1.6%. When the bridge is used, the Received Signal Strength Indication (RSSI) was also within the typical values for the LoRa receiver. This work presents some solutions to add security to a LoRa based telemetry application using Software Defined Radio (SDR). In this application an SDR Bridge, composed of an SDR transmitter and an SDR receiver, was inserted between the LoRa nodes and the end-user. The SDR Bridge added a layer of security to the communication link by encrypting the signals transmitted by the first SDR and decrypting the signals received at the input of the second SDR. The encryption algorithm used in this case was the Advanced Encryption Standard (AES) algorithm with a 128-bit encryption key. Estimation of the Packet Loss Ratio (PLR) showed an average PLR of about 1.6% when encryption was added within the SDR Bridge. Moreover, estimation of the Received Signal Strength Indication (RSSI) versus distance showed that the signal received from the SDR Bridge is around 10dBm more powerful than that received directly from the LoRa. Finally, it should be noted that this research work can be extended to other interesting applications such as the use of the SDR Bridge for space telemetry applications using low earth orbit satellites like CubeSat. In this application, the CubeSat communication subsystem could be an SDR that collects data from different IoT sensors on the surface of the earth and then sends it to an SDR based ground station [15].

Javier Alvaro Rivera Suaña (2021) et al. presented a work on Using Open-Source Software QucsStudio to Design a Microwave Amplifier for SDR Applications. This paper presents the analysis and design of a microwave amplifier for Software-Defined Radio (SDR) applications. The amplifier is implemented using the Heterojunction Bipolar Transistor technology (HBT-MMG3014NT1), designed to have the maximum transducer gain by applying distributed matching circuit elements. The amplifier is designed by using the open-source software QucsStudio (Quite Universal Circuit Simulator), with a resonance frequency design at 1.9 GHz. Then it is fabricated on a commercial FR4 substrate. The measurement results have been shown that the proposed amplifier design achieves 10.4 dB of gain at 1.9 GHz, and it has an acceptable broadband frequency response from 1.06 GHz up to 1.96 GHz with a 10 dB of attenuation. The amplifier has been tested with a primary amplitude modulation using the SDR HackRF one device. The aim of this work was to analyze and design a microwave amplifier for the SDR application where the full design of the amplifier has been performed by using

the opensource software QucsStudio. The amplifier has been characterized using VNA equipment, where it is achieved 10.4 dB of gain at the frequency design of 1.9 GHz. However, the measured result of the reflection coefficient S_{11} has presented a slight frequency shifted. This behavior is due to the dielectric properties used for the FR4 substrate since they were needed for the analysis and perform the simulation of the amplifier. Therefore, this frequency-shifted has more relationship with the relative permittivity used for the substrate. Hence, the process to characterize the substrate should be performed with a more accurate value in order to minimize the shifted frequency between the measurements and simulations results. An SDR application has been developed in order to test the performance of the amplifier designed. Where a basic amplitude modulation AM was developed at 1.5 GHz since the dynamic frequency of the SDR device is limited up to 1.7 GHz. Hence, the gain measured at 1.5 GHz was around 12.4 dB, which was quite bigger than the gain of 10.5 dB analyzed by using the spectrum analyzer, since the power measured without using the amplifier was -83.95 dBm and using the amplifier designed this power transmitted by SDR device was increased up to -73.45 dBm, which seems that there is a losing gain around 1.9 dB by using the SMA adapter. Finally, our developed project proposes an alternative method for including QucsStudio in fields of interest for research and education. The universities of Latin America dedicated to engineering careers can also use this new virtual tool to improve the study and teaching of high-frequency applications [8].

Stepan Panchenko (2021) et al. presented a work on Interception wideband FM signals with RTL-SDR. –This article presents a Python program to receive and demodulate FM signals, which is based on software-defined radio (SDR). RTL-SDR receiver R820T2 connects to a computer via a USB port and can receiving 100KHz – 1.7GHz electromagnetic signals. The antenna is included with RTLSDR. The receiver circuit is represented by a threshold detector with signal accumulation. If the signal level is higher than the specified value in the program, the frequency is memorized, and the signal is written to the file. In the experiment the signal was searched in two frequency bands. Radio stations were found, the signal from each was recorded in a separate file. In all recording's speech is clearly audible. Using a broadband antenna, changing the algorithm for receiving signals in a wider frequency band and with other modulations we can improve the recording quality. The power spectral density (PSD) of signals, algorithm of the program and demodulated signal spectrum are presented. An

experiment was carried out to perform a Python program based on SDR searched for an FM signal. In the range of 87.5-108.0 MHz, 12 radio stations were found, the signal from each was recorded in a separate file for 20 seconds. In the range of 474-477 MHz, a radio signal was found at a frequency of 476 MHz, which was recorded in a file for 8 seconds. In all recording's speech is clearly audible, but the signals contain interference and sometimes interrupted. Using a broadband antenna can improve the recording quality. In addition, the algorithm can be improved for better reception of signals in a wider frequency band and with other modulations. Future work will look at the other existing algorithms for signal detection and their comparative analysis will be given. The program can be used to intercept communication channels as a passive detector [16].

Mallikarjuna Gowda C P (2021) et al. presented a work on A Software Defined Radio (SDR), uses software in a personal computer, or in an embedded system, to implement a major part of the signal processing. Modern wireless communication systems utilize this technology at a vast rate. This is because it can be set to any frequency band as well as carry out various modulation/demodulation strategies. In this paper, we have implemented the design to be able to work at any frequency, within the FM frequency band. We have also outlined the utilization of SDR and Raspberry Pi as a single communication system; for the transmission and reception of signals in the FM frequency band. Components like amplifiers, modulators and demodulators are typically implemented in hardware; whereas in this case, they are implemented by using software in a Raspberry Pi FM (Frequency Modulation) Transmitter. This is done with the help of general-purpose input output pins. Hence, it can be used in various fields like defense, civilian wireless communications, among others. We make use of several toolboxes like DSP System Toolbox, Communication System Toolbox and Signal Processing Toolbox for the simulation of the reception on Simulink. Filters, mathematic function, delay, product, FIR Decimation are the specific blocks present in the toolbox used. We also install an RTL-SDR external support package for the communication toolbox. This setup can be modified to cater to various other applications in different fields, by increasing the range of the transmitter. One such application is FM broadcasting, where users with an FM tuner will be able to listen to audio broadcasted by FM stations in their respective cities [12].

Rui Tang (2022) et al. presented a work on Zoned Mapping Network from SDR Video to HDR Video. HDR video is popular for its brilliant colors, incredible brightness and rich details. Considering the strict production conditions of HDR video, most videos are currently saved in SDR format. Converting massive SDR videos into HDR format through technical methods can quickly fill the vacancy of HDR videos in the market and improve the utilization efficiency of film and television resources. In this paper, we propose a zoned mapping network to convert the video format. According to SDR OETF, the video frames are firstly segmented into three regions, highlight, medium and darkness. Then a tone mapping model is designed and respectively trained for the above three regions. Moreover, a detail enhancement model is proposed to form a composite inverse tone mapping network. Experiments show that our method can not only achieve good subjective visual quality, but also accomplish excellent results on various objective metrics, such as PSNR, SSIM, VIF, etc. We propose a novel mapping method from SDR video to HDR video, which condenses the task into three points: gamut extension, signal value redistribution and detail recovering. Our model, zoned mapping network (ZMNetwork), separately processes the highlight, medium and darkness areas, and effectively reduces the number of parameters and improves converting efficiency. Modules with different purposes are designed for different areas, so that the processing results achieve better effect [13].

2.2 OPEN PROBLEMS IN EXISTING SYSTEM

Traditional radio systems were designed to communicate with one or two waveforms. Two types of people with different types of traditional radios were not able to communicate. Different set of hardware for different types of radio communication which limit cross functionality and can only be modified with physical intervention. This results in high production costs and little flexibility in supporting multiple waveform standards. Several problems were faced such as vulnerability for GPS, Current fully functional SDRs are bulky, with components connected via wires, and last at most hours on a single battery charge, Optimization, Difficult to accurately identify unknown target signals and determine threats, and could not implement effective electronic attack, Hardware is complex in nature and inflexible [9].

CHAPTER 3

METHODOLOGY

3.1 EXISTING METHODOLOGY

Traditionally, a radio has been considered to be the 'box' that connects to the antenna and everything behind that, however, many system designs are segmented into two separate subsystems. The radio and the digital processor. With this segmentation, the purpose of the radio is to down convert and filter the desired signal and then digitize the information. Likewise, the purpose of the digital processor is to take the digitized data and extract out the desired information. An important point to understand is that a digital receiver is not the same thing as digital radio(modulation). In fact, a digital receiver will do an excellent job at receiving any analog signal such as AM or FM. Digital receivers can be used to receive any type of modulation including any analog or digital modulation standards. Furthermore, since the core of the digital processor is a digital signal processor (DSP), this allows many aspects of the entire radio receiver itself be controlled through software. As such, these DSPs can be reprogrammed with upgrades or new features based on customer segmentation, all using the same hardware. The FM transmitter is a low power transmitter and it uses FM waves for transmitting the sound, this transmitter transmits the audio signals through the carrier wave by the difference of frequency. The carrier wave frequency is equivalent to the audio signal of the amplitude and the FM transmitter produces a VHF band of 88 to 108MHZ. The following Fig3.1 shows the block diagram of the FM transmitter and the required components of the FM transmitter are; microphone, audio pre-amplifier, modulator, oscillator, RF- amplifier, and antenna. There are two frequencies in the FM signal, the first one is the carrier frequency and the other one is audio frequency. The audio frequency is used to modulate the carrier frequency. The FM signal is obtained by differing the carrier frequency by allowing the AF. The FM transistor consists of the oscillator to produce the RF signal. The main function of an FM receiver circuit is to receive the radio signal and converts it into the audio signal. FM receiver circuits are mainly used in broadcast receiver stations. A good FM receiver circuit should be able to receive signals properly, high bandwidth, very low noise, very low interferences, etc. Here, you will find the block diagram of FM Receiver which will help you to understand the working principle of FM Receiver [9].

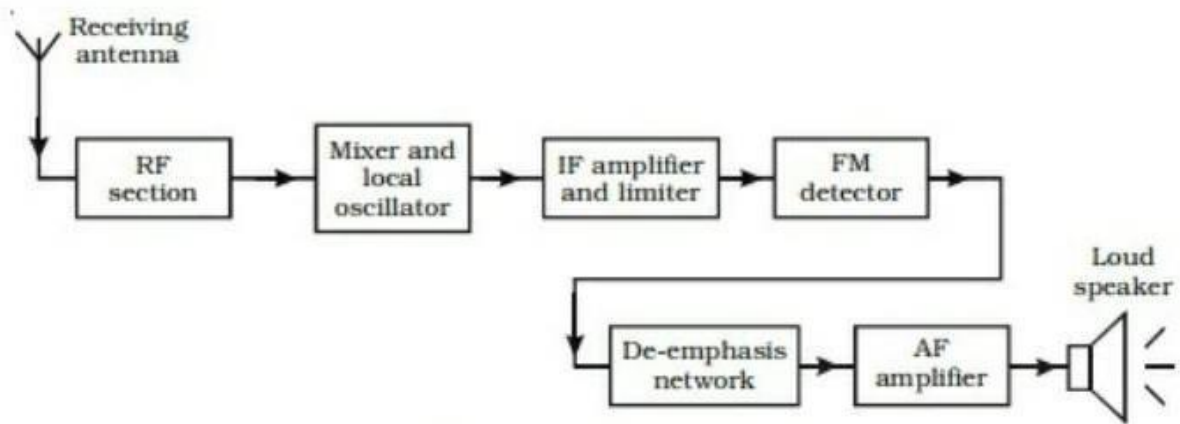


Fig 3.1 FM Receiver

FM transmitter as illustrated in fig 3.2 is the whole unit which takes the audio signal as an input and delivers FM modulated waves to the antenna as an output to be transmitted. FM transmitter consists of 6 main stages.

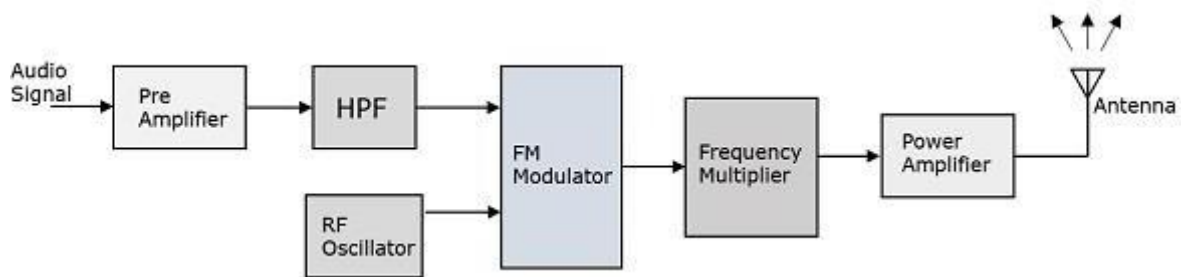


Fig 3.2 FM Transmitter

Another existing system approach allows a different type of communication system requirements such as standard, protocol, or signal processing method, to be deployed by using the same set of hardware and software such as USRP and GNU Radio respectively. For researchers, this approach has opened the door to extend their studies in simulation domain into experimental domain. However, the realization of SDR concept is inherently limited by the analog components of the hardware being used. Despite that, the implementation of SDR is still new yet progressing, thus, this approach intends to provide an insight about its viability as a high re-configurable platform for communication system. This system presents the SDR-based transceiver of common digital modulation system by means of GNU radio and USRP [9].

3.2 ANALOG AND DIGITAL RECEIVER USING NI LABVIEW AND USRP SDR (PROPOSED METHODOLOGY)

In the conventional radio system, the major disadvantage is that it is mostly composed of hardware and as such it is difficult to be re-configured. The basic premise in SDR as a wireless communication system is its ability to reconfigure by changing the software used to implement functions typically done by hardware in a conventional radio. The proposed radio system consists of a SDR transmitter and a SDR receiver using NI USRP and LabVIEW. In an SDR transmitter, software is used to implement different types of modulation procedures, while analog-to-digital converters (ADCs) and digital-to-analog converter (DACs) are used to change from one type of signal into another. Antennas, audio amplifiers and conventional radio hardware are used to process analog signals. Typically, an SDR receiver uses an ADC to change the analog signals from the antenna into digital signals that are processed using software on a general-purpose processor. At transmitting path, the input of digital system could be anything, either analog or digital. This input, term wise called message, is converted into sequence of binary digits by the source encoder. The channel encoder adds redundancy to the binary sequence to increase the reliability of the received data and improves fidelity of the received signal. Next, the encoded input is passed to digital modulator, which serves as the interface of communication channel. On the other hand, reverse procedures are done at receiving end to recover the input. In accordance to the referred system, there are numbers of readily available processing blocks that can be used to implement the system in NI LabVIEW. But in general, the processing blocks are source/sink, encoder/decoder, and modulator/demodulator. The next part will brief on the modulation schemes implemented in this system. The intended system is a common digital communication system of PSK, FSK and QAM. Instead of using GNU radio, NI LabVIEW is used to assemble the components to deliver the aforementioned system. As scripting gives more freedom in manipulating the flow of the data across the processing blocks in NI LabVIEW, the data flow can be repeated in the loop to accumulate the number of errors in order to compute the error rate of the system. An SDR can seamlessly communicate with multiple radios that support different wireless standards. It can also perform bridging between radios as a single multi-channel and multistranded SDR can act as a translator for all the radios dedicated to a particular frequency. This technique has the potential to dramatically increase the optimal use of available spectrum [18].

3.2.1 MODULATION SCHEME

Different modulation schemes like QAM, PSK, FSK are employed using NI LabVIEW.

3.2.1.1 QAM

64QAM is chosen as the modulation scheme for the proposed work. M-array quadrature amplitude modulation (M-QAM) is a modulation scheme that conveys data by modulating the data transmission onto the amplitude via two carrier signals. Quadrature Amplitude Modulation appears to increase the efficiency of transmission for radio communication systems by utilizing both amplitude and phase variations. QPSK is one of the fundamental modulation schemes for orthogonal frequency division multiplexing systems (OFDM). It is a stable modulation technique with good spectral efficiency. However, during transmission, the carrier signal can undergo numerous phase changes. Quadrature Phase Shift Keying (QPSK) is a form of Phase Shift Keying in which two bits are modulated at once, selecting one of four possible carrier phase shifts (0, 90, 180, or 270 degrees). QPSK allows the signal to carry twice as much information as ordinary PSK using the same bandwidth. Quadrature amplitude modulation, QAM may exist in what may be termed either analogue or digital formats. The analogue versions of QAM are typically used to allow multiple analogue signals to be carried on a single carrier. For example, it was used in the old PAL and NTSC television systems, where the different channels provided by QAM enabled it to carry the components of chroma or colour information. In radio applications a system known as C-QUAM is used for AM stereo radio. Here the different channels enable the two channels required for stereo to be carried on the single carrier. Digital formats of QAM are often referred to as "Quantised QAM" and they are being increasingly used for data communications often within radio communications systems. Radio communications systems ranging from cellular technology as in the case of LTE through wireless systems including WiMAX, and Wi-Fi 802.11 use a variety of forms of QAM, and the use of QAM will only increase within the field of radio communications. Quadrature amplitude modulation, QAM, when used for digital transmission for radio communications applications is able to carry higher data rates than ordinary amplitude modulated schemes and phase modulated schemes. Basic signals exhibit only two positions which allow the transfer of either a 0 or 1. Using QAM there are many different points that can be used, each having defined values of phase and amplitude. This is known as a constellation diagram. Although QAM appears to increase the efficiency of transmission for radio communications systems by utilising both

amplitude and phase variations, it has a number of drawbacks. The first is that it is more susceptible to noise because the states are closer together so that a lower level of noise is needed to move the signal to a different decision point. Receivers for use with phase or frequency modulation are both able to use limiting amplifiers that are able to remove any amplitude noise and thereby improve the noise reliance. This is not the case with QAM. The second limitation is also associated with the amplitude component of the signal. When a phase or frequency modulated signal is amplified in a radio transmitter, there is no need to use linear amplifiers, whereas when using QAM that contains an amplitude component, linearity must be maintained. Unfortunately, linear amplifiers are less efficient and consume more power, and this makes them less attractive for mobile applications [10].

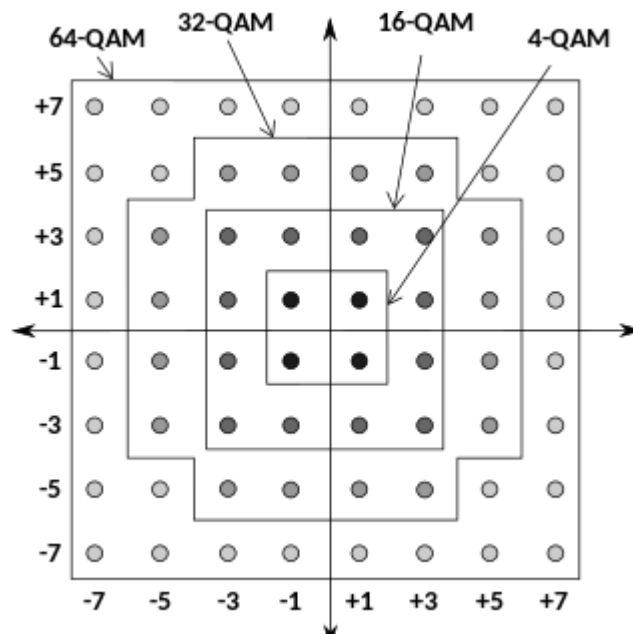


Fig 3.3 Constellation points for 4-QAM, 16-QAM, 32-QAM, and 64-QAM overlapped

The simplest and most commonly used QAM constellations as shown in fig 3.3 consist of points arranged in a square, i.e., 16-QAM, 32-QAM and 64-QAM (even powers of two). Non-square constellations, such as Cross-QAM, can offer greater efficiency but are rarely used because of the cost of increased modem complexity. Communication systems designed to achieve very high levels of spectral efficiency usually employ very dense QAM constellations. For example, current home plug AV2 500-Mbit/s powerline Ethernet devices use 1024-QAM and 4096-QAM [10].

3.2.1.2 FSK

Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is encoded on a carrier signal by periodically shifting the frequency of the carrier between several discrete frequencies. The technology is used for communication systems such as telemetry, weather balloon radiosondes, caller ID, garage door openers, and low frequency radio transmission the VLF and ELF bands. A digital modulation technique that allows data transmission by changing the frequency of the carrier wave according to the digital modulating signal is known as Frequency Shift Keying (FSK). The simplest form of FSK is Binary frequency shift keying (BFSK). Here, the frequency of the carrier wave changed between discrete binary values of the modulating signal as demonstrated in fig 3.4. Thus, the frequency of the carrier shows variation according to the binary message signal. In principle FSK can be implemented by using completely independent free-running oscillators, and switching between them at the beginning of each symbol period. In general, independent oscillators will not be at the same phase and therefore the same amplitude at the switch-over instant, causing sudden discontinuities in the transmitted signal. In practice, many FSK transmitters use only a single oscillator, and the process of switching to a different frequency at the beginning of each symbol period preserves the phase. The elimination of discontinuities in the phase (and therefore elimination of sudden changes in amplitude) reduces sideband power, reducing interference with neighbouring channels [16].

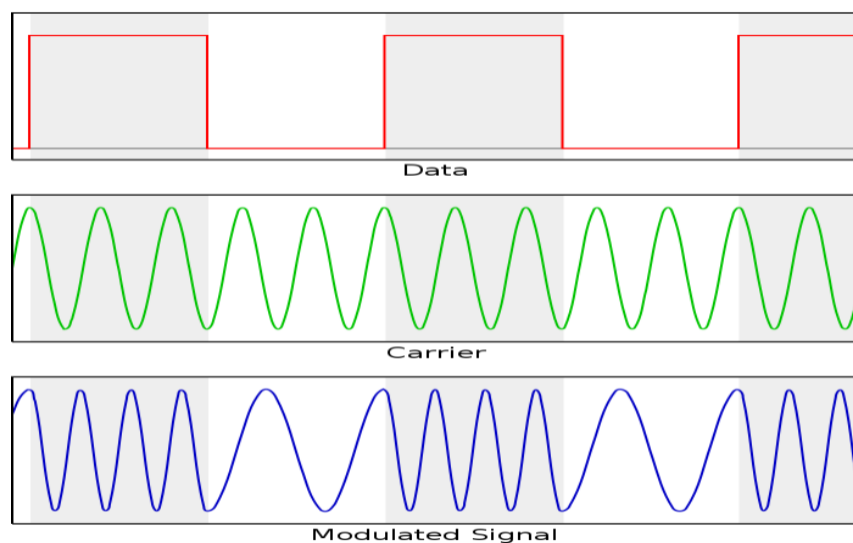


Fig 3.4 Binary FSK waveform

Simple process to construct the circuit, zero amplitude variations, supports a high data rate, Low probability of error, High SNR (signal to noise ratio), More noise immunity than the ASK, Error-free reception can be possible with FSK, Useful in high-frequency radio transmissions, Preferable in high-frequency communications, Low-speed digital applications are some of the advantages of Frequency Shift Keying. Thus, the frequency shift keying is one of the fine digital modulation techniques to increase the frequency characteristics of the input binary signal. Frequency-shift keying (FSK) is a method of transmitting digital signals using discrete signals. The two binary states -- logic 0 (low) and 1 (high) in a binary frequency-shift key mechanism -- are each represented by an analog waveform. Logic 0 is represented by a wave at a specific frequency, and logic 1 is represented by a wave at a different frequency. The distance between logic 0 and logic 1 is known as the deviation or shift point. A modem converts the binary data from a computer to FSK for transmission over telephone lines, cables, optical fiber or wireless media. The modem also converts incoming FSK signals to digital low and high states, which the computer can understand from a binary standpoint. When transmitting data between nodes, the distance between the digital states dictates how much data can be transmitted within a specific length of time. Placing the logic 0 and logic 1 states too far apart will create slow throughput rates. However, if the frequency changes are too close together, it can create what is known as intersymbol interference (ISI) -- a condition which can cause errors on the receiving end of the connection. Thus, for maximum throughput and to prevent ISI, signals should be as close together as possible. By FSK modulation technique we can achieve error-free communication in a few digital applications. But this FSK has finite data rate and consumes more bandwidth can be overcome by the QAM, which is known as quadrature amplitude modulation. It is the combination of amplitude modulation and phase modulation. FSK has also contributed to other digital transport innovations, leading to several spectrum modulation variants, including: Minimum-shift keying, which is used to convert a digital signal into analog signals, Gaussian minimum-shift keying, which is a constant-envelope type of modulation, Audio frequency-shift keying, which is a modulation technique that represents digital data, Continuous-phase frequency-shift keying, which is a continuous form of analog frequency modulation. Despite its bandwidth limitations, FSK is still used today in certain situations where high-reliability transport is needed for low-bandwidth applications. FSK can also operate using more than two binary discrete frequencies. MFSK uses the M-ary orthogonal modulation technique that can transmit two or more bits simultaneously [16].

3.2.1.3 PSK

Phase-shift keying (PSK) is a digital modulation process which conveys data by changing (modulating) the phase of a constant frequency reference signal (the carrier wave). The modulation is accomplished by varying the sine and cosine inputs at a precise time. It is widely used for wireless LANs, RFID and Bluetooth communication. Data communication is rising with different forms of communication formats like analog to digital to carry data along with different modulation forms. There are different types of PSK where each one has its own benefits and drawbacks. An option of the optimum format has to be prepared for every radio communication system. To make the correct option, it is essential to have knowledge of how PSK works. The Phase Shift Keying is one kind of digital modulation method. This kind of method is used to transmit data by modulating otherwise changing the phase of the carrier signal which is known as a reference signal. The digital data can be represented with any kind of digital modulation method by using a limited number of separate signals. This kind of modulation method uses a limited number of phases where each phase can be assigned with binary digits. Generally, every phase encodes an equivalent number of bits. Every bit's pattern forms the symbol that is denoted by the exact phase. A convenient method to represent PSK schemes is on a constellation diagram. This shows the points in the complex plane where, in this context, the real and imaginary axes are termed the in-phase and quadrature axes respectively due to their 90° separation. The amplitude of each point along the in-phase axis is used to modulate a cosine (or sine) wave and the amplitude along the quadrature axis to modulate a sine (or cosine) wave. By convention, in-phase modulates cosine and quadrature modulates sine. In PSK, the constellation points chosen are usually positioned with uniform angular spacing around a circle. This gives maximum phase-separation between adjacent points and thus the best immunity to corruption. They are positioned on a circle so that they can all be transmitted with the same energy. In this way, the moduli of the complex numbers they represent will be the same and thus so will the amplitudes needed for the cosine and sine waves. Two common examples are "binary phase-shift keying" (BPSK) which uses two phases, and "quadrature phase-shift keying" (QPSK) which uses four phases, although any number of phases may be used. Since the data to be conveyed are usually binary, the PSK scheme is usually designed with the number of constellation points being a power of two [7].

BPSK (also sometimes called PRK, phase reversal keying, or 2PSK) is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK as shown in fig 3.5. It does not particularly matter exactly where the constellation points are positioned, and in this figure, they are shown on the real axis, at 0° and 180° . Therefore, it handles the highest noise level or distortion before the demodulator reaches an incorrect decision [7].

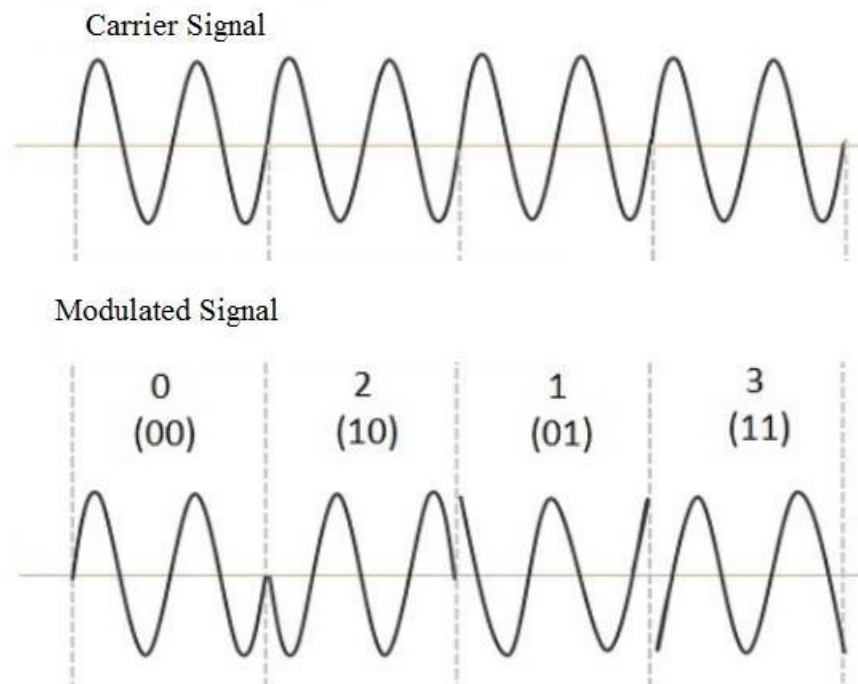


Fig 3.5 Phase-Shift-Keying-Waveform.

It provides good noise immunity, Compared to BPSK, bandwidth used by PSK is reduced to half. The information transmission rate of Phase Shift Keying is higher as it transmits two bits per carrier symbol, Carrier power remains constant as the variation in the PSK amplitude is small, Effective utilization of available transmission bandwidth, Low error probability compared to other methods, The disadvantage of PSK compared to BPSK is the circuit complexity. BPSK technique is the simplest among all the PSK techniques. In this, each signaling element is represented by a single data bit. Here, the carrier undergoes two phase reversal such as 0° and 180° . In phase shift keying the digital bit sequence is first converted to NRZ bipolar signal which directly modulates the carrier wave [7].

3.3 BLOCK DIAGRAM OF THE SDR TRANSMITTER AND RECEIVER

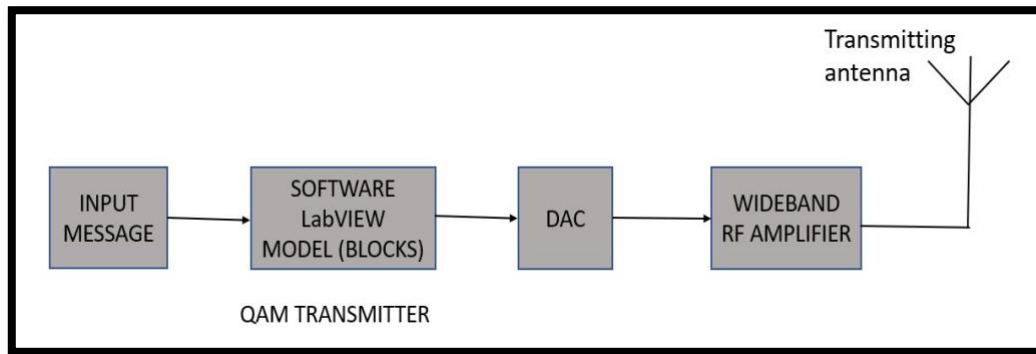


Fig 3.6 Block diagram of the SDR Transmitter

3.3.1 DIGITAL TO ANALOG CONVERTER

A DAC converts an abstract finite-precision number (usually a fixed-point binary number) into a physical quantity as shown in fig 3.6 (e.g., a voltage or a pressure). In particular, DACs are often used to convert finite-precision time series data to a continually varying physical signal. A DAC can reconstruct the original signal from the sampled data provided that its bandwidth meets the requirements of the Nyquist-Shannon sampling theorem (i.e., a baseband signal with bandwidth less than the Nyquist frequency). Digital sampling introduces quantization error (rounding error) that manifests as low-level noise in the reconstructed signal [5].

3.3.2 WIDEBAND RF AMPLIFIER

A radio-frequency power amplifier (RF power amplifier) is a type of electronic amplifier that converts a low-power radio-frequency signal into a higher-power signal. Typically, RF power amplifiers drive the antenna of a transmitter as shown in fig 3.6. Design goals often include gain, power output, bandwidth, power efficiency, linearity (low signal compression at rated output), input and output impedance matching, and heat dissipation. The basic applications of the RF power amplifier include driving to another high-power source, driving a transmitting antenna and exciting microwave cavity resonators. Among these applications, driving transmitter antennas is most well-known. The transmitter-receivers are used not only for voice and data communication but also for weather sensing (in the form of a radar). RF power amplifiers using LDMOS (laterally diffused MOSFET) are the most widely used power semiconductor devices in wireless telecommunication networks, particularly mobile networks [5].

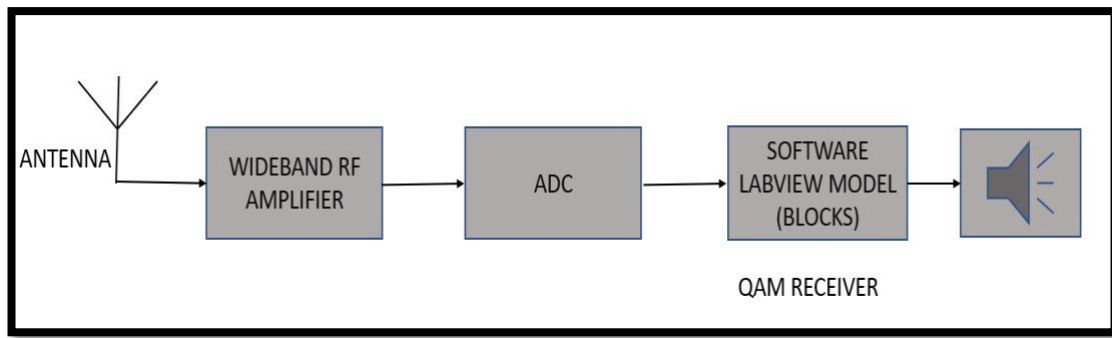


Fig 3.7 Block diagram of the SDR Receiver

3.3.3 ANALOG TO DIGITAL CONVERTER

A converter that is used to change the analog signal from RF amplifier to digital is known as an analog to digital converter or ADC converter as shown in fig 3.7. This converter is one kind of integrated circuit or IC that converts the signal directly from continuous form to discrete form. This converter can be expressed in A/D, ADC, A to D. The inverse function of DAC is nothing but ADC. The analog to digital converter symbol is shown below. The process of converting an analog signal to digital can be done in several ways. There are different types of ADC chips available in the market from different manufacturers like the ADC08xx series. So, a simple ADC can be designed with the help of discrete components [5].

3.4 ADVANTAGES OF THE SDR TRANSMITTER AND RECEIVER

Today's SDR, in contrast, is a general-purpose device in which the same radio tuner and processors are used to implement many waveforms at many frequencies. The advantage of this approach is that the equipment is more versatile and cost effective. Additionally, it can be upgraded with new software for new waveforms and new applications after sale, delivery, and installation. Software-defined radios can be quickly and easily upgraded with enhanced features. In fact, the upgrade could be delivered over-the-air. Software-defined radios can talk and listen to multiple channels at the same time. New kinds of radios can be built that have never existed. Smart radios or cognitive radios (CRs) can look at the utilization of the RF spectrum in their immediate neighbourhood and configure themselves for the best performance. An SDR can take advantage of underutilized spectrum with the help of cognitive radio which always senses if some spare spectrum is present there in the surroundings environment. If the owner or primary user

of the spectrum is not using it, an SDR can borrow the spectrum and assign it to a secondary user until the owner requires it again. This technique has the potential to dramatically increase the optimal use of available spectrum. The software radio approach, however, results in a compact and in some cases, a power-efficient design. As the number of functionalities increase, same piece of hardware is reused to implement multiple interfaces thus a smaller number of different hardware components are required as well as power consumption is lowered. In the course of deployment, current services may need to be updated or new services may have to be introduced. A flexible architecture of SDR allows improvements and addition of already existing or new functionality through software only instead of replacing the hardware platform or user terminals. The time to market of a commercial product is a key consideration in modern engineering design. Software radio implementation and upgradation of devices via software reduces the design complexity by freeing the designers from the tiresome job associated with analog hardware design and their implementation. An SDR can seamlessly communicate with multiple radios that support different wireless standards. It can also perform bridging between radios as a single multi-channel and multistranded SDR can act as a translator for all the radios dedicated to a particular frequency. The flexible architecture would allow the SDR to support multiple wireless standards. With rapid growth of different wireless standards like Bluetooth, IEEE 802.11 (WLAN) etc. it is now possible to enhance the services of a radio by leveraging other devices that provides complimentary services such as data-audio-video transfer via Bluetooth or finding accurate position via GPS etc. Due to this multi-functionality property of SDR, as different wireless standards continue to evolve, the functionality of SDR can be enhanced by supporting these standards by simply updating or installing new software changing the underlying hardware [8].

CHAPTER 4

IMPLEMENTATION DETAILS

4.1 LABVIEW SIMULATION OF SDR TRANSMITTER AND RECEIVER

A transmitter and receiver were created for the experimental setup using NI LabVIEW. LabVIEW software is used to implement and stimulate different modulation techniques like QAM, FSK, PSK. LabVIEW version 20 is installed.

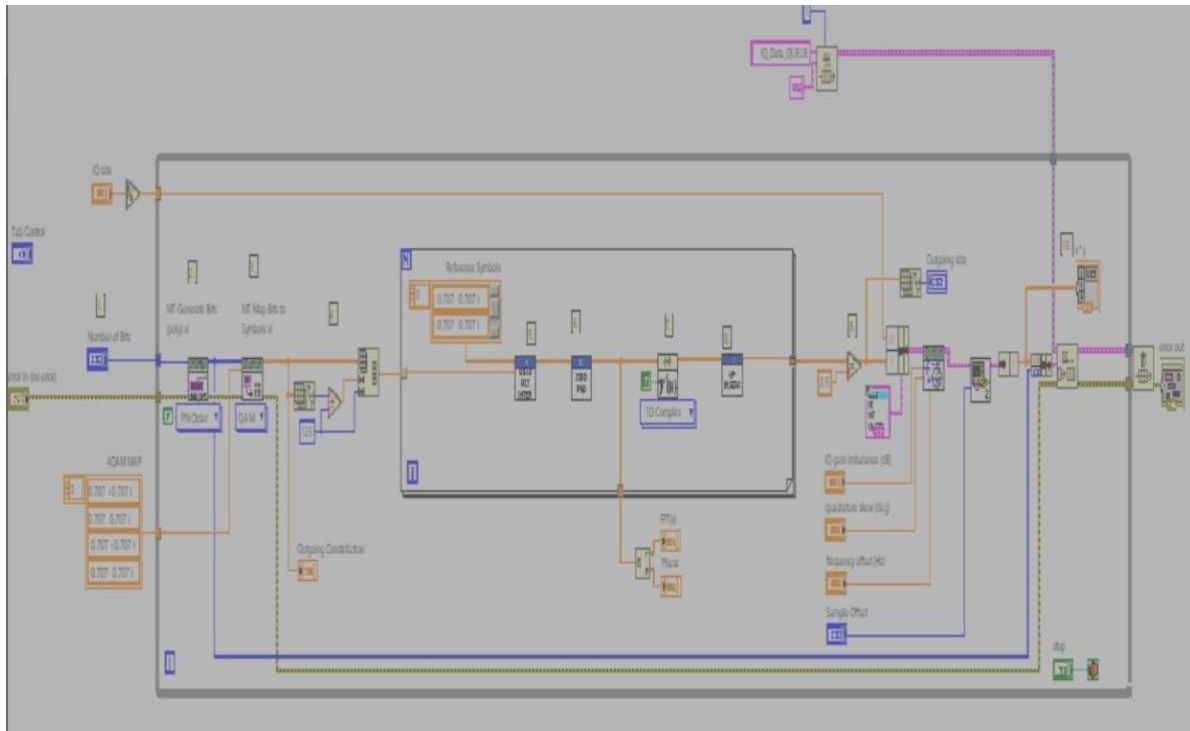


Fig 4.1 QPSK and OFDM Transmitter circuit in LabVIEW

The design of the transmitter and receiver is made using NI LabVIEW and shown in fig 4.1 and fig 4.2 respectively. Also, FSK and PSK modulation techniques are implemented to study more about the transmitter and receiver in software defined radio. This model provides a continuous streaming implementation of OFDM. This example provides easy to read and easy to modify OFDM reference design based on LTE-like parameters (with regards to sub-carriers, reference symbols, and null subcarriers. It includes both a simulated and USRP based implementation to aid in offline work with impairments.

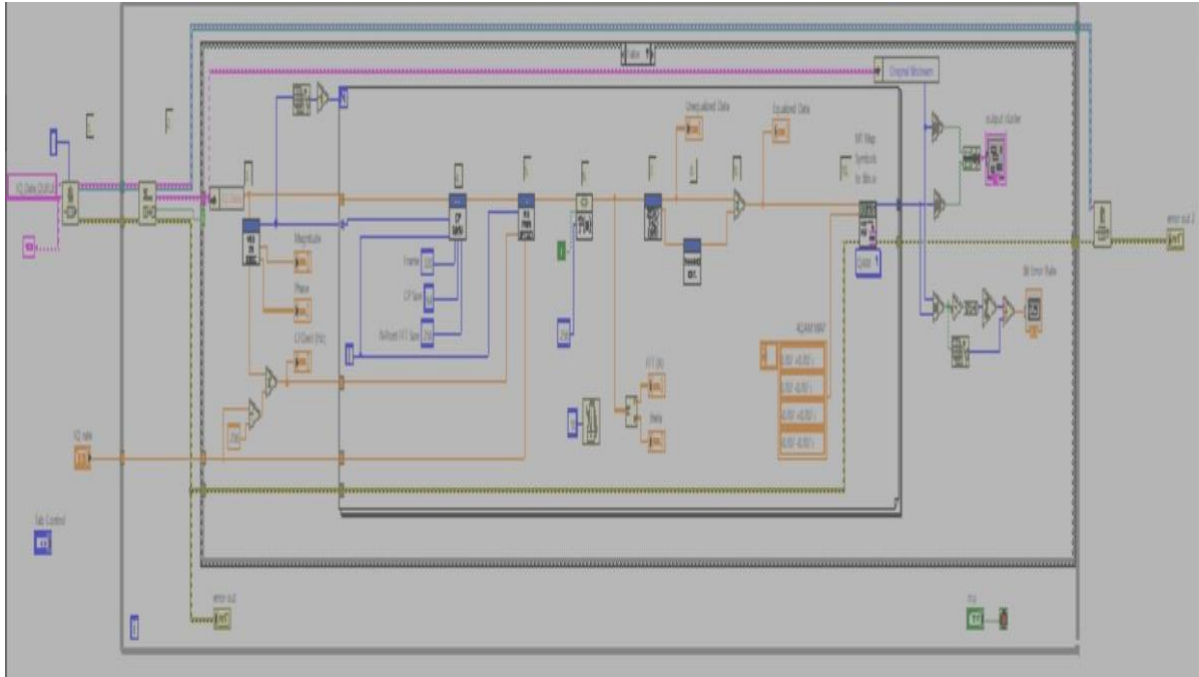


Fig 4.2 QPSK and OFDM Receiver circuit in LabVIEW

Noise signal is given to the transmitter as shown in fig.4.3 and the respective Bit Error Rate is noted for each of the modulation techniques. By doing so, we could know the better noise rejecting modulation technique.

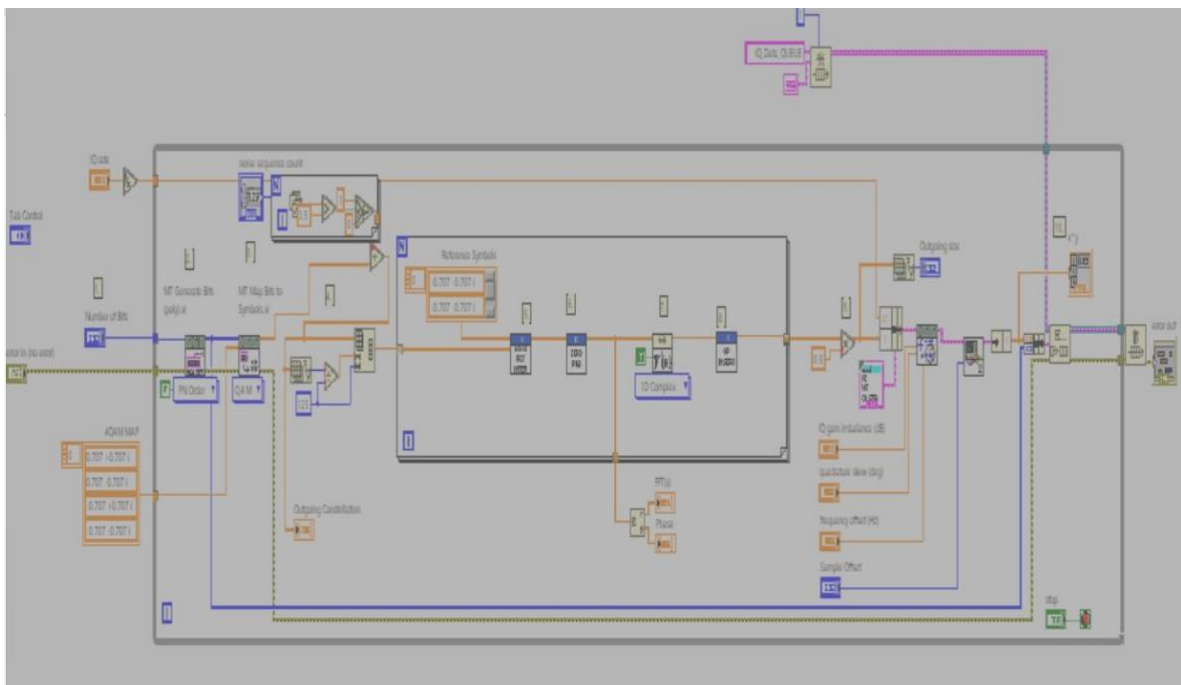


Fig 4.3 QPSK and OFDM Transmitter circuit with noise in LabVIEW

External noise signal is added to the transmitter as shown in Fig 3.7 to analyse the performance of different modulation techniques like QAM, FSK and PSK in LabVIEW. The corresponding signal distorted by noise is received at the receiver end. The Bit Error Rate (BER) for each of the noise sequence count sent is noted at the receiver end. Similarly, the BER is noted for different modulation techniques mentioned earlier. The local oscillator LO Frequency adds IQ rate and carrier frequency of the signal. niUSRP Configure Signal VI can be used with a transmitter session. It sets the IQ rate, carrier frequency, gain, and active antenna. For multiple USRP configurations the channel list specifies a specific USRP. Not all IQ rates, frequencies and gains are valid. While Loop Repeats the code within its sub diagram until a specific condition occurs. A While Loop always executes at least one time. MT Generate Bits (poly) VI polymorphic instance generates Galois pseudo noise (PN) bit sequences. The VI repeats the selected pattern until it generates number of total bits that you specify. Use this instance to specify a PN sequence order based on which the VIs selects a primitive polynomial that returns an msequence. This VI is polymorphic (poly), meaning that there are several versions (instances) of the VI available to choose from depending on the data type you wish to work with. MT Map Bits to Symbols VI Maps bits to complex valued symbols for PSK, QAM, PAM, ASK and CPM modulation schemes and frequency deviations for FSK and MSK modulation schemes. Data Reference Interleave VI Inserts known reference symbols, interleaves symbols. Zero Padding VI Pads beginning and end of symbols up to size N. Inverse FFT VI Computes the inverse discrete Fourier transform (IDFT) of input sequence FFT(X). You must manually select the polymorphic instance you want to use. niUSRP Write Transmitter Data (Poly) VI niUSRP Write Transmitter Data VI allows you to send IQ data to the USRP so that it may transmit that data at the carrier frequency specified by the niUSRP Configure Signal VI. This VI is polymorphic (poly), meaning that there are several versions (instances) of the VI available to choose from depending on the data type you wish to work with. niUSRP Close Session VI niUSRP Close Session VI closes the current Transmitter session and releases the memory in use by that session. MIMO OFDM Receiver VI Snippet niUSRP Open Rx Session VI is the first VI that is used to create a software session with the USRP for receiving an RF signal. A session is necessary to send configuration data and retrieve IQ data from the USRP. niUSRP Property Node VI: Gets or sets NI-USRP properties [4].

CHAPTER 5

SYSTEM DESIGN

5.1 HARDWARE SETUP

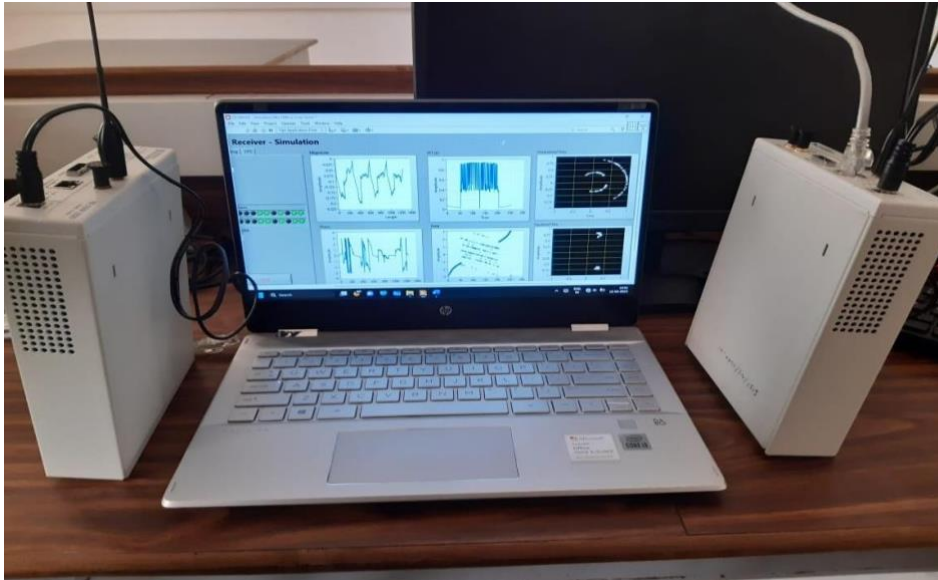


Fig 5.1 USRP real time setup

The setup uses two USRP N210 with CBX (40MHz) daughterboard connected to laptop running i7 and i5 intel CPU processor at receiver and transmitter side respectively as shown in fig 5.2 and 5.3. Loopback cable is used as communication channel between these USRPs as shown in fig 5.1. niUSRP Configure Signal VI can be used with a receive (Rx) session. It sets the IQ rate, carrier frequency, gain, and active antenna. For multiple USRP configurations the channel list specifies a specific USRP. Not all IQ rates, frequencies and gains are valid. niUSRP Initiate VI starts the receive session and tells the USRP that all configuration is complete and that the USRP should begin to capture IQ data (samples). niUSRP Fetch Rx Data (Polymorphic) VI allows you to retrieve IQ data from a USRP that has an Rx session created with the niUSRP Open Rx Session VI. Van De Beek VI uses Maximum likelihood symbol time and carrier frequency offset (CFO) estimator in OFDM. Redundant information contained within the cyclic prefix enables this estimation without additional pilots. Removes cyclic prefix (CP) from a frame and extracts N-point data symbols. One Frame contains CP+DATA. Zero pad Removal and DE interleave VI Removes zero padding, DE interleaves data and extracts reference symbols Channel Estimation Linear VI: Estimates channel based on received reference symbols

and known reference symbols. MT Maps Symbols to Bits VI: Maps complex valued PSK, QAM, PAM, ASK, FSK, MSK and CPM modulated symbols to an output bit stream based on the symbol map that you specify. niUSRP Close Session VI closes the current Rx session and releases the memory in use by that session [4].



Fig 5.2 USRP real time setup for QAM Transmitter

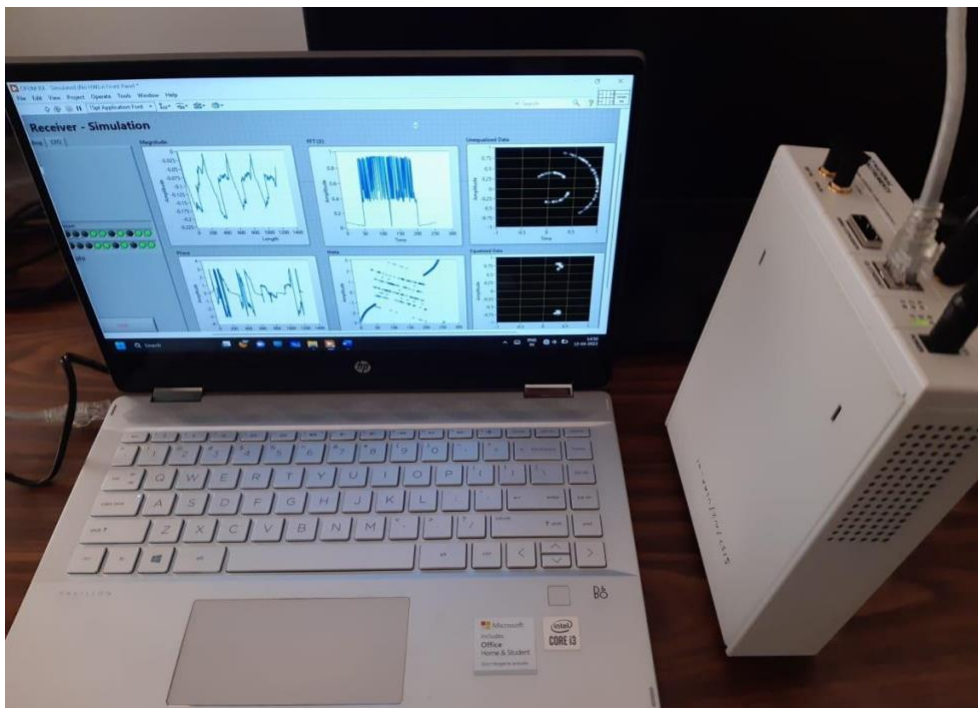


Fig 5.3 USRP real time setup for QAM Receiver

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1 INTRODUCTION

This chapter discusses about the practical results obtained while implementing the project.

6.2 RESULTS OBTAINED

In the simulation mode, different modulation techniques such as FSK, PSK, QAM are employed for processing the signals using LabVIEW. In Fig 6.1, the bit stream transmitted by the QAM transmitter is represented graphically. Fig 6.2 displays the equalized and Unequalized data that was received using the QAM receiver.

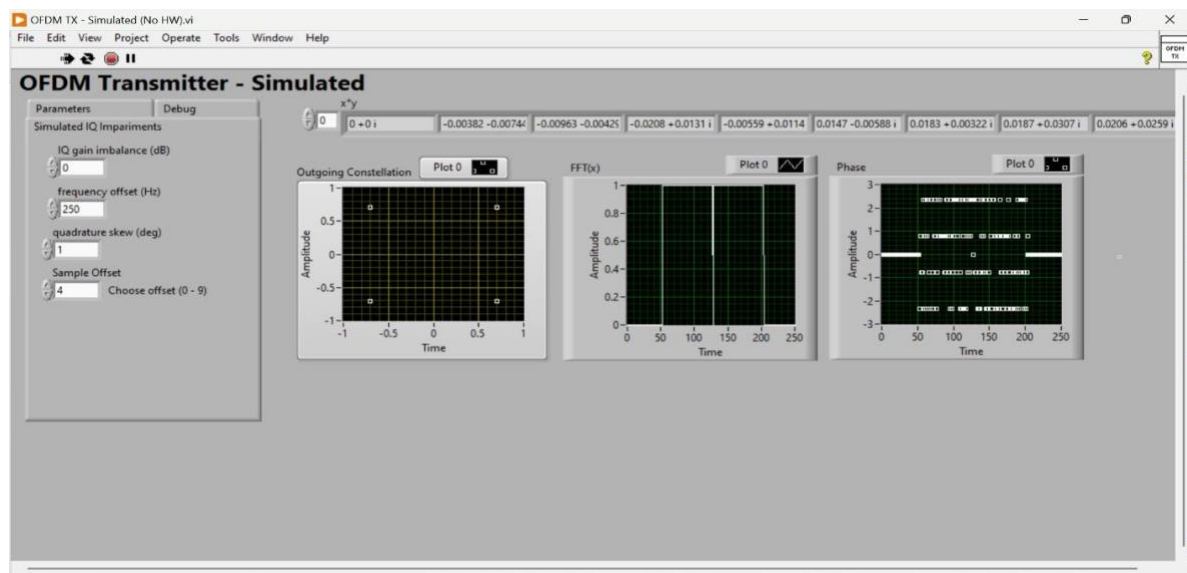


Fig 6.1 QAM transmitter output

When a bit stream is transmitted without any external noise, the corresponding output is received at the receiver side. Many modulating schemes are employed with no noise and respective Bit Error Rate (BER) are noted. For QAM with no noise the BER value is found to be 0.163. Likewise, for FSK and PSK the BER value without noise at the receiver end is 0.339 and 0.165 respectively. Even without any noise it is clear that PSK and QAM have better Bit Error Rate than FSK.

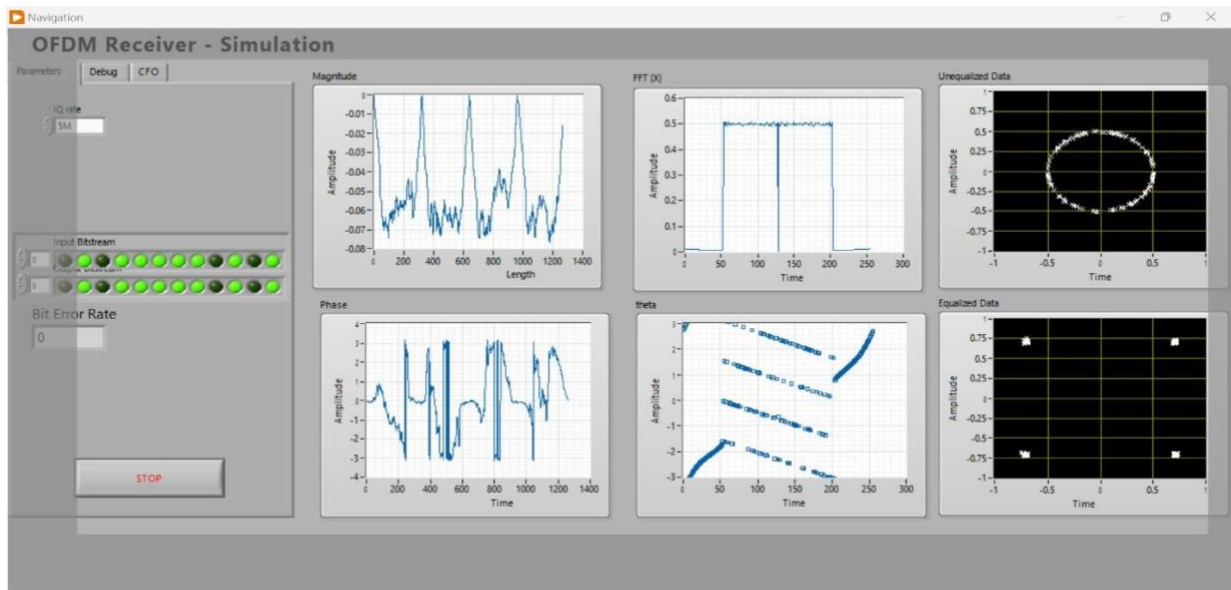


Fig 6.2 QAM receiver output

When a bit stream is transmitted with noise, corresponding distorted signal is received at the receiver side. Many modulating schemes are implemented and different level of noise count is given to study about the Bit Error Rate (BER) for each scheme. Fig.6.3 shows the transmitted QAM modulated signal with a noise sequence count of 3. Distorted signal is sent to the receiver. Fig.6.4 clearly shows the distorted signal at the receiver side with a BER of 0.253.

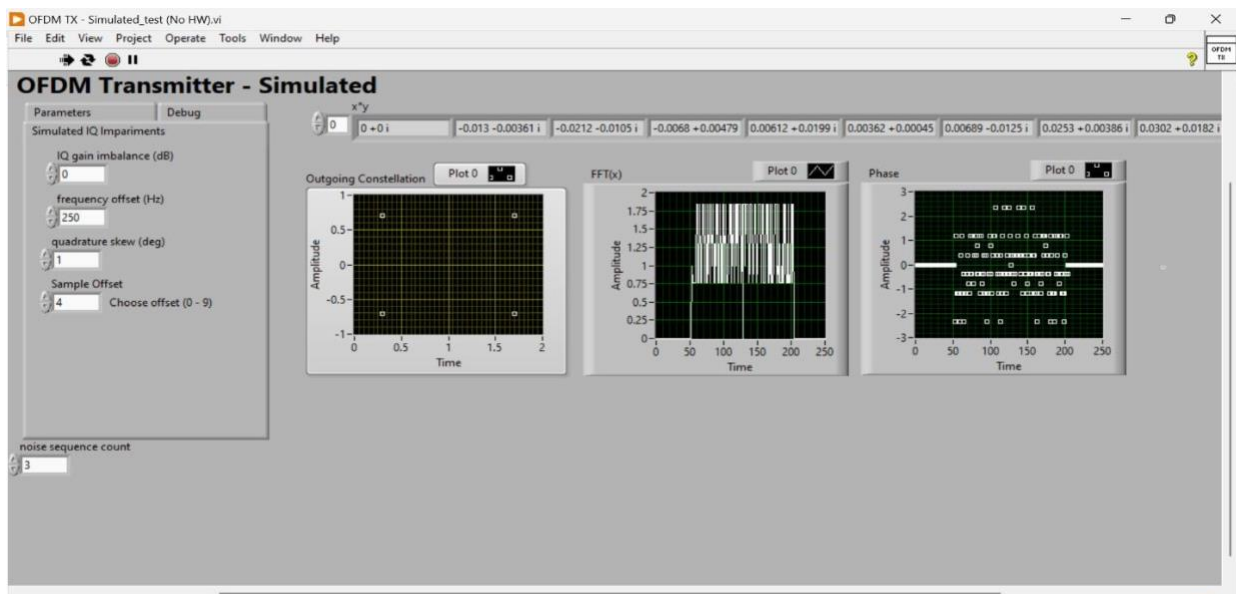


Fig 6.3 QAM Transmitted signal with Noise Sequence Count 3

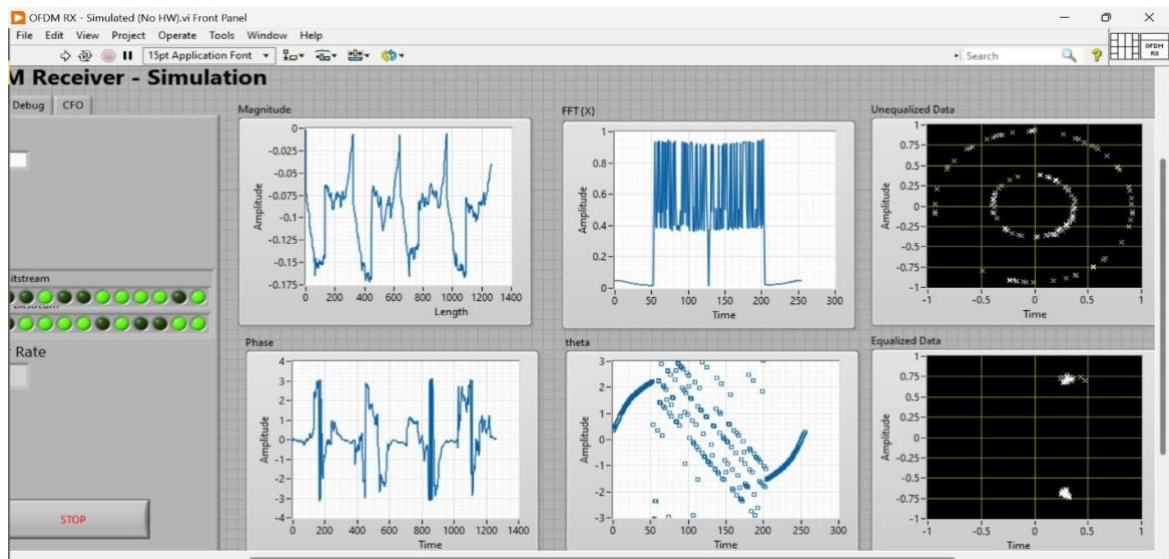


Fig 6.4 QAM Received signal with Noise Sequence Count 3

Different noise sequence count is given and respective BER values are noted. The following table shows the various modulation techniques and the corresponding Noise Sequence Count and BER values.

Table 6.1 Noise Sequence Count and BER values.

SI. NO	MODULATION	NOISE SEQUENCE COUNT	BIT ERROR RATE	E _b /N ₀ (EXISTING SYSTEM)	BIT ERROR RATE (EXISTING SYSTEM)
1	QAM	Nil	0.163	1	0.136
		1	0.248	2	0.092
		3	0.253	3	0.056
		5	0.263	4	0.030
2	FSK	Nil	0.339	--	--
		1	0.491		
		3	0.509		
		5	0.512		
3	PSK	Nil	0.165	1	0.242
		1	0.177	2	0.196
		3	0.265	3	0.150
		5	0.312	4	0.109

Random count of bits (noise) is added at the transmitter side like 1,2,3 etc for all the modulation schemes. For all the noise count added corresponding distorted signals are received and analysed. When the noise sequence count is given as 1, the BER value for QAM, FSK and PSK are 0.248, 0.491 and 0.177 respectively. Similarly, When the noise sequence count is given as 3, the BER value for QAM, FSK and PSK are 0.253, 0.509 and 0.265 respectively. When the noise sequence count is given as 5, the BER value for QAM, FSK and PSK are 0.263, 0.512 and 0.312 respectively. From the table above, graph is plotted to study the BER more accurately. The graph as shown in fig 6.5 clearly depicts that, the more the noise sequence count, more is the Bit Error Rate. Also, PSK and QAM modulation shows very less BER compared to any other modulation scheme used here. This study helps in learning more about BER with different modulation techniques using LabVIEW.

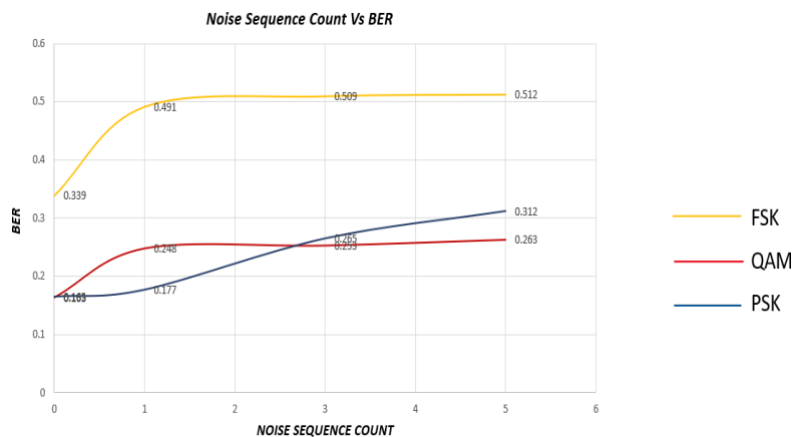


Fig 6.5 Noise sequence count Vs BER

6.3 INFERENCE

From the table 6.1 we can infer that, when noise sequence count increases, the bit error rate increases as well. The above table clearly justify that PSK serves as a better choice among the other modulation techniques employed. The lower bit error rate ensures the reliability of the system. The existing system has implemented only QAM and PSK, whereas we tried and implemented QAM, PSK and FSK. The existing system has studied the Bit Error Rate for different signal to noise ratio, and QAM seems to have lesser BER than PSK. Even though the existing system has shown good results, the BER values are better noted in our work without any circuit complexity and accuracy.

CHAPTER 7

CONCLUSION AND FUTURE WORK

7.1 CONCLUSION

Thus, SDR serves as an effective and reliable radio system that can be utilized in communication systems. The flexibility offered by SDR systems allows us to reconfigure the software maintaining the same set of hardware supporting a wide variety of changing radio protocols in real time. SDR system allows us to receive and transmit any type of radio protocol just by running a new software. One of the reasons why SDR came into picture is to design a radio to communicate irrespective of frequency band limitations. Currently SDRs are mainly implemented in defence sector. In the future commercial applications involving SDRs can be seen. It can be concluded that USRP and NI LabVIEW is a reliable SDR platform tools to emulate the transceiver of digital communication system such as the simple system presented in this paper. The flexibility offers by this platform allows re-configurability at the software level while maintaining the same hardware to facilitate various communication protocols or standards. The flexibility also allows bridging between simulation and real experimental domains that opens more possibility towards intelligent application to be explored Today's SDR, in contrast, is a general-purpose device in which the same radio tuner and processors are used to implement many waveforms at many frequencies. The advantage of this approach is that the equipment is more versatile and cost effective. Additionally, it can be upgraded with new software for new waveforms and new applications after sale, delivery, and installation. Software-defined radios can be quickly and easily upgraded with enhanced features. In fact, the upgrade could be delivered over-the-air. Software-defined radios can talk and listen to multiple channels at the same time. New kinds of radios can be built that have never existed. Smart radios or cognitive radios (CRs) can look at the utilization of the RF spectrum in their immediate neighbourhood and configure themselves for the best performance. The vision of SDR is implementing a single radio device containing software controlled digital hardware that can emulate any radio signal of evolving or already existing wireless standards simply by updating software without replacing the underlying hardware platform. Although SDR technology faces several hurdles, many positive approaches are being introduced to overcome them. These make it suitable to contribute in the development of future generations of wireless communication technology by resolving the limitations of traditional hardware structure.

7.2 FUTURE WORK

In the future, this paper shall be extended by exploring the capability of the platform in analysing the received signal in order to recover the information transmitted in practical wireless system. This work can be further enhanced by adding new technologies like Internet of Things (IOT) and implementing them in the latest communication developments like 5G and 6G which will be very reliable and versatile for the betterment of the upcoming communication world.

7.4 IMPLEMENTATION CHALLENGES

Security Issues: The wireless communication is prone to interference and security threats. In SDR, security threat is major as the consequence of its reconfiguration capability for handling different wireless standards. Reconfigurability is increased by adjusting signal parameters (like frequency, power, and modulation types) through installing or downloading new software instead of removing and replacing hardware components. The successful deployment of SDR technologies will depend on the design and implementation of essential security mechanisms to ensure the robustness of networks and terminals against security threats. Some major security aspects and their protection techniques are as follows. 1) Insertion of malicious software to SDR terminals: Malicious software can be downloaded by an attacker to the SDR terminals. This can be prevented by authentication and verification of software by using Digital Signature to ensure that only authorized software is activated. 2) Alteration or destruction of the configuration data: Configuration data which is needed by the SDR components to perform its functions can be corrupted or removed from the SDR platform. This can be resolved by using data integrity which maintains accuracy and consistency of data over its entire life cycle of SDR. 3) Overuse of processing and memory resources: This threat causes abnormal increase in the consumption of processing or memory resources of the SDR platform to cause degradation of service (DoS). SDR can be protected from this threat by using Trusted Computing (TC) via digital certificate. TC component control the access of resources according to specific permission right. 4) Data Extraction from SDR components: Attacker collects configuration data of SDR components, air interface data or user data which can be used in subsequent attacks. This can be avoided by the integrity of the Security Administrative Module (SAM) which controls modification, activation, and execution of the software modules. 5) Unauthorized use of SDR services: Due to this threat, a malicious software or applications can access or use services of the

SDR platform for which it does not have the proper access level. The Automatic and Calibration Unit (ACU) represent a protection technique against this security threat related to communication service of SDR. If a malicious signal is activated in the SDR node, the ACU can prevent it from transmitting in unauthorized bands.

B. Increased complexity and development cost in SDR: multiple signals are designed to run on a single platform and platform can be reconfigured at different times to host different signals according to users need. For example, a single programmable channel can replace two separate dedicated hardware channels. But compared to hardware intensive radio, SDR increases complexity of a manufacturer's design and development process. Open-source hardware such as USRP and software called GNU Radio Companion (GRC) are commonly used to do experiments in SDR. Since the cost of USRP is high, a low cost set up is needed which is easily affordable. A low-cost alternative is proposed known as Realtek Software Defined Radio (RTL-SDR) along with an RF mixer. RF mixer converts signal to higher frequencies and thereby bringing the signal to the tuning range of RTL-SDR.

C. High speed of ADCs and DACs and their synchronization with DSP: The sampling capabilities of ADCs and DACs are a key challenge for the implementation of SDR systems. The ability to digitize real time high frequency signal is fundamental for bridging the analog domain with the digital domain. In the original SDR concept, the RF signal was directly digitized through a high-speed ADC after antenna at the receiver side. Such a high-speed ADC is very power intensive. Further the data generated by the high-speed ADC is required to be processed by a processor operating at similar high speed. The power consumption of processors at GHz clock rate is also enormous resulting in a system with power consumption of several tens of watts. This difficulty can be solved by use of an RF front end designed appropriately that can produce a desired band at IF frequency of relatively much lower bandwidth compared to the input bandwidth of SDR and the requirements of high-speed ADC are greatly relaxed. Thus, an RF frontend has the potential to make the SDR technology suitable for commercial use. Another challenging issue related to sampling rates is the timing and synchronization required to be maintained within the radio. In order to avoid the mismatch of sampling rates, it is important that the clock rates of the digital signal processing devices (Microprocessors, FPGAs, DSPs) are equivalent and translatable to be synchronized with the clock of the hardware components in the analog domain of the SDR transceiver. This synchronization is major concern to SDR designers. Channelization and sample rate conversion are often needed to match the sampling rate at the output of the ADC to the clock rate of processing

hardware used to implement the receiver as well as to interface the digital hardware that creates the modulated signals to the DAC.

D. Increased power consumption: The software and digital logic implementation imposes a computational burden on the SDR platform that leads to an increase in power consumption. To mitigate the expected increase in complexity leading to a decrease in energy efficiency, cooperative wireless networks are introduced. Cooperative wireless network enables the concept of resource sharing. Resource sharing is interpreted as collaborative signal processing. This interpretation leads to the concept of a distributed signal processor. Orthogonal Frequency Division Multiplexing (OFDM) and the principle of Fast Fourier Transform (FFT) are described as an example of collaborative signal processing. Hence, the designers must choose trade-off between flexibility and energy efficiency.

E. Designing of antennas over a wide range of frequencies: Another challenge lies in designing antennas over a wide range of frequencies since the antennas propagate signals differently for different frequencies transmitted. This leads to the development of Multiple Input-Multiple Output (MIMO) concept and tunable reconfigurable antenna implementation within an SDR to maintain uniform and consistent antenna characteristics over a broad range of frequency or multiband frequencies. In addition, an electronic circuit called 'Antenna tuner' connects the antennas to the rest of the circuit. They are optimized for different antennas and must be matched for optimal power performance. It improves power delivery to the antenna under poor antenna matching condition. However, this requirement complicates the radio design and prevents the implementation of systems with many different frequency ranges on the same SDR platform [14].

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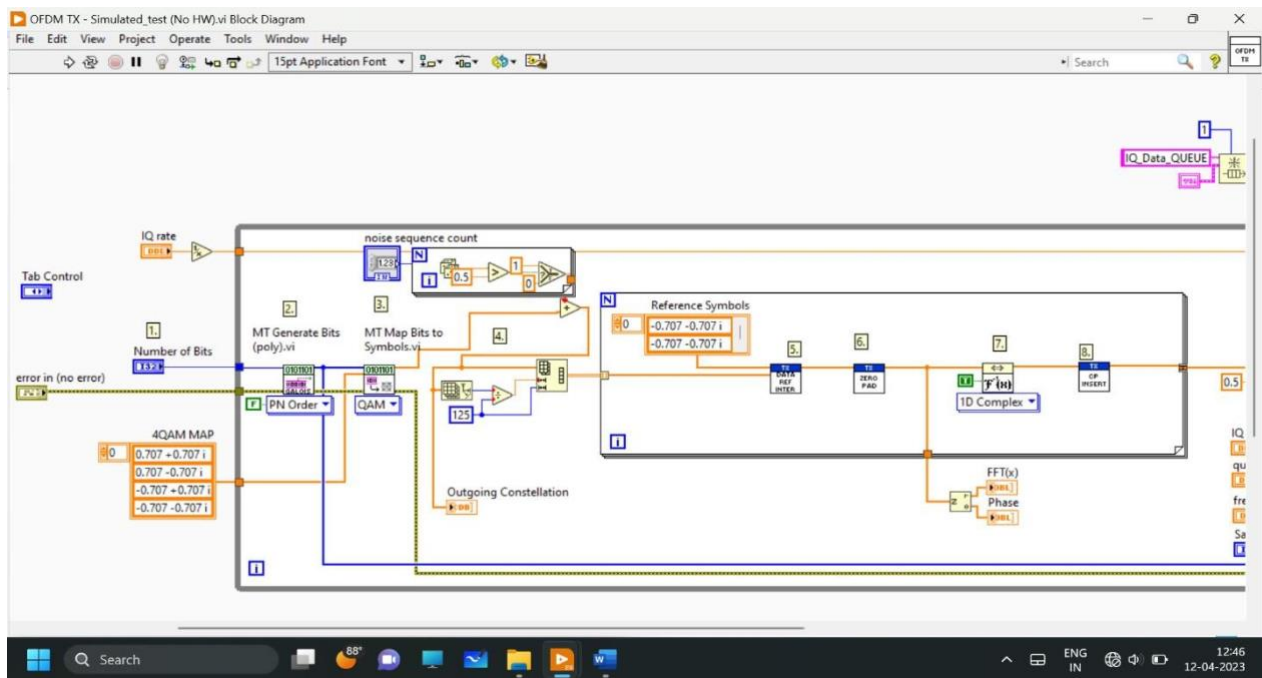
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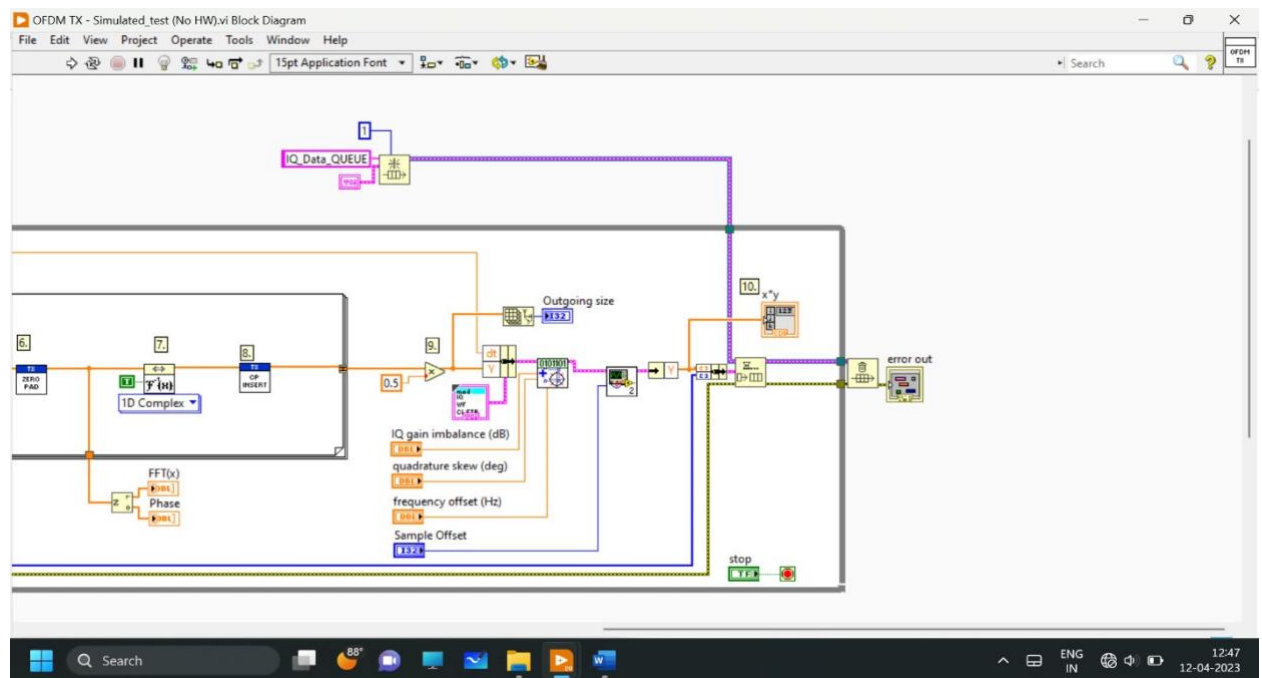
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APPENDIX

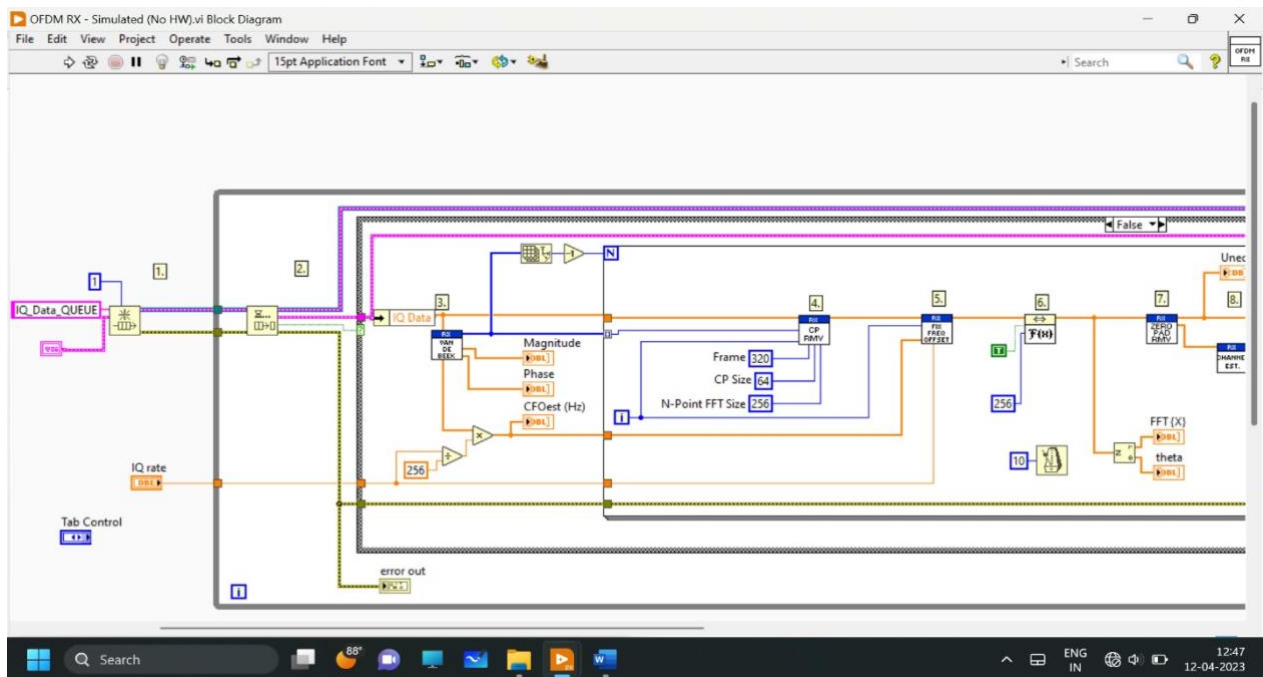
A. SCREENSHOTS



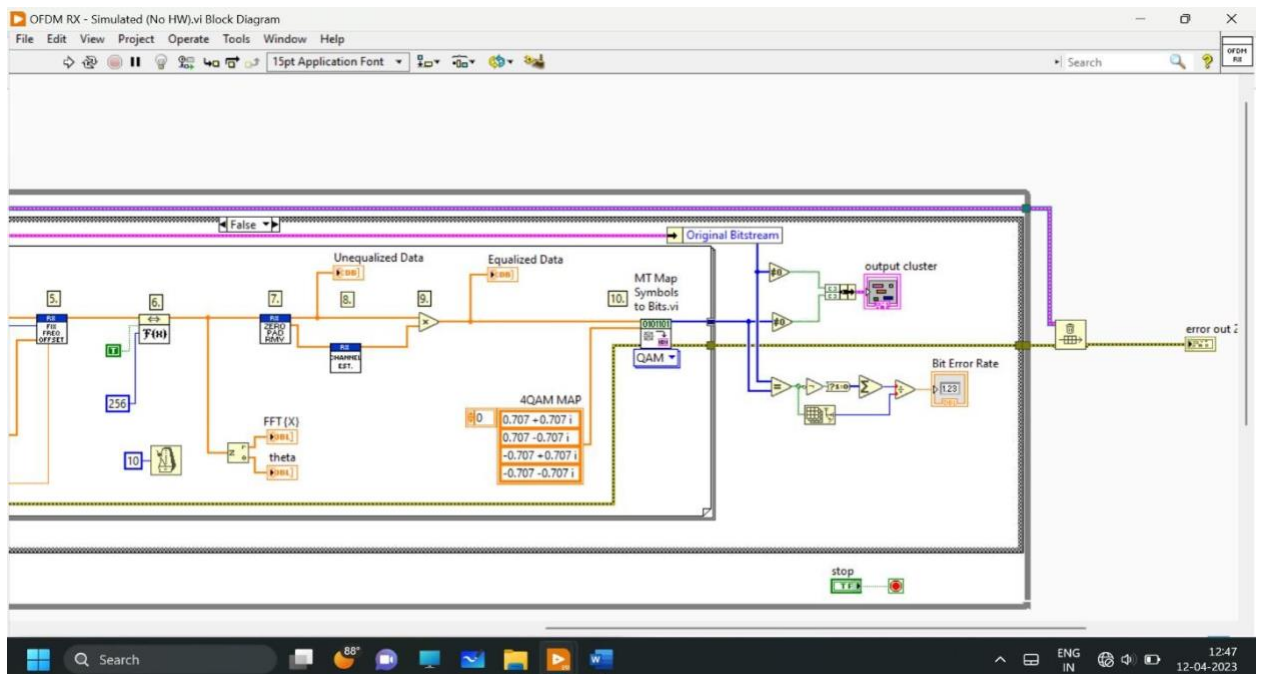
QPSK and OFDM Transmitter circuit in LabVIEW



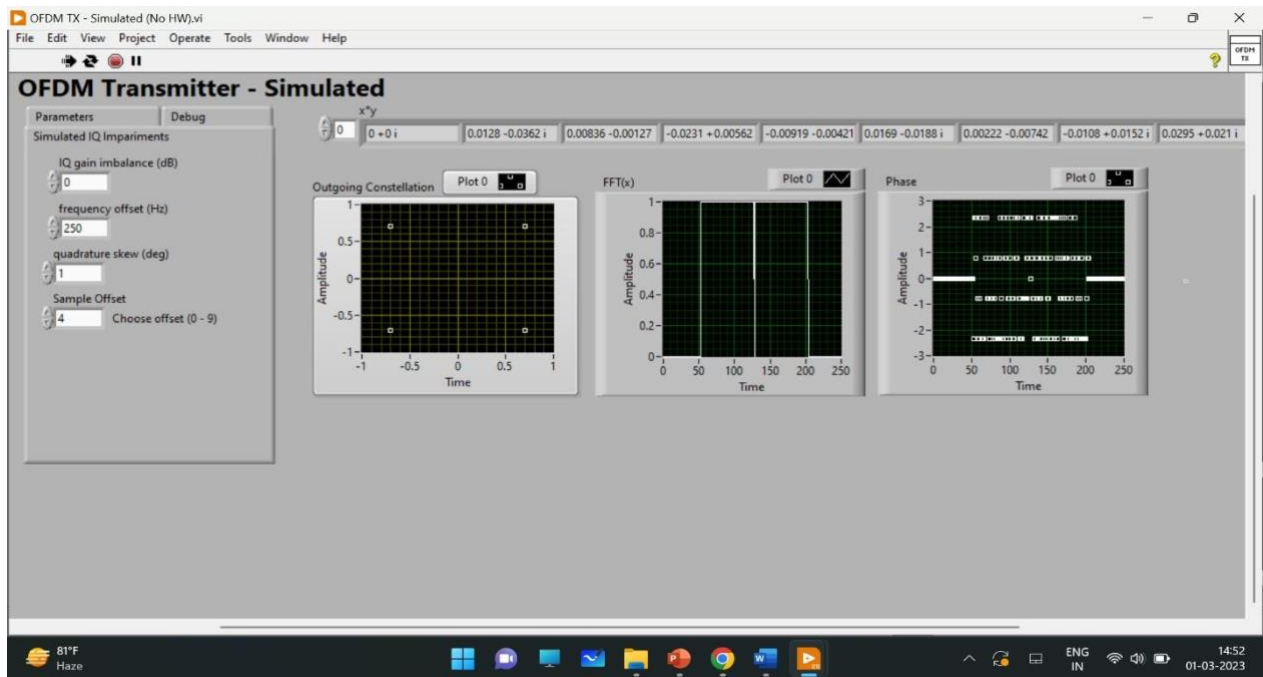
QPSK and OFDM Transmitter circuit in LabVIEW



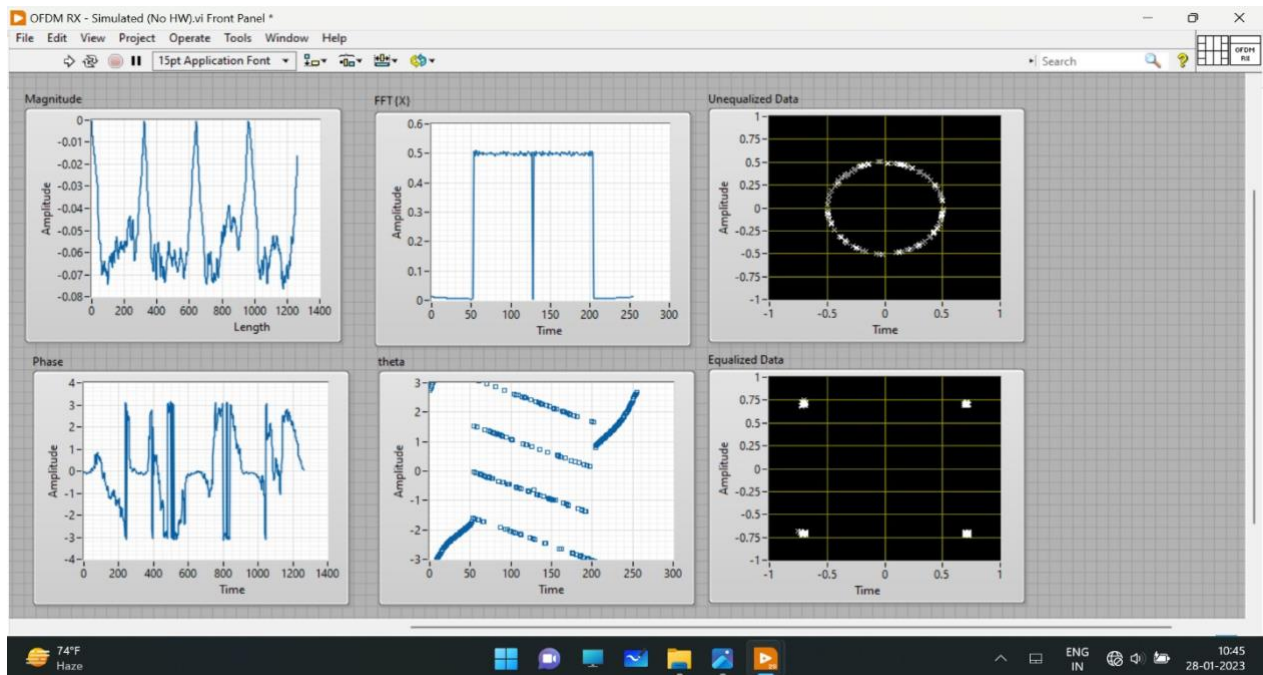
QPSK and OFDM Receiver circuit in LabVIEW



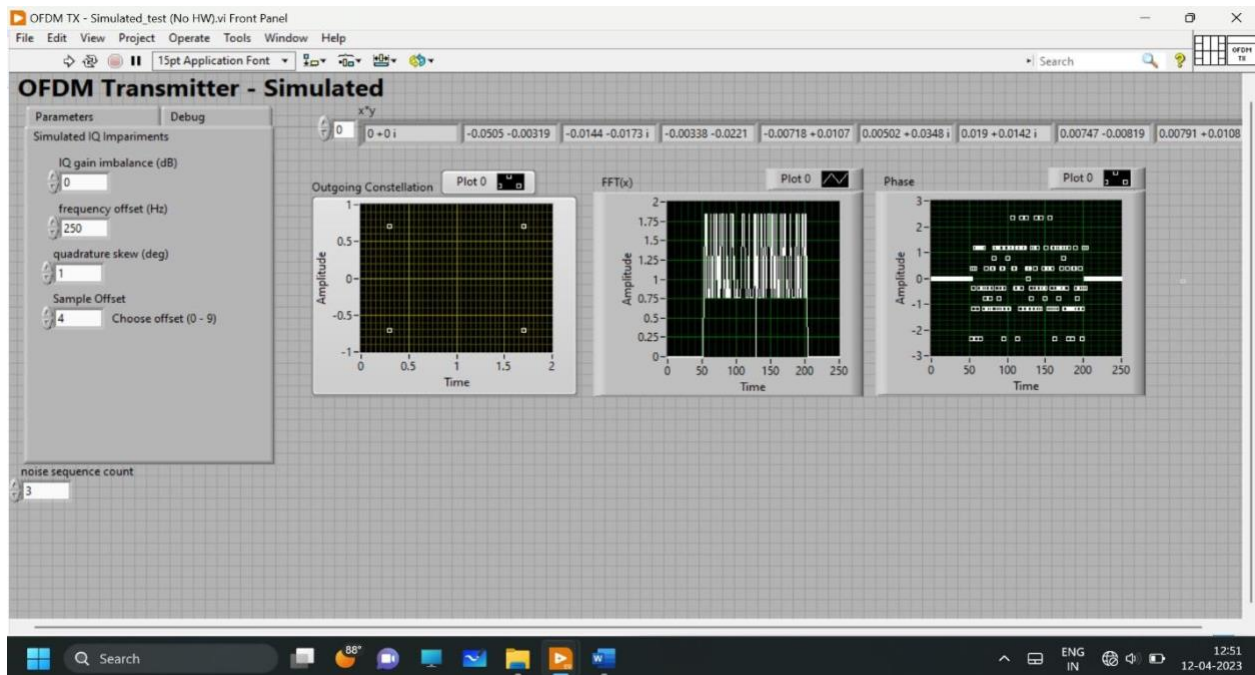
QPSK and OFDM Receiver circuit in LabVIEW



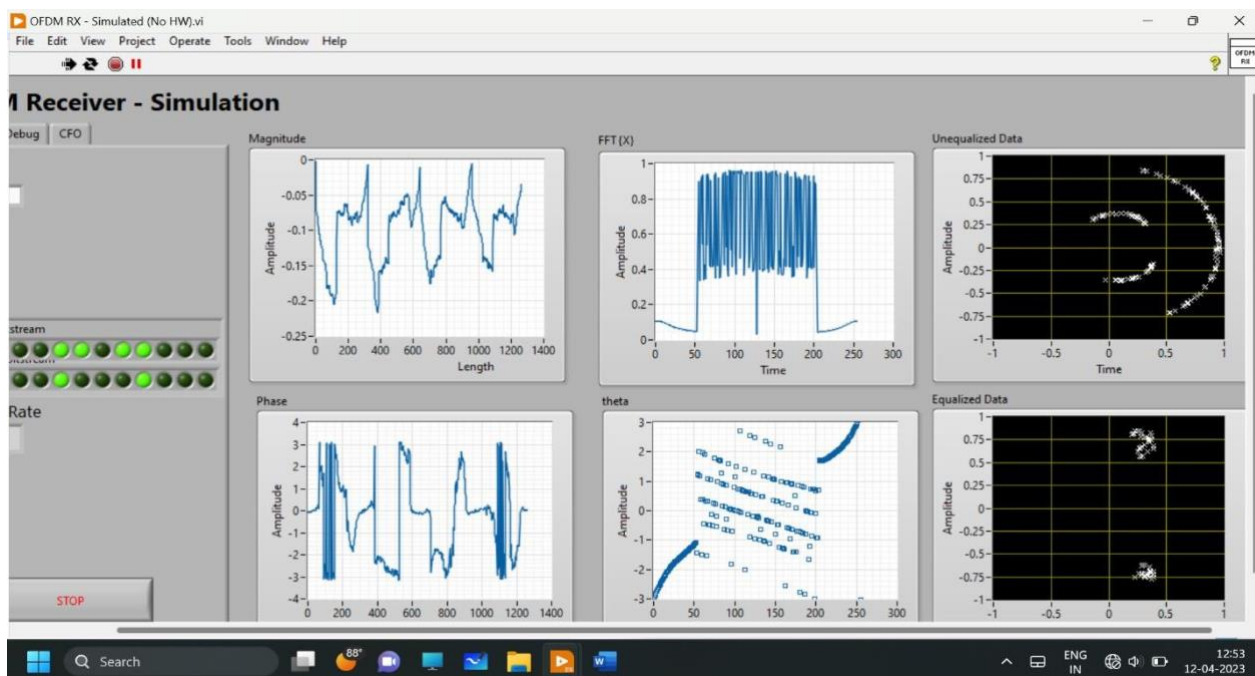
QAM transmitter output



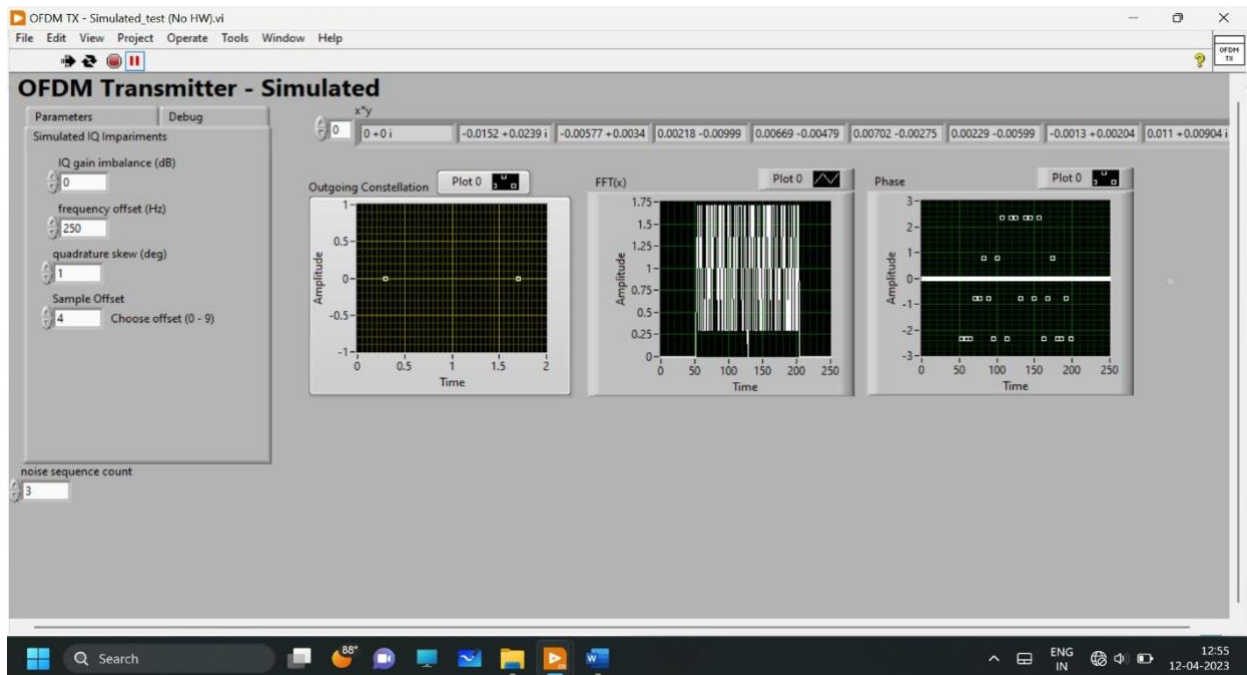
QAM receiver output



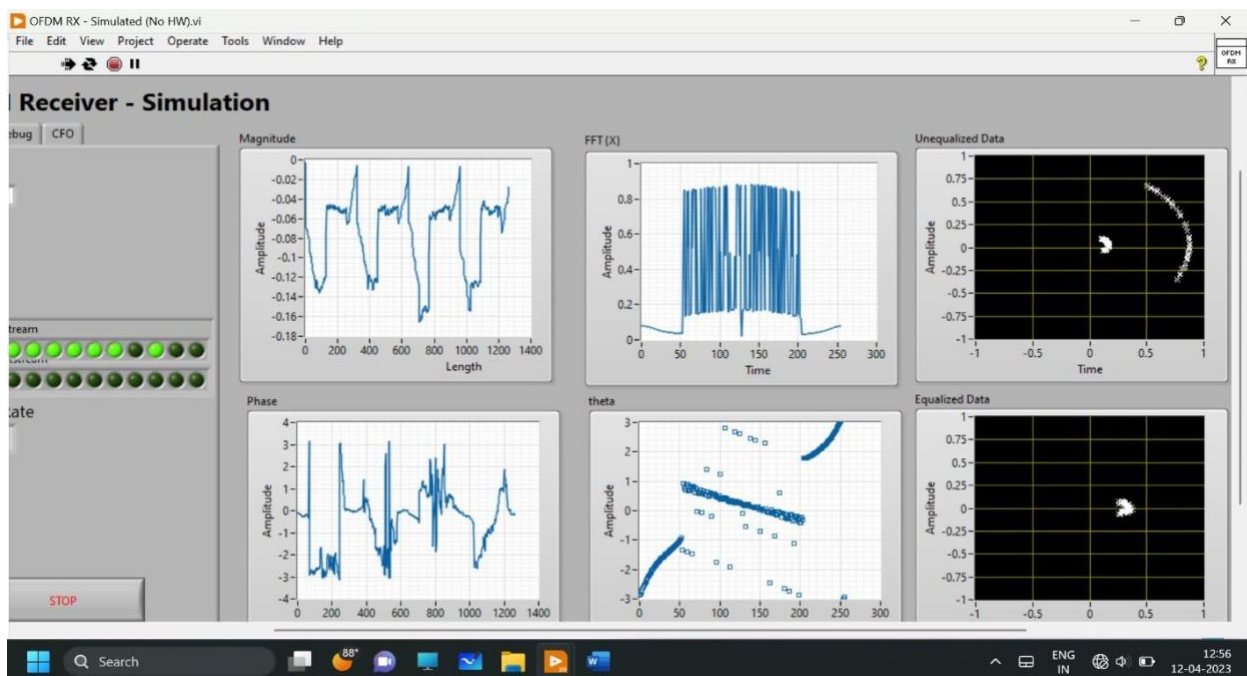
QAM Transmitted signal with Noise Sequence Count 3



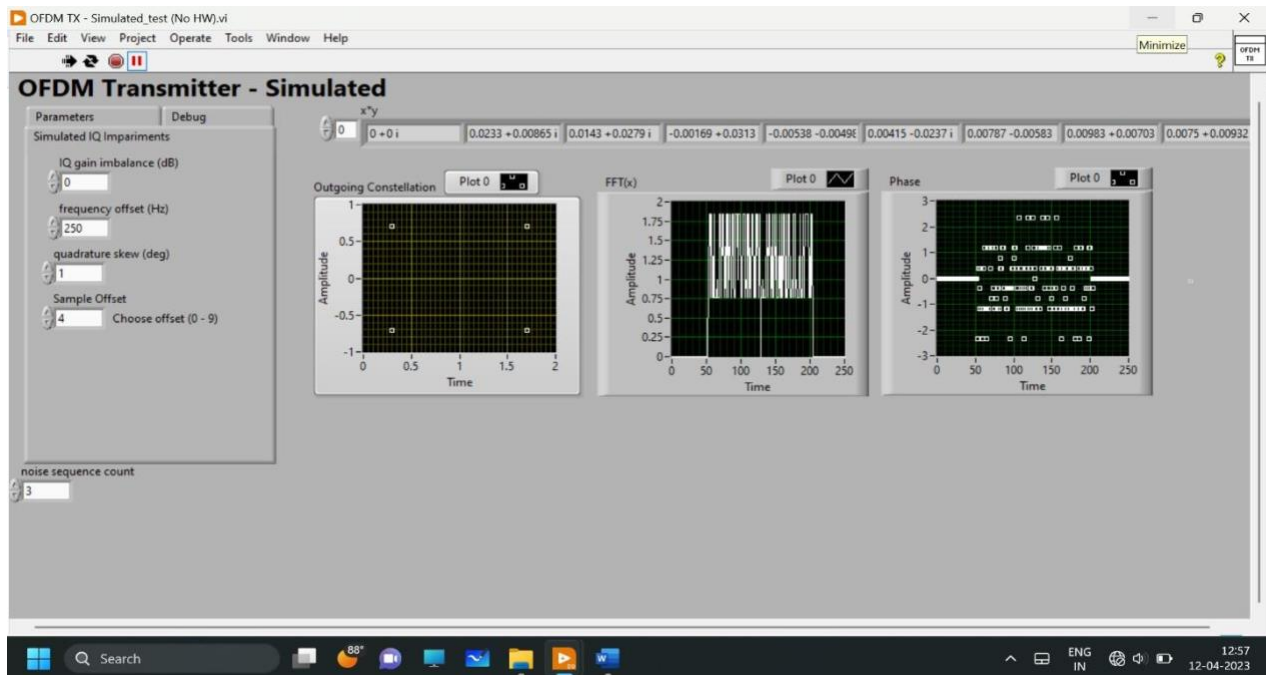
QAM Received signal with Noise Sequence Count 3



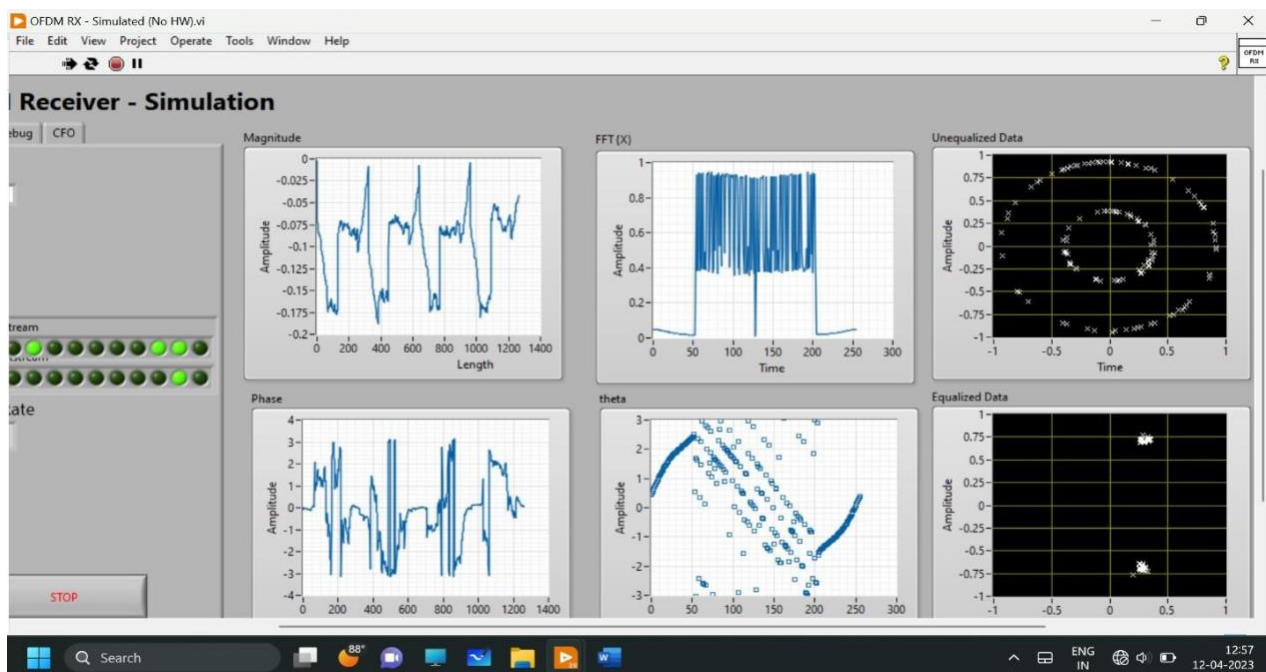
FSK Transmitted signal with Noise Sequence Count 3



FSK Received signal with Noise Sequence Count 3



PSK Transmitted signal with Noise Sequence Count 3



PSK Received signal with Noise Sequence Count 3

B. RESEARCH PAPER

ANALOG AND DIGITAL RECEIVER USING NI LABVIEW AND USRP SDR

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Abstract—In this paper, we discuss current developments in software-defined radio wireless communication system design (SDR). Variables that are frequently enforced through tackle are in contrast to those that are enforced through software on a specific computer or operating system in software defined radio (SDR). A sizable portion of signal processing is moved to the general-purpose CPU rather than being finished in a special-purpose processor. A radio created in this way can send and receive a variety of radio protocols depending only on the software being used. The Universal Software Radio Peripheral (USRP) is then used to create an analog and digital receiver in the megahertz (MHZ) band. A signal in the megahertz band is input using the USRP board. The test and dimension development software NI LabVIEW was used to create this system. In comparison to standard receivers, using an SDR grounded receiver enables us to obtain genuinely high-position performance. This receiver can be used in operations where it is necessary for them to be rigid so that they can quickly be adjusted to accommodate various norms, waveforms, and diapason ologies. This rigidity is essential for military and commercial radio addicts who need to be able to quickly adapt their systems to shifting operational conditions and dangers. Proponents like the Wireless Innovation Forum predict that software-defined radios will eventually replace traditional radio dispatching as the industry standard.

Keywords—Software-Defined Radio (SDR), NI LabVIEW, Universal Software Radio Peripheral (USRP), Wireless Communication.

I. INTRODUCTION

The technological landscape is always evolving. The emergence of new communications technology has fundamentally altered how we communicate. SDR is a comparable invention in the telecom sector (Software Defined Radio). A software-defined radio that can also see its surroundings, keep track of changes, and react to them is known as a cognitive radio (CR). Because software radio can create radios that alter on the cover, giving drug users fresh options, it represents a revolution in radio design. Software radio systems still have a significant degree of inflexibility, which gives drug users and radio innovators the freedom to create and use cutting-edge capabilities that traditional radio systems would consider sensitive. Consequently, by software reconfiguring the modem, SDR is

utilized to construct radios supporting numerous interfaces like CDMA, GSM, and Wi-Fi with just a single modem. [1].

II. OUTLINE TO SDR

A radio system known as an SDR communication system enforces elements that are typically imposed in hardware (e.g., mixers, pollutants, amplifiers, modulators demodulators, sensors) using software on a specific computer or other p]embedded computing bias. It consequently converts radio tackle issues into software issues. Software is utilised to define the transmitted waveforms and software demodulates the entered waveforms. These are the basic characteristics of software radio. Most radios process audio using analogue circuitry or analogue circuitry integrated with digital chips, which is in contrast to this [1].

A. Universal Software Radio Peripheral

NI Universal Software Radio Peripheral (USRP) bias software defined radios are employed for Radio Frequency operations. You can utilize NI USRP transceivers for operations in dispatched exploration and teaching since they can transmit and accept RF signals in a variety of bands. A direct conversion analogue frontal end is used by USRP tackle. Instead of being completed in a special-purpose processor, a significant portion of signal processing is moved to the general-purpose CPU. A radio created in this way can send and receive a variety of radio protocols depending only on the software being used. The Universal Software Radio Peripheral is then used to build an analogue and digital receiver in the megahertz (MHZ) band (USRP). The USRP board is used to input a signal in the megahertz range using high-speed analog-to-digital transformers (ADCs) and digital-to-analog transformers (DACs) outfitted with an FPGA for both digital down conversion (DDC) and digital up conversion (DUC). The analogue front end of the receiver chain, which is highly sensitive and capable of receiving minuscule signals, is the first step in the receiver chain. Direct down conversion is then used to digitize those signals into in-phase and quadrature baseband signals. High-speed analog to digital conversion is followed by down conversion, a DDC that reduces the slice rate and

packetizes I and Q for transmission to a host computer via Gigabit Ethernet for additional processing. I and Q are created on the host computer and then sent via Ethernet to the USRP tackle at the start of the transmitter block. A DUC first prepares the signals for the DAC, after which the DAC and I-Q mixing immediately up-convert the signals to produce an RF frequency signal that is also amplified and transmitted. [3].

B. LabVIEW

Masterminds create automated exploration, confirmation, and product test systems using LabVIEW, a graphical programming environment. LabVIEW is another name for Laboratory Virtual Instrument Engineering Workbench. The LabVIEW programming model, sometimes referred to as G, is based on the availability of data. Although that sub If there is sufficient data available, a function or sub VI will run. The arrangement of a graphical block diagram (the LabVIEW source code), on which the programmer connects multiple function bumps by drawing cables, determines the amount of prosecution. Every knot can execute once all the input data are accessible since these cables propagate variables. Since this may be the true for several bumps at once, LabVIEW naturally executes in parallel. The built-in scheduler automatically utilizes multi-processing and multi-threading approach by multiplexing numerous Zilches vestments across the bumps prepared for prosecution. [3].

III. SYSTEM DESIGN

The fundamental components of digital communication used in this paper are briefly explained in this section.

A. Transmitter

The FM transmitter works as a low power transmitter that sends audio signals using FM swells, a carrier swell brought on by a change in frequency. The carrier swell frequency is a natural component of the audio signal of the breadth, which is generated by the FM transmitter in a VHF band between 88 and 108 MHz. The FM transmitter is shown in block form in the following image. A microphone, an audio pre-amplifier, a modulator, an oscillator, an RF amplifier, and an antenna are needed for the FM transmitter. The carrier frequency, which is the first, and the audio frequency, which is the second, make up the FM signal. The carrier frequency is modulated using audio frequency. The FM signal can be created by changing the carrier frequency. The RF signal is produced by the oscillator in the FM transmitter [1].

B. Receiver

An FM receiver circuit's primary job is to accept the radio signal and transform it into an audio signal. The majority of broadcast reception stations employ FM receiver circuits. A good FM receiver circuit should be able to accept signals as they should be, have a high bandwidth, be extremely quiet, be free of interference, etc. Next, you'll see a block illustration of an FM receiver that will help you comprehend how it functions [7].

C. OFDM

Orthogonal frequency-division multiplexing distributes a single information stream among numerous closely spaced narrowband subchannel frequencies in place of using a single Wideband channel frequency. As an illustration, each bit in the conventional sluice might be represented by a component of the signal with a duration of one minute and a bit spacing of 0.25 ns. When using OFDM to resolve the signal across four element aqueducts, each bit can be represented as 4 ns of the signal with a 1 ns gap between them. The overall data rate is maintained at 4 bits every 5 ns, but the signal integrity is improved. An OFDM system can be used in a variety of ways with various characteristics, guard intervals, and modulation algorithms. Because it is the most common technique, encoded orthogonal frequency-division multiplexing (COFDM), which includes encoded forward error correction, is frequently used interchangeably with OFDM [1].

D. QAM

The QAM (quadrature breadth modulation) technique is used to combine two AM (breadth modulation) signals into a single channel. This technique doubles the effective bandwidth of the system. Along with palpitation AM (PAM), QAM is also used in digital systems like wireless operations. A QAM modulator serves as a translator, helping to recast digital packets into an analogue signal in order to transmit data without interruption. When utilized for digital transmission for radio dispatching activities, quadrature breadth modulation, or QAM, is more suitable to transmit advanced data rates than conventional breadth modulated systems and phase modulated schemes. There are just two spots on introductory signals that permit the transfer of either a 0 or 1. There are several different points that can be utilized with QAM, each with specific phase and breadth values. This is an example of a constellation. A single signal can transport data at a significantly higher rate since the different points on the constellation illustration are given different values [1].

IV. EXPERIMENTAL SETUP

A transmitter and receiver were created for the experimental setup using USRP and LabVIEW. The modes used in this experiment are as follows:

A. Stimulation mode

LabVIEW software is used to implement, stimulate, and use OFDM and QAM modulation techniques in this mode, as demonstrated in Figs. 1 and 2. Software-wise, LabVIEW version 20 is installed.



Fig.1 QPSK and OFDM Transmitter

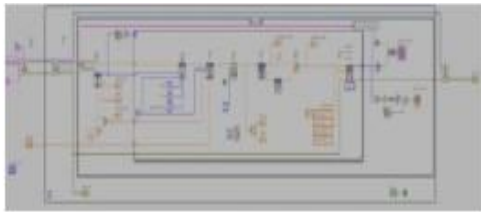


Fig.2 QPSK and OFDM Receiver

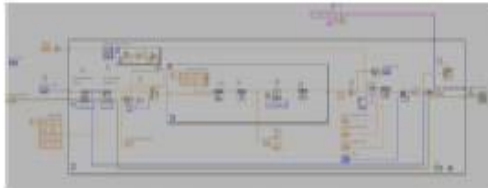


Fig.3 QPSK and OFDM Receiver with Noise

Also, FSK and PSK modulation techniques are implemented to study more about the transmitter and receiver in software defined radio. Noise signal is given to the transmitter as shown in Fig.3 and the respective Bit Error Rate is noted for each of the modulation techniques. By doing so, we could know the better noise rejecting modulation technique.

B. Real mode

In this mode, real-world signals are captured, sent, and received using the USRP SDR. On each side, one NI USRP is utilized for the transmitter and the other for the reception. On either side, computers are connected to the two USRPs.

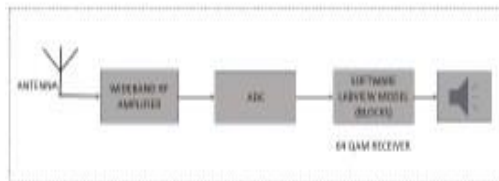


Fig.3 QPSK and OFDM Receiver

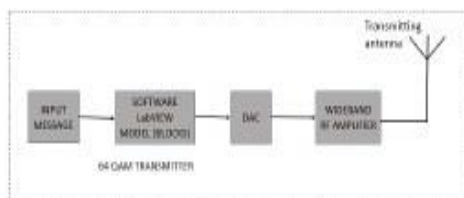


Fig.4 QPSK and OFDM Transmitter

Figs. 3 and 4 depict the general block diagrams of a receiver and transmitter, respectively.

V. RESULTS AND DISCUSSION

In the simulation mode, different modulation techniques such as FSK, PSK, QAM are employed for processing the signals using LabVIEW. In Fig. 5, the bit stream transmitted by the QAM transmitter is represented graphically. Figure 6 displays the equalized and Unequalized data that was received using the QAM receiver.



Fig.5 Transmitter output

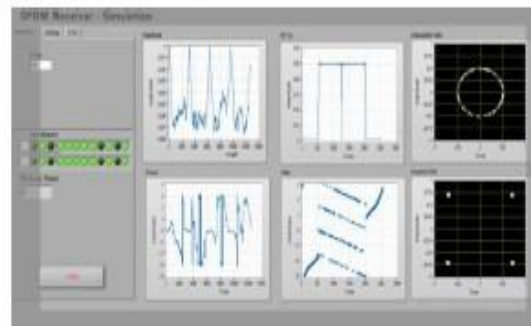


Fig.6 Receiver output

When a bit stream is transmitted with noise, corresponding distorted signal is received at the receiver side. Many modulating schemes are implemented and different level of noise count is given to study about the Bit Error Rate (BER) for each schemes.

Fig.7 shows the transmitted QAM modulated signal with a noise sequence count of 3 . Distorted signal is sent to the receiver. Fig.8 clearly shows the distorted signal at the receiver side with a BER of 0.253.

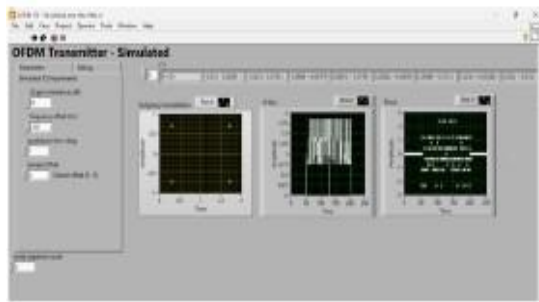


Fig.7 QAM Transmitted signal with Noise Sequence Count 3

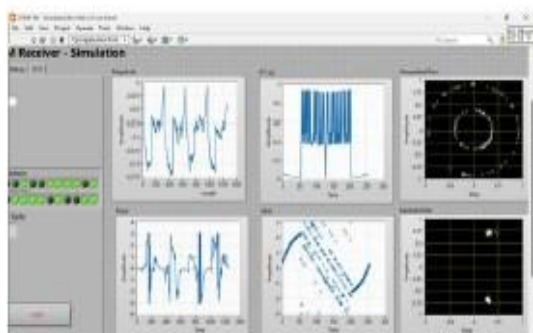


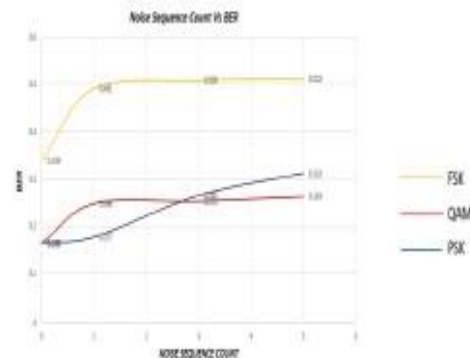
Fig.8 QAM Received Signal with Noise

Different noise sequence count is given and respective BER values are noted. The following Fig.9 shows the various modulation techniques and the corresponding Noise Sequence Count and BER values.

Sl.NO	MODULATION	NOISE SEQUENCE COUNT	BIT ERROR RATE
1	QAM	Nil	0.163
		1	0.248
		3	0.253
		5	0.263
2	FSK	Nil	0.339
		1	0.493
		3	0.509
		5	0.512
3	PSK	Nil	0.165
		1	0.177
		3	0.265
		5	0.312

Fig.9

From the table shown earlier graph is plotted to study the BER more accurately.



The graph clearly depicts that, the more the noise sequence count, more is the Bit Error Rate. Also, PSK modulation shows very less BER compared to any other modulation scheme used here. This study helps in learning more about BER with different modulation techniques using LabVIEW.

VI.CONCLUSION

We can conclude that USRP and LabVIEW serve as dependable and reliable SDR platform tools to design a transceiver as shown in this paper. This platform allows for software reconfigurability without changing the current hardware implementation, which gives it a lot of flexibility. Thus, paving the way for more innovations with the software. By examining the signals in this platform, this work will be expanded for use in real-world wireless communication applications.

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