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OFDM Data Streaming Using USRP 2944R and LabVIEW

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ABSTRACT—

In recent years there has been an increasing demand for high data rates on mobile communications networks because of broadband multimedia applications. To increase data rates over a radio link from Kb/s to Mb/s with good Quality-of-Service (QoS), many issues related to wireless transmissions occurs. For example multipath reception, delay in a radio channel, fading, Inter Symbol Interference (ISI) etc. The solution for this is OFDM data streaming. The NI Universal Software Radio Peripheral (USRP) is computer hosted RF transceivers used for development and exploration of Software-Defined Radio (SDR). The NI-USRP transceivers can transmit and receive the radio-frequency signals in a several bands and can be used for application in communication education and research. In this paper, the performance of OFDM data streaming using USRP 2944R and LabVIEW is analyzed. The parameters such as constellations, carrier frequency and Van de Beek algorithm is incorporated. Varying the distance between the transmitter and receiver antennas, the Bit Error Rate (BER) & Signal to Noise Ratio (SNR) is calculated.

Keywords*—OFDM, Van de Beek Algorithm, USRP, LabVIEW.*

1. INTRODUCTION

The Orthogonal Frequency Division Multiplexing (OFDM) is one of the widely adopted schemes in wireless technologies such as Wi-Fi and LTE due to its high transmission rates, and the robustness against Inter Symbol Interference (ISI). OFDM has been the core technology of the fourth-generation mobile communication due to its strong ability to resist channel fading and high spectral efficiency. OFDM is a multi- carrier modulation technique which divides the available spectrum into many carriers. OFDM uses the spectrum efficiently compared to Frequency Division Multiplexing Access (FDMA) by spacing the channels much closer together and making all orthogonal to one another to prevent interference between the closely spaced carriers. In this project we have implemented to analyze performance of OFDM data streaming transceivers using USRP 2944R and LabVIEW.

The basic principle of OFDM is to split a high-rate data stream into a number of lower data rate streams that are transmitted into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. It employs DFT/IDFT to replace the banks of sinusoidal generator and the demodulators significantly to reduce the implementation complexity of OFDM modems. OFDM system can be implemented with USRP 2944R.

The “Software Defined Radio” (SDR) i.e., USRP (Universal Software Radio Peripheral) is very flexible and is able to obtain the most of the functions of wireless communication systems with the minimum cost. Radio in which some or all of the physical layer functions are software defines is known as SDR.

In data communications and networking, OFDM is a method of digital data modulation; where by a single stream of data is divided into several separate sub-streams for transmission via multiple channels. OFDM uses the principle of Frequency Division Multiplexing (FDM), where the available bandwidth is divided into a set of sub-streams having separate frequency bands. OFDM was introduced in 1966 by Chang at Bell Labs and was improved by Weinstein and Ebert in 1971.

OFDM is a specialized FDM having the constraint that the sub-streams, in which the main signal is divided, are orthogonal to each other. Orthogonal signals are signals that are perpendicular to each other. A main property of orthogonal signals is that they do not interfere with each other. When any signal is modulated by the sender, its sidebands spread out either side. A receiver can successfully demodulate the data only if it receives the whole signal. In case of FDM, guard bands are inserted so that interference between the signals, resulting in cross-talks, does not occur. However, since orthogonal signals are used in OFDM, no interference occurs between the signals even if their sidebands overlap. So, guard bands can be removed, thus saving bandwidth. The criteria that need to be maintained are that the carrier spacing should be equal to the reciprocal of the symbol period. In order that OFDM works, there should be very accurate synchronization between the communicating nodes. If frequency deviation occurs in the sub-streams, they will not be orthogonal any more, due to which interference between the signals will occur.

The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate ISI and use echoes and time-spreading (in analog television visible as ghosting and blurring, respectively) to achieve a diversity gain, i.e. a SNR improvement. This mechanism also facilitates the design of single frequency networks (SFNs) where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be re-combined constructively, sparing interference of a traditional single-carrier system.

The remaining of the paper is organized as follows: Section II discusses various literatures related to the techniques used in this work. Section III covers the details of OFDM techniques. The implementation of OFDM data streaming using USRP is discussed in Section IV. Section V presents the overall results and the discussion thereon. Section VI includes the conclusion.

2. RELATED LITERATURE

Various papers related to full-duplex wireless communication system, NI USRP and LabVIEW is discussed in this section.

[1] Mubashir Rehman , Raza Ali Shah, Muhammad Bilal Khan, "RF Sensing Based Breathing Patterns Detection Leveraging USRP Devices", Ajman university, 2021. Non-contact detection of the breathing patterns in a remote and unobtrusive manner has significant value to healthcare applications and disease diagnosis, such as in COVID-19 infection prediction. In this paper, software-defined radio (SDR)-based radio frequency (RF) sensing techniques and machine learning (ML) algorithms are exploited to develop a platform for the detection and classification of different abnormal breathing patterns. ML algorithms are used for classification purposes, and their performance is evaluated on the basis of accuracy, prediction speed, and training time.

[2] S. Dhanasekar, P. Malin Bruntha, T. Mary Neebha, "An Area Effective OFDM Transceiver System with Multi-Radix FFT/IF FT Algorithm for Wireless Application", ICACCS, 2021. An area effective Orthogonal Frequency Division Multiplexing (OFDM) transceiver design with Multi-radix FFT/IFFT algorithm is introduced for wireless applications. The Pseudo-Random Binary Sequence (PRBS) will be sent as input to OFDM Transmitter, which is passed on using orthogonal frequency.

[3] Jose Herrera-Bustamante, Vanessa Rodriguez Ludena, "Design and implementation in USRP of a preamble-based synchronizer for OFDM systems", IEEE, 2020. The Orthogonal Frequency Division Multiplexing (OFDM) is one of the most widely adopted schemes in wireless technologies such as Wi-Fi and LTE due to its high transmission rates, and the robustness against InterSymbol Interference (ISI). However, OFDM is highly sensitive to synchronism errors, which affects the orthogonality of the carriers.

[4] Arshad Ali, "LabVIEW and Internet of things(IOT)Based remote monitoring of lab experiments to enhance collaboration between universities", IJITEE, April 2020.With increasing use of internet globally, many people work from home instead of going to offices it saves time as well as cost for both employer and employee .To collaborate the universities and design the sample experiments by using LabVIEW integrated with IoT for handling of lab experiments.

[5] Adriana Moreno, Jesus Omar Lacruz, Joerg Widmer, "Open Source RFNoC-Based Testbed for Millimeter-wave Experimentation USRP Software Defined Radios" , ISCAS, 2020. Millimeter-wave communications require suitable experiment platforms that allow validation and field tests in both academics, industries research environments. Design and implement the hardware processing blocks required to decode the preamble and compliment of frames.

[6] Nariman A, Salam Bauomy, Eslam Ahmed Elbeh, "Design of SDR Simulation for Wireless Communication between Ground Station and CubeSat Implemented by LabVIEW", JAC-ECC, 2020. Developing small satellites is continuously growing in both CubeSat and other customized platforms. Many universities and other organizations around the world are investing in this type of space technology for various applications ,such as space explorations ,remote sensing .

[7] Yedukondalu Kamatham, Sushmitha Pollamani, "Implementation of OFDM system with Companding for PAPR Reduction using NI-USRP and LabVIEW", IEEE, MAY 2020. An OFDM transceiver is implemented in LabVIEW with Universal Software Radio Peripheral (USRP), such that system complexity is less and BER performance is good. To reduce the PAPR, Companding techniques are well-thought-out which includes Square Root Companding (SQRT), Logarithmic Rooting (Log R) and Tangential Rooting Companding (TanhR). OFDM is also one of the prominent competing Multi Carrier Modulation schemes for considering even 5G wireless communications systems.

[8] Dr. Dereje Shiferew, Addisalem Hailegnaw, Alemie Assefa., "Lab VIEW based Fuzzy Logic Controller for PLC", University of Melbourne, 2020 May. Fuzzy logic controller is designed on LabVIEW particularly for tank water level control. The inputs to fuzzy logic controller are water level in the tank and outflow rate are taken by the help of PLC from the tank level sensor and flow rate sensor. LabVIEW access sensor values using NI OPC-Server. NI OPC-server connect LabVIEW and PLC. Then these inputs are analyzed on LabVIEW. After analyzing the inputs fuzzy logic controller decision is transferred to PLC which then manipulate the actuator in this particular case the DC pump driver.

[9] A. Gaber, A. Nahler, W. Nitzold and M. Anderseck, "USRP-based mmWave Prototyping Architecture with Real-Time RF Control", IEEE, 2021. In this paper, introduce a simple Software-Defined-Radio (SDR) based prototyping architecture with an FPGA-based real-time RF control implementation that can agnostically interface different mm Wave phased antenna array types to a USRP. It is used to investigate on a system-level if beam reciprocity is applicable. The test is executed in an indoor environment at 26.45 GHz (NR band n258).

[10] V. Y. Mikhaylov and R. B. Mazepa, "USRP Devices Application for Modeling Signal-Like Interference in Wireless Networks", SYNCHROINFO, 2020. The object of consideration is wireless networks of the 802.11 standard, also modeling options for the intruder active impact on the physical environment to evaluate the effectiveness of information interaction in the presence of signal-like interference. The subject of the study is the development of software and hardware solutions based on the USRP architecture and LabVIEW software environment for modeling the intruder active impact at the physical level, aimed at destroying or reducing the information interaction effectiveness of wireless network clients. The purpose of the study is to substantiate the possibility and evaluate the effectiveness of the USRP devices and LabVIEW software environment for prototyping specialized hardware and software devices use.

[11] O. R. B. Sayco and A. C. Gordillo, "Design and Implementation for a USRP – Based Visible Light Communications Transceiver", UNSAISCOMM, 2019. In this article we report the results obtained from the design and implementation of an analog front-end prototype for Visible Light Communications (VLC). Complementary, a software defined radio device, the USRP (Universal Software Radio Peripheral), is used for producing a BPSK modulated signal. The obtained bit error rate (BER) is 9.76637×10 -5 at a bit rate of 2.5 Mbps and a distance of 160 cm between transmitter and receiver. The obtained BER is less than the FEC limit of 3.8×10 -3.

[12] Shuping Dang, Guoqing Ma, Basem Shihada, Mohamed-Slim Alouini., "A Novel Error Performance Analysis Methodology for OFDM-IM", IEEE**,** February 17 2019. Error performance is one of the most important and interesting aspects of OFDM-IM, which has been analyzed in most works. However, two key approximations to derive the closed-from expressions of Block Error Rare (BLER) and/or average Bit Error Rate (BER). The first one is to utilize the union bound assisted by the Pair wise Error Probability (PEP) analysis, and the second one is to employ an exponential approximation of Q-function.

3. TECHNIQUES USED IN OFDM

Transmitter

Figure 1 shows the simplified block diagram of OFDM transmitter. The serial input data is mapped to appropriate symbol to represent the data bits. These symbols are in serial and need to convert into parallel format since IFFT module requires parallel input to process data. The serial to parallel module does the conversion. These parallel symbols are transformed from frequency domain to time domain using IFFT module. These signals are converted into serial format and add a cyclic prefix to data frame before being transmitted.

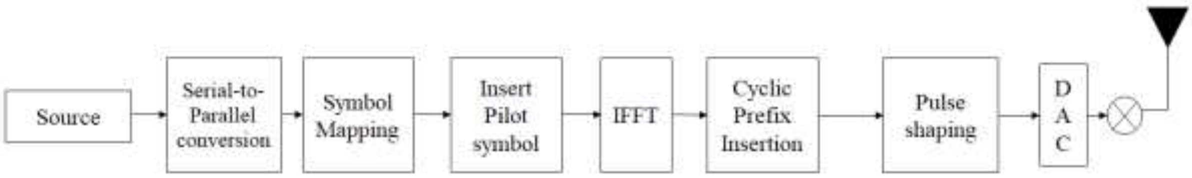


Fig 1: Block diagram of OFDM Transmitter

Receiver

Figure 2 shows the basic block diagram for receiver module. There are five modules in the receiver block and as mention before, cyclic prefix removal will not be included in the design. The received data is in serial format, thus, since FFT input is in parallel, a parallel to serial converter. The conversion is required since the serial data need to be transmitted. Finally the serial output is module which use to converts from serial to parallel is required. Output from FFT is converted back to serial format through demodulated using de-mapping module to get the transmitted data.

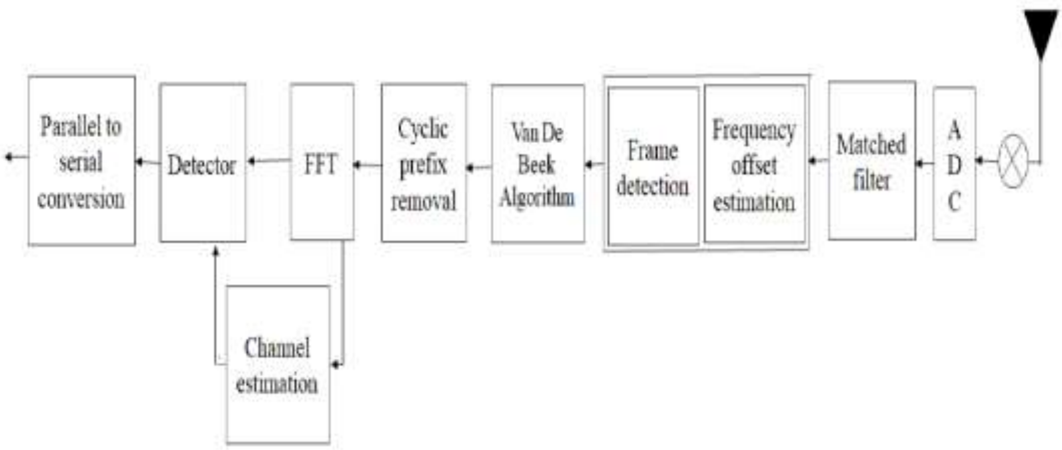


Fig 2: Block diagram of OFDM Receiver

Van de Beek algorithm

Figure 3 shows block diagram of Van de Beek exploiting the redundancy created by the CP, we can estimate time and frequency parameters. This is most commonly done by averaging the correlation of the CP and the end of the OFDM symbol. Van de Beek is used for the synchronization in the receiver part.

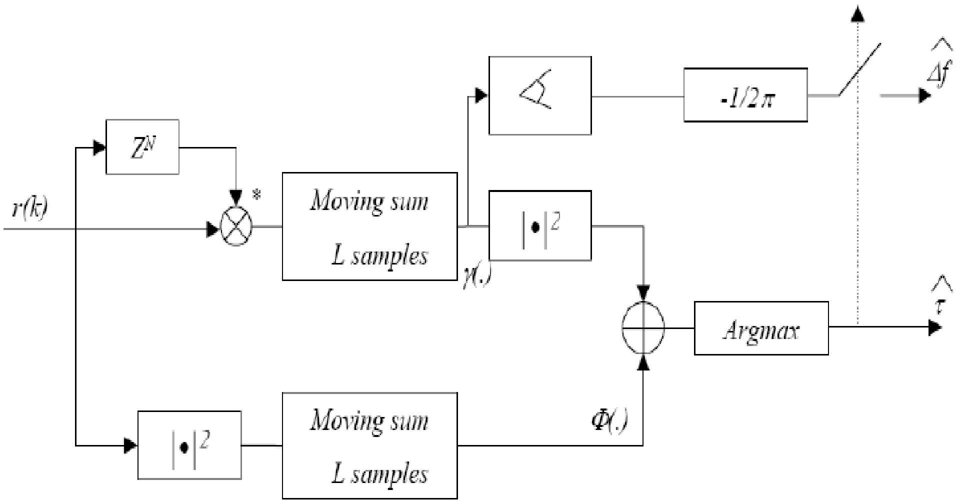


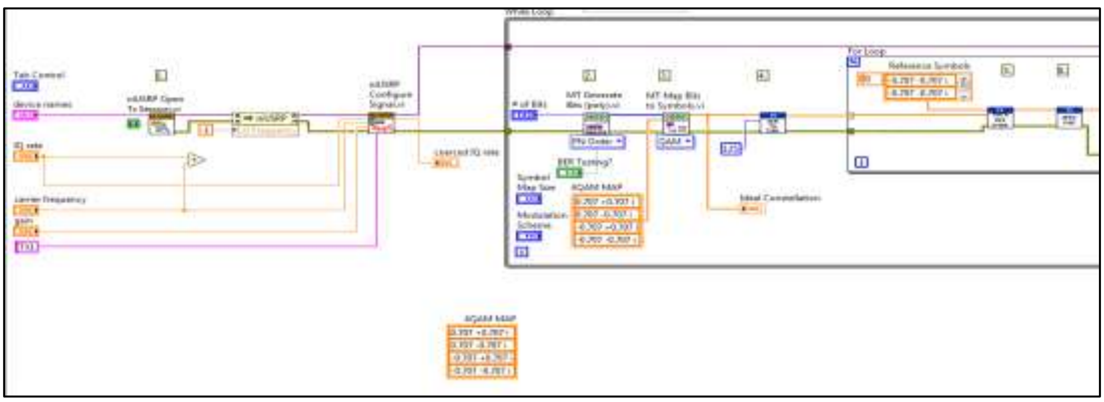
Fig 3: Block diagram of Van de Beek Algorithm

4. IMPLEMENTATION OF OFDM USING USRP

OFDM Transmitter

Figure 4 shows the block diagram of OFDM transmitter. OFDM transmitter includes the following steps:

1. USRP is initialized by setting the TX parameters and moving the LO outside the transmission band.
2. Random data bits are generated (PN Sequence) (125 bits).
3. Bits are mapped to QAM symbols (625 symbols).
4. Array of symbols are divided into 5 sets of 125-point data sets and OFDM symbols is built (125 pts per OFDM symbols).
5. One of 25 reference symbols are inserted after every 6th data symbol (150 pts per OFDM symbol).
6. 53 zeroes are inserted at the edges of the passband and 1 zero at DC (25 pts per OFDM symbol).
7. Inverse FFT is performed to convert the frequency domain design to a time domain signal (256-point IQ time domain waveform).
8. A 64-point cyclic prefix is inserted by duplicating the last 64 points of the array at the beginning (320point IQ time domain waveform).
9. 5time domain OFDM waveform is scaled to a complex magnitude below 1, typically below 0.7 for each I and Q (1600-point IQ time domain waveform).
10. I and Q are transmitted using the niUSRP Write Tx Data.vi.



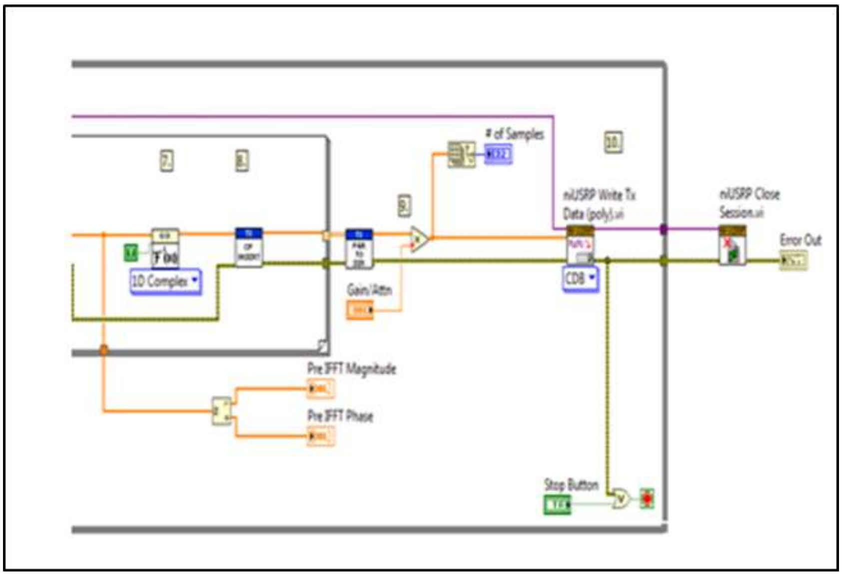
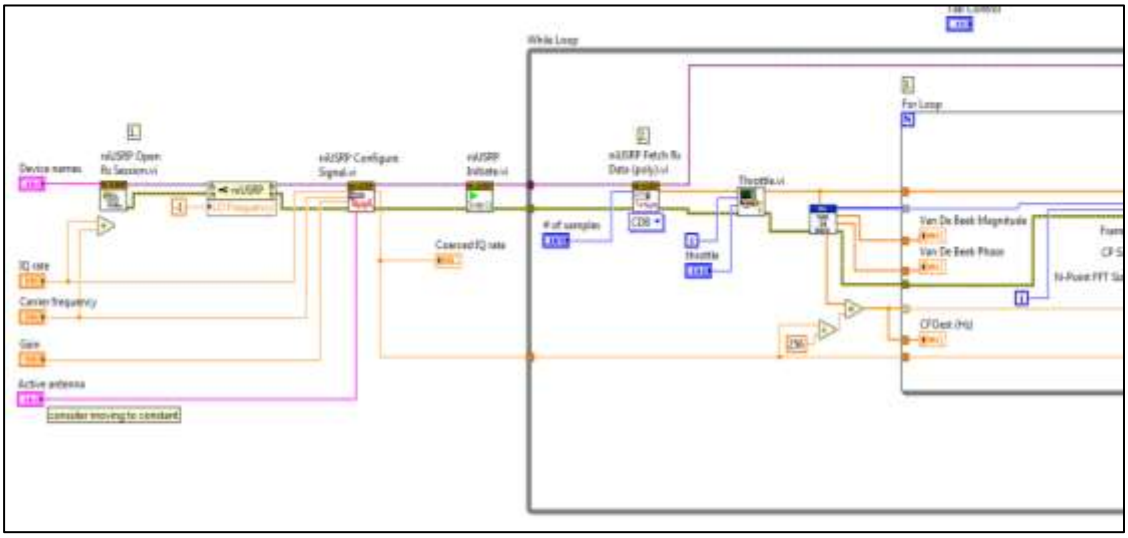


Fig 4a and 4b: Block diagram of OFDM Transmitter

Receiver

Figure 5 shows the block diagram of OFDM receiver. OFDM receiver consists of following steps:

1. USRP is initialized by setting the RX parameters and moving the LO outside the transmission band.
2. Random data bits are generated (PN Sequence) (125 bits).
3. Van De Beek algorithm is used to detect the cyclic prefix locations for synchronization and to estimate frequency offset.
4. Cyclic prefix is removed.
5. Frequency offset is removed from the incoming signal.
6. FFT is performed to convert the time domain OFDM symbols to the frequency domain.
7. Data bits, reference bits are separated and zero padding is removed.
8. Equalization coefficients is computed using a linear fit for both I and Q based on reference symbols.
9. Equalization is applied to the data symbols.
10. Data symbol mapping is converted back to data bits.



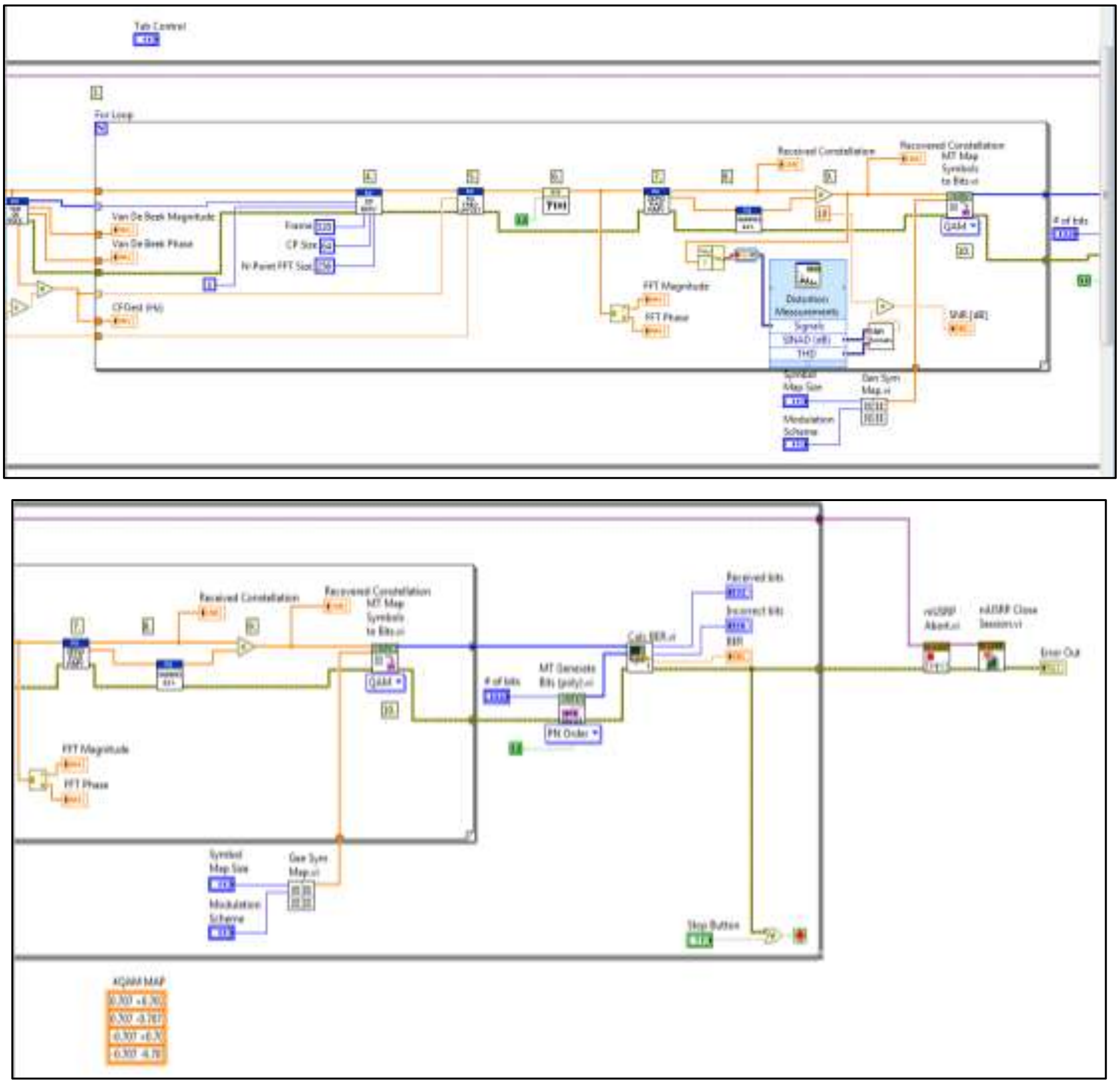


Fig 5a,b,c Block diagram of OFDM Receiver

5. RESULTS

The screenshots of results obtained on running the VI file are shown below in figures 6 to 8. Analysis is made on the OFDM multicarrier technique and It shows that OFDM allows data transmission to reduce InterSymbol Interference, Computation of Signal to Noise ratio(SNR) using NI-USRP 2944R combining with LabVIEW software.

- Implementation of NI USRP 2944R Transmitter and Receiver is done .

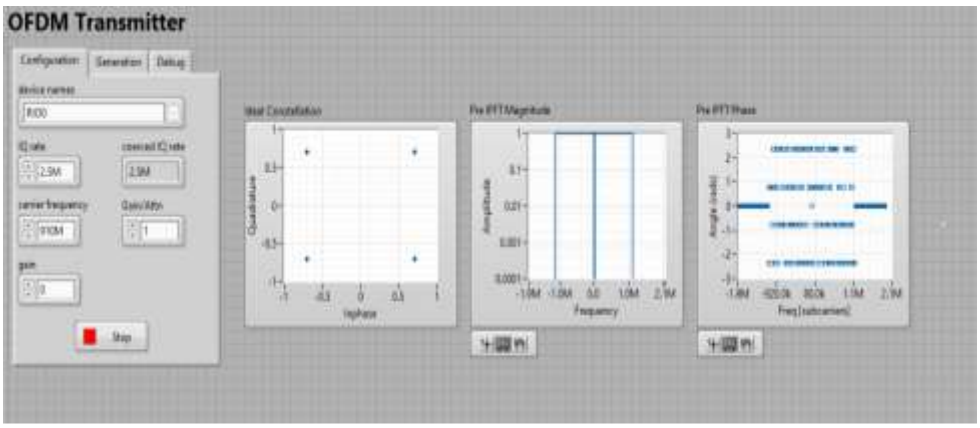


Fig 6: Configuration Setup and Transmitted constellation of OFDM

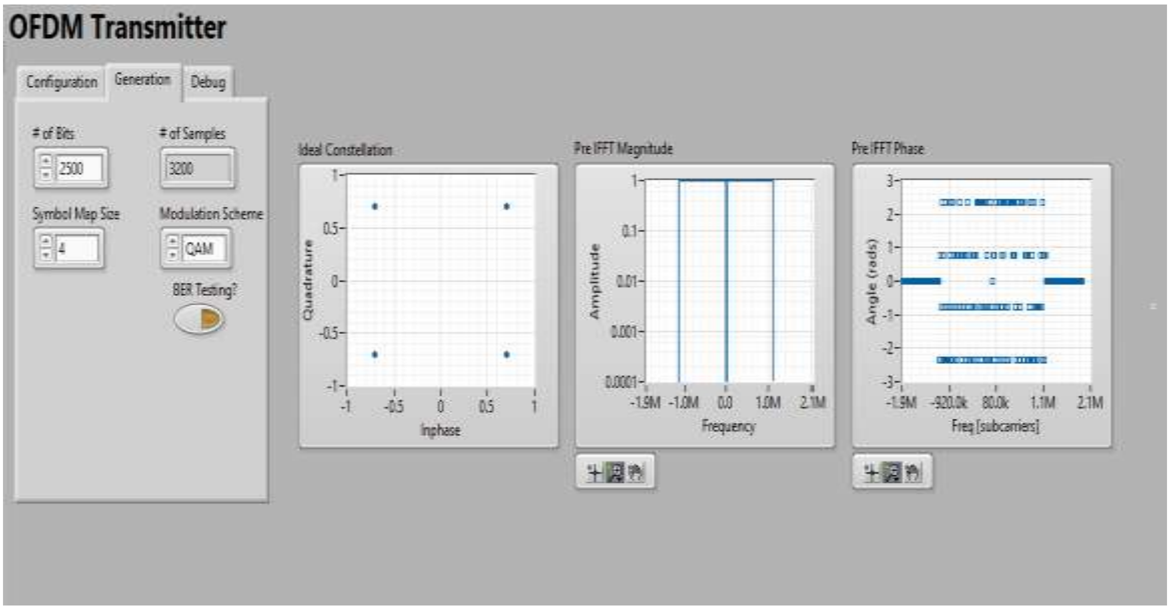


Fig 7: Generation parameters of OFDM Transmitter

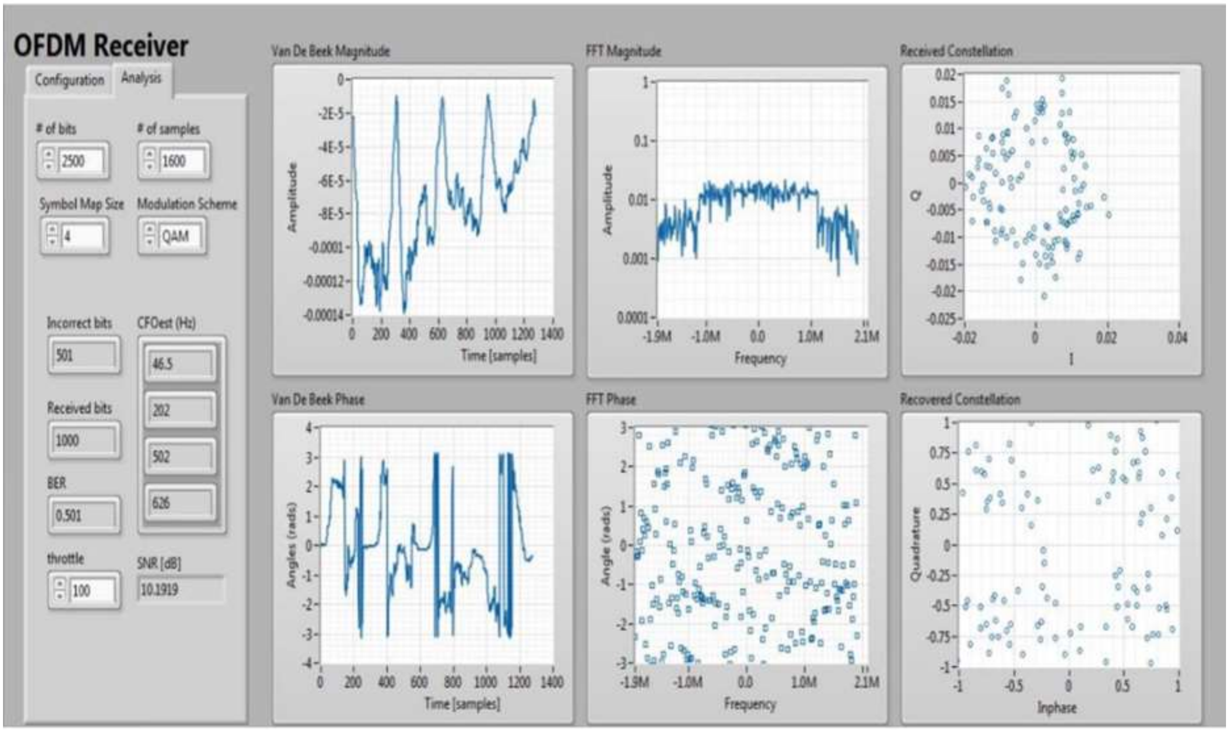


Fig 8: Analysis and Received Waveforms of OFDM Receiver

BER and SNR outputs are displayed in Fig 8 displaying the performance of OFDM Receiver.

6. CONCLUSION

The different problems of wireless communication have been considered and suitable solution has been realised. The text signal is transmitted using QAM modulation technique. QAM is an important modulation scheme because of its widespread adoption in current technologies. The QAM technique is implemented in LabVIEW with the help of NI USRP 2944R.

The Inter Symbol Interference is reduced between the successive OFDM symbols using Van de Beek synchronization algorithm. The Bit Error Rate obtained is 0.501. This lower BER shows that there is less multipath fading. The Signal to Noise ratio obtained is 10.1919 dB. This higher SNR shows that there is less noise in the received signal within the line of sight between the transmitter and receiver at a distance of 10cm.

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[12] Shuping Dang, Guoqing Ma, Basem Shihada, Mohamed-Slim Alouni, "A Novel Error Performance Analysis Methodology for OFDM-IM", IEEE Wireless Communications Letters Volume 8, Issue 3, June 2019.