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APPRAISAL OF OFDM FOR MULTI-CARRIER, HIGH-SPEED DATA RATE WIRELESS COMMUNICATION NETWORKS

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Abstract:
Orthogonal Frequency Division Multiplexing (OFDM) is used to achieve multi-carrier signals and high- Speed data rate in free space. OFDM-based systems operate in the hostile multipath radio environment, which allows efficient sharing of limited resources. This research work was designed, developed and simulated an OFDM System using the basic blocks of Simulink in MATLAB/Simulink software, to support multi-carrier, high-speed data rates. This was achieved in backing of collection and review of high-quality research papers, which reported the latest research developments in OFDM communications networks, and its applications in future wireless systems.

The research work significantly increases the speed of data rate signals, and many critical problems associated with the applications of OFDM technologies in future wireless systems are still looking for efficient solutions. This would overcome the global issues and challenges facing the limited bandwidth in wireless communication network.

Keywords: - *MATLAB/Simulink, OFDM, high-speed data rate, and multicarrier signals*

1. Introduction

In these days, the need of multicarrier network and high speed data rates on mobile communications networks becomes high due to many issues related to wireless transmission and broadband and multimedia applications. The multi-carrier high-speed data rates technologies are the answer to these issues. A summary of major research in significant stages are noted that used of multi-carrier high-speed data rates technologies such as OFDM systems to replace the used of single-carrier modulation techniques are necessary (Mondragon-Torres, Kommi and Battacharya (2011). Other contributions of multi-carrier modulation techniques include the limitations of bandwidth, and the speed of the data rates or power of transmission which need significant increase. However, OFDM transmit different sub-carriers; between sub-carriers is guard-band to avoid interference that is to eliminate or reduce inter-symbol interference (ISI) and inter-carrier interference (ICI). The sub-carriers are designed to be orthogonal, these allow sub-carriers to overlap and saved Bandwidth, that achieving higher data rate signals (Bodhe, Narkhede and Joshi (2012).

Furthermore, in single carrier network if you send single carrier frequency and when that carrier frequency become useless, due to either fading or other interference like ISC and ICI one station loses of service. But since OFDM takes one-word carrier and spreads it over several smaller carriers, so even if you have one fading in one specific frequency the station still has other useful channels, which can still convey the information. So instead of numerous adjacent symbols being destroyed, only some symbols are little bit distorted, spectral overlapping among sub-carriers is allowing improved spectral efficiency and used of steep band pass filter is eliminated (Premnath, Wasden and Farhang-Boroujeny (2013). In multicarrier transmission where subcarriers are orthogonal to each other in frequency domain, it also distributes data over many numbers of carriers that are spread out at precise frequencies. This spacing gives the orthogonality in this method that prevents the demodulators from detecting other frequencies rather than their frequency. This process is demonstrated in figure 1 below by the guard interval and cyclic prefix. Cyclic prefix it reduces or even eliminates the ISI. This technique supports simple frequency domain processing, equalization and channel estimation. It used to change multipath by making channel estimation simple.

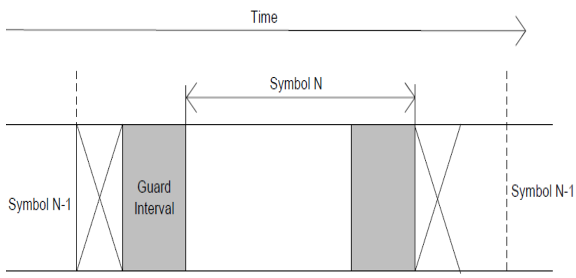

Figure: - 1. Guard Interval and cyclic Prefix (Gulzar., Nawaz and Thapa (2011)

In single carrier system frequency selective channels caused ISI at the receiver; equalization will apply noise critically in frequencies where channels reaction is poor as result single carrier performance is disturb because of higher attenuation in some bands since all used frequencies are haven equal important (Bodhe, Narkhede and Joshi (2012). But in multicarrier (OFDM) the spectrum used is divided into narrow sub-bands and then separate data is transmitted in each band using different carriers. Power and rate of transmission in a different band depend on the responds of the channel in that band, and there is no ISI since in each narrow sub-band the channel responds are almost flat (Baltar and Nossek (2012). The first product profiles for mobile WiMAX have yet to be chosen as the standard is not yet approved, OFDM is the very key modern multi-carrier wireless technology forms the basis for 4G (fourth generation) wireless communication system in LT and WiMAX (LaSorte, Barnes and Refai, (2008).

In the OFDM the sub-carriers are designed to be orthogonal, these allows sub-carriers to overlap and saved Bandwidth, that make data rate higher (Baltar and Nossek (2012). In OFDM the carriers are all generated by single transmitter in a special way that allow them to be tight much closer together and spend a much wider Bandwidth that means we can reduce or eliminate Guard-Band. And sub-carriers can be packed tightly without interference with each other and fall offset at band edges. The different between non-overlapping multicarrier signals and overlapping ones as using overlapping methods can save much more bandwidth up to 50% than the non-overlapping one and used to transmit the same signal (Hariprasad and Sundari (2015). The figure: - 8 below shows OFDM system build using the basic block of Simulink using BPSK. The general block diagram of OFDM is illustrates in figure 2 below:

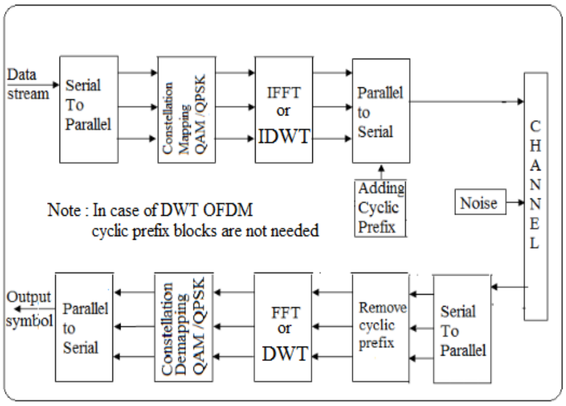

Figure: 2. General Block Diagram of OFDM System (Kanpur (2013)

A. The main aims and objectives of this research work are:

To design and develop OFDM systems that; show both OFDM transmitted and received signals (multi-carrier signals for information exchange between systems).

1. To study and understand the principle of OFDM in wireless communications network.
2. To study characteristics of wireless communications channels and understand the performance of a simulation for different scenarios
3. Finally, to design and develop a system which will produce multi-carrier signals, significantly increase the speed of data rate on the simulation results, which can be used and be expanding in wireless communication network.

2. Literature Review

This section provides an overview on the other research works that have been done on OFDM systems the researches that carried out indicate the importance of OFDM systems by many researched work. Many researchers give different design solution to the challenges associated with multiple carrier transmission using OFDM systems. Many studies have been getting desired results which can be used to improve the system performance and reduce the effect of ISC and ICI which still need further enhancement.

2.1 Global Wireless Communication systems

High data rate up to Gbps and precisely operate in 60-GHz frequency will be used in Broadband wiless communications. Furthermore, one can see this matter from another point of view, many people debating whether such higher-capacity systems is required, beleaving that all of the compression procedure deloped and the type of applications 10s of meggerbits per second. Since, high- capacitysystems become necessary there is a need to give perspective of what should be the ''underline research topic'' in the area of the telecommunications. In views of what are the possible solution, in order to folow the demands of society in the future as far as communication is concerned, systems capacity is one of the major matters to be addressed due to the forseen increase in needs for new services, based on multimedia. personnel mobility will developed new challenges to the development of new personel and mobile communication systems. According to (Prasad (2004) ‘it is unsafe to limits on wireless data rates considering economic constraints since broadband is depend on data rate capacity’.

From this it can be concluded that: Even if at an unquestionabe point it may look “ academic’’ to developed a system for a high capacity much high than required, even though there are no need for such high capacity system appllications. It is suffecently good while to do it since almost surely in the fureture such applications will be in reality for the need of such capacity system or even beyoung that 5 Gigger bits per second, the story of fiber optics is shed light on that (Prasad (2004).

I. Wireless Technology Today

In this present day, basically, five wereless technologies have made an impact, namely, wireless global area networks (WGANs), wireles wide area networks (WWANs), wireless personal area networks (WPANs), wireless local area networks (WLANs), and wireless broadband-personel area networks (WB-PANs), as demonastrates in figure 3.

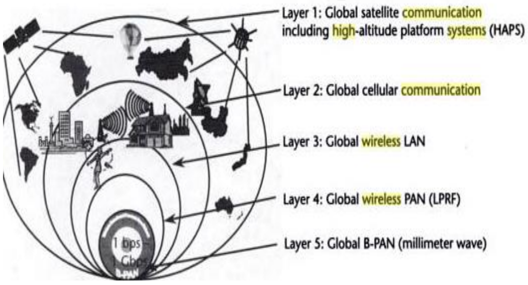

Figure 3: Five layers of wireless communications that provide [10]

II. Wireless Technology in the Future

To make sure that, all process associated with better performance of services of wireless technology, each wireless technology is moving toward future standardization. This standardization work is focusing on wireless technology for provision of any types of data. Here data consist of everything, audio, gamming, video, or any other application. A possible future situation is illustrates in figure 4, all relevant parties in wireless communication technologies should work together while providing all of the services to users anywhere any time. Clearly, it is believed that the OFDM systems are next target technologies of most modern wireless communication system (Kulkarni and Bhalchandra (2012).

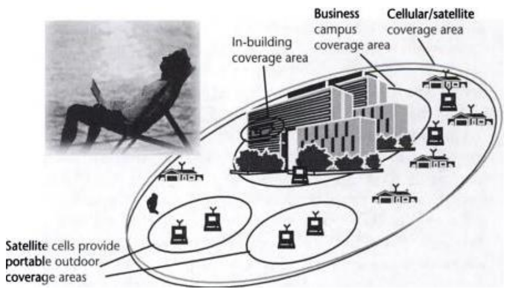

Figure 4: Future of Wireless Standardization [10]

2.2 The concept of OFDM

The idea of OFDM was intended in earlier 1960s, it was not able to be attained until the emergence of Fast Fourier transform (FFT) with the emergence of inverse Fast Fourier transform (IFFT) was made possible to generate OFDM system (Gomes, Al-Daher and Fernandes (2014). The idea of using Multi-Carrier technologies such as OFDM parallel-data transmission and frequency division multiplexing (FDM) was earliest started in the middle of 1960s (Kulkarni and Bhalchandra (2012).

OFDM involves FDM which divide the available Bandwidth into many subcarriers and allow multiple users to access the system simultaneously. In multi-carrier FDM the data of the user can be separated into multiple sub-stream and transmit them in parallel, to make the data rate high. We can see in figure 5 below how using overlapping methods can save much more bandwidth than the non-overlapping one, 50% of bandwidth used to transmit the same was saved (Bodhe, Narkhede and Joshi (2012).

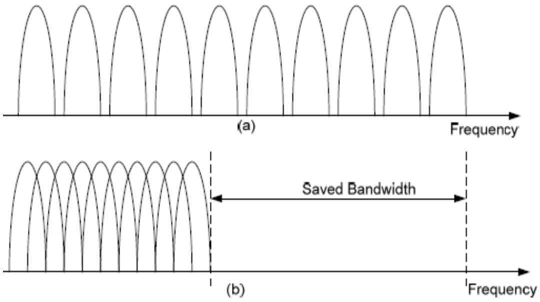

Figure: 5. Conventional multicarrier method (a) - FDM, and (b) - OFDM (Hariprasad and Sundari (2015)

3. Methodology

This stages shows the techniques approached adapted to carry out the research work, of designing and developing of OFDM systems, which would be simulated on MATLAB/Simulink software to produce OFDM input and output signals. These have been achieved by reviewing of high-quality research papers.

3.1 Implementation

After the systems are designed and simulated this section provides comprehensible explanation about the final stages of the search work, and simulation results obtained by the system. The final stages of this research work implementation were OFDM input and output signals from the simulation results as shown in figures below using different modulation schemes.

The first stage of the design is flow chart which illustrates in figure 6 below.

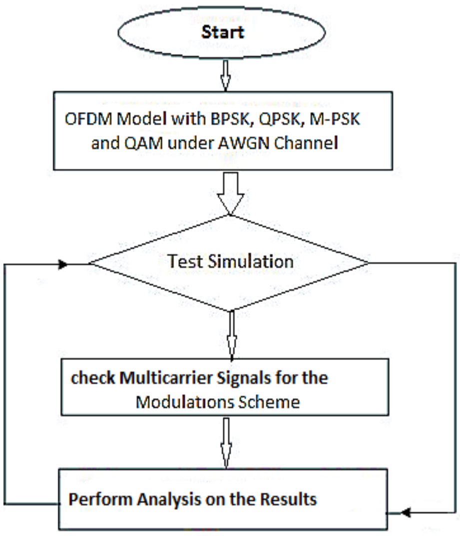

Figure 6: Flow Chart

3.2 The OFDM Model

The second stage of the design is the OFDM system as shown in figure 7 below. This OFDM model was designed using Simulink blocks in MATLAB/Simulink software, OFDM spectrum was achieved using Mux and Demux which were used in serial to parallel and parallel to serial conversion respectively, but better result were obtained using Buffer and Unbuffer to replace the used of Mux and Demux. BPSK, QPSK and QAM modulator and de modulator with up to 32 numbers of subcarriers used were used to carry out the OFDM model system designed differently, to simulate the FFT OFDM and IFFT OFDM model system. The modulators and demodulators are placed in transmitter and receiver side accordingly. The generated OFDM input signal of the FFT transmitter transmits without noise to the Multipath Rayleigh fading and AWGN channels. The IFFT receiver signals received with the channel noise as expected.

The transmitted signal is likely free from out-of-band harmonics, the out of band harmonics were more pronounced in received signal. Thus, the receiver was subject to certain degree of noise, errors are introduced in the demodulation and decoding processes. The performance of BPSK, QPSK and QAM simulations modulators and demodulators placed in transmitter and receiver side was observed in the frequency spectrum. Both signals were observed and analysed the effect of noise over AWGN and multipath Rayleigh fading channels by comparing the transmitted and received signals and compared the simulated data with theory. This paper has achieved better performance in terms of OFDM spectrum in FFT-IFFT based OFDM transmitter and receiver that for input signals were the same with output signals.

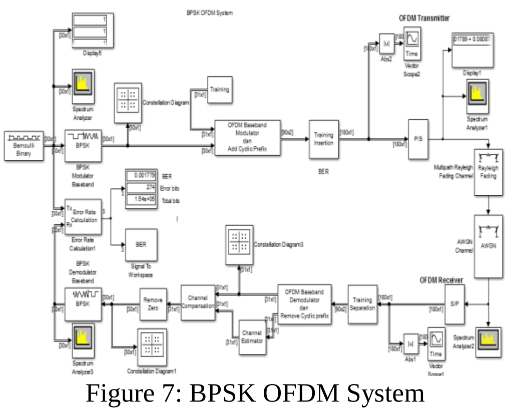

Figure 7: BPSK OFDM System

4. Simulation Results of OFDM input and output Signals

However, OFDM simulation results between the transmitter and receiver signals, transmitted single carrier signal and received multiple carrier signals in the frequency spectrum respectively. Both signals are observed and analyze the frequency spectrums conclude the results by comparing the transmitted and received signals and compared the simulated data with theory. The simulation results obtained has achieved better results.

4.1 BPSK, QPSK and QAM Simulation Results of OFDM spectrums

The OFDM receiver and transmitter signals are illustrates in figures 8 to 43 below thus, the transmitted OFDM signal transmitted without noise to the Multipath Rayleigh fading and AWGN channels. Likewise, the OFDM receiver signal received with channel noise as anticipated, channel induced noise disturbs the received signal, and OFDM output signal is the same with original input signal.

4.2 Analysis of Power Spectrum of BPSK, QPSK and QAM OFDM Signals

In each of the BPSK, QPSK and QAM four OFDM signals were observed, namely; input, transmitter, receiver and output signals respectively. However, by locking at the higher of the display in the power spectrum (dBm) which is the power of the frequency, it was observed that the single carrier signal was divided into narrow sub-bands in the transmitter and receiver signals. The sub-carriers were observed to be orthogonal with channel noise on the receiver signals. The spectrum signals confirm that QAM has less noise effect than QPSK and BPSK under the same transmission rate. The overall power spectra for the cases of OFDM systems with 32- QAM subcarriers has better performance in terms of noise enhance effect. The higher data rate signals were achieved since sub-carriers were designed to be orthogonal, overlap and saved Bandwidth as illustrates in figure 8 to 43 bellow.

4.2.1 The BPSK modulator

Baseband is a modulation scheme that modulates using the binary Phase Shift Keying technique, the output signal is baseband presentation of the modulated data. This modulation scheme accept vector and column input data, the input must be discrete time binary value signal. The output data type of this modulation scheme could be set to Inherit via back propagation, double, user-define, and single fixed-point.

4.2.4 QPSK Modulator Baseband

The modulator takes a scalar of column vector data. If input type parameters set to Bit, the input contains pairs of binary values; the modulator would takes column vectors with event lengths. And if the phase offset parameters set to $\pi/2$.

4.2.5 AQM Modulator Baseband

The Rectangular QAM modulator baseband is a modulation scheme that modulates the input signal using M-array quadrant amplitude modulation; it also has a constellation on a rectangular lattice. The output is baseband presentation of the modulated data.

4.3 BPSK Simulation Results of OFDM spectrums

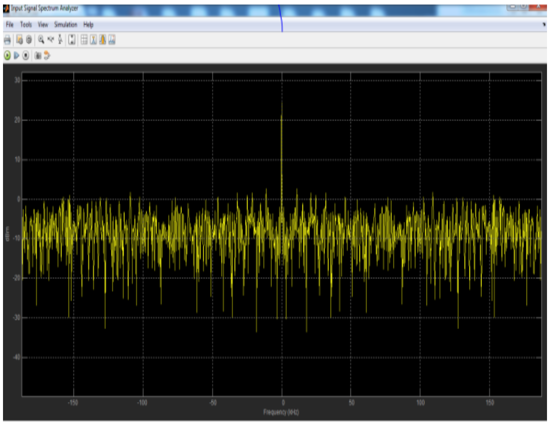

Figure 8: BPSK-OFDM input signal

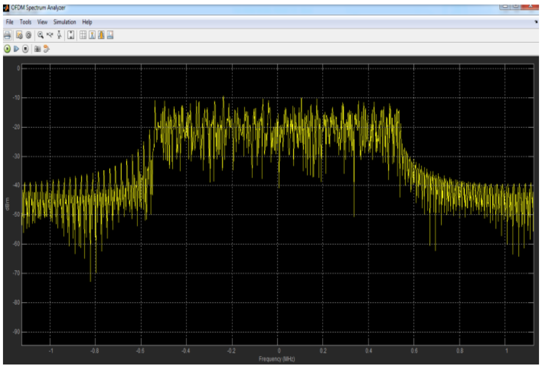

Figure 9: BPSK-OFDM transmitter signal

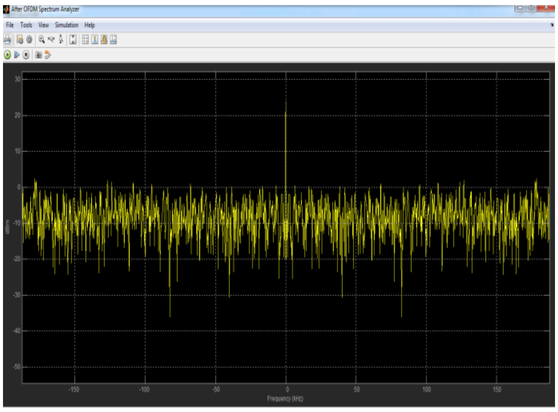

Figure 10: BPSK-OFDM Received signal

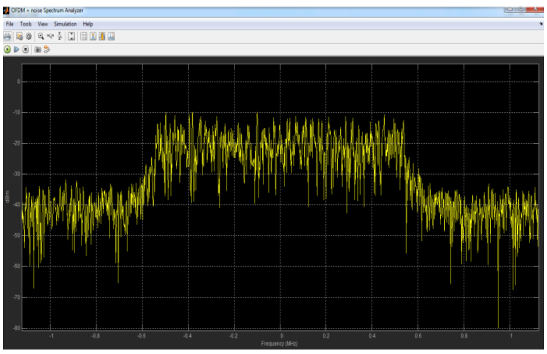

Figure 11: BPSK-OFDM Output signal

4.4 QPSK Simulation Results of OFDM spectrum

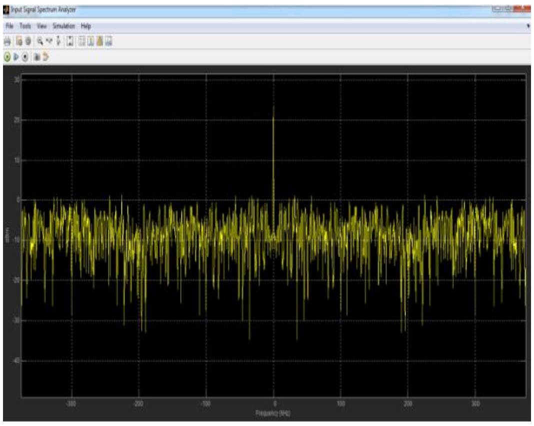

Figure 12: QPSK-OFDM input signal

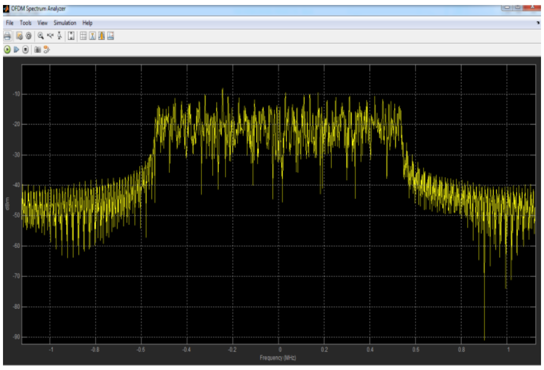

Figure 13: QPSK-OFDM transmitter signal

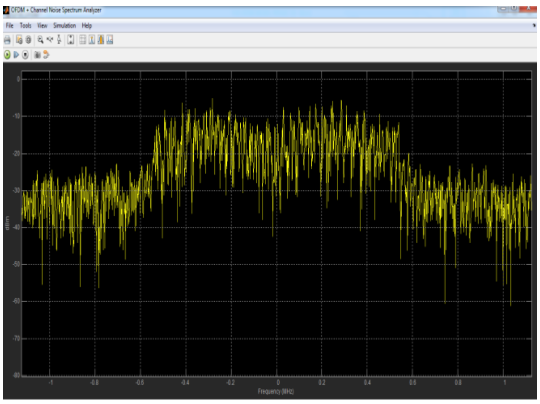

Figure 14: QPSK-OFDM Received signal

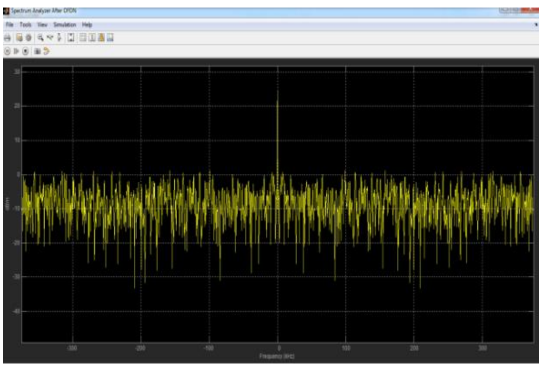

Figure 15: QPSK-OFDM Output signal

4.5 8-PSK Simulation Results

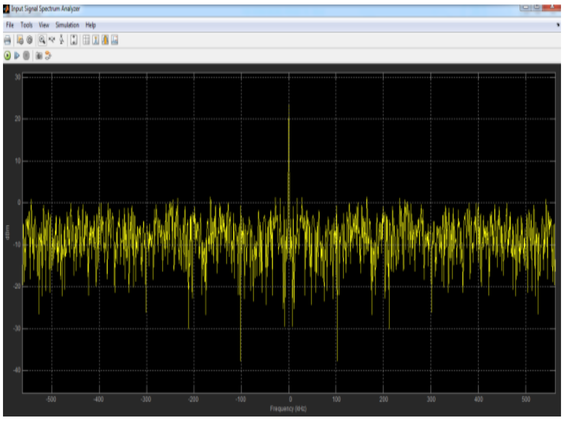

Figure 16: 8-PSK-OFDM input signal

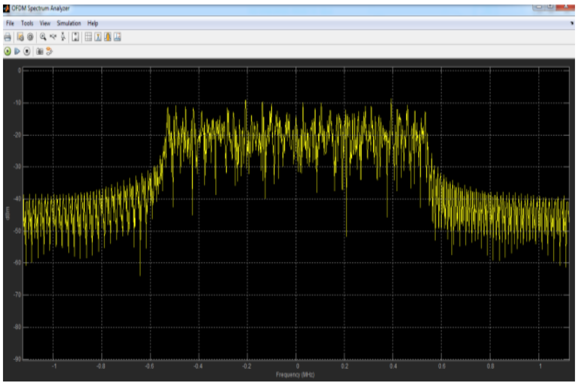

Figure 17: 8-PSK-OFDM transmitter signal

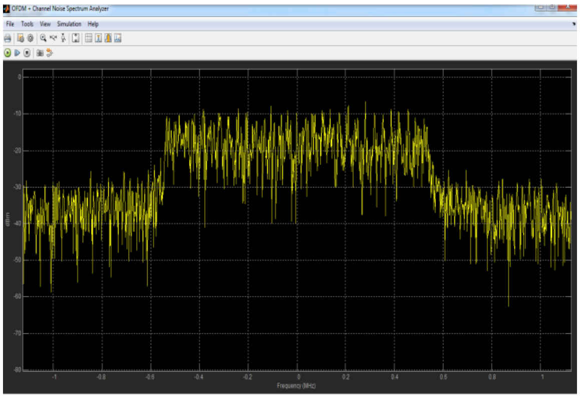

Figure 18: 8-PSK-OFDM receiver signal

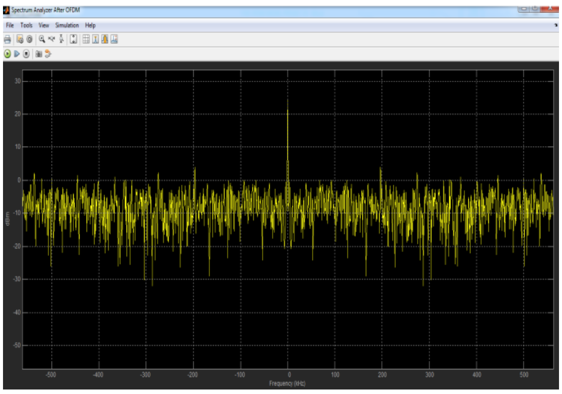

Figure 19: 8-PSK-OFDM Output signal

4.6 16-PSK Simulation Results of OFDM

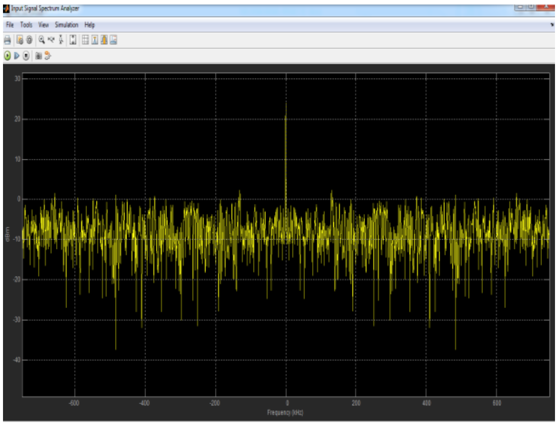

Figure 20: 16-PSK-OFDM input signal

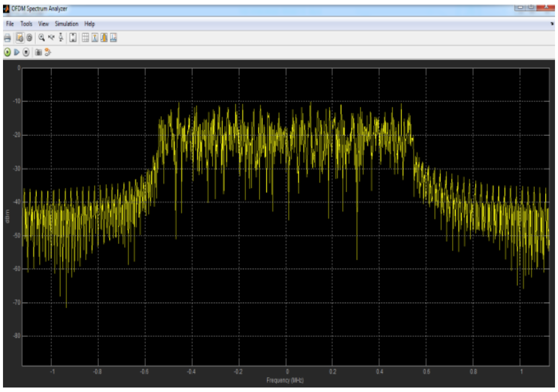

Figure 21: 16-PSK-OFDM transmitter signal

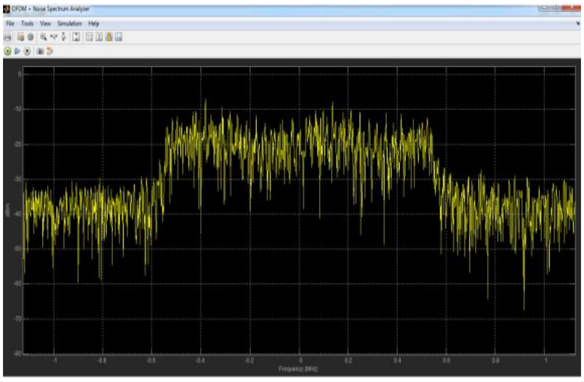

Figure 22: 16-PSK-OFDM Received signal

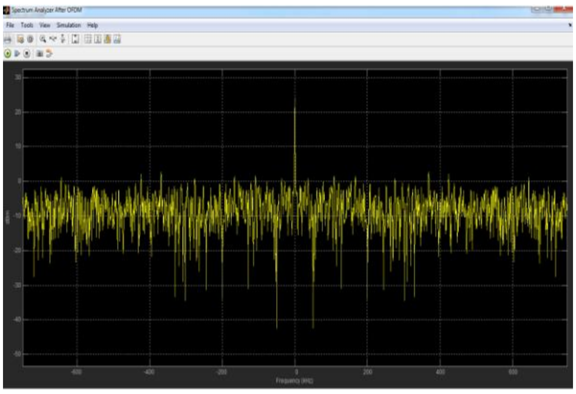

Figure 23: 16-PSK-OFDM Output signal

4.7 PSK Simulation Results of OFDM spectrum

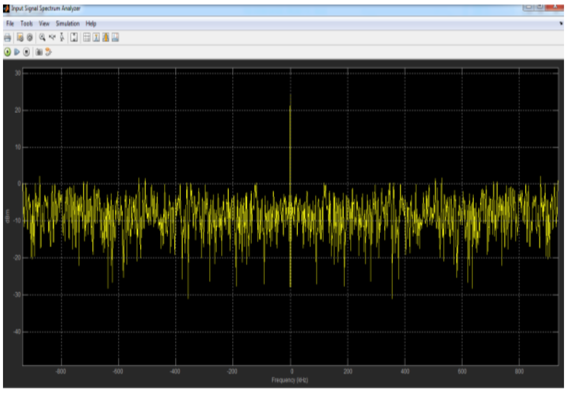

Figure 24: 32-PSK-OFDM input signal

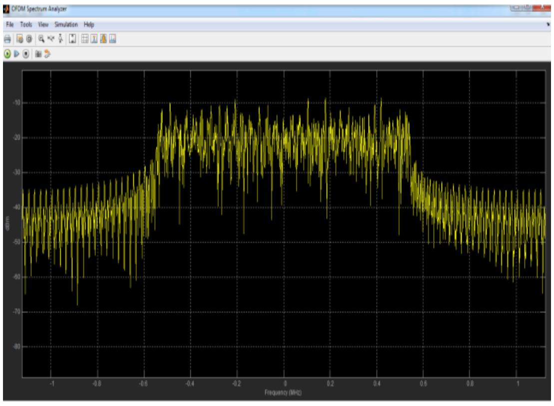

Figure 25: 32-PSK-OFDM transmitter signal

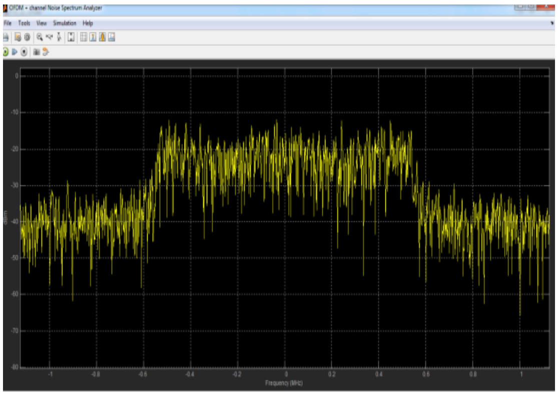

Figure 26: 32-PSK-OFDM Received signal

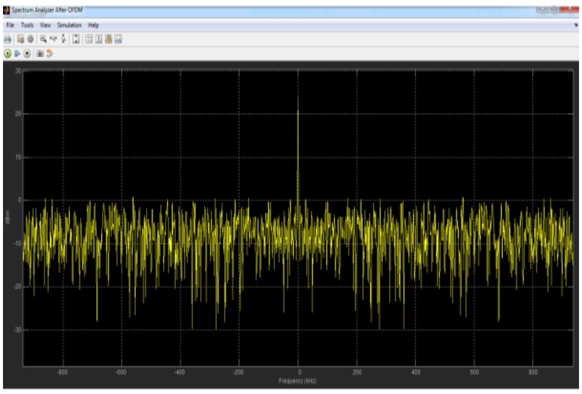

Figure 27: 32-PSK-OFDM Output signal

4.8 4 QAM Simulation Results of OFDM spectrum

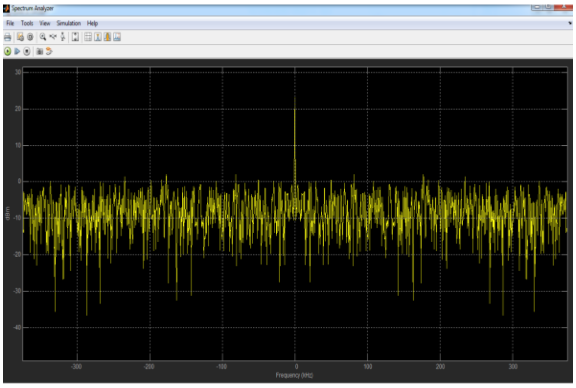

Figure 28: 4-QAM -OFDM input signal

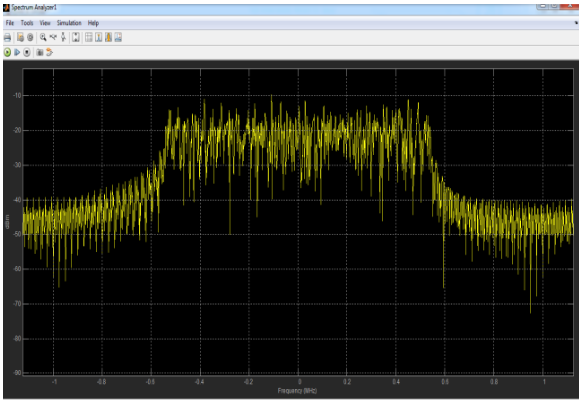

Figure 29: 4-QAM-OFDM transmitter signal

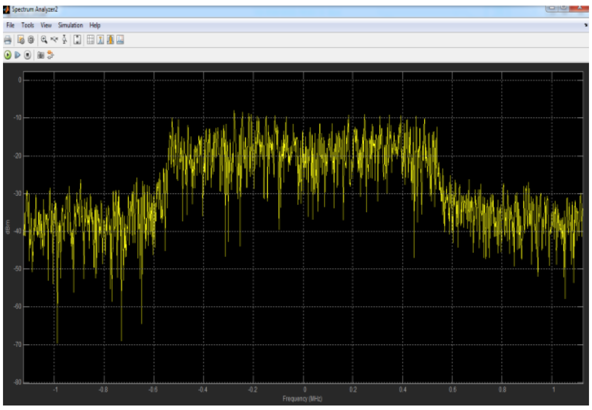

Figure 30: 4-QAM-OFDM Received signal

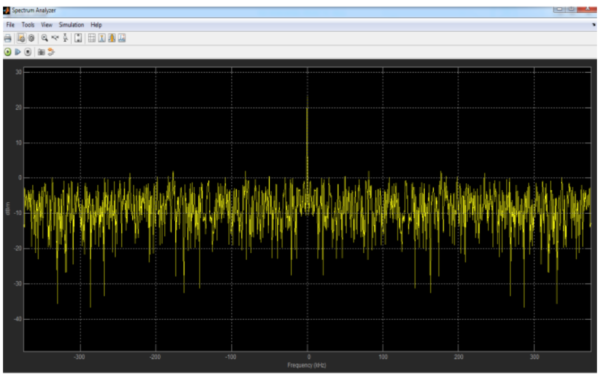

Figure 31: 4-QAM-OFDM Output signal

4.9 8-QAM Simulation Results of OFDM spectrum

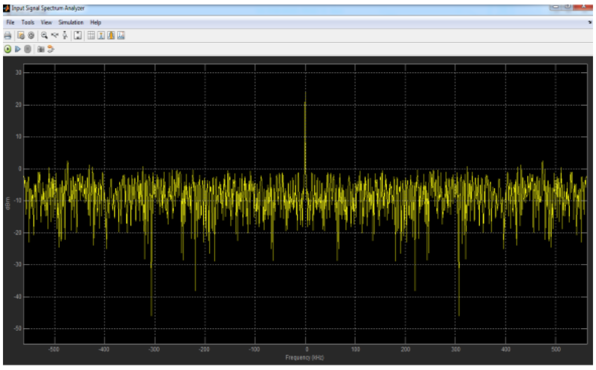

Figure 32: 8-QAM-OFDM input signal

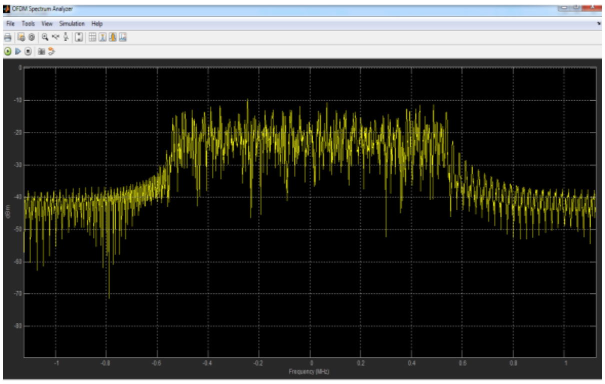

Figure 33: 8-QAM-OFDM transmitter signal

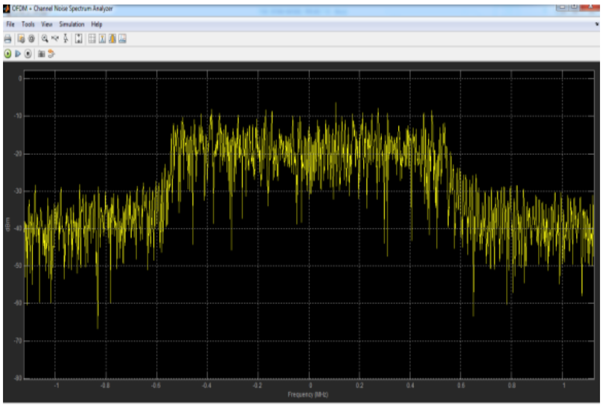

Figure 34: 8-QAM-OFDM Received signal

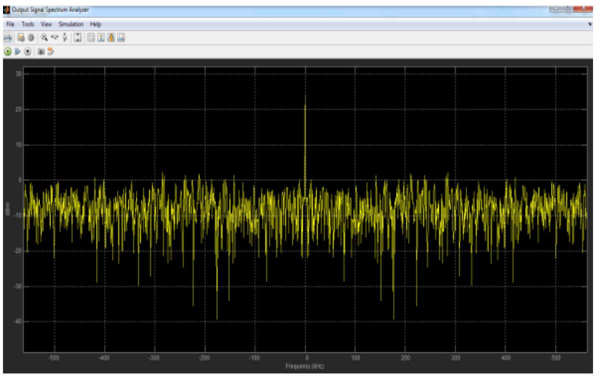

Figure 35: 8-QAM-OFDM Output signal

4.10 16QAM Simulation Results of OFDM spectrum

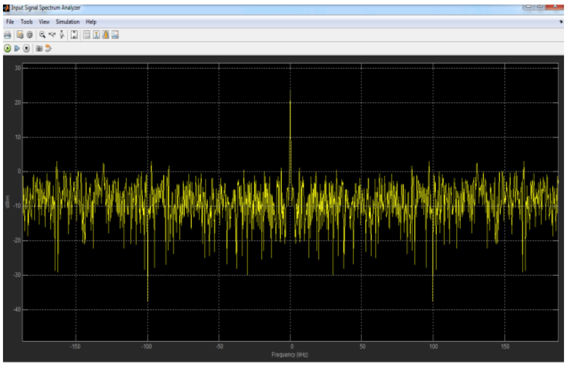

Figure 36: 16-QAM-OFDM input signal

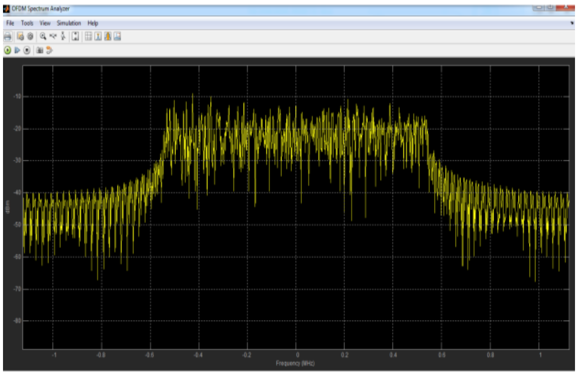

Figure 37: 16-QAM-OFDM transmitter signal

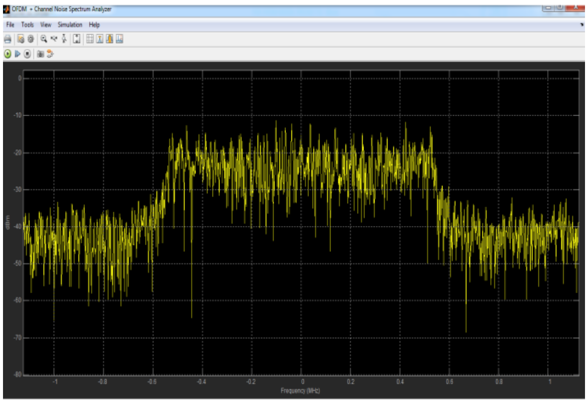

Figure 38: 16-QAM-OFDM Received signal

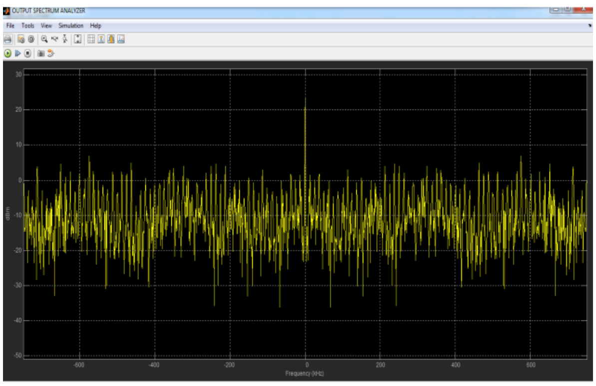

Figure 39: 16-QAM-OFDM Output signal

4.11 32-QAM Simulation Results of OFDM spectrum

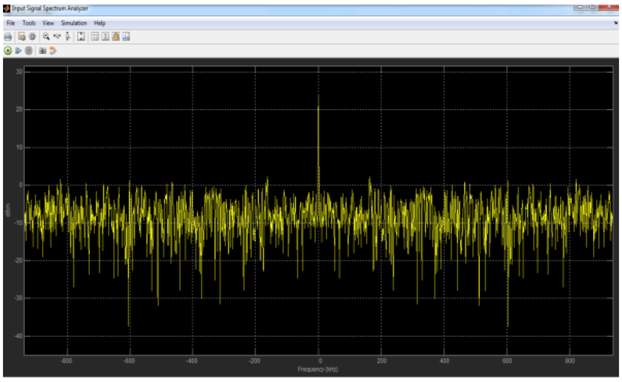

Figure 40: 32-QAM-OFDM input signal

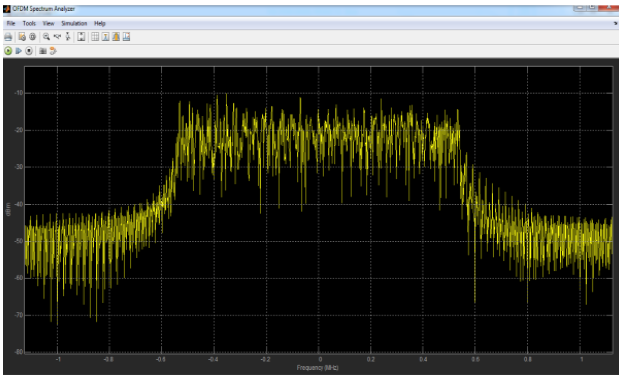

Figure 41: 32-QAM-OFDM transmitter

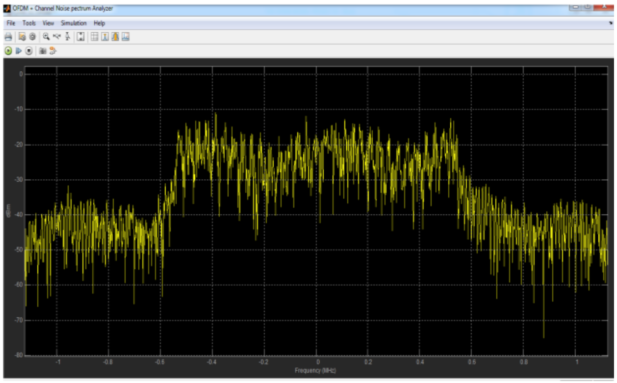

Figure 42: 32-QAM-OFDM Received signal

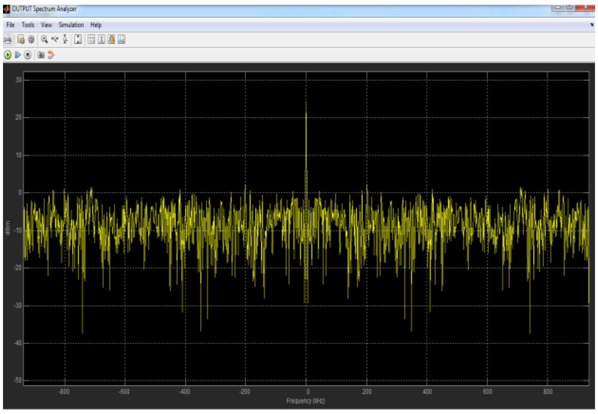

Figure 43: 32-QAM-OFDM Output signal

4 Conclusion

As it demonstrates above in the OFDM spectrums the aims of the research work were achieved, the paper shows the spectra of the sub-carriers accurately, noise effect on the OFDM transmitted signals and how OFDM return the channel noise sine output signals were the same with the input signals. The input (single) carrier signal was divided into narrow sub-bands and then separate data is transmitted in each band using different carriers. Power and rate of transmission in a different band depend on the responds of the channel in that band. The sub-carriers are designed to be orthogonal, these allows sub-carriers to overlap and saved Bandwidth, that achieving higher data rate signals.

A user close to the base station would normally be assigned a larger number of channels with high modulation scheme such as 32 QAM (quadrature amplitude modulation). The modulation scheme could gradually shift from 16 QAM to Quaternary Phase Shift Keying (QPSK) (four channels) and even binary phase shift keying (BPSK) (two channels) at longer ranges. The data amount drops as the channel capacity and modulation change, but the link maintains its strength.

5 Recommendation

Since the data amount drops as the channel capacity and modulation change at longer ranges, a high modulation scheme such as 64 QAM (quadrature amplitude modulation) and above should be used in the next OFDM system design.

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My name is **Engr. Muhammad Bello Abdullahi MNSE;** I am indigent of Bungudu local government, Zamfara State, Nigeria and an academic staff of Abdu Gusau Polytechnic, Talata Mafara, Zamfara State, Nigeria. I am currently lecturing in the department of electrical and electronic engineering as senior lecturer, serving as head of the department. I have obtained Master of Science (MSc) in electrical and electronic engineering from Coventry University United Kingdom. I am registered engineer with the Council for the Regulation of Engineering in Nigeria (COREN) and member Nigerian Society of Engineers (NSE). I have published many papers in the polytechnic journal as well as international journals some of them include; Securing Nigeria's Sustainable Economic Growth through Online Marketing, Distribution Automation the Better Way forward in Nigeria's Power Supply, HVDC Power Network, Evaluation of BER Performance of FFT-OFDM for Wireless Communication Network and Free-Space Optical Communication, Design And Implementation of Helical Antenna For Transceiver Propagation. I have always had an interested in the field of electrical and electronic engineering particularly communication engineering. The cause is very personal; it could be my ability for working independently, team work and problem solving.