Study Of Performance Parameters Effects On OFDM Systems

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Abstract

The actual and next communication schemes tend to use OFDM systems in order to provide high baud rates, less intercarrier interference, and less intersymbol interference. OFDM has become the core of most 4G communication systems as fixed Wi-Fi system (IEEE802.11a standard), mobile Wi-Fi system (IEEE802.11b standard), fixed WiMAX system (IEEE802.16a standard), mobile WiMAX system (IEEE802.16e standard), and Long Term Evolution (LTE) system. In this paper the detailed simulation of different OFDM systems with different constellation mapping schemes will be obtained using MATLAB-2011 program to study the effect of various design parameters on the system performance.

Keywords: *Orthogonal Frequency Division Multiplexing (OFDM); Field Programmable Gate Array (FPGA); Hardware Description Language (HDL); Inverse Fast Fourier Transform (IFFT); Fast Fourier Transform (FFT); Cyclic Prefix (CP); Bit Error Rate (BER); Signal to Noise Ratio (SNR).*

1. Introduction

OFDM is a multicarrier modulation technique that has developed into a popular scheme for wideband digital communication because of its ability to cope with severe channel conditions without complex equalization filters; e.g. attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath. Channel equalization is simplified because OFDM may be viewed as using many slowly-modulated narrow band signals rather than one rapidly-modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols possible affordable, making it to handle time-spreading and eliminate ISI and ICI[1-10].

The aim of our paper is to give an idea of what is an OFDM system, its main structure and the analysis of the obtained results of the simulations testing. This OFDM system is able to support different M-QAM modulation schemes. Also this paper aims to study the effect of the variation of different design parameters on OFDM systems with different digital modulation schemes.

The next of this paper is organized as follows; section-II provides the related work, section-III introduces OFDM overview, section-IV presents simulation results, and conclusions.

2. Related Work

Moisés Serra [3] shows the design of an OFDM transmitter as a part of an OFDM demonstrator Hiperlan/2 based, Ma. José Canet [4] shows implementation issues of a digital transmitter for an OFDM based WLAN systems and benchmarks some optimized VHDL area results against System Generator results, Canet's work is focused on the solutions for the OFDM signal generation in base-band and in intermediate frequency (IF). Chris Dick [5] emphasizes the suitability of high-level design tools when designing sophisticated systems, and the importance to design FPGA systems rather than ASIC to one day accomplish the SDR "Software Defined Radio" concept and gives a high-level overview of the FPGA implementation giving some deep to the synchronization, packet detection, preamble correlate channel estimation and equalization; that is mainly at the OFDM receiver. Ludovico de Souza et al. [6] present a FPGA implementation capable to support 802.11 wireless modems but just as a validating and prototyping stage for an ASIC. Joaquin Garcia, Rene Cumplido [7] focuses on the FPGA suitability to support IF processing for the Std. IEEE 802.11a and the resource area and timing requirements either for rapid prototyping or to take advantage of re-configurability in order to be able to support different standards. Y. Awad, L. H. Crockett and R. W. Stewart [8] investigate the efficient FPGA implementation of an OFDM transceiver design for the IEEE 802.20 physical layer. Paul Guanming Lin [9] demonstrates the concept and feasibility of an OFDM system, and investigates how its performance is changed by varying some of its major parameters. This objective is met by developing a MATLAB program to simulate a basic OFDM system. O. Grigoriadis, H. S. Kamath [10] use a

MATLAB simulation of OFDM to see how the BER of a transmission varies versus the SNR.

3. OFDM Overview

OFDM is an attractive modulation scheme used in broadband wireless systems that encounter large delay spreads. OFDM avoids temporal equalization altogether, using a cyclic prefix technique with a small penalty in channel capacity. Where Line-of-Sight (LoS) cannot be achieved, there is likely to be significant multipath dispersion, which could limit the maximum data rate. Technologies like OFDM are probably best placed to overcome these, allowing nearly arbitrary data rates on dispersive channels. [11]. Each subcarrier can be modulated independently as shown in Fig. 1. The spectra of the subcarriers overlap, but the subcarrier signals are mutually orthogonal as shown in Fig. 2 [11].

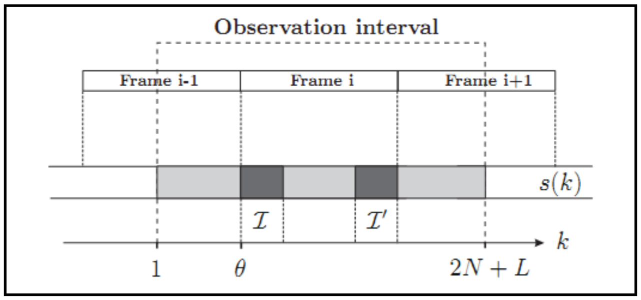

Fig.1 Structure of OFDM signal with cyclic extended frames

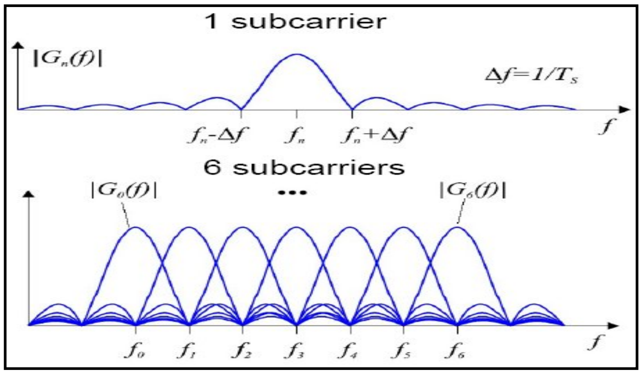

Fig. 2 OFDM Subcarriers in Frequency Domain

3.1 OFDM Advantages

In general, OFDM systems have the following advantages: (i) efficient use of spectrum.; (ii) resistant to frequency selective fading; (iii) Eliminates ISI (Inter-Symbol Interference) and ICI (Inter-Carrier Interference); (iv) can recover lost symbols due to the frequency selectivity of channels; (v) channel equalization; (vi) computationally efficient [11].

3.2 OFDM Disadvantages

OFDM systems have the following disadvantages: (i) High synchronism accuracy; (ii) Multipath propagation must be avoided in other orthogonality not be affected, and (iii) Large peak-to-mean power ratio due to the superposition of all subcarrier signals, this can become a distortion problem (Crest Factor).[11]

3.3 OFDM Transceiver

The block diagram of an OFDM transceiver is shown in Fig. 3. [9]. The basic component will be discussed in the next few subsections.

3.3.1 OFDM Transmitter

The main components of OFDM transmitter are shown in Fig.3 [9]. The randomizer is used as random bit generator. The first three blocks are used for data coding and interleaving. The coded bits will be mapped by the constellation modulator using Gray codification, this way an + jbn values are obtained in the constellation of the modulator. The serial to parallel converter converts the data bits from the serial form to the parallel form. The Inverse Fast Fourier Transform (IFFT) transforms the signals from the frequency domain to the time domain; an IFFT converts a number of complex data points, of length that is power of 2, into the same number of points but in the time domain. The number of subcarriers determines how many sub-bands the available spectrum is split into [11, 12]. The Cyclic Prefix (CP) is a copy of the last N samples from the IFFT, which are placed at the beginning of the OFDM frame to overcome ISI problem. It is important to choose the minimum necessary CP to maximize the efficiency of the system [16].

3.3.2 OFDM Receiver

The main blocks of OFDM receiver are observed in Fig.3 [9]. The received signal goes through the cyclic prefix removal and a serial-to-parallel converter [11]. After that, the signals are passed through an N-point fast Fourier transform to convert the signal to frequency domain. The output of the FFT is formed from the first M samples of the output. The demodulation can be made by DFT, or better, by FFT, that is it efficient implementation that can be used reducing the time of processing and the used hardware [14]. FFT calculates DFT with a great reduction in the amount of operations, leaving several existent redundancies in the direct calculation of DFT [13-15].

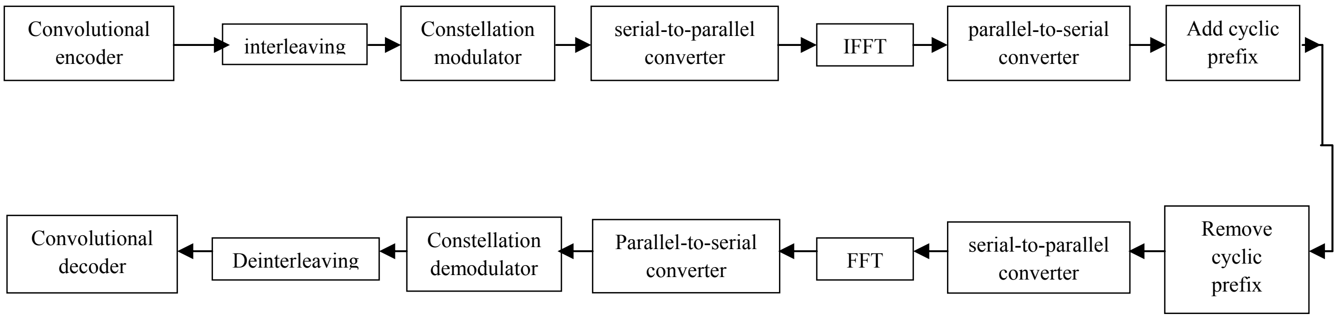

Fig. 3 OFDM Transceiver

4. Simulation Results

The presented OFDM system in the above few subsections will be simulated using MATLAB-2011 on a personal computer of the following specifications: (i) Intel processor 3.2 GHZ Pentium-four; (ii) 2MB cache RAM; (iii) 2 GB RAM; (iv) SATA hard disk 250GB. In this part the simulation of different OFDM systems with different M-QAM schemes using MATLAB Simulink tools will be obtained. The effect of different parameters on the simulation of the OFDM system using MATLAB program is discussed through the following experiments. After that the comparison between these systems will be illustrated and then we can determine the best one of them.

4.1 Experiment-1

In this experiment, the study of changing FFT/IFFT length with fixed SNR will be discussed. The optimum practical value used for the SNR is 60 dB in the case of using Additive White Gaussian Noise (AWGN) channel. The FFT/IFFT lengths that have been used are 8-points, 16-points, 32-points, 64-points, 128-points, 256-points, 512 points, and 1024 points. This experiment has been applied on OFDM system with 4-QAM, 16-QAM, and 64-QAM. The simulation results for this experiment are shown in the following figures.

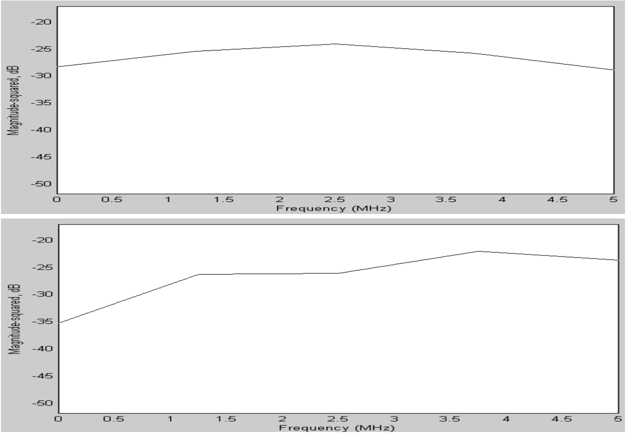

Fig. 4 OFDM with 4-QAM, 8-points IFFT/FFT with SNR=60 dB

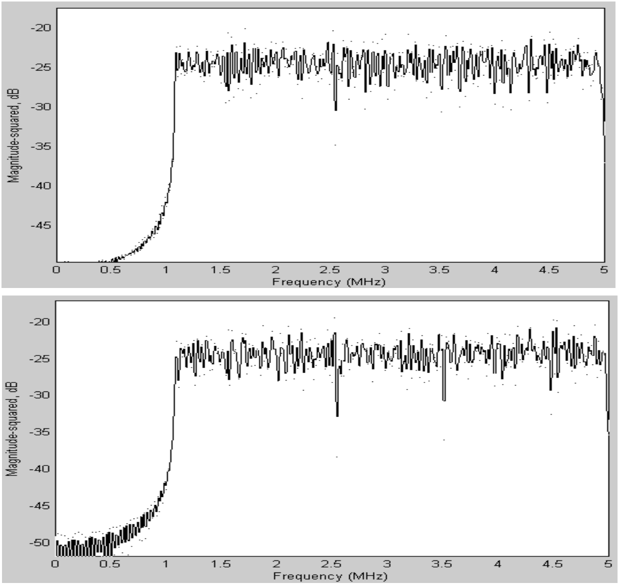

Fig. 5 OFDM with 4-QAM, 1024-points IFFT/FFT with SNR=60 dB

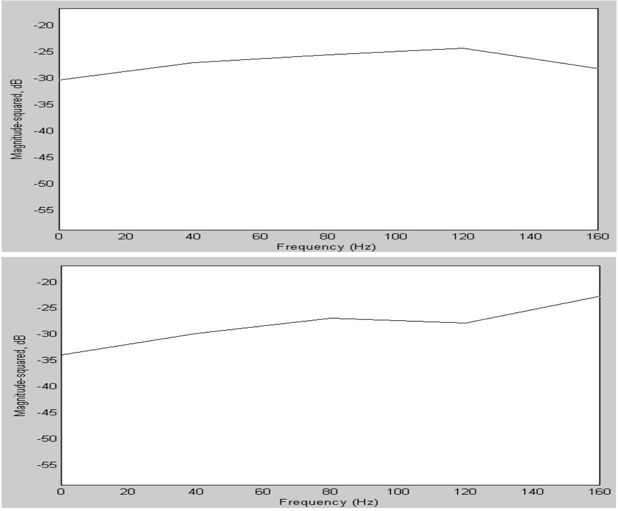

Fig. 6 OFDM with 16-QAM, 8-points IFFT/FFT with SNR=60 dB

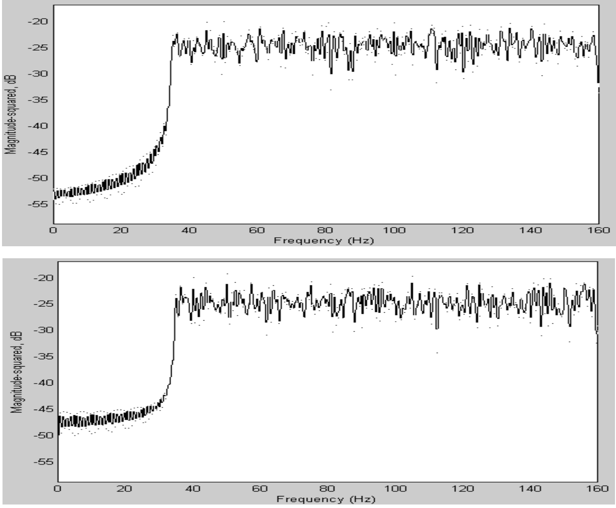

Fig. 7 OFDM with 16-QAM, 1024-points IFFT/FFT with SNR=60 dB

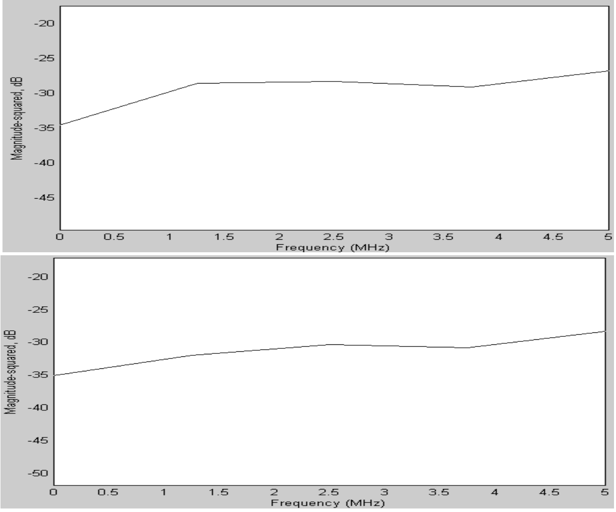

Fig. 8 OFDM with 64-QAM, 8-points IFFT/FFT with SNR=60 dB

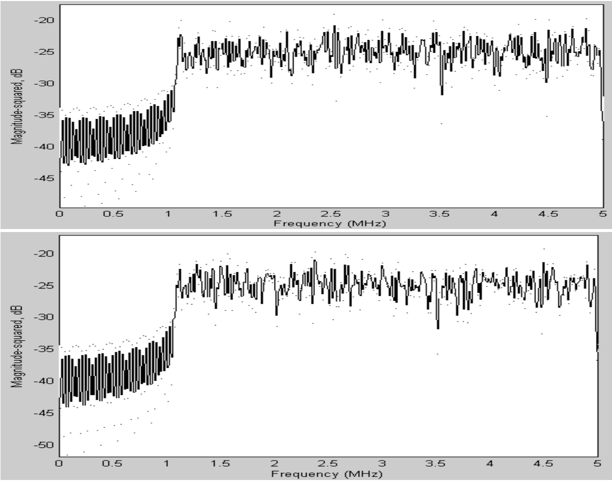

Fig. 9 OFDM with 64-QAM, 1024-points IFFT/FFT with SNR=60 dB

The simulation results for the worst case (8-points FFT) and the best case (1024-points FFT) were presented in the above figures for OFDM with 4-QAM, 16-QAM, and 64-QAM. The result from this experiment is that the more FFT/IFFT length, the more accurate and more practical use of OFDM system; i.e. more subcarriers can be used as shown from the spectra of OFDM signals that are observed in the previouse figures.

4.2 Experiment-2

In this experiment the study of changing the SNR with fixed FFT/IFFT length will be discussed. The optimum length used for FFT/IFFT is 1024-points as discussed in experiment-1. The SNR values will be from 10dB to 60dB by step of 1dB. This experiment has been applied on OFDM system with the same M-QAM schemes as in the previous experiment. The simulation results for this experiment are shown in the following figures.

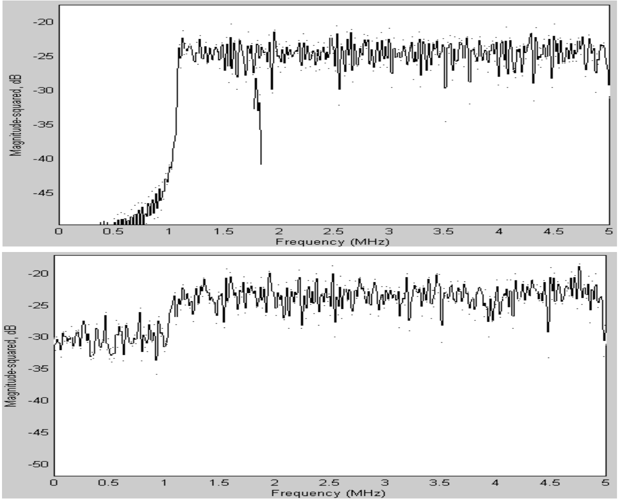

Fig. 10 OFDM with 4-QAM, 1024-points IFFT/FFT with SNR=10 dB

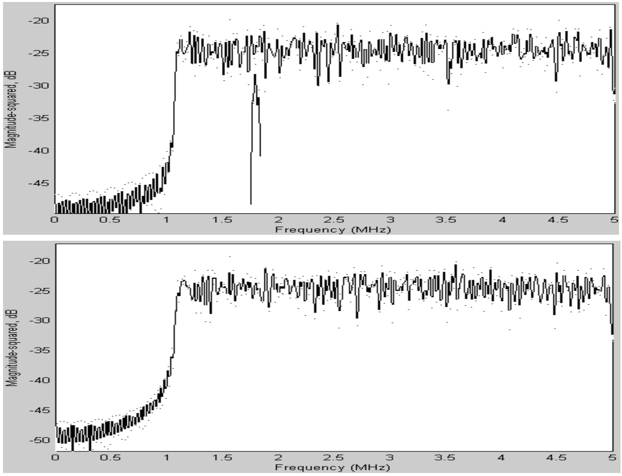

Fig. 11OFDM with 4-QAM, 1024-points IFFT/FFT with SNR=60 dB

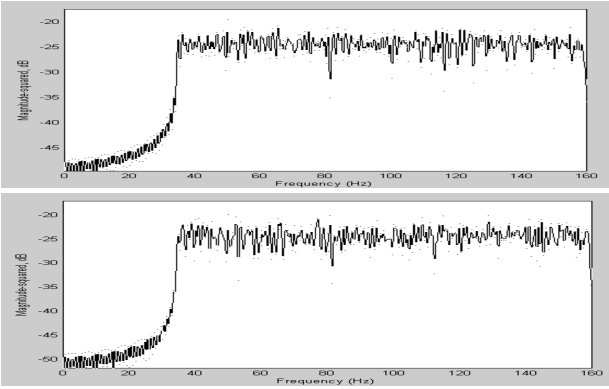

Fig. 12 OFDM with 4-QAM, 1024-points IFFT/FFT with SNR=70 dB

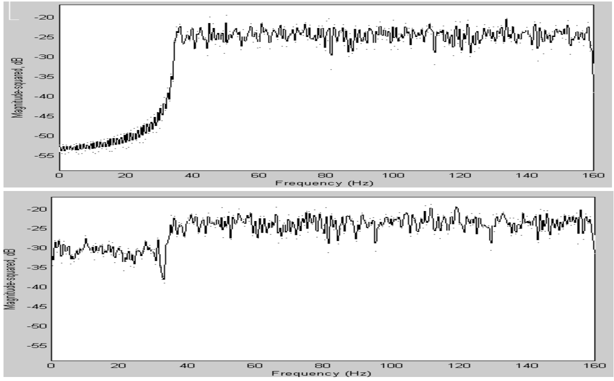

Fig. 13 OFDM with 16-QAM, 1024-points IFFT/FFT with SNR=10 dB

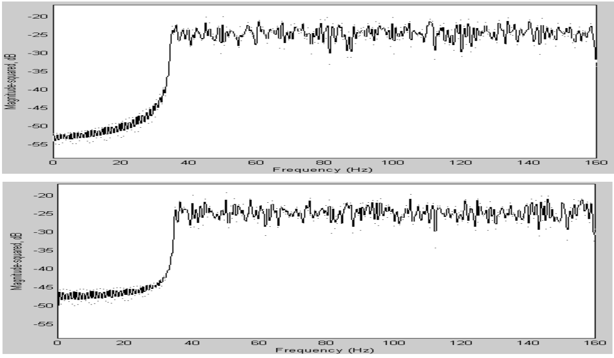

Fig. 14 OFDM with 16-QAM, 1024-points IFFT/FFT with SNR=60 dB

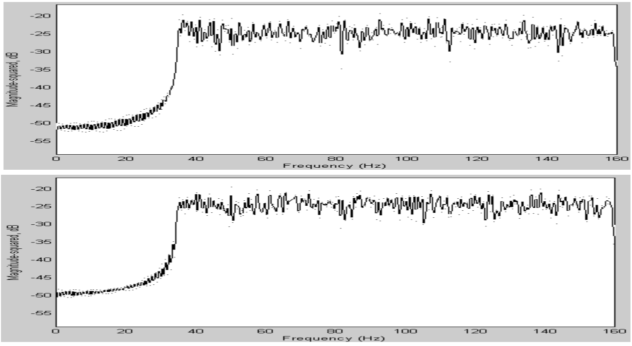

Fig. 15 OFDM with 16-QAM, 1024-points IFFT/FFT with SNR=70 dB

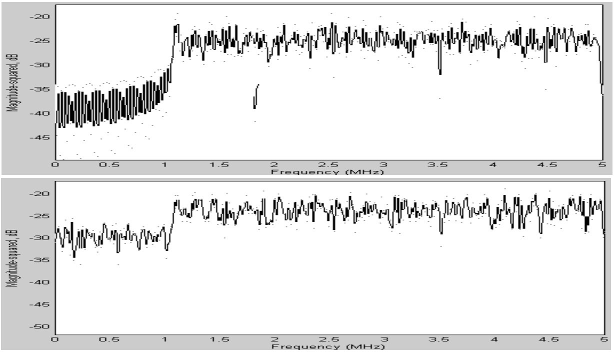

Fig. 16 OFDM with 64-QAM, 1024-points IFFT/FFT with SNR=10 dB

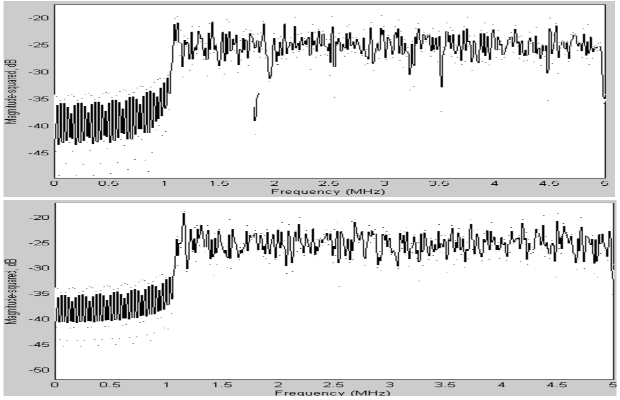

Fig. 17 OFDM with 64-QAM, 1024-points IFFT/FFT with SNR=60 dB

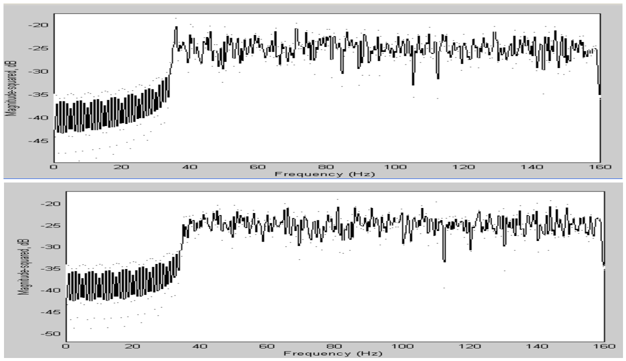

Fig. 18 OFDM with 64-QAM, 1024-points IFFT/FFT with SNR=70 dB

The simulation results for the worst case (SNR=10dB) and the best case (SNR=60dB) were presented in the above figures for different OFDM systems. From the results of this experiment, we get that the optimum value for the SNR is 60dB for minimum AWGN. After this value there is nearly no effect.

4.3 Experiment-3

In this experiment we discuss the effect of changing of the SNR over the scatter plot for complex digital modulator/demodulator with the same SNR values as in experiment-2. This experiment has been applied on OFDM system with the same M-QAM schemes as in the last experimenrs. The simulation results for this experiment are shown in the following figures.

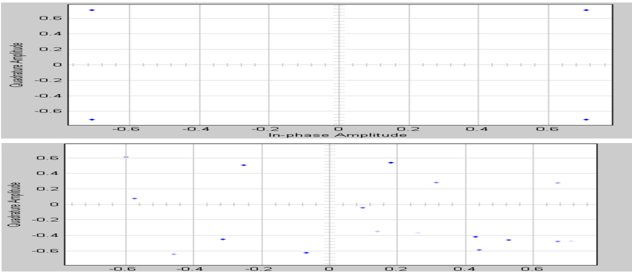

Fig.19 OFDM with 4-QAM; scatter plot for modulator/demodulator, SNR=10 dB

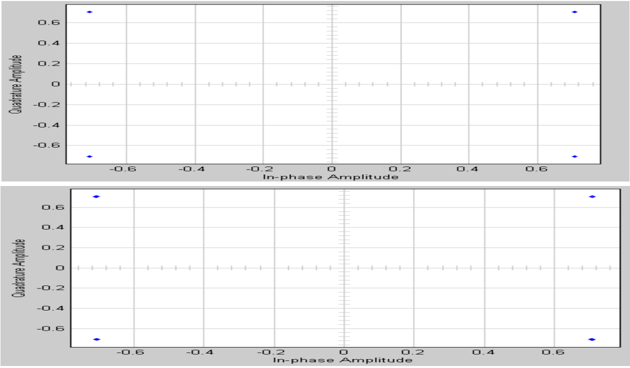

Fig.20 OFDM with 4-QAM; scatter plot for modulator/demodulator, SNR=60 dB

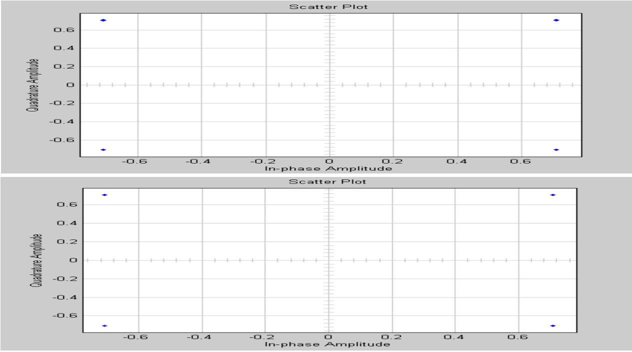

Fig.21OFDM with 4-QAM; scatter plot for modulator/demodulator, SNR=70 dB

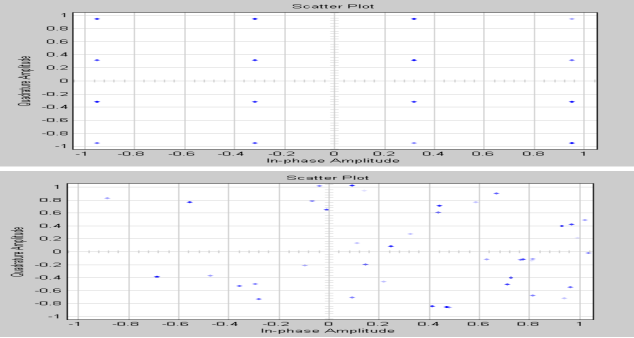

Fig. 22 OFDM with 16-QAM; scatter plot for modulator/demodulator, SNR=10 dB

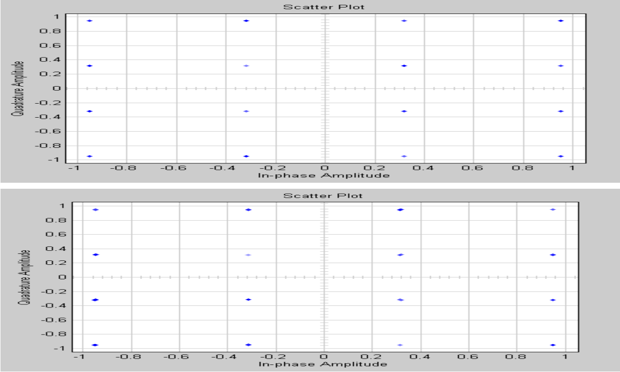

Fig.23 OFDM with 16-QAM; scatter plot for modulator/demodulator, SNR=60 dB

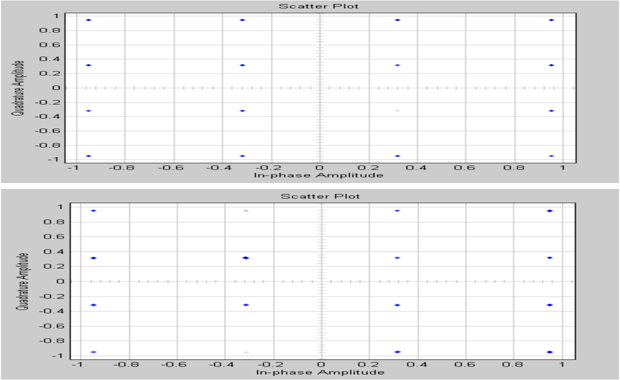

Fig. 24 OFDM with 16-QAM; scatter plot for modulator/demodulator, SNR=70 dB

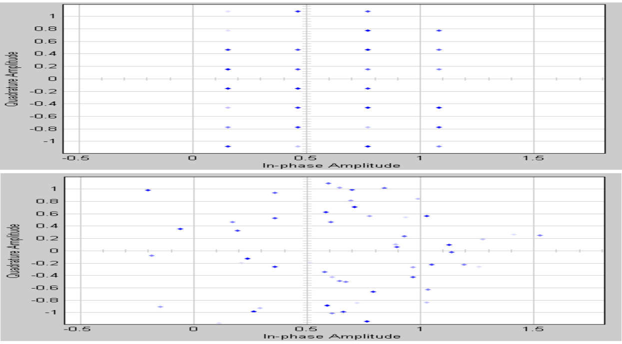

Fig. 25 OFDM with 64-QAM; scatter plot for modulator/demodulator, SNR=10 dB

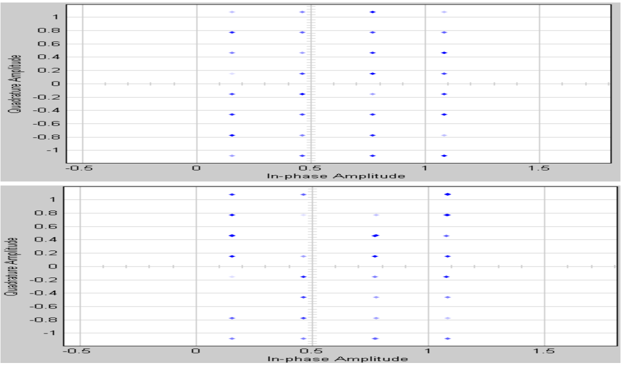

Fig. 26 OFDM with 64-QAM; scatter plot for modulator/demodulator, SNR=60 dB

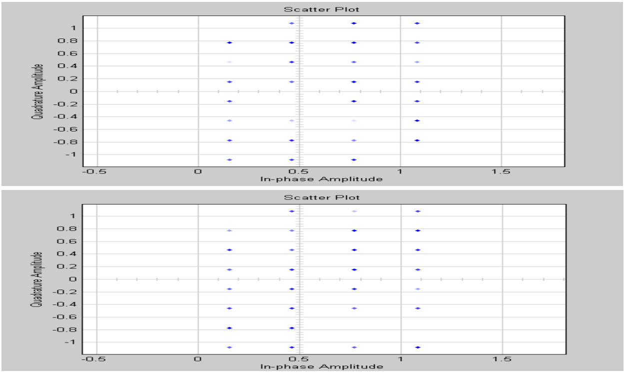

Fig. 27 OFDM with 64-QAM; scatter plot for modulator/demodulator, SNR=70 dB

From the experimental results of this experiment shown in the previous figures we get that the optimum value for the SNR is 60 dB for minimum scattering in the output of the modulator and demodulator.

4.4 Comparison between M-QAM schemes

The comparison between different M-QAM schemes is illustrated in the following figure.

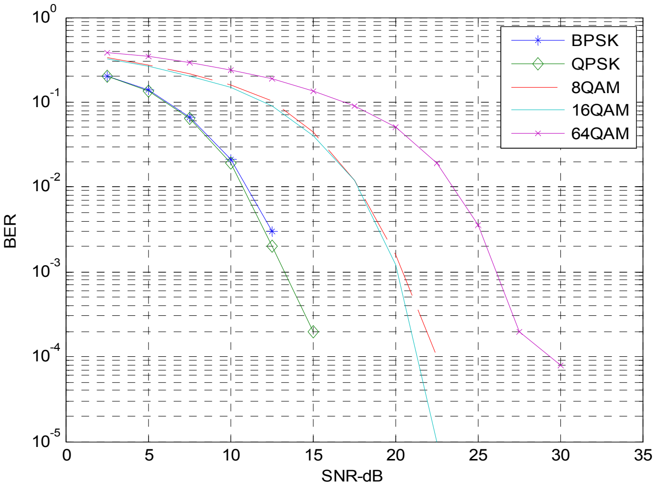

Fig. 28 The relation between BER and SNR for different OFDM

We get from this figure that the system of 64-QAM is the best system because of large SNR value and small BER value.

5. Conclusions

The simulation results for OFDM system with different M-QAM schemes have been observed. There were three experiments for that; in the first experiment the changing of FFT/IFFT length with fixed SNR has been studied, in the second experiment the changing of the SNR with fixed FFT/IFFT length has been discussed, and in the third experiment the effect of the variation of the SNR over the scatter plot at the demodulator has been presented. The main results of our experiments were that the optimum FFT/IFFT length was 1024 points and the best value for the SNR was 60dB; and we get that after this value there is no effect of varying the SNR value. After that the comparison between different OFDM systems has been discussed and we get that the optimum system is the OFDM system with 64-QAM for max SNR and min BER values.

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