Image Processing Using OFDM

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Abstract - In today's communication world we are having drastic changes in the format related to OFDM system An OFDM system deals with multiple channels over which information are sent at different frequencies to boast up bandwidth efficiency. During communication an extra unwanted noise signals come across with real signal due to any reason In this project we have dealt with these noise called AWGN in which at the receiver side Bit error rate is improved to recover real image that was sent from transmitter to receiver In order to achieve this we have gone through various modulation techniques such as QAM BPSK QPSK etc These techniques were used for audio or video signals in OFDM but in this project it has been done for image processing to recover original image Along with this IFFT and FFT filters are used at the transmitter and at the receiving end of OFDM system.

Keywords: Wireless communication, equalization, Orthogonal frequency division multiplexing (OFDM), binary phase shift keying (BPSK), Quadrature phase shift keying(QPSK).

I. INTRODUCTION

Wireless communication standards which are existing and under development, adopt or consider adopting orthogonal frequency-division multiplexing (OFDM) as new modulation technique. OFDM has become definitive modulation scheme in future wireless communication systems. For better ways of living has been instrumental in advancing human civilization. Communication services are available at any time and place free people from the limitation of being attached to certain devices. Nowadays, thanks to the progress in wireless technology, affordable wireless communication service has become a reality. Mobile phones made people comfortable whenever and wherever they want. Digital audio and video broadcasting gives consumers high-resolution, better-quality and interactive programs. The devices are thin, light, small and inexpensive in their form. Smart mobile phones are capable of multimedia and broadband internet access is being shown up on the shelves.

Many projects studying wireless networks with variable extents of coverage are in the process. They will make wireless access to internet backbone from, either indoors or outdoors and in rural or metropolitan areas. In this, their evolution and future progress will be seen. The important role that the orthogonal frequency-division multiplexing (OFDM) technique has in wireless communication systems will become very clear.

Now, most people fulfil the need for information and entertainment through audio and video broadcasting. The inauguration of AM radio can be seen to the early twentieth century, whilst analog TV programs were first broadcast in the Second World War. In middle of twentieth century, FM radio programs were available. These technologies were on analog communication, brought news, music, drama, movies and much more into our lives. To provide more programs, digital broadcasting techniques, such as digital audio broadcasting (DAB) and digital video broadcasting (DVB), started to substitute the analog broadcasting technologies in the past several years.

Modern wireless communication systems give many advantages, such as mobility, easy access to signal and device installation; however, they have more limitations than wireline transmission systems, it has limited capacity, spectrum shortage and some service quality uncertainties. With wireless communication systems, signals are sent over the air in the radio-frequency (RF) band.

There are many non-ideal factors that change the quality of the receiving signals and, thus, the reliability of modern wireless communication. As an outcome, these wireless channel changes places of different fundamental limitation on the capability of modern wireless communication systems.

II. OFDM SYSTEM

In OFDM system, a high-data rate channel can be divided into number of *N* number of low data-rate sub channels and each and every sub channel can be modulated in different and varied sub-carrier. Those low data rate sub channels have bandwidth less than that the coherence bandwidth of the channel.

On carrying out this so each and every sub channel have a flat-fading and equalization at the receiver is minimum amount complexity. By choosing a set of (orthogonal) carrier frequencies of special kind, high spectral efficiency can be obtained because of the spectra of the SCs overlapping, while on mutual influence among the SCs are avoided.

In an OFDM environment the input bit can be multiplexed into number of N symbol, each and every with symbol period of T, and each symbol stream can be used to modulate the parallel sub carriers. The sub carriers can be used in this separated by $1/NTs$ in frequency domain, so they are used as an orthogonal over (0, Ts).

A typical OFDM transceiver system is shown in fig 2.1 initially, serial to parallel converter converts the input bits stream into a set groups of the $log2M$ bits, where in which M may alphabet of size of digital modulation scheme are being used in different sub carrier. Overall N symbols $X(k)$ can be formed and created. Then, the N symbols can be mapped to IFFT. These IFFT corresponds to the orthogonal sub-carriers in the OFDM symbol.

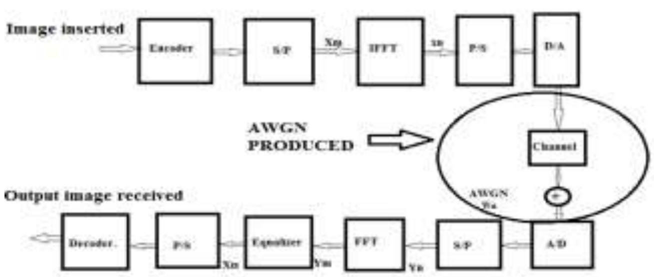

Fig.2.1 A typical OFDM transceiver system.

$$x(n) = \frac{1}{N}\sum_{M=0}^{N-1} Xmxe^{j2\pi mn/N} \quad 0 \le n \le N-1$$

Where we say X_m can be baseband symbols on our each sub-carriers. The digital-to-analog (D/A) converter then leads to an analog time-domain signal which can be transmitted through the channel. The digital-to-analog (D/A) converter leads to an analog time-domain signal which can be transmitted through our channel. Before transmitting the OFDM symbol cyclic prefix must also be appended at the facing end of symbol. At our receiving end, the cyclic prefix get removed then the signal can be converted before its back to a discrete N point sequence $y(n)$, for each sub-carrier. This discrete signal can be demodulated by using an N-point fast Fourier transform (FFT) operation at the receiver. The demodulated symbol stream is given by:

$$Y(m) = \sum_{n=0}^{N-1} y(n)e^{j2\pi mn/N} + W(m) \qquad 0 \le m \le N-1$$

Where, $W(m)$ shown to the FFT of the sample of w (n), which is its AWGN channel.

1) OFDM Principle

In OFDM system, there are mainly two principles are being used as follows:

1. IFFT and FFT are being used for that respectively, modulating and demodulating the data constellations over orthogonal SCs [1]. These signal processing algorithms substituting the banks of I/Q-modulators and demodulators that are required.

Focus on the input of the IFFT, N data constellation points are present, where there is N is the number of FFT points. (i is an index on the SC; k is an index on the OFDM symbol). These constellations are taken according to any of different phase shift keying (PSK) or by QAM signaling set (symbol mapping). The number of N output samples of the IFFT, on becoming TD form the baseband signal carrying the data symbols on a set of N orthogonal SCs. In our real system not all of these N possible SCs can be used for data.

2. The second important principle is of introduction of a cyclic prefix as a GI, whose length should reach the maximum excess delay of the multipath propagation channel. Owing to the cyclic prefix, the transmitted signal transform into periodic and the effect of the time-dispersive multipath channel changes into equivalent to a cyclic convolution, removing the GI at the receiver. Because of the properties of the cyclic convolution, the effect of the multipath channel becomes limited to a point wise multiplication of the transmitted data constellations by the channel TF or FT of the channel IR that is, the SCs that remain orthogonal. the bad outcome of this principle is a decrement of effective transmit power, during redundant GI are transmitted. Most of the time GI is picked of a length of one tenth to a quarter of the symbol period, give rise to an SNR loss which is of 0.5 to 1 db.

The equalization (symbol demapping) needed for determing the data constellations becomes an element wise multiplication of FFT output by inverse of estimated channel TF (channel estimation). In order to take phase modulation schemes, multiplication by complex conjugate of channel estimate can execute the equalization. Much differential detection can be implemented as well, where our symbol constellations of adjacent SCs or subsequent OFDM symbols may be compared to get the data.

2) AWGN Channel

A noise can be regarded as unnecessary electrical signals that are constantly found in electrical systems. When such unwanted electrical signals get superimposed on a clean signal, the product will be an unclear signal. This ambiguity makes it very difficult for the receiver to decide on the correct symbol, and therefore restricts the rate of information transmission. Noise can have different sources, natural and manmade.

Natural noise is mainly generated from electrical circuits, component noise and atmospheric disturbances. Man-made noise, on the other hand, is generated from sources like spark-plug ignition, radiating electromagnetic signals and switching transients. Although engineers try to reduce and to some extend eliminate the noise and its effect by shielding, filtering and correct selection of modulation, but there remains one type of natural source, known as Johnson or thermal noise which can never be eradicated. Such natural noise types are a result of thermal movement of electrons in electrical components (i.e. resistors and wires etc.). As described most of the communication systems that use channel as a medium for transmission face distortion due to presence of noise in the channel.

A very common mathematical channel model, which has also been implemented in this research project, is the Additive White Gaussian Noise (AWGN) channel. This channel model has been extensively used in determining the most suitable modulation type, modulation order and comparison between the different encoding schemes. The AWGN is a well-recognized channel model as it represents a physical reality, provided that the thermal noise at the receiver is the only source of interference [26].

Nonetheless, due to their simplicity, AWGN are commonly characterized to symbolize for a man-made noise or other multiuser interferences.

In AWGN channel, a white Gaussian noise is added to a real or complex input signal. Depending on the real or complex format of the input signal, the Gaussian noise added will be either real or complex, therefore producing a real or complex output signal respectively; inheriting its sample time from the input signal. This channel model uses the signal processing random source for generating the noise. In doing so, the random numbers are generated using the Ziggurat method, which is the same method used by the MATLAB random function.

A Probability Distribution Function (PDF) of a Gaussian distributed random variable *n*, with mean value of μ, and the variance of σ can be written as:

$$\frac{1}{\sigma\sqrt{2\pi}}\exp\,[1/2(n/\sigma)^2]$$

Where:

- *P(n)* : PDF of a Gaussian distributed random variable *n*
- σ^2 The Variance of *n*

The normalized Gaussian density function can be obtained when the mean value (μ) equals 0, and σ = 1. The normalized PDF is shown in

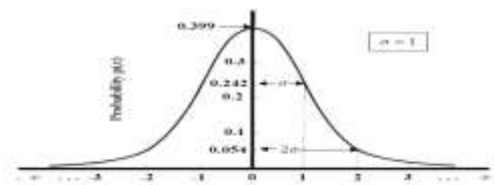

Fig 2.2 Normalized σ = 1 Gaussian probability density function of an AWGN channel

- The noise *n (t)* is an ***additive*** random disturbance of the useful transmitted signal *S (t),* illustrated in Eqn.
- This noise is categorized as ***white*** noise, as its Power Spectral Density (PSD) is constant.
- The noise has ***Gaussian*** distributed random variable with mean of zero and stationary characteristic.

The received signal in the time interval of 0 $0 \le t \le T$ can be expressed the typical model for the transmitted signal passed through an AWGN

channel and received signal out of the channel [25].

$$r(t)= Sm(t)+n(t)$$

Where:

r (t) : Received Signal

Sm (t) : Transmitted Signal

n (t) : Sample function of the AWGN process with power density function

The Cumulative Distribution Function (CDF) of a Gaussian or normally distributed random variable can be presented as Eqn [16]:

$$F(x)=\frac{1}{2}[1 +erf(\frac{x-\mu}{\sqrt{2\sigma}.\sigma})]$$

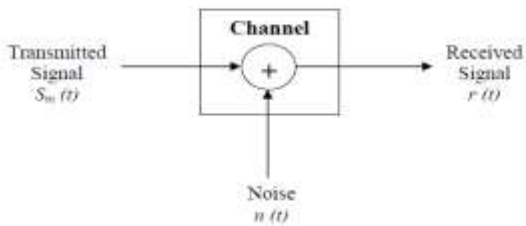

Fig 2.3 Typical model for the transmitted signal passed through an AWGN channel and received signal out of the channel [14]

III. PROPOSED OFDM SYSTEM

This section aims to provide principal and theoretical background to digital modulation, and different digital band pass modulation techniques. This section will present the step by step results for the designed fundamental OFDM modem. As depicted in Fig. the simplified OFDM transceiver is divided into three main sections of Transmitter, Channel and Receiver, results of which are presented below. Modulation/De-modulation, IFFT/FFT, CP insertion/removal are the most important blocks in this simplified OFDM transceiver.

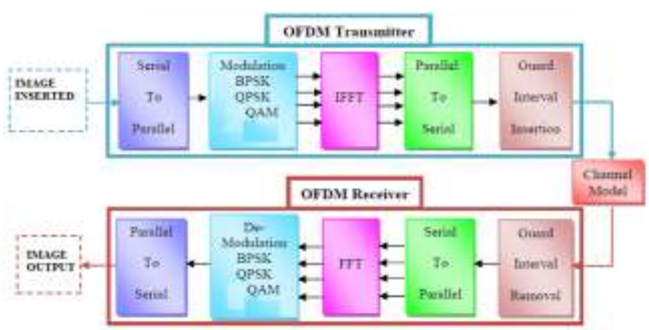

Fig 3.1 OFDM Trans-receiver

In order to simulate this OFDM modem, a channel bandwidth of 1 MHz, with 128 subcarriers has been selected. In addition, symbol duration of 128 µs and guard interval of 20 µs have been chosen.

IV. SIMULATION AND RESULTS

The simulation of OFDM transmitter is discussed in this section, containing the step by step results and discussions. The architecture of this particular OFDM transmitter is depicted in Fig.

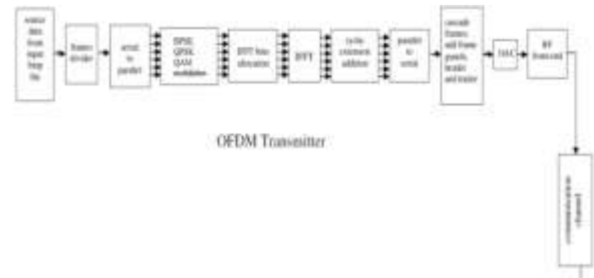

Fig 4.1 OFDM Transmitter.

1) OFDM transmitter

As depicted and highlighted in Fig, the initial stage prior to the actual OFDM transmission is to transmit the generated message, where this message could be either randomly generated binary values, audio sound, or digitally processed image.

Simulation of this part uses the uniformly distributed pseudorandom numbers, by using the “rand(m,n)” function which produces a 1 by 2500 pseudorandom values, where 2500 represent the number of bits. In order to produce random binary values, the previously produced values are required to be rounded to their nearest integer value.

This is achieved by the use of “round” function, which produces 1 by 2500 bits (zeros and ones). Fig depicts the random binary generated message.

It is important to note that the input message illustrated in Figure 3.20 and the following figures presenting an output for each block, is only part of the full message, and therefore only gives an indication of 12 bits out of 2500 bits.

The core of the OFDM transmitter is the modulator, which modulates the input data stream frame by frame. Data is divided into frames based on the variable symbol per frame, which refers to the number of symbols per frame per carrier. It is

defined by: symb_per_frame = ceil(2^13/carrier_count). This limits the total number of symbols per frame (symb_per_frame * carrier_count) within the interval of [2^13, 2*(2^13-1)], or [8192, 16382]. However, the number of carriers typically would not be much greater than 1000 in this simulation, thus the total number of symbols per frame would typically be under 10,000. This is an experimentally reasonable number of symbols that one frame should keep under for this MATLAB program to run efficiently; thereby symb_per_frame is defined by the equation shown above. If the total number of symbols in a data stream to be transmitted is less than the total number of symbols per frame, the data would not be divided into frames and would be modulated all at once.

Following the simulation results for the main types of modulation scheme, the principal and theoretical background to the main blocks of an OFDM transmitter, including basic principle of OFDM, implementation of IFFT, and cyclic prefix were presented.

The stated basic digital modulation techniques in an OFDM were next illustrated. In doing so, a high-level technical computing language called MATLAB was used in order to design and implement the outlined OFDM communication system. More specifically, a step by step simulation response for each block of the transmission section of the designed fundamental OFDM modem, consisting of the most important blocks such as Modulation, IFFT and CP insertion were presented. Summary of this sequential step by step simulation of the transmission section are as follows:

1) The random binary message were generated

2) These binary message were converted from serial format into a parallel

3) The parallel binary message were modulated using the BPSK

4) The IFFT were applied in order to find the corresponding time waveform

5) The cyclic prefix was added by copying a percentage of the OFDM symbol and Pre pending it to the transmitted symbol.

Fig shows a block diagram of a generic OFDM system. ADC, DAC, and RF front-ends (Amplification, RF up conversion/down conversion, etc.) are not simulated in this project. This MATLAB simulation program consists of six files.

OFDM_SIM.m shall be run while other m-files will be invoked accordingly. Source data for this simulation is taken from an 8-bit grayscale (256 gray levels) bitmap image file (*.bmp) based on the user's choice. The image data will then be converted to the symbol size (bits/symbol) determined by the choice of *M*PSK from four variations provided by this simulation. The converted data will then be separated into multiple frames by the OFDM transmitter. The OFDM modulator modulates the data frame by frame. Before the exit of the transmitter, the modulated frames of time signal are cascaded together along with frame guards inserted in between as well as a pair of identical headers added to the beginning and end of the data stream. The communication channel is modeled by adding Gaussian white noise and amplitude clipping effect.

The receiver detects the start and end of each frame in the received signal by an envelope detector. Each detected frame of time signal is then demodulated into useful data. The modulated data is then converted back to 8-bit word size data used for generating an output image file of the simulation.

Error calculations are performed at the end of the program. Representative plots are shown throughout the execution of this simulation.

2).OFDM Receiver

The simulation of OFDM receiver is discussed in this section, containing the step by step results and discussions. The architecture of this particular OFDM receiver is depicted in Fig

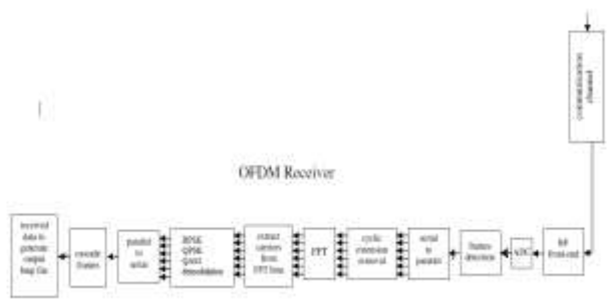

Fig 4.2 OFDM Receiver.

The OFDM receiver basically does the reverse operation to its transmitter, where initially the guard interval is detected and then removed. Later, the FFT of each symbol is then taken to find the original transmitted spectrum. The phase angle of each transmission carrier is then evaluated and converted back to the original transmitted data by demodulating the received phase. The suitable data size received are then combined and re-formatted back to the original serial data stream.

As depicted in Fig the initial stage for OFDM reception is to receive the output signal from the channel, where the signal is corrupted with applied noise within the channel that needs to be removed. The received input signal to the OFDM received, and removal of noise is shown in Fig. A trunk of received signal in a selective length is processed by the frame detector (*ofdm _frame _ detect.m*) in order to determine the start of the signal frame.

For only the first frame, this selected portion is relatively larger for taking the header into account. The selected portion of received signal is sampled to a shorter discrete signal with a sampling rate defined by the system. A moving sum is taken over this sampled signal. The index of the minimum of the sampled signal is approximately the start of the frame guard while one symbol period further from this index is the approximate location for the start of the useful signal frame. The frame detector will then collect a moving sum of the input signal from about 10% of one symbol period earlier than the approximate start of the frame guard to about one third of s symbol period further than the approximate start of the useful signal frame. The first portion, with a length of one less than a symbol period of this moving sum is discarded. The first minimum of this moving sum is the detected start of the useful signal frame.

3) System Configurations and Parameters

Table 1. PARAMETER TABLE.

Parameters	Values
Source Image Size	1200 * 1500
IFFT size	2048
Number of Carriers	1024
Modulation Method	BPSK QPSK QAM
Peak Power Clipping	6 db
Signal-to-Noise Ratio	9 db

At the beginning of this simulation MATLAB program, a script file *ofdm _ parameters.m* is invoked, which initializes all required OFDM parameters and program variables to start the simulation. Some variables are entered by the user.

The rest are either fixed or derived from the user-input and fixed variables. The user input variables include:

1) Input file – an 8-bit grayscale (256 gray levels) bitmap file (*.bmp);

2) IFFT size – an integer of a power of two;

3) Number of carriers – not greater than [(IFFT size)/2 – 2];

4) Digital modulation method – BPSK, QPSK, QAM.

5) Signal peak power clipping in dB;

6) Signal-to-Noise Ratio in dB.

The number of carriers needs to be no more than [(IFFT size)/2 – 2], because there are as many conjugate carriers as the carriers, and one IFFT bin is reserved for DC signal while another IFFT bin. is for the symmetrical point at the Nyquist frequency to separate carriers and conjugate carriers. All user-inputs are checked for validity and the program will request the user to correct any incorrect fields with brief guidelines provided. An example is shown in Table 1. This script also determines how the carriers and conjugate carriers are allocated into the IFFT bins, based on IFFT size and number of carriers defined by the user conjugate carriers spreading out on 512 IFFT bins.

Two properties of a typical communication channel are modelled. A variable clipping in this MATLAB program is set by the user. Peak power clipping is basically setting any data points with values over clipping below peak power to clipping below peak power. The peak-to- RMS ratios of the transmitted signal before and after the channel are shown for a comparison regarding this peak power clipping effect.

Channel noise is modelled by adding a white Gaussian noise (AWGN).

It has a mean of zero and a standard deviation equaling the square root of the quotient of the variance of the signal over the linear Signal-to-Noise Ratio, the dB value of which is set by the user as well.

4) Proposed simulation process in MATLAB

Seven graphs are plotted during this OFDM simulation:

1. Magnitudes of OFDM carrier data on IFFT bins; Since all magnitudes are ONE, what this plot really shows is how the carriers are spread out in the IFFT bins.

2. Phases translated from the OFDM data; In this graph, it’s easy to see that the original data has a number of possible levels equal to 2 raised to the power of symbol size.

3. Modulated time signal for one symbol period on one carrier +4 Modulated time signal for one symbol period on multiple (limiting to six) carriers.

4. Magnitudes of the received OFDM spectrum this is to be compared to the first graph.

5. Phases of the received OFDM spectrum this is to be compared to the second graph.

6. Polar plot of the received phases A successful OFDM transmission and reception should have this plot show the grouping of the received phases clearly into 2^symbol-size constellations.

The first four plots are derived from OFDM modulation while the last three are from demodulation. None of these plots include a complete OFDM data packet. The first three plots represent only the first symbol period in the first frame of data, whereas the fourth plot represents up to the first six symbol periods in the first frame. Since the first and last portion of the received/modulated data have higher probability of getting errors due to imprecision in synchronization, a sample of symbol period used by the fifth, sixth, and seventh plots is from the approximate middle of a frame, which is also approximately the middle one among all data frames. However, it's still possible that the sample taken for the demodulation plots is still erroneous on certain trials of this MATLAB simulation. It is important to note that even if the fifth, sixth, and seventh plots don't show reasonable information, the overall OFDM transmission and reception would still likely be valid since these plots only represent one symbol period among many.

5) Picture Quality versus Signal to Noise Ratio

In addition to the transmission of bits (zeroes and ones) and following the comparative performance studies on the OFDM modem by means of analyzing those using different techniques and scenarios which has so far been the subject of this chapter; the next stage is the transmission of an image which will be considered in this section.

Furthermore, this section will illustrate the work undertaken in order to improve the degradation performance of OFDM system in the presence of high noise in the channel.

The transmission of an image through an OFDM system with channel of different noise level. As it is illustrated in this table, the first image in the left hand side column is the original input image, and the image next to it is the gray scale image of the original input image. The gray scale image is the image to which the different techniques such as the convolution encoding/decoding, modulation/ demodulation in the transmitter and receiver will be applied.

As it is illustrated like many other digital communication systems, the performance of this OFDM system is only acceptable, up to some critical channel noise level. In other words, if the noise level is raised above that critical level, the performance of the system fails very quickly. Such matters may highly affect the performance of the wireless telecommunications, where the drops in the signal may lead to diminution in reliability of the communication. The advantage of the currently designed OFDM system is that, when the channel is under a high noise condition, the system outputs a worse image quality rather than Completely loosing the transmitted image. This is depicted in the pictures of Table 5. with SNR value of 3 or 6 dB. This image transmission through the noisy channel has been simulated by using the same MATLAB code as for the bits transmission, where the signal to noise ratio (SNR) of the channel is varied from 1dB to 20 dB, with the image quality measured at 3 dB increments. In this OFDM system, the FEC technique was also used with the 64 - QAM modulation technique which illustrate that:

Using 64 – QAM carries higher data rates, which is essential when dealing with image transmission.

Modulation techniques such as 16QAM perform better than higher order modulation such as (64 QAM) under high noise channel condition with SNR < 12dB.

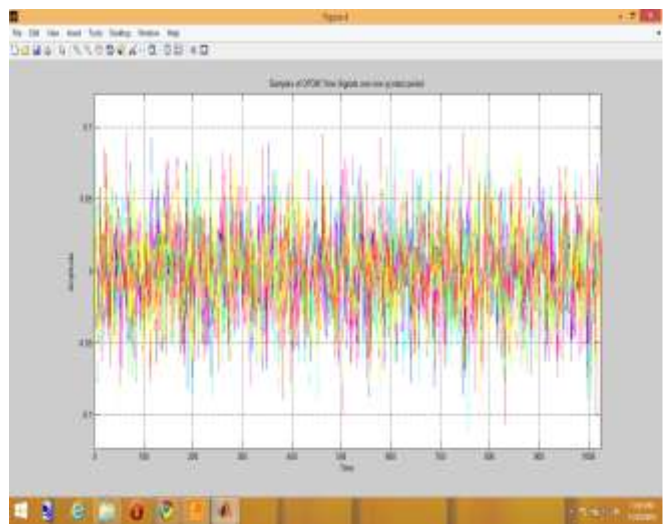

Fig 4.3 Samples of OFDM Time Signals over one symbol period.

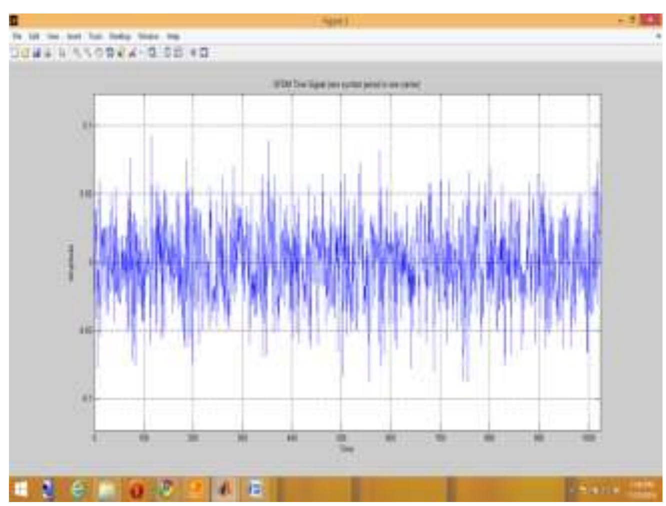

Fig 4.4 OFDM Time Signal (one symbol period in one carrier).

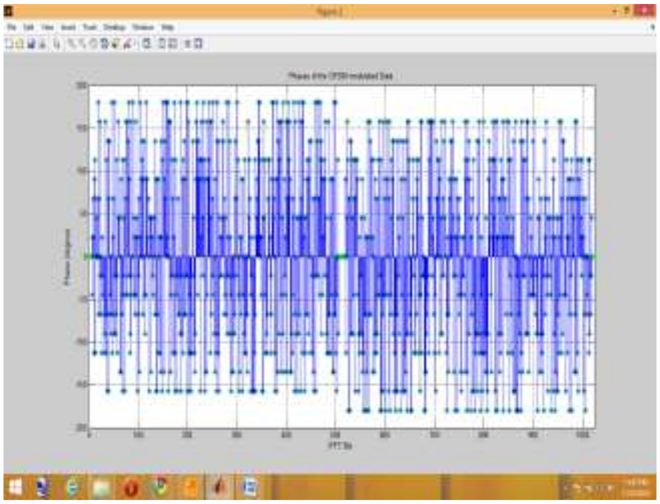

Fig 4.5 Phases of the OFDM modulated Data.

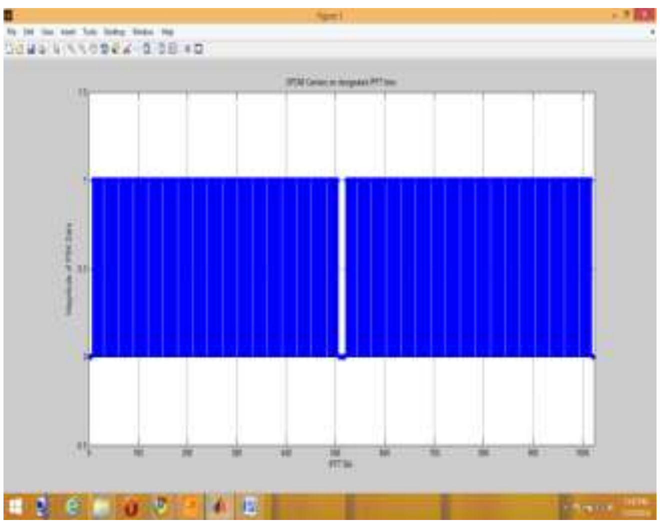

Fig 4.6 OFDM Carriers on designated IFFT bins.

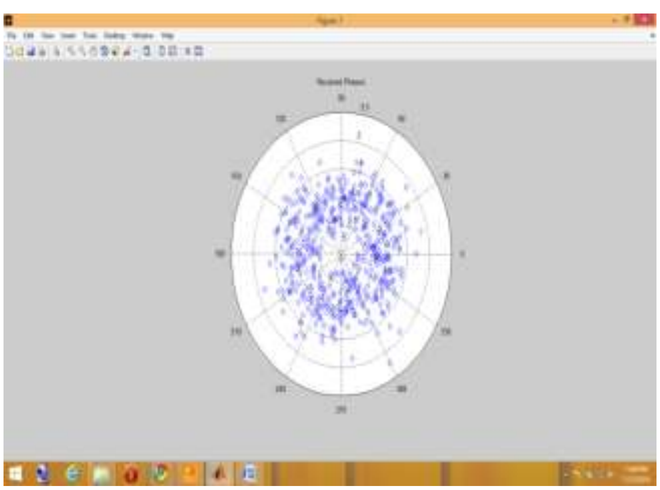

Fig 4.7 Received Phases.

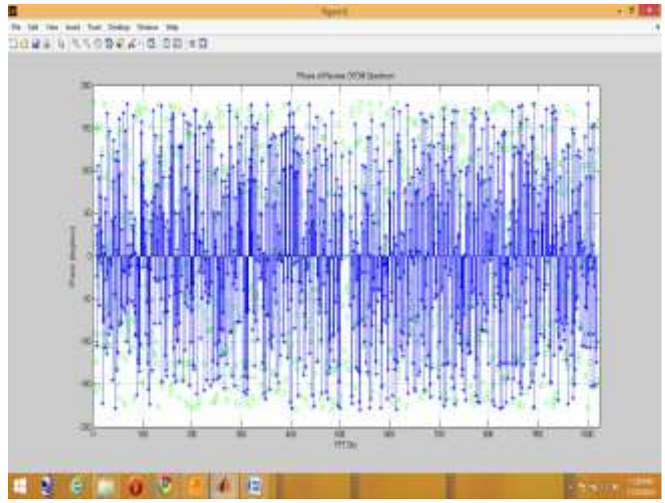

Fig 4.8 Phase of Receive OFDM Spectrum.

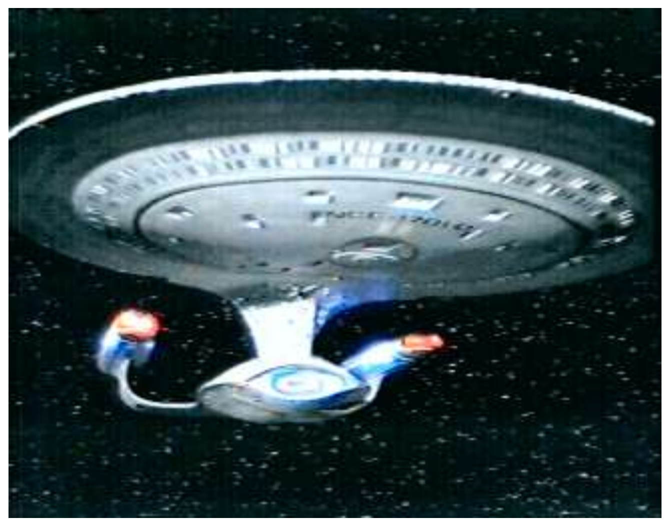

Fig 4.9 Image to be TX.

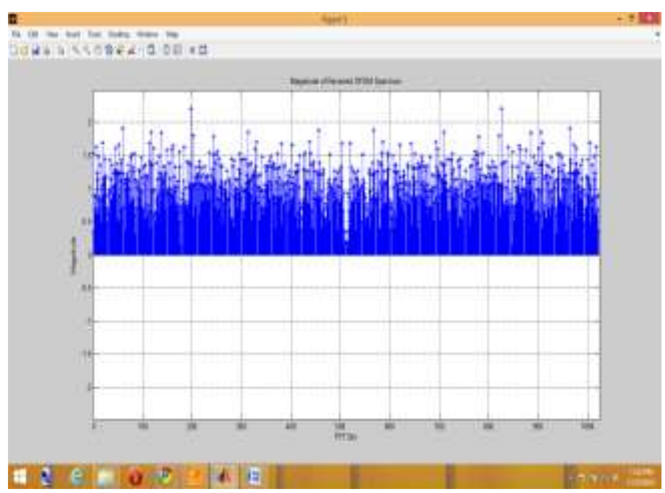

Fig 4.10 Magnitude of Received OFDM Spectrum

Fig 4.11 16BPSK

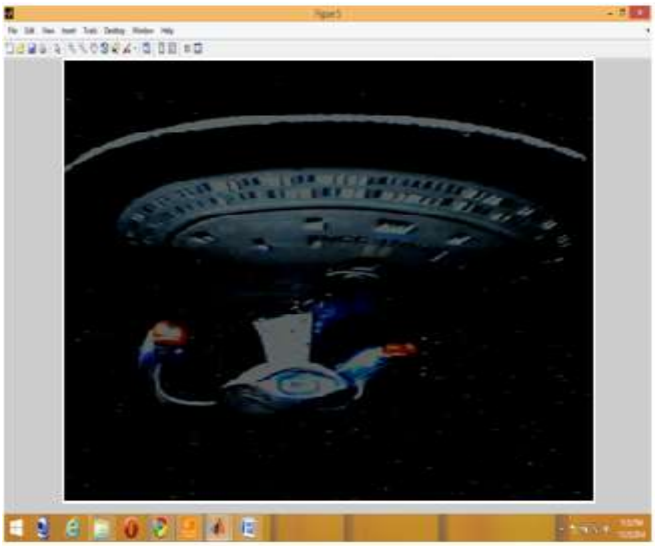

Fig 4.12 QPSK

Fig 4.13 QAM.

V. CONCLUSION AND FUTURE WORK

The decisive and proactive aim of this research project was to design and implement an OFDM system for powerline-based communication, by using simulation of the operation of virtual transmitter and receiver. Importantly the only aim of this research was to design an OFDM modem for a powerline-based communication to propose and examine a outstanding approach in comparing the various modulation order, different modulation type, implementation of FEC scheme and also application of different noise types and using all for the two modelled channels (AWGN and Powerline modelled channel) in an endeavour to understand and know the most suitable technique for the transmission of message or image over communication system.

For simulating an OFDM that associated signal could be corrupted by power line type of noise the closed model in this field was adoption of Power line colored background noise, but most of the simulations in this project are the outcome of AWGN only.

The results' oriented summary presented above and contributions made by this research have shown that in presence of AWGN and Power line colored background noise cause a significant improvement in the performance and after that the transmission of the system, various framing techniques such as the use of modulation and error correction techniques, can minimize the effect of the noise and interference.

Adding to that the existence of certain assumptions and limitations in this study limited the outcome and contributions of this work for providing a more accurate comparison between the techniques, and right estimation of the errors in actual powerline systems. It is important to notice the highlight and recommend some of the areas where if assigned time and facilities; more research, investigation and improvements would be excellent. Following is a list of scope for further research:

With an ideal channel and perfect timing synchronization between the transmitter and receiver is not the case related to the real communication systems, but the imperfect conditions present over the communication system can be corrected by using standard digital signal processing (DSP) techniques in the transmitter and receiver ends. This is very important that the use of these digital signal processing techniques oriented to application dependent, if change in specific parameter of the DSP techniques gives out a different performance. The idea of synchronization for OFDM communication systems presented in [9, 10] can be taken forward and applied to the system presented in the current research.

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