Performance Evaluation of OFDM in Audio System for DAB

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Abstract - This paper presents the analysis of OFDM technique with audio sound signals using as an input, with the objective to show the advantages of multi-carrier OFDM modulation method compared with single-carrier 16-QAM for application in Digital Video Broadcasting (DAB).Programs and algorithms were utilizing MATLAB R2006a and using GUI to show the output of a sounds signals received while at receiver after its being transmitted from Transmitter. The output results will show the quality of the audio signals graphically and in form of audio received. The programs as well as GUI can accurately distinguish the output results of the audio signals received that simulates by OFDM and 16-QAM methods.

Keywords: FFT, OFDM, QAM

I. INTRODUCTION

Orthogonal frequency division multiplex (OFDM) modulation is being used more and more in telecommunication, wired and wireless. OFDM is especially suitable for high speed communication due to its resistance to Inter-Symbol Interference. The advantages of this modulation are the reason for its increasing usage [1]. OFDM can be implemented easily, it is spectrally efficient and can provide high data rates with sufficient robustness to channel imperfections [2].

A problem that commonly found in high speed communication system is inter-symbol interference (ISI).ISI occurs when a transmission of signals interferes with itself and the receiver cannot decode the transmission correctly. For example, in a wireless communication system as shown in Figure 1, the same transmission of data signals is sent in all directions. Because the signal reflects from large objects such as buildings, plants or mountains, the receiver sees more than one copy of signal. In communication engineering, we called this as multipath channel [3]. Since the indirect paths take more time to travel to receiver, the delayed copies of the signal interfere with the direct signals and causing Inter-symbol Interference (ISI).

This project will focus on Orthogonal Frequency Division Multiplexing (OFDM) simulation and implementation. OFDM is especially suitable for high speed communication due to its resistance to ISI [4].As communication systems increase their information transfer speed, the time caused by multipath remains constant, ISI becomes a limitation in high-data-rate Communication [5].OFDM avoids this problem by sending many low speed transmissions simultaneously. For example, Figure 2 shows two ways to transmit the same four pieces of binary data. Suppose that this transmission takes four seconds. Then each piece of data in the left picture has duration of one second. On the other hand, OFDM would send the four pieces simultaneously as shown on the right. In this case, each piece of data has duration of four seconds. This longer duration leads to less problems with ISI. Another reason to consider OFDM is low-complexity implementation for high Speed systems compared to traditional single carrier techniques [6].

A. FAST FOURIER TRANSFORM (FFT)

The Fast Fourier Transform (FFT) is a matrix-based algorithm for calculating the Discrete Fourier Transform (DFT), discovered by a number of independent workers in the 1950's. It is the cornerstone of modern signal processing. The analysis of a sound signal represented in frequency domain is of a great use. The process of Fourier transform converts a discrete signal x[n] from time domain (TD) representation into a frequency domain (FD) representation $X[e^{jw}]$ by the equation:

$$X\left[e^{jw}\right] = \sum_{n=-\infty}^{\infty} \mathrm{x[n]}\, e^{-jwn} \tag{1}$$

B. OFDM

Orthogonal Frequency Division Multiplexing (OFDM) is a frequency Division Multiplexing (FDM) scheme utilized as a digital multi-carrier modulation method [7].A OFDM block diagram is as show in Figure.1. A large number of closely-spaced orthogonal sub-carrier is used to carry data. The data is divided into several parallel data streams or channels, one for each sub-carrier [8]. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth. OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over wired, used in applications such as digital television and audio broadcasting, wireless networking and broadband internet access [9].

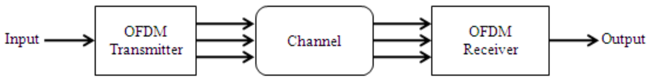

Figure.1: OFDM Block Diagram

C. QAM

QAM plays an importance process of modulation technique in order to make the source information signal compatible to the channel in order to make it successfully being transmitted to the receiver. QAM is a modulation scheme which conveys data by changing or modulating the amplitude and the phase of two carrier waves in which these two waves are usually sinusoids and are out of phase with each other by 90^0. This is because the QAM process involves two input signal that is classified as in phase component, I-channel and quadrature component Q-channel [10]. During this project, there are one constellation orders of QAM that has been studied which are 16-QAM.A 16-QAM block diagram is as show in Figure.2

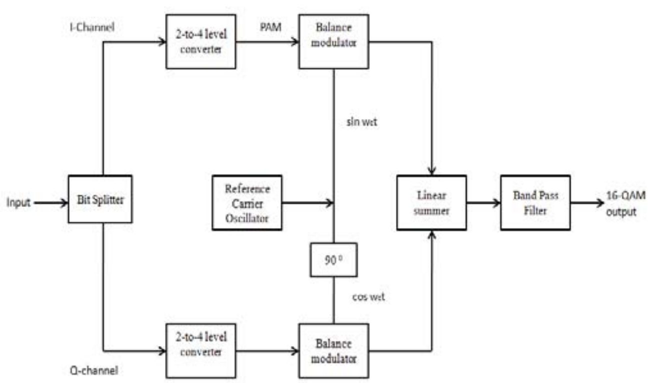

Figure 2: 16-QAM Block Diagram at Transmission Part

II. METHODOLOGY.

This project consists of MATLAB simulation of OFDM modulation technique.16-QAM modulation technique has been chosen to compare with OFDM technique. The MATLAB software version R2006a has been used to do a simulation. The simulation will show and prove the benefit of OFDM technique compare to 16 QAM in terms of Time Response, BER and audio sound signal data received quality. In this simulation analysis an audio sound input has been used to show the benefit of multi-carrier OFDM compared to single-carrier 16 QAM. The audio sound used is in *.*wav* format.

This project will focus on Orthogonal Frequency Division Multiplexing (OFDM) research and simulation. OFDM is especially suitable for high-speed communication due to its resistance to ISI. As communication systems increase their information transfer speed, the time for each transmission necessarily becomes shorter. Since the delay time caused by multipath remains constant, ISI becomes a limitation in high-data-rate communication. OFDM avoids this problem by sending many low speed transmissions simultaneously. For example, Figure.3 shows two ways to transmit the same four pieces of binary data.

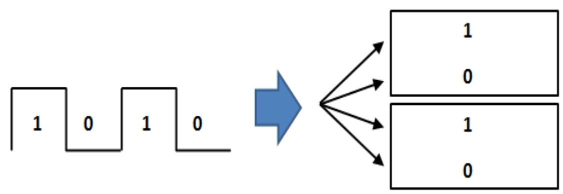

Figure .3 : Traditional Versus OFDM communication

Suppose that this transmission takes four seconds. Then, each piece of data in the left picture has duration of one second. On the other hand, OFDM would send the four pieces simultaneously as shown on the right. In this case, each piece of data has duration of four seconds. This longer duration leads to fewer problems with ISI. Another reason to consider OFDM is low-complexity implementation for high-speed systems compared to traditional single carrier techniques.

Figure.4 shows the flow chart used for OFDM simulation. At the Transmitter, firstly the audio sounds input data from serial stream to parallel set. Each set of data contains one symbol, Si, for each subcarrier. For example, a set of four data would be (S_0 S_1 S_2 S_3). Before performing the Inverse Fast Fourier Transform (IFFT), the data set is arranged on the horizontal axis in frequency domain as shown on Figure 5.

The symmetrical arrangement about the vertical axis is use by IFFT to manipulate the data. An inverse Fourier transform converts the frequency domain (FD) data set into samples of the corresponding time domain (TD) representation of the data. IFFT is special for useful in OFDM because it generates samples of a waveform with frequency components satisfying orthogonality conditions. Then, the parallel to serial block creates the OFDM signal by sequentially output the time domain samples.

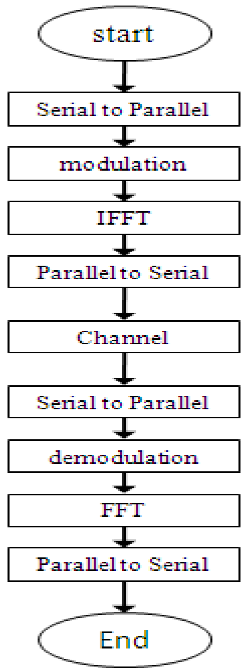

Figure 4: OFDM Flowchart

The channel simulation allows examination of common wireless channel characteristics such as noise, multipath, and clipping. By adding random data to the transmitted signal, simple noise is simulated. Multipath simulation involves adding attenuated and delayed copies of the transmitted signal to the original. This simulates the problem in wireless communication when the signal propagates on many paths. For example, a receiver may see a signal via a direct path as well as a path that bounces off a building. Finally, clipping simulates the problem of amplifier saturation. This addresses a practical implementation problem in OFDM where the peak to average power ratio is high.

The receiver performs the inverse of the transmitter. First, the OFDM data are split from a serial stream into parallel sets. The Fast Fourier Transform (FFT) converts the time domain samples back into a frequency domain representation. The magnitudes of the frequency components correspond to the original data. Finally, the parallel to serial block converts this parallel data into a serial stream to recover the original input data

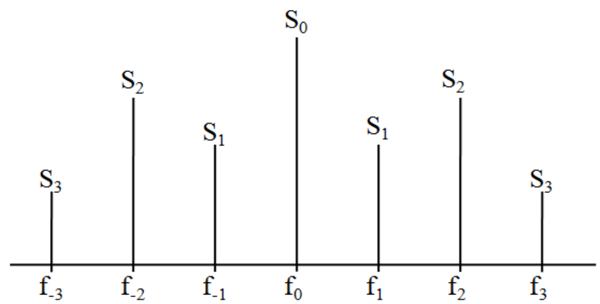

Figure 5: Frequency Domain Distribution of Symbols

The signals that being used as an input to the Transmitter for the simulation of OFDM and QAM are audio sound signals. The audio sound signals were taken from the produce of guitar plucking a chord sounds. The sounds is in *.wav format. There are 2 types of guitar plucking chord sounds signals being used for: *Short* and *Long* sounds signal from the guitar. This is meaning that there a 2 sounds signal types for OFDM and 16-QAM (QAM_Long.wav, QAM_short.wav,OFDM_Long.wav,and,OFDM_short.wav) being used for input to Transmitter of QAM and OFDM in simulation. By using 2 types of the sound signal will give the user to be more obvious and understands the simulations. The reasons for using the audio sounds signals format in *.wav is because the compatibility of MATLAB R2006a software features with the sound signal format.

III. RESULTS AND DISCUSSION

The MATLAB simulation accepts inputs of audio sound files for OFDM simulation. It then generates the corresponding OFDM transmission, simulates a channel, attempts to recover the input data, and performs an analysis to determine the transmission error rate. In order to compare OFDM to a traditional single carrier communication system, a 16-QAM simulation can be performed. These simulations are dynamic, allowing the user to set parameters determining the characteristics of the communication system. Two simple demonstrations of OFDM communication were developed with a graphical user interface (GUI) following the style of MATLAB toolbox demonstrations.A OFDM performance is show in the following figure.Firstly as show in the Figure.5 is a front page GUI windows used for a performance of OFDM.a audio signal will go through a multipath channel as shown in a Figure.6 and Figure.7,is a multipath strength with Small and Large value of multipath.

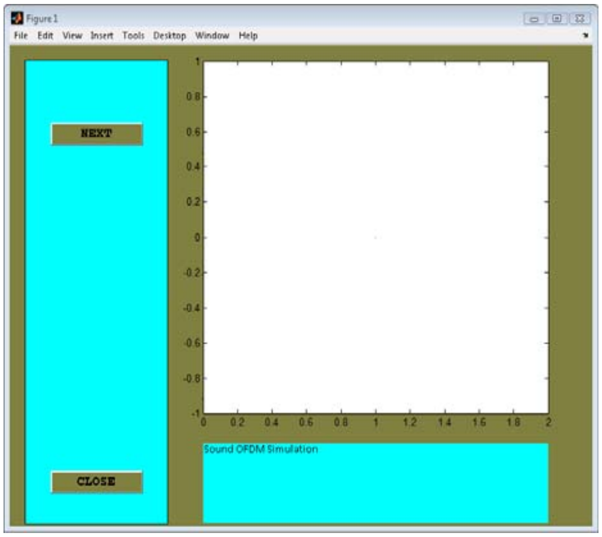

Figure.5: Front page GUI window

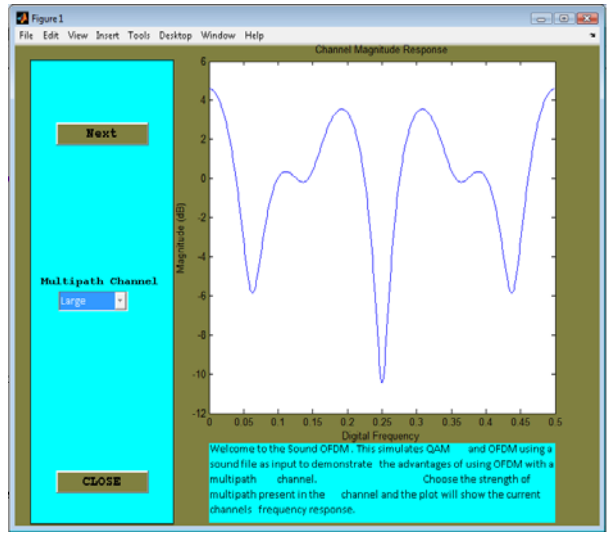

Figure.6: Multipath Channel with Large Strength

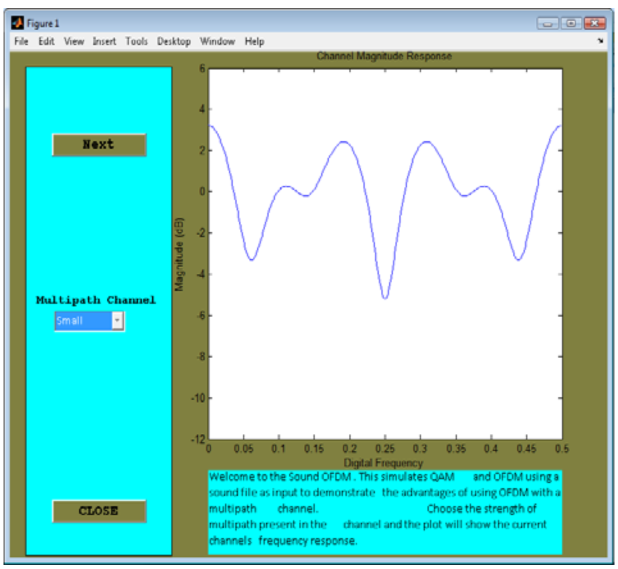

Figure.7: Multipath Channel with Small Strength

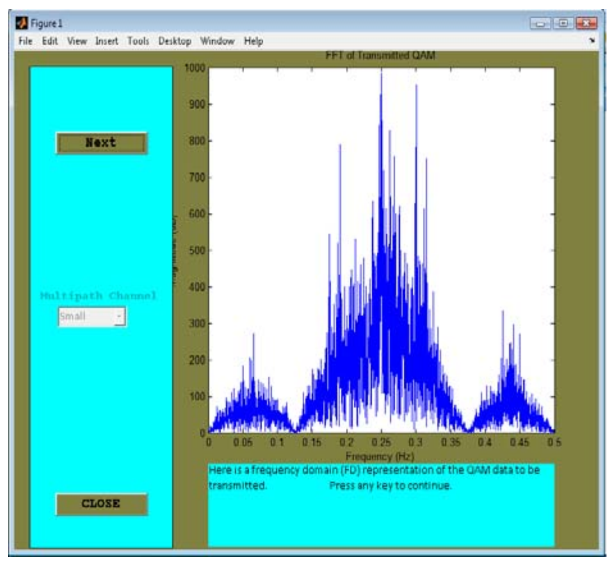

Figure.8: FFT of Transmitted QAM

Figure.8 show A frequency domain for QAM.Fast Fourier Transform is used to transform a signal from Time Domain into Frequency Domain.16-QAM is a single-carrier transmission. For 16-QAM transmission, the plot shows that the channel frequency response (in black color) and the received data (red color).The received data is slightly distorted due to the fading channel caused by multipath.

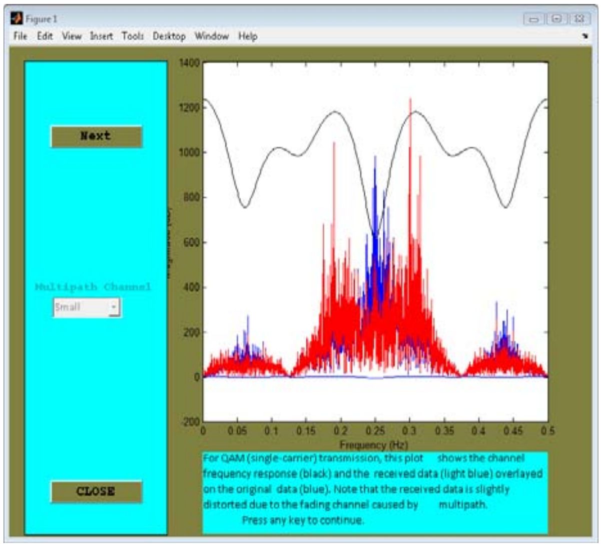

Figure.9: Single-Carrier QAM Transmission

Figure.11 shows the transformation from Time Domain to Frequency Domain by using Fast Fourier Transform (FFT).Figure.11 show that a Fast Fourier Transform (FFT) for OFDM. For OFDM (multi-carrier) transmission, plot shows that the channel (black color) and received data(red color) overlayed on the original data (blue color).Note that the OFDM received data also exhibits multipath distortion. The OFDM signal is spread out over more bandwidth than 16-QAM since OFDM uses many carrier frequency.

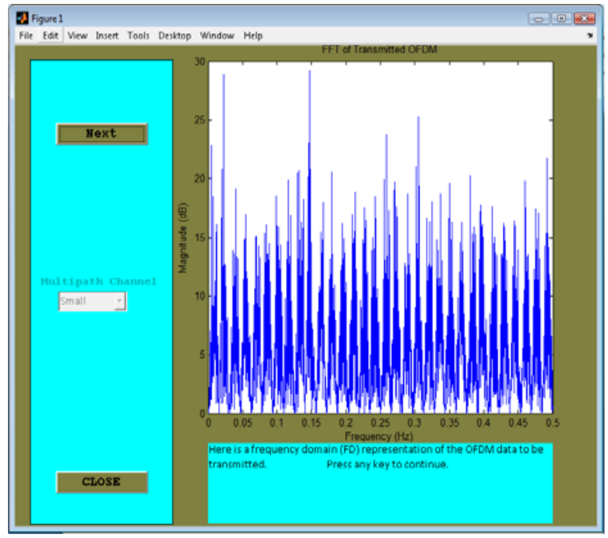

Figure.11: FFT of Transmitted OFDM

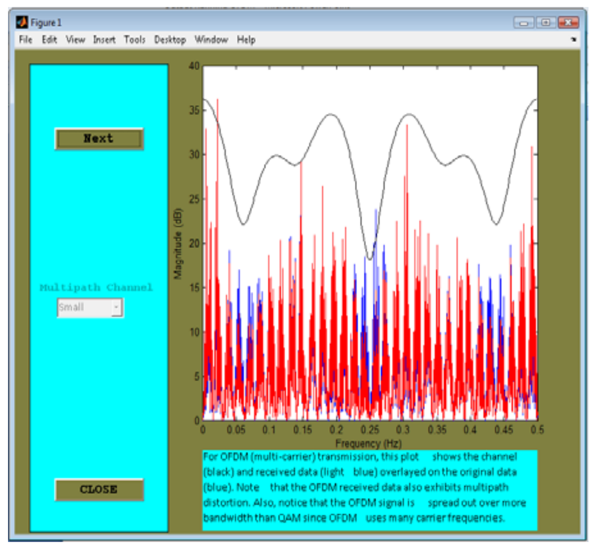

Figure.10: Multi-Carrier OFDM Transmission

Figure.12 shows that the audio sound file after going through with 16-QAM and OFDM modulation technique .We can see that the plotting of the sound ,Amplitude versus frequency show the comparison among original sound signal ,sound by using 16-QAM and OFDM analysis. Its shows that the plotting graph of sound that using OFDM technique is most similarly like original sound signal. So its proof that OFDM technique is better than 16-QAM.The performance of the sounds also can be proof by hearing the generated sound as show in figure.12.There has 2 type of *.wav sound: Short and Long sounds.When we click from the QAM button we can hear that the noise distortion of the *.wav sounds. Meaning that there has a noise when a audio sound signal using 16-QAM method. For OFDM method we can hear that the sound is exactly like original sounds.The time response also shows that OFDM methods is shorter than 16-QAM methods. The time response is show in Figure.13.

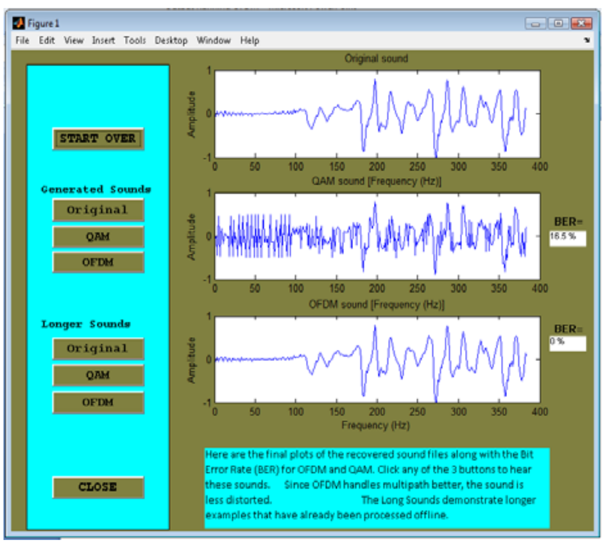

Figure.12: Comparison plot output of Original Sounds, QAM sounds and OFDM Sound

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------------------------------------------------------------
QAM simulation
Transmitting
Simulating Channel
Receiving
Time for QAM simulation=0.079987 seconds.

------------------------------------------------------------
OFDM Simulation
Transmitting
Simulating Channel
Receiving
Time for OFDM simulation=0.068622 seconds.
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Figure.13 Time response for OFDM and 16-QAM methods

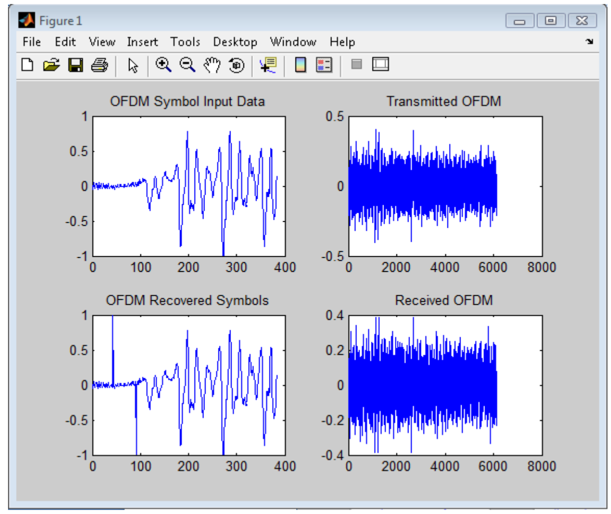

Figure.14: OFDM Input and Output

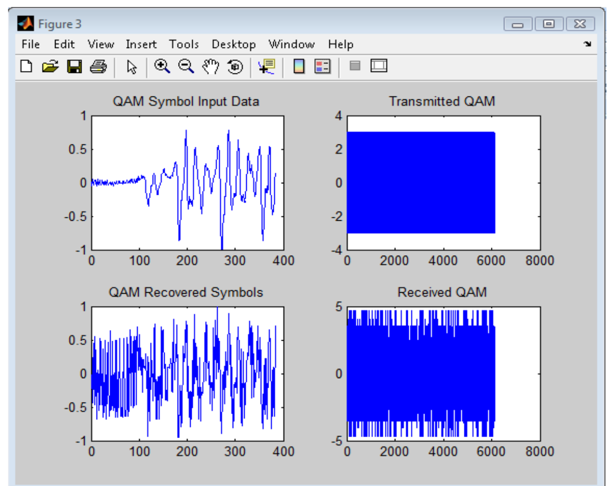

Figure.15: 16-QAM Input and Output

V. CONCLUSIONS

This paper presented the performance and analysis simulation of OFDM modulation methods for audio signals. The simulations were show and proof the advantages of OFDM modulation method compared to 16-QAM modulation methods. This MATLAB simulation proves that OFDM is better suited to a multipath channel than a single carrier transmission technique such as 16-QAM

From the GUI operation, it shows that the interface is very user-friendly. The GUI is accessible to users of all backgrounds and greatly streamlines the feature extraction and feature identification process. The user is required to enter a wav file of the input signal, the extraction is then performed and the output is displayed. The extraction is completed within seconds and the entire process is intuitive, as guided by GUI dialogue boxes.

The most challenging part of this research is in programming the analysis using M-File Editor in MATLAB. As a new user of MATLAB, a lot of tutorials and researches on MATLAB programming have been done in order to understand the M-File code before being able to do the programming for the analysis

VI. FUTURE DEVELOPMENT

As for a future development to make this current study to be more informative and powerful a researcher may also to include a Channel Phase Shift Detection and correction, Error Correction by Coding, Adaptive Transmission and Peak to Average Power Ratio consideration.

Finally, the future work also includes several improvements to the GUI. Some modifications like adding graphic objects such as a slider for zoom in function, check box or popup menu can be made in making the GUI looks more interesting and interactive.

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