Comparative Analysis of OFDM System For QPSK and 16-QAM Modulation Scheme

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Abstract- **Technology for broadcasting radio signals has progressed fast in the last few years because of the growing need for high-quality sound services and data transmission in mobile environments. Radio broadcasting technology has progressed swiftly. This paper compares an OFDM (Orthogonal Frequency Division Multiplexing) system for 16-QAM modulation (Quadrature Amplitude Modulation) and QPSK Modulation. This work shows that the OFDM with 16-QAM modulation for audio signal transmission is better than QPSK Modulation. For the theoretical approaches, AWGN (Adaptive White Gaussian Channel) is commonly implemented for modeling noise channels because it is easy to implement, and mathematical modeling is easy. The input data is taken randomly as well as an audio signal. The simulation is done in a MATLAB environment.**

Keywords: **AWGN Channel, 16-QAM Modulation, Sound signal, OFDM system.**

1. INTRODUCTION

A basic communication system modifies data using a single carrier frequency. Each symbol so consumes all of the available bandwidth. Inter-symbol interference (I.S.I.) may happen if a frequency-selective channel is utilized. The symbol period must be much greater than the delay time to prevent inter-symbol interference (I.S.I.) [1]. Long symbol periods result in poor data rates and inefficient transmission since the relationship between data rate and symbol period is inverse.

The bandwidth is divided into sub-bands using an FDM (Frequency Division Multiplexing) technology so that numerous carriers can transmit simultaneously [2]. A high total data rate can be achieved by placing carriers close to one another in the spectrum. Inter-carrier interference (I.C.I.) between the two carriers will result from a lack of space. Guard bands must be placed between nearby carriers to prevent inter-carrier interference, lowering the data rate. Both issues can be solved using a multi-carrier digital communication technology like OFDM (Orthogonal Frequency Division Multiplexing). The foundation of OFDM is partitioning the available spectrum orthogonally into several narrowband sub-channels, each of which experiences almost flat fading.

Orthogonality justifies the close spacing of the carriers, even if they overlap, by building a high-data-rate communication system from several low-data-rate carriers. Low data rates for each carrier significantly reduce inter-symbol interference [3]. OFDM was initially proposed in 1966 [4], but it has only lately started to take over as the "modem of choice in wireless applications." It is currently interesting to experiment with some of its characteristics through the underlying workings of OFDM. OFDM systems have gotten a lot of interest lately. Asymmetric digital subscriber lines in the European digital broadcast radio system are an example of a wired environment where it is used (ADSL). Twisted pair wires are used in digital subscriber lines (DSL) to provide a high data rate. Applications are currently present in the bulk of high data rate wideband communications. In audio and video broadcasting, the utilization of high data rate transmissions in a multipath environment is frequent (DAB and DVB). When using OFDM, one broadcast multiplex can be sent simultaneously by several transmitters using a single-frequency network (S.F.N.). Copper cable lines are used by ADSL to transmit data at a high rate. The problem here is that it's unclear what the line's characteristics are, and they could change depending on who uses it.

High-speed transmissions (10 Mb/s) in an interior context are possible with hyper LAN/2 wireless LAN networks (robust multipath environment). This research project aims to establish the viability and idea of an OFDM system while also examining how various factors affect its performance. Simulating a rudimentary OFDM system in MATLAB accomplishes this goal. The mechanism of an OFDM system can be examined via this evolution, and the properties of an OFDM system can be investigated through a complete MATLAB application.

2. HARDWARE ARCHITECTURE: SYSTEM DESCRIPTION

The transmission systems, channel model, and P.S.A. channel estimate for OFDM systems will be introduced in this part. The image codec properties employed in our simulation are also summarised.

2.1 OFDM System

A high-level diagram of an OFDM system is shown in the image below. Serial-to-parallel (S/P) converters organize input signals into blocks, and each block's data is mapped into a collection of complicated constellation points, such as X[0,k],....., X[N-1,k]. An OFDM block is a common name for the mapped data block. The total number of subchannels and the index of the OFDM blocks are shown in this figure 1.

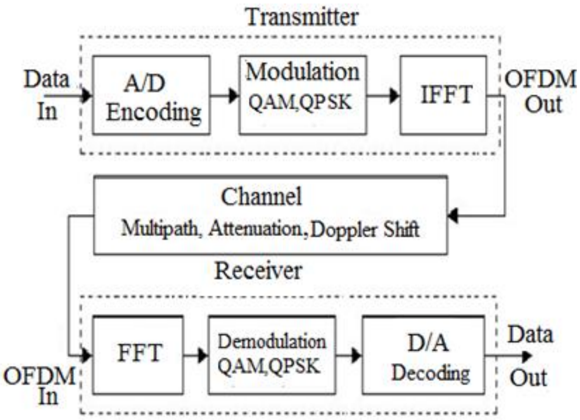

Figure 1: Graphical representation of OFDM System

The inverse fast Fourier transform modulates the signal after it has been mapped (IFFT). To avoid inter-symbol interference, a cyclic prefix is introduced (I.S.I.). A parallel-to-serial (P/S) converter transforms the modulated data block and cyclic prefix into an OFDM signal. Fast Fourier transform demodulation removes the cyclic prefix at the receiving end (FFT). The interference between successive OFDM signals is avoided when the cyclic prefix is greater than the length of the channel impulse response. Parallel independent sub-channels are used in this situation, and the received signal is represented as a series of parallel independent sub-channels.

$$Y[n, k]= H[n, k]X[n,k] + w[n,k], \qquad n= 0,1,.., N-1$$

Y[n,k] is the received signal, X[n,k] is the transmitted signal, and H[n,k] and w[n,k] are the channel frequency response and the added Gaussian noise, correspondingly. There are n sub-channels and k OFDM blocks in this example. A Gaussian random variable, w[n, k], simulates the channel noise samples. With zero mean and variance, σ^2 and it is presumed that it is independent of different n's or k's.

2.2 Main Issues with OFDM

1. Considering that an OFDM signal results from the superposition of several modulated sub-channel signals, an OFDM signal's peak-to-average power ratio (PAPR) may be significant compared to the average signal level. This is a situation where we need to minimize the peak-to-mean power ratio and enhance amplification.
2. Co-channel Interference: Adaptive antenna methods and OFDM broadcasts are used to mitigate co-channel interference in cellular communications systems.

2.3 Design Methodology

The encoded OFDM Signal is stored in MATLAB during the design technique. Encoding is given at the OFDM input. In the last stage, the output is decoded in OFDM.

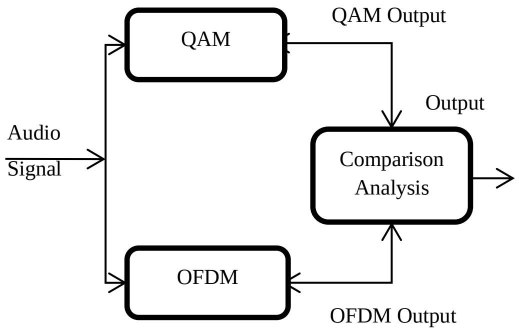

Figure 2: MATLAB Simulation Block Diagram

I) Subsystems Description: Encoding of the input to the system

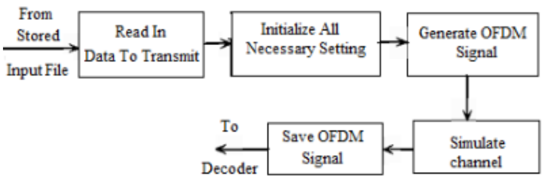

Figure 3: Encoded System

To begin transmission, the first block reads in data. The input is encoded and sent using the second block's initializations. The next stage is to create a typical channel over which the OFDM signals will travel. At this point, all that is left is to save the newly encoded OFDM signal to a file in the same directory as the original input .wav. Decoding of the input to the system:

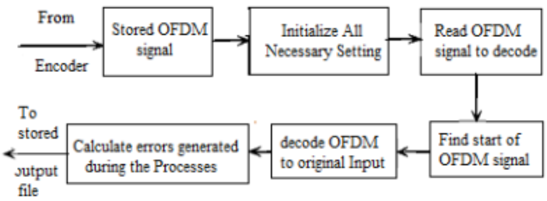

Figure 4: Decoded System

End of MATLAB simulation block in Decoding End of MATLAB simulation. The first step establishes the parameters required to return the signal to its original format. It then decodes the saved OFDM file from the input by reading the saved OFDM file. At this time, the beginning of the OFDM signal is discovered, and the decoding begins. An error detection tool is then used to measure all the simulation's discrepancies. This will give a sense of how well the code was written and the various outcomes of the system when it was created.

3. MATLAB IMPLEMENTATION

In this paper, There are four types of modulation and demodulation that we implement in MATLAB during the implementation process: 16-QAM with OFDM and QPSK Modulation.

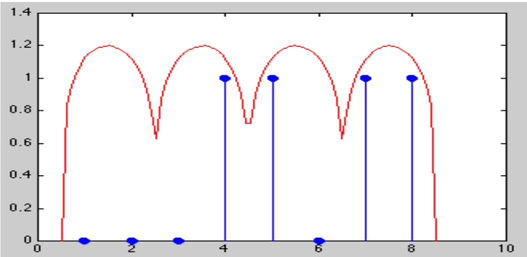

Figure 5. Input IFFT signal in OFDM

Binary data are encoded in OFDM using an IFFT (Inverse Fast Fourier Transform). Since these frequencies don't interact with each other due to IFFT's arithmetic, A single frequency will be allocated to each pair of blue data points that fall below the red hump, as shown in figure 5.

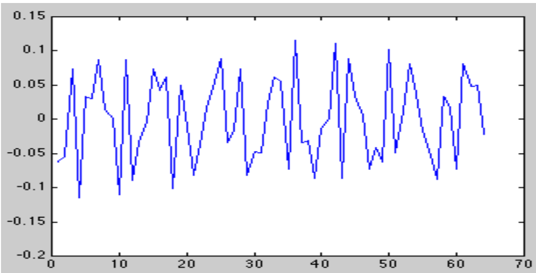

Figure 6. Transmitted signal of OFDM

It is now possible to broadcast and receive this OFDM signal over a medium. Wired or wireless communication may be used for this media or channel. This technique is reversed to get the original binary data lost during transmission.

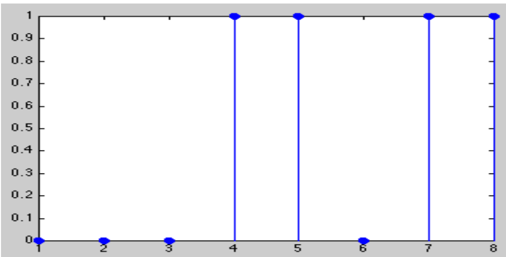

Figure.7. FFT signal

An FFT (Fast Fourier Transform), displayed in the figure, is used to extract the binary data. The FFT is the polar opposite of the IFFT, which is what was utilized to create the OFDM signal. In a multipath channel, OFDM is compared to 16-QAM. No, modest, or high amounts of multipath can be selected by the user. There is an explanation for each of the screenshots in the text box.

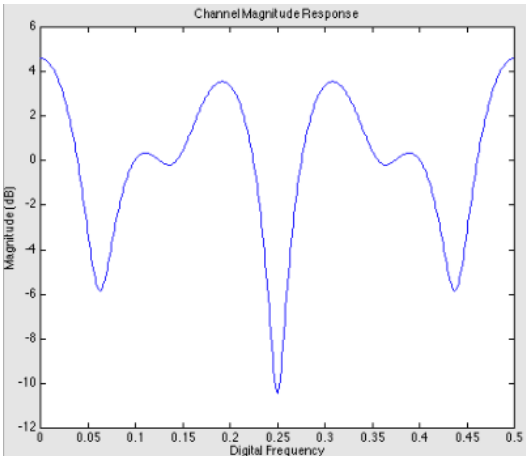

Figure 8. Sound OFDM Demo for QAM Simulation

Here is a sample of the OFDM demo's sound. This mimics QAM and OFDM with a sound file as input to demonstrate the advantages of OFDM in multipath channels. After selecting the strength of the multipath channel, the frequency response of the channel is displayed in the figure. In the region of 0.05 to 0.5, the digital frequency output plot is presented in blue, as shown in Figure 9.

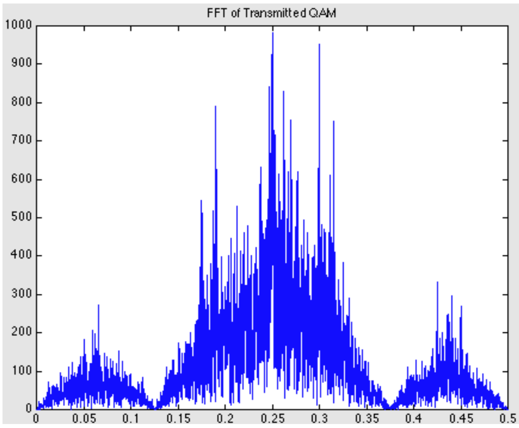

Figure 9. F.D. representation of QAM data transmission

The QAM data to be conveyed is expressed in the frequency domain (F.D.). After that, press the Enter key to resume the program.

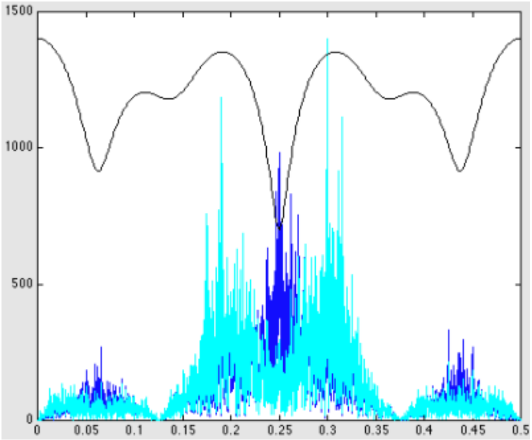

Figure 10. QAM signal carrier transmission

This figure 10 depicts the transmission of QAM signal carriers, with the channel frequency response shown by a black line, the received data shown in light blue, which is overlaid over the original data shown by blue. We see that the data we get is slightly distorted because of the fading channel generated by multipath. After that, we can press any key to continue the program.

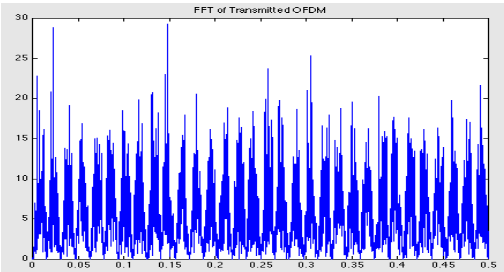

Figure 11. F.D. representation of OFDM data transmission

Figure 11 presents the transmitted OFDM data in a frequency domain (F.D.) to analyze the frequency harmonics transmitted in OFDM data. After that, press any key to continue the program.

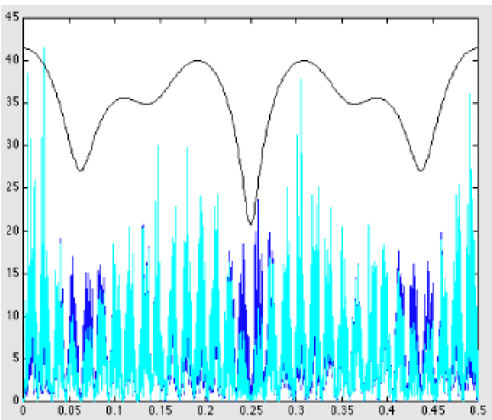

Figure 12. OFDM Multi-carrier transmission

Figure 12 depicts OFDM multi-carrier transmission; the channel frequency is shown in black, and the received data is shown in light blue overlaid on top of the original data, which is shown in blue. We see multipath distortion in the OFDM data we received. Due to OFDM's use of multiple carrier frequencies, the signal is dispersed over a wider bandwidth than QAM.

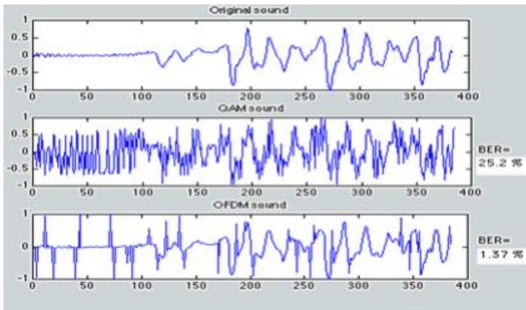

Figure 13. Final plots of recovered sound files for OFDM and QAM

Figure 13 shows the final plot of recovered sound files and the BER (Bit Error Rate) for QPSK modulation and 16-QAM modulation with the OFDM Transmission scheme. This graph shows the difference in BER between the two different sound formats: QPSK is 25.2%, while 16-QAM with OFDM is 1.37%. Listen to these noises by clicking any of the three buttons. Sound is less distorted because of OFDM's superior ability to manage multipath. This is an example of a lengthier sound.

Although the simulation code is used in the two G.U.I. examples, not all of its features are shown. Users may change the FFT size, number of carriers, input types, and channel characteristics by editing the setup m-file. Analysis of the communication system is also possible with this tool. Input and output OFDM, 16-QAM, and the constellation of the received 16-QAM signal are shown. Examples of these plots may be found in Figure. 14 and 15.

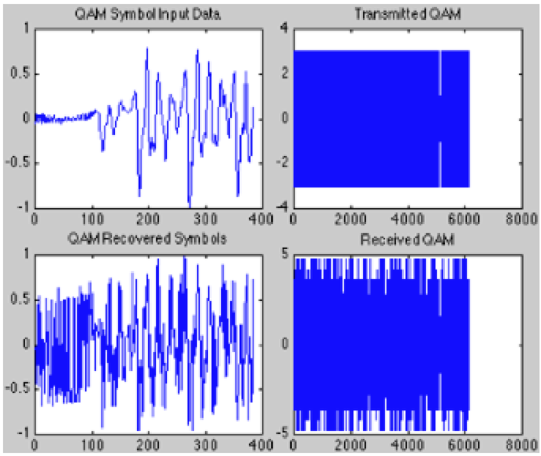

Figure 14. QAM Input and Output

The QAM signal received has some BER or bit error rate. The BER of an OFDM multi-carrier communication signal is lower for 16-QAM modulation than the OFDM modulation scheme.

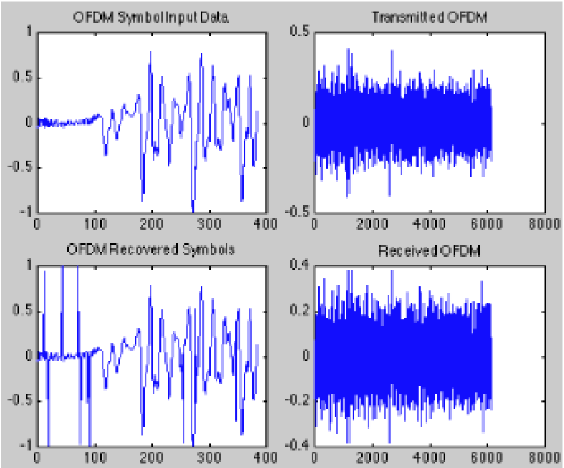

Figure 15. OFDM input and output

4. CONCLUSION

This paper presents the comparative analysis of OFDM signal transmission through the QPSK and 16-QAM modulation schemes. This comparison is made for random as well as an audio signal. According to the results, the OFDM approach for 16-QAM is more suitable for multipath channels than QPSK for random and audio (.wav) signals. After analyzing the multipath propagation, the BER for 16-QAM Modulation over OFDM is less than QPSK Modulation. We also noticed that the BER is also less for 16-QAM modulation as compare to QPSK modulation.

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