Analysis of OFDM Integration with 256-QAM and QPSK Modulation Schemes Using Simulink

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***Abstract*—This Matlab Simulation tries to investigate the effect of using Orthogonal Frequency Division Multiplexing together with the 256-QAM and M-PSK. OFDM being a multiple carrier technique, its effect will be investigated when coupled up with QAM which is a single carrier technique involving magnitude and phase variation and also PSK which is also a single carrier technique involving phase variation for encoding. The analysis on performance metrics such as spectral efficiency, Bit Error Rate and Signal to Noise ratio will be compared between the two modulation techniques. When OFDM is incorporated in the systems significant improvements on spectral efficiency and robustness to multipath fading are noted. These insights enable us identify suitable modulation schemes to fit in our communication systems.**

***Index Terms*—OFDM, 256-QAM, M-PSK, Simulink, Modulation, Bit Error Rate, Signal-to-Noise Ratio, Spectral Efficiency.**

I. Introduction

The advent of Orthogonal Frequency Division Multiplexing spans back to 1990 [1] . The European Telecommunications Standards Institute (ETSI) were looking for a solution for Digital Broadcasting and so they developed OFDM [2]. Fortunately, the creation of OFDM aided a lot of communication techniques such as Wireless LAN (IEEE 802.11), Digital Video Broadcast (DVB) ,Asynchronous Digital Subscriber Line (ADSL) [3], Wireless LAN (IEEE 802.11) [4], WiMAX (IEEE 802.16) [5] and others. With time, the incorporation of OFDM to our communication channels have increased and this can be seen with their application in communications networks such as 4G, 5G and a preferred candidate to 6G. The basic principle of OFDM involves division of the available bandwidth into several narrow subcarriers,each with different frequency and orthogonal to each other. Transmitting information this way enables mitigation of channel problems such as multipath fading since their is spectral overlap of subcarriers [6]. OFDM supports various modulation schemes including Phase Shift Keying(PSK) and Quadrature Amplitude Modulation(QAM) [7]. PSK can be further subdivided into BPSK and QPSK whereas QAM can be subdivided into 4-QAM,16-QAM,64QAM and 128-QAM.

QAM modulation schemes or techniques involve using a single carrier and varying it amplitude and phase to encode data. The higher the QAM level the higher the data rate but also the higher the noise sensitivity and the lower the power efficiency. PSK on the other hand uses a single carrier and varies only the phase to encode data. The higher the PSK level the higher the data rate but the higher the noise sensitivity and the lower the power efficiency.

II. Objective

This paper details the analysis of OFDM block using 256 QAM and QPSK. Its used to study Bit loss, Packet loss and total bits counted and effect on the bit rate by using phase noise plus AWGN channel.

III. Motivation

OFDM has proven its benefits in its application in the 4G and 5G networks and is sure to be a worthy candidate in the new era of 6G network. OFDM makes use of parallel narrow-band subcarriers, which has made it popular compared to others that use single-band wide carriers to transmit infor-Mation. Its benefits to the communication sector include high spectral efficiency and robustness to multipath fading. With the evolution of 6G comes higher frequency requirements and new technologies, which OFDM's scalability, cost-effectiveness and maturity provides a strong foundation for the launch of 6G.

IV. Statement of the Problems

There are two statement of problem in OFDM using 256 QAM and QPSK. The initial problem is Orthogonality. Carrier orthogonality is a problem which can lead to wrong operation of OFDM systems. The idea to use several carriers solves the problem especially if they are orthogonal to each other. The other problem happens in the receiver where there is poor synchronization to process the incoming signals correctly.

V. Proposed Work

This Simulink model explores the performance metrics of 256 QAM and QPSK when OFDM is incorporated in both of them. Some of the constraints that will be implemented in our communication channel include phase noise and AWGN. Our performance metrics will be analyzed in terms of: packet loss, total bits transmitted, bit loss, bit rate, and signal delays. These model will demontrate the trade-offs between the two encoding schemes. 256-QAM offers higher data rates compared to QPSK but is more susceptible to noise due to increased constellation. QPSK on the other hand is simple to implement offering great robustness but at a cost of reduced data rate. This study explores how each different modulation schemes handles different channel conditions such as phase noise and AWGN and focuses on their influence on ICI, ISI and maintenance of orthogonality. Understanding this enables one to choose a suitable modulation scheme based on the available communication channel.

VI. Simulation

A. Case one: Simulink model of OFDM using 256-QAM with AWGN plus Phase noise

This is a simulink model of OFDM with 256 QAM when the communication channel is subjected to Additive White Gaussian Noise (AWGN) plus phase noise. The simulink model provides us results which are generated between transmitter and receiver. From these results we get to analyse the bit rate error,bit loss and effect of OFDM implementation in 256-QAM.

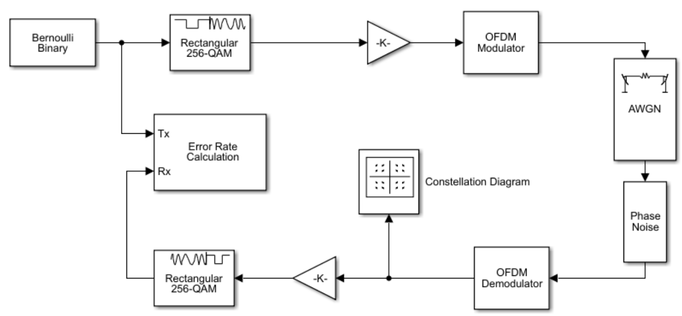

Fig. 1.

B. Case one: Simulink model of OFDM using Q-PSK with AWGN plus Phase noise

This is a simulink model of OFDM with Q-PSK when the communication channel is subjected to Additive White Gaussian Noise (AWGN) plus phase noise. The simulink model provides us results which are generated between transmitter and receiver. From these results we get to analyse the bit rate error,bit loss and effect of OFDM implementation in Q-PSK.

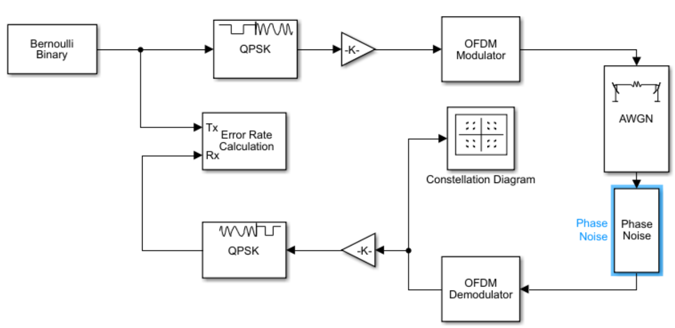

Fig. 2.

VII. Results from Simulations

A. Case one: OFDM model using 256-QAM with AWGN plus Phase noise

The constellation points as seen form our constellation diagram are unevenly dispersed suggesting the presence pf

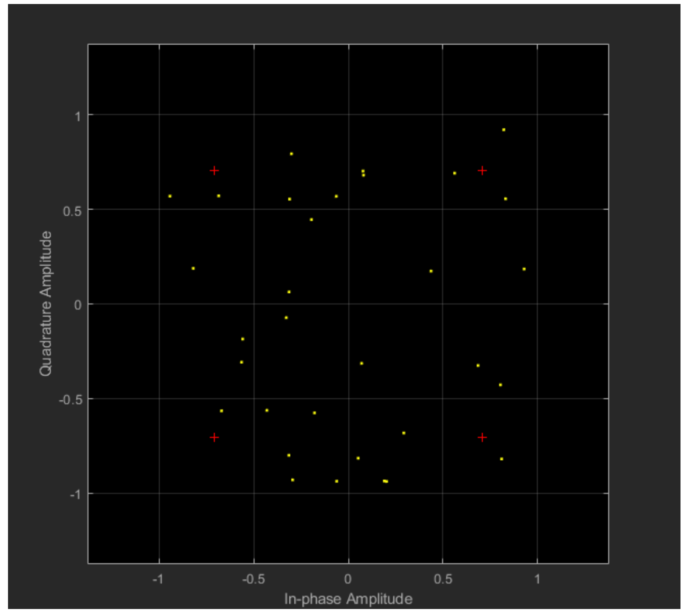

Fig. 3. Constellation Diagram for 256 QAM

AWGN and phase noise channel impairment. In Ideal conditions the 256-QAM constellation points are uniformly distributed in the grid.

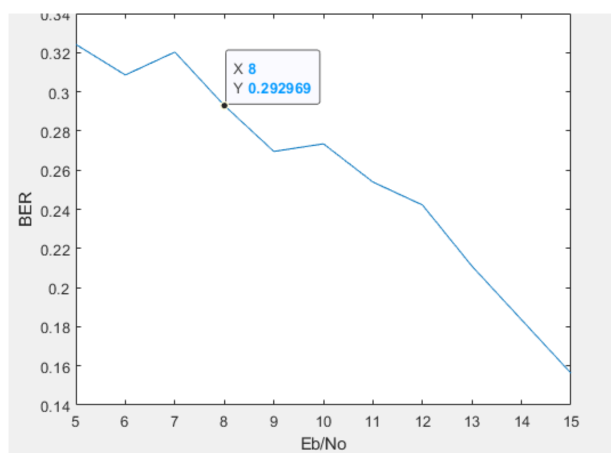

Fig. 4. Graph of BER Vs Eb/No Analysis

As seen in the graph, BER decreases with increasing Eb/No;which is in consonance with the expected performance of digital modulation schemes in AWGN channels [8].

B. Case one: Simulink model of OFDM using 256-QAM with AWGN plus Phase noise

From the above constellation diagram, four distinct points are observable as compared to that of 256-QAM. Similar to the 256-QAM there is deviation of the costellation points form their ideal positions. This is contributed by the presence of phase noise and AWGN.

As seen in figure 6, BER decreases with increasing Eb/No;which is in consonance with the expected performance

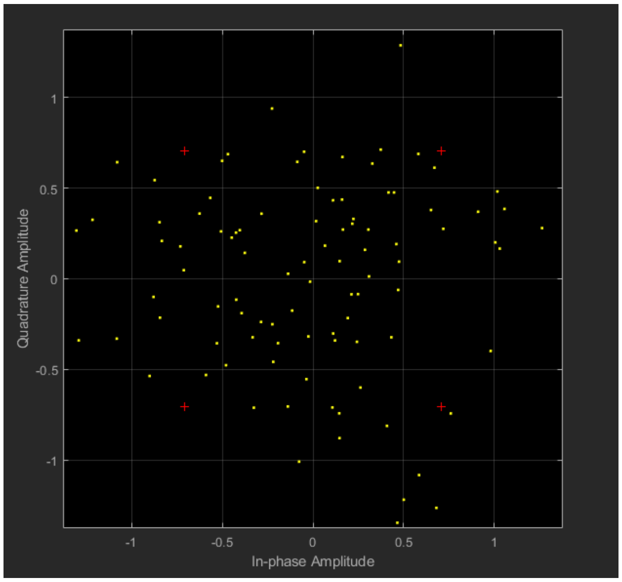

Fig. 5. Constellation Diagram for QPSK

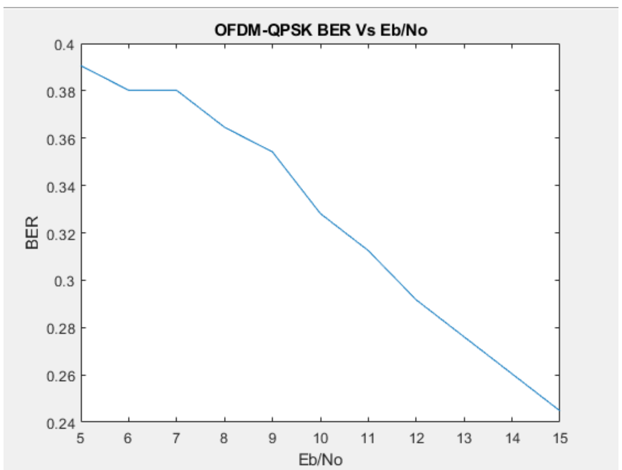

Fig. 6. Graph of BER Vs Eb/No Analysis

of digital modulation schemes in AWGN channels

VIII. Discussion

A. Case one: Simulink model of OFDM using 256-QAM with AWGN plus Phase noise

From the constellation diagram, the deviation of the constellation points from their set positions is caused by phase noise and AWGN influence. The deviation from the ideal points is less pronounced compared to the 256-QAM constellation observed in previous experiments, implying that QPSK is more robust to noise, a well-known characteristic of lower-order modulation schemes.

Analysis of the BER vs Eb/No graph shows that at low Eb/No values i.e 5-6 dB, the BER is high approximately 0.35. This signifies the noise impact on the received signal. Increasing Eb/No i.e 14-15 dB improves BER substancially dropping to around 0.25. Therefore increasing the signal to noise power reduces BER.

Our OFDM in use contains the following paraenter (FFT size = 256 , cyclic prefix length = 16 , guard band = [16;16]). In a basic wireless communication channel implementation of cyclic prefix length is of importance because it aids in the mitigation of multipath fading and ISI [9].Our chosen prefix length of 16 samples is greater than the expected channel delay spread providing an effective ISI suppression. 16 subcarriers acting as the upper and lower edges of the OFDM spectrum reduces the inter-channel interference from the adjacent frequency bands[10].

The influence of BER affects the constellation points directly. When the Eb/No values are low, dispersion between the constellation points are high and the receiver struggles to make accurate sense of what has been transmitted. High Eb/No values ensures even clustering of these constellation points enabling the receiver to reliably decipher the different symbols.

OFDM reduces the effect of frequency-selective fading [11] by dividing the 256 QAM into multiple low rate subcarriers .On the other hand OFDM has some downsides such as introducing High Peak-to-Average-Power-Ratio (PAPR) impacting power amplification efficiency [12].

B. Case one: Simulink model of OFDM using Q-PSK with AWGN plus Phase noise

From the constellation diagram, the deviation of the constellation points from their set positions is caused by phase noise and AWGN influence. In QPSK the clustering of the received symbols is uniform across the four constellation points suggesting that noise affects all symbols equally.

Analysis of the BER vs Eb/No graph shows that at low Eb/No values i.e 5-6 dB, the BER is high approximately 0.35. This signifies the noise impact on the received signal. Increasing Eb/No i.e 14-15 dB improves BER substancially dropping to around 0.25. Therefore increasing the signal to noise power reduces BER.

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IX. Conclusion

In terms of Data rate the 256-QAM , with its 256 constellation points eight bit per symbol transmission whereas QPSK with 4 constellation points enables two bit transmission. Therefore for high data rate transmission 256-QAM is more prefered to QPSK.

From the constellation diagrams QPSK is more robust to noise compared to 256-QAM. The QPSK constellation points are more clusterd compared to that of 256-QAM. From the BER curves, we get to spot that QPSK acheives a lower BER with increase of Eb/No faster compared to 256-QAM. These deductions show that QPSK is more robust to noise compared to 256-QAM.

X. Future Scope

From this study, problems in communication channels corrected by OFDM have been evaluated and solutions provided. Since research is a never ending process a new beginning is inevitable. Therefore, following are the works that may be considered as a future scope in this direction:

i. An algorithm of timing offset estimation can be further researched for channel estimation within OFDM system.

ii. The proposed joint frequency and timing offset estimator can be utilized for MIMO OFDM system.

iii. The proposed method of PAPR reduction can be researched for its performance within MIMO OFDM system.

v. The closed form expression of Bit Error Rate including the proposed PAPR reduction method, could be analytically derived.

vi. The windowing technique of ICI reduction can be combined and analyzed with ICI self cancellation scheme

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