Analysis of OFDM with 256-QAM and QPSK Modulation Schemes MATLAB

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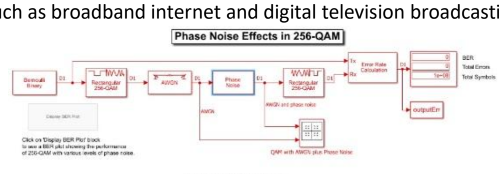
Abstract—This Simulation tries to investigate the effect of using Orthogonal Frequency Division Multiplexing together with the 256-QAM and M-PSK. OFDM being a multiple carrier technique, its effect will be investigated when coupled up with QAM which is a single carrier technique involving magnitude and 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

Quadrature Amplitude Modulation (QAM) is a key digital modulation technique widely adopted in modern communication systems for its ability to efficiently transmit large volumes of data within limited bandwidth. Among its variants, 256-QAM stands out due to its high data transmission capacity, which makes it ideal for applications requiring significant data throughput, such as broadband internet and digital television broadcasting.



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.

• The Bernoulli Binary Generator block generates a random signal consisting of a sequence of 8-bit binary values in the range [0, 255].
• The Rectangular QAM Modulator Baseband block modulates the signal using baseband 256-ary QAM.
• The AWGN Channel block models a noisy channel by adding white Gaussian noise to the modulated signal.
• The Phase Noise block introduces noise in the angle of its complex input signal.
• The Rectangular QAM Demodulator Baseband block demodulates the signal.
These additional model blocks can help you interpret the simulation.
• The Constellation Diagram block a displays constellation diagram of the signal with AWGN and phase noise added

The Error Rate Calculation block counts bits that differ between the received signal and transmitted signal.
• The To Workspace block, labeled output Error, outputs the results to the workspace for use when plotting the results.
• A Callback Button labeled Display BER Plot opens a plot showing the Eb/N0 performance curves for 256-QAM transmission and reception at various levels of phase noise

II. OBJECTIVE

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

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 information. 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 statements 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

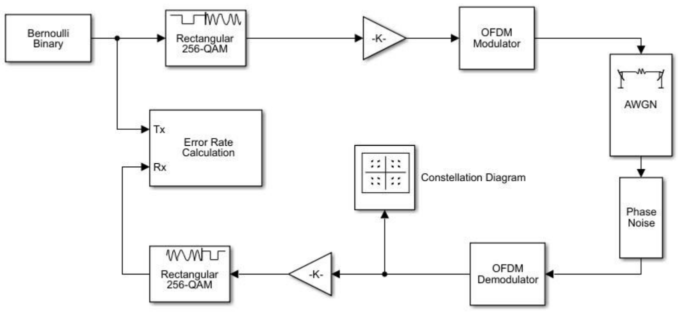
This Simulink model investigates the performance of 256-QAM and QPSK when integrated with OFDM under varying channel conditions, including phase noise and AWGN. Performance metrics such as packet loss, total bits transmitted, bit loss, bit rate, and signal delays are analyzed to evaluate the trade-offs between these modulation schemes. While 256-QAM supports higher data rates, it is more vulnerable to noise due to its dense constellation structure. Conversely, QPSK is simpler to implement and offers greater noise resilience but at the cost of reduced data throughput. This study examines how each modulation scheme responds to channel impairments, such as inter-carrier interference (ICI) and inter-symbol interference (ISI), and how they maintain orthogonality. These insights are crucial for optimizing communication system design under different transmission environments.

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 model provides us results which are generated between transmitter and receiver. From these results we get to analyze the bit rate error,bit loss and effect of OFDM implementation in 256-QAM.



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1.

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

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.

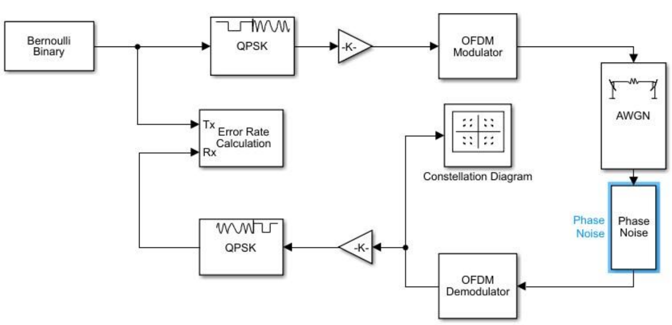


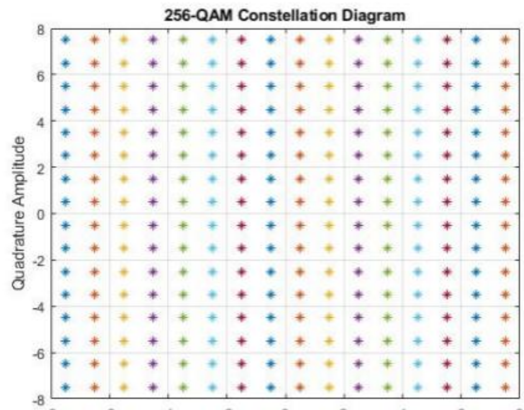
Fig. 2.

VII. RESULTS FROM SIMULATIONS

A. Case one: OFDM model using 256-QAM with AWGN plusPhase 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.

B. *Case one: Simulink model of OFDM using 256-QAM with AWGN*

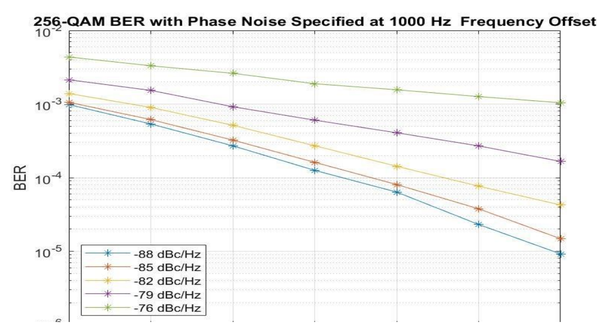


Fig. 4. Graph of BER Vs Eb/No Analysis

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].

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 of digital modulation schemes in AWGN channels

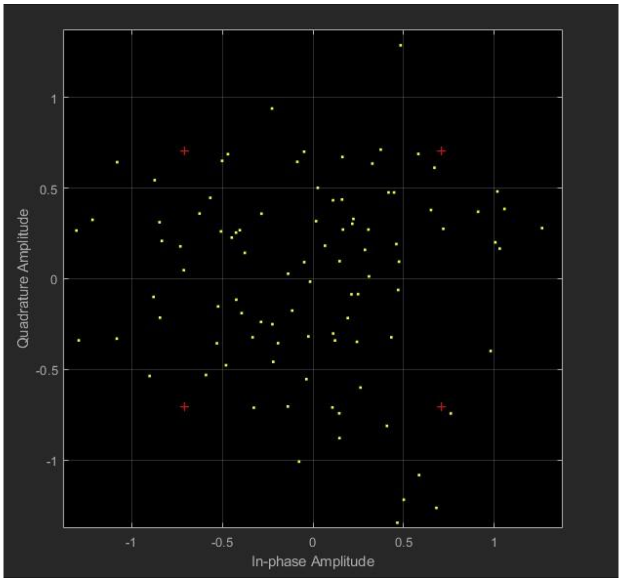


Fig. 5. Constellation Diagram for QPSK

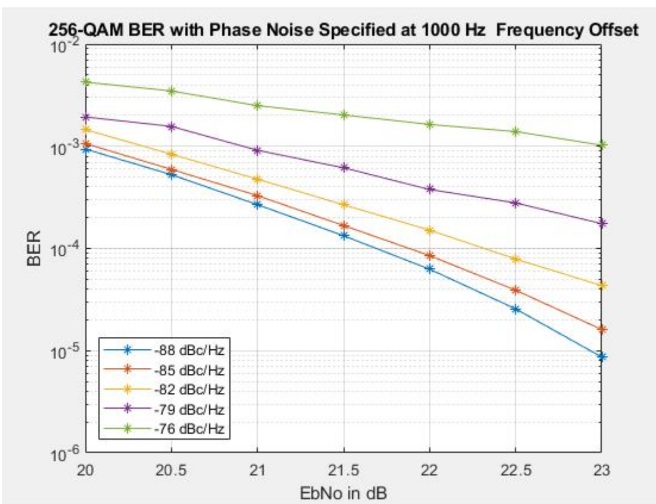


Fig. 6. Graph of BER Vs Eb/No Analysis

VIII. DISCUSSION

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

In the analysis of the OFDM model with 256-QAM under AWGN and phase noise, it was observed that phase noise and AWGN contribute to the deviation of constellation points from their ideal positions. Despite this, the use of OFDM helped reduce the impact of frequency-selective fading by splitting the 256-QAM signal into multiple low-rate subcarriers. However, challenges such as High Peak-to-Average-Power Ratio (PAPR) affecting power efficiency were noted. The BER performance showed high error rates at lower Eb/No values, with a significant drop in BER as Eb/No increased.

When using QPSK under the same conditions, the constellation diagram indicated more evenly clustered points, demonstrating that noise affected all symbols uniformly. QPSK achieved lower BER at faster rates compared to 256-QAM as Eb/No values increased, highlighting its robustness to noise.

Both scenarios demonstrated the importance of cyclic prefix length and guard bands in mitigating inter-symbol and inter-channel interference.

IX. Conclusion

256-QAM offers higher data rates with its ability to transmit eight bits per symbol, compared to QPSK's two bits per symbol, making it ideal for applications requiring high throughput. However, QPSK demonstrated greater resilience to noise, with tighter clustering of constellation points and faster BER improvement as Eb/No increased. The findings emphasize the trade-off between data rate efficiency and noise robustness in selecting modulation schemes for communication systems

X. FUTURE SCOPE

This study has evaluated the issues present in communication channels and demonstrated the effectiveness of OFDM in mitigating these challenges. As research is a continuous process, new opportunities for advancement always emerge. Potential directions for future work include:

1. Further exploration of timing offset estimation algorithms to enhance channel estimation within OFDM systems.
2. Application of the proposed joint frequency and timing offset estimator in MIMO-OFDM systems.
3. Investigation of the proposed PAPR reduction method for its performance within MIMO-OFDM systems.
4. Analytical derivation of a closed-form expression for Bit Error Rate (BER) incorporating the proposed PAPR reduction technique.
5. Integration and evaluation of the windowing technique for ICI reduction in combination with ICI self-cancellation schemes.

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