Analysis of 256-QAM Performance

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***Abstract*—In this report, a 256-QAM communication system was analyzed and modeled using MATLAB and Simulink. The system was then studied for its performance in the presence of different noise scenarios such as AWGN and phase noise. The simulation employed pivotal elements including QAM modulator and demodulator blocks, noise channels (AWGN & phase noise), and error rate calculation. Results were analyzed with bit error rate (BER) calculations and constellation diagrams. Moreover, the research analyzed the effect of using the OFDM block and swapping the 256-QAM modulation scheme with different ones such as M-PSK. It was found that using higher signal-to-noise ratios produces lower BER, and that phase noise causes considerable distortion. OFDM increased tolerance to noise, while M-PSK provided greater robustness to phase noise (though at the expense of spectral efficiency). These insights point out the compromises made in the design of stable communication systems.**

***Index Terms*—**

I. Introduction

QUADRATURE Amplitude Modulation (QAM) is a widely used technique, valued for its ability to transmit high data rates over limited bandwidth. QAM maintains the frequency of the carrier, while changing the amplitudes of the in-phase and quadrature components . This experiment focuses on analyzing the performance of a 256-QAM system under the influence of Additive White Gaussian Noise (AWGN) and phase noise using MATLAB and Simulink for simulation.

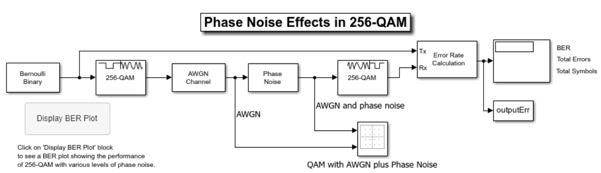

Fig. 1. Phase noise effect in 256-QAM

- 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 `outputErr`, 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.

QAM is a single-carrier modulation technique that acts effectively as dual carrier modulation. To be specific, the single carrier undergoes a Hilbert transformation creating a 90○ separation between the initial carrier and the created carrier, which is coincidentally orthogonal1 to the original carrier when demodulation is concerned.

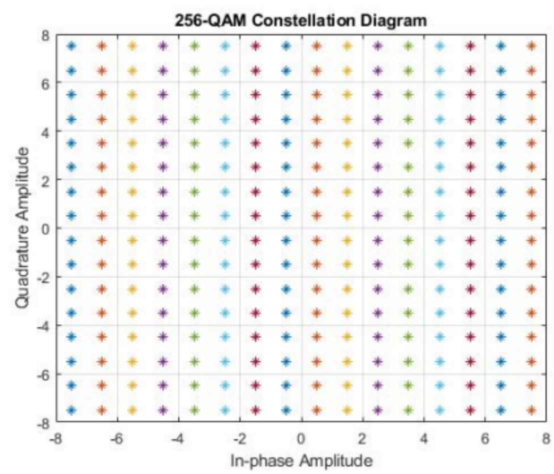

Fig. 2. 256-QAM constellation diagr

TITLE AND HEADINGS. The main title should be in Times (or Times Roman) 14-point boldface centered over both columns. In the main title, please initially capitalize nouns, pronouns, verbs, adjectives, and adverbs; do not capitalize articles, coordinate conjunctions, and prepositions (unless the title begins with such a word). Initially capitalize only the first word in first-, second-, and third-order headings. Leave two blank lines before author names(s)/affiliation(s).

II. Materials and Methods

MATLAB and Simulink softwares were used

Open MATLAB and launch Simulink to create a blank model workspace.

Insert Key Blocks from the Communication Toolbox such as bernulli binary generator, 256 QAM madulator and demodulator, AWGN channel, phase noise, display block etc.

Arrange the blocks and establish connections based on the provided block diagram.Ensure the signal flows sequentially through the generator, modulator, AWGN channel, phase noise, demodulator, and error rate calculator.

Link scopes to monitor constellation diagrams, eye diagrams, and BER plots. Configure Simulation Parameters

Execute the simulation by clicking ”Run.”Record and observe the contellation diagrams, eye diagrams and display output.

Generate and Analyze the BER Plot. Use the BER Plot block to graph the bit error rate for different Eb/No values.

Replace the 256-QAM Modulator and Demodulator blocks with OFDM Modulator and Demodulator blocks.

Connect the OFDM blocks within the existing signal path.Rerun the simulation and observe changes.Save new constellation and eye diagrams.Compare the BER performance of OFDM versus 256-QAM.

Replace the 256-QAM Modulator and Demodulator with M-PSK Modulator and Demodulator blocks.Select a modulation order, such as 16-PSK, for testing.Simulate and compare results with the previous configurations.Observe changes in BER, eye diagrams, and constellation clarity

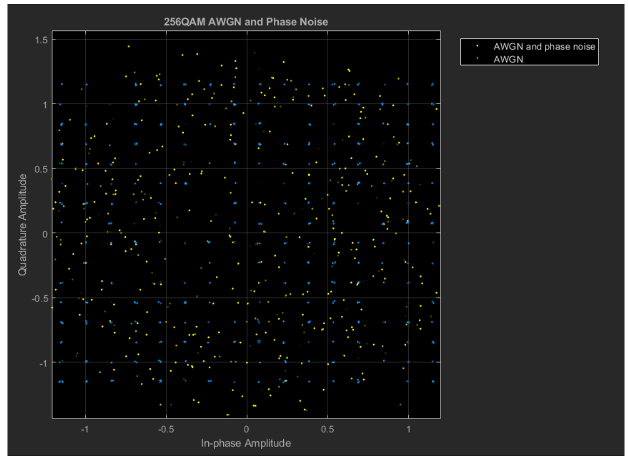

Fig. 4. Constellation diagram of 256-QAM for Eb/No=100 dB and PNLD=-30 dBc/Hz

III. Results

The constellation diagram displayed by the first scatter plot in Fig. 3 is a constellation diagram of 256-QAM for Eb/No=100 dB and without the presence of phase noise.

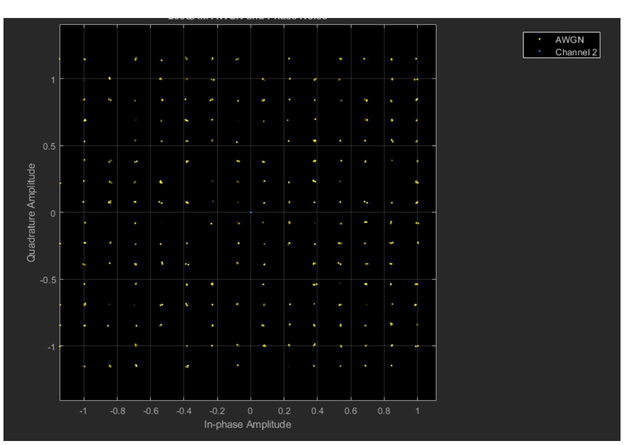

Fig. 3. 256-QAM constellation diagram without phase noise

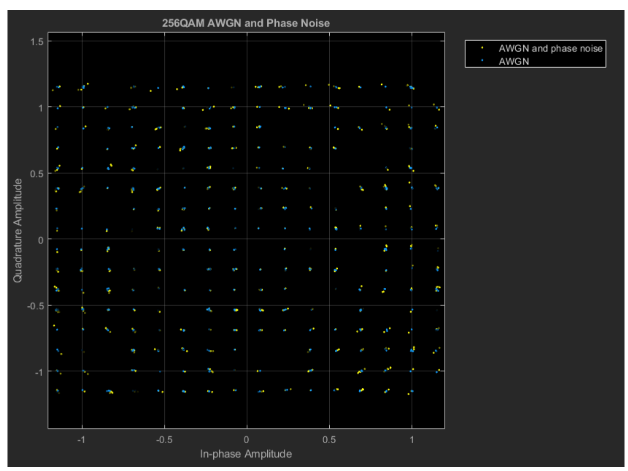

Fig. 5. Constellation diagram of 256-QAM for Eb/No=100 dB and PNLD=-80 dBc/Hz

The Scatter Plot Scope placed after the Phase Noise block gives different result for each Phase Noise Level Density(PNLD). Resulting constellation diagrams for PNLD=-30 dBc/Hz and PNLD=-80 dBc/Hz are displayed in Fig.4 and Fig.5, respectively.

To study the effect of phase noise on BER performance of 256-QAM modulation technique, the phase noise level density is varied . Simulation of BER curve for each of values [-88 -85 -82 -79 -76] dBc/Hz of a PNLD is performed and the result is shown in Fig.6.

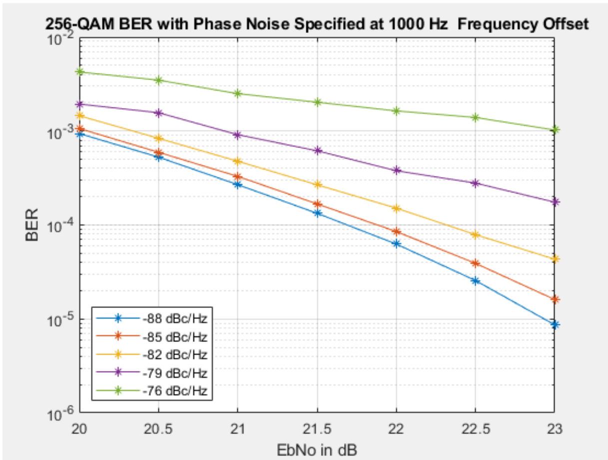

Fig. 6. BER vs. Eb/No for 256-QAM at different phase noise level densities

After adding OFDM blocks ;OFDM modulator and demodulator into the system as shown in the block diagram in Fig.7,we see a contellation diagram with scattered points in Fig 8

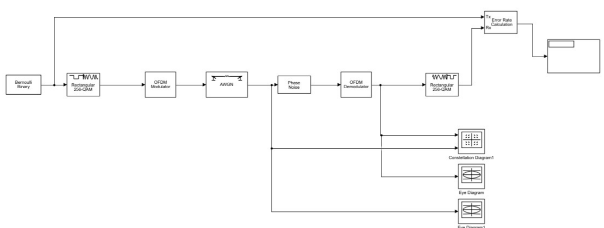

Fig. 7. OFDM block diagram

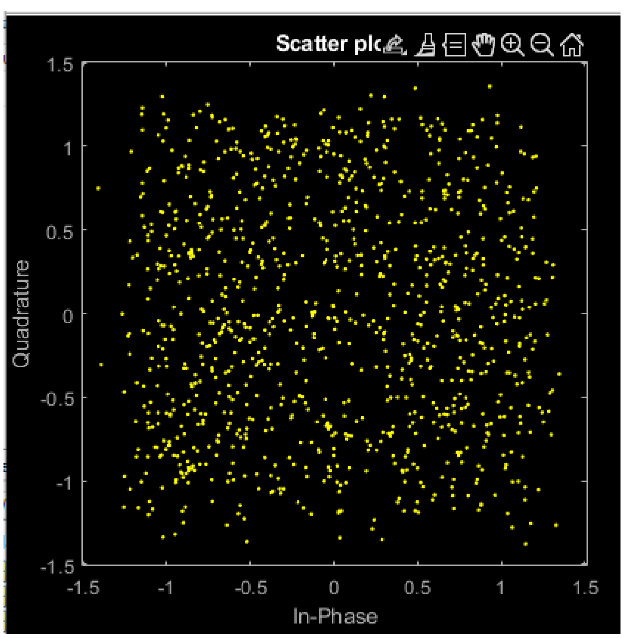

Fig. 8. OFDM scatter plot

To examine how 256-QAM would behave with different modulation schemes, the 256-QAM block was replaced with M-PSK block; M-PSK modulator and demudulator as shown in the block diagram in Fig.9.

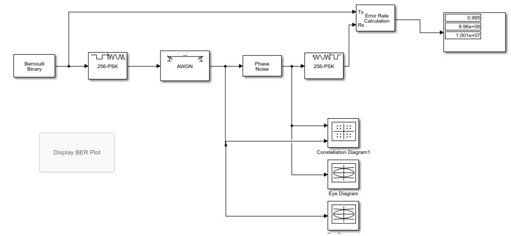

Fig. 9. M-PSK block diagram

The constellation diagram of the M-PSK modeling scheme was ring-shaped with the contellation clusters forming ring as depicted in Fig.10

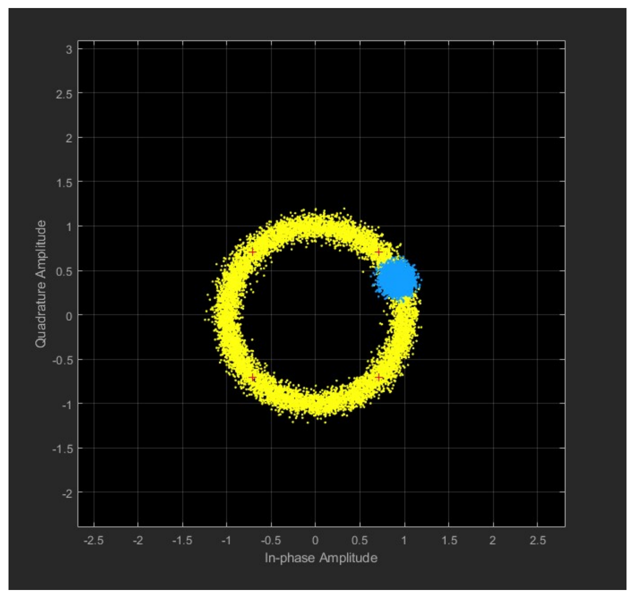

Fig. 10. M-PSK contellation diagram

IV. Discussion and Summary

The constellation diagram of 256-QAM under AWGN and without the presence of phase noise as shown in Fig.3, shows well defined clusters corresponding to the modulation states. In the absence of phase noise the clusters remain centered at their ideal positions, with minimal spreading. The clean seperation of states highlights the high SNR condition, making the system highly reliable for transmission. It reflects the optimal performance of 256-QAM in an AWGN dominateed channel,emphasizing its capability for high data rate transmission.

Fig.4 and Fig.5 represent the Scatter Plot placed after the Phase Noise block. It is evident that with the introduction of phase noise,there is a significant angular displacement of the clusters when compared to the previous state that had no phase noise. Resulting constellation diagrams for PNLD=-30 dBc/Hz and PNLD=-80 dBc/Hz differ in that the reduction of the phase noise level from -30 dBc/Hz to -80 dBc/Hz results in a signifacnt reduction in angular diplacement of the clusters.

In Fig,6 we have a plot that represents a BER vs EbNo for a 256-QAM at different phase noise level densities. It is evident from the plot the BER(Bit Error Rate) value reduces as the phase noise level reduces. This is because phase noise introduces random phase deviations in the trasmitted signal causing constellation points to spread leading to errors but as the phase noise levels reduce the contellation points become more stable and remain closer to their ideal points hence minimizing error.

In the OFDM block diagram in Fig.7, OFDM divides the transmitted data into multiple orthogonal subcarriers. Each subcarrier carries a 256-QAM symbol. The combination of OFDM and phase noise creates a **cumulative distortion**. Phase noise affects each subcarrier differently, introducing random rotations or jitter to the constellation points. As seen in the scatter plot on Fig.8, this results in the points being less tightly clustered compared to a standalone 256-QAM system. The constellation diagram it produces reflects the **aggregate effect** of all subcarriers after demodulation. However, imperfections could increase noise and distort the diagram.

To test other modeling schemes ,we used M-PSK modelling. It was added to the block diagram in place of the 256-QAM block so that the difference in output can be observed. and rightly so the output were diffrerent as shown in Fig.10. In **256-QAM**, both the amplitude and phase of the carrier signal are modulated. This results in a **grid-like constellation**. In **M-PSK**, only the **phase** of the carrier signal is modulated, while the amplitude remains constant. This creates a **circular or ring-shaped constellation**. Phase noise in particular can cause a rotation or smearing effect along the ring since it directly impacts the phase of the signal. M-PSK generally has a higher error probability compared to QAM for the same signal-to-noise ratio (SNR). This is because the points in M-PSK are closer to each other (smaller angular separation) as the modulation order increases.

ACKNOWLEDGMENT

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[9](https://github.com/ctimmins96/256-QAM-Research-Paper GitHub)- ctimmins96/256-QAM-Research-Paper: Code Repository for my 256-QAM Research Paper that included discussion of Viterbi and error detection codes