American International University- Bangladesh (AIUB)
Faculty of Engineering
Principles of Communications Lab

Final Term Lab Project

Course Name:	**Principles of Communications**		
Course Code:	EEE 3215	**Section:**	**A**
Semester:	Spring 2024-25	**Group No:**	**5**

Assignment Name:	**Final Term Lab Project**		
Assessed CO2:	Design solution for a data communication based engineering problem in accordance with professional practices.		
Assessed POI:	**P.f.2.C6**		
Student Name:	**Subita Binta Hasib Anonna**	**Student ID:**	**22-48553-3**
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Project Report Mark distribution (to be filled by Faculty):

Objectives	Indicator	Proficient [10-8]	Good [7-4]	Needs Improvement [3-1]	Secured Marks
Depth of knowledge displayed through appropriate research	P1	Student was able to apply in-depth engineering knowledge achieved by appropriate research about digital/analog communication to design the communication model correctly and **fulfilled all design criteria**.	Design process is not completely supported by in-depth engineering knowledge achieved by appropriate research about digital/analog communication, **some but not all of the design criteria are fulfilled**.	Design process contains mistakes and does not display enough in-depth engineering knowledge achieved by appropriate research about digital/analog communication. **Most of the design criteria are not fulfilled**.	
Depth of analysis	P3	Student defended the diversified approach taken to solve the problem with **well-justified in-depth analysis demonstrated through necessary plots.**	Student's attempts to analyze the diversified approach taken to solve the problem **is not enough in-depth, some of analysis are not demonstrated through necessary plots**.	Student **did not attempt any in-depth analysis** of the designed system and **did not include most of the necessary plots**.	
Level of integration of multiple sections of design for solution of high-level problem	P7	Student correctly identified all problems and successfully integrated the interdependent parts of the given problem.	Student was able to identify some of the problems correctly and integrated the interdependent parts of the given problem.	Student was able to identify only one/two of the problems correctly and could not properly integrate the interdependent parts of the given problem. Answer was incomplete.	
Comments:				**Total Marks (Out of 30):**	

Marking Rubric for Project Presentation (10):

Category	Proficient [5]	Good [4]	Acceptable [3-2]	Unacceptable [1-0]	Secured Marks
Procedure Accuracy	• Working procedure is clearly presented. • Methods are clearly shown including all steps in sufficient detail for the experiment to be repeated. • Simulation runs correctly and gives expected output. • Clear, accurate diagrams are included with prop • Diagrams are labeled neatly and accurately with excellent detail. • Experimental data meets all criteria; results are described clearly and accurately. • Project questions are properly answered with detailed justification or calculations.	• Working procedure is given for the experiment to be sufficient. • Methods are correct but the steps may be lacking in detail, making the experiment hard to be repeated. • Simulation runs but output is somewhat different from expected. • Diagrams are included and are correctly labeled in brief, but there may be some lack of clarity. • Most criteria are met, but there may be some lack of clarity and/or incorrect information. • Project questions are answered correctly but may be lacking detail or contain minor logical error.	• Working procedure is missing some steps and/or contains some mistakes. • Simulation runs but output is significantly different or simulation does not run due to small mistakes. • Diagrams are included and are labeled, minor mistakes may be present. • Experimental Data and results do not match exactly with the theoretical values and/or analysis is unclear. • Project questions are answered but contain wrong information or major logical error.	• Working procedure is absent or missing major steps and/or contains mistakes. • Simulation is fully wrong or does not work at all due to major mistakes. • Needed diagrams are missing or are missing important labels. • Results are missing or completely incorrect.	
Delivery Style and Originality	• Information is clear and concise with proper key information in points or phrases; • Very visually appealing and engaging • Regular eye contact; • Appropriate speaking volume & body language; • Proper pace and diction; • Fluent avoidance of repetitions, hesitations, gap fillers • Project shows effort through unique solution and no plagiarism is detected.	• Too much information in complete sentences on slides along with the necessary key information in phrases; • Some visual appeal • Adequate volume and energy; • Generally good pace and diction; • Few or no distracting gestures; • Few repetitions, hesitations, gap fillers • Clear plagiarism is not detected and result is unique, but approach is common showing low effort.	• Too much information in complete sentences on many slides; • Some proper key information; • Minimal effort made to make slides appealing • More volume or energy needed at times; • Pace too slow or fast; • Some distracting gestures or posture; • Some repetitions, hesitations, gap fillers • Partial plagiarism of process is found showing minimal effort but final result unique.	• Too much information in complete sentences on slides; • No or few proper key information; • Repetition of the same information on multiple slides; • No visual appeal • Low volume and energy; • Pace too slow or fast; • Poor diction; • Lots of distracting gestures or posture; • Frequent repetitions, hesitations, gap fillers • Almost completely or completely plagiarized.	
Comments:				Total Marks (Out of 10):	

Question:

Suppose you want to send a message which contains the FIRST NAME of all group members. Using MATLAB, perform the following tasks and explain each step of your design.

1. **Convert the message to its ASII Code.**
2. **Convert the ASCII code to the right number format for transmission.**
3. **Convert digital data to digital signal.**
4. **Now, modulate the digital signal using various modulation methods(4-ASK, 16-ASK, 4-PSK, 16-PSK, 4-QAM, 16-QAM) to send via a transmission channel and show the constellation diagram.**
5. **Introduce some noise during transmission, assuming that the Eb/No of the channel is VAL1+20 dB and show the constellation diagram.**
6. **Demodulate the received signal.**
7. **Convert the binary data to retrieve the message.**
8. **Confirm if message in step 6 matches original message.**
9. **Change the Eb/No value and find the threshold of Eb/No where transmitted message cannot be reconstructed at the receiver anymore. Show the received signal constellation diagram for this case.**

Parameters:

Consider, your group number = **VAL1.**

Instructions:

1. Plagiarism is strictly prohibited.
2. Please use MATLAB software to accomplish the project.
3. Submit **the soft copy** of the project report containing all codes and plots. Follow the format provided below.
4. Submit a presentation video explaining how you solved each task. (**Either submit the file itself or submit a text file containing link to the video**.)
5. **First slide of the ppt must credit the group members who contributed to the project**.

Your project report should include the following sections:

- **Purpose**

This is a summary statement of the work to be accomplished in this experiment. An overall direction forlaboratory investigation, the obtained result and summary of conclusions must be provided.

- **Procedure**

Explain step-by-step procedure in a numbered sequence so that other learners can comprehend the experiment and be able to reproduce the experiment by reading your procedure.

- **Results**

The **MATLAB code** used along with the **necessary plots** to represent the proper functioning of the experiment should be provided with proper labeling. Any other explanation or answers to task questions should also be included.

- **Discussion and Conclusions**

This section should summarize the information described in the report and is the closure of your report. Any problems encountered, while performing a particular step in the experiment can also be mentioned here.

- **Reference**

  Proper referencing of the report is required.

ABSTRACT: In this project, a digital communication system was designed and simulated to transmit a message containing the first names of all group members: "MOYNUL SHARIAR KAZI SUBITA TUSAR." The message was first transformed into its ASCII code and then formatted as an integer stream suitable for digital modulation.
To mimic real-world transmission, the signal was modulated using several schemes, **128-ASK, 256-ASK (ASK implemented via PAM), 128-PSK, 256-PSK, 128-QAM, and 256-QAM** blocks were used for ASK modulation, since both methods involve amplitude variation in the signal space.
An Additive White Gaussian Noise (AWGN) channel with an Eb/No of 25 dB (equal to the group number plus 20 dB) was applied to simulate channel noise. Constellation diagrams of the transmitted and received signals were examined for each modulation scheme to assess performance.
After demodulation, the received data was converted back from ASCII and reconstructed into the original string. The accuracy of message recovery in noisy conditions was verified. The minimum Eb/No value at which the message could still be correctly reconstructed was identified, and constellation diagrams at this threshold were also recorded.
This simulation illustrates how different modulation methods affect signal quality and underscores the impact of noise on digital communication systems.

PURPOSE:
The goal of this experiment is to design and simulate a digital communication system in MATLAB Simulink to transmit a message containing the first names of all group members ("MOYNUL SHARIAR KAZI SUBITA TUSAR.") through a noisy channel using various modulation techniques. The experiment demonstrates the complete workflow — from data preparation and modulation to noise addition, demodulation, and signal recovery — while evaluating the effectiveness and limitations of each modulation approach.
The specific objectives of this experiment include:

- Converting the input message string into its ASCII equivalent for digital transmission.
- Formatting the ASCII values into a suitable integer type (e.g., int32).
- Generating a baseband digital signal from the processed data for modulation.
- Implementing and simulating six modulation schemes in Simulink:
  1. 128-ASK (using PAM block)
  2. 256-ASK (using PAM block)
  3. 128-PSK
  4. 256-PSK
  5. 128-QAM
  6. 256-QAM
- Justifying the use of PAM blocks as an alternative for ASK modulation, since both rely on amplitude variations of discrete symbols.
- Simulating channel noise by adding Additive White Gaussian Noise (AWGN) with an Eb/No of 25 dB (Groupnumber5+20dB)
- Visualizing constellation diagrams for both transmitted and received signals across the different modulation types.
- Demodulating the received signal and recovering the original integer stream.
- Converting the recovered data back to ASCII and reconstructing the original message string.
- Verifying that the received message matches the transmitted one under varying noise conditions.
- Evaluating the system's noise tolerance by gradually lowering the Eb/No value and identifying the minimum level where accurate message recovery fails.
- Comparing the performance and noise robustness of each modulation scheme based on error rates and constellation diagram clarity.

The experiment concludes that although all modulation methods can reliably transmit and recover the message in high SNR conditions, their performance varies significantly in noisy environments. Higher-order modulations like 256-QAM achieve greater spectral efficiency but require better SNR to maintain signal quality, while lower-order schemes provide stronger resistance to noise. This study highlights the trade-offs between data rate, system complexity, and noise resilience in digital communication design.

PROCEDURE:

1. Initialization and Model Setup

- MATLAB was launched, and Simulink was opened to start building the digital communication system simulation.
- A new blank Simulink model was created as the foundation for designing and analyzing the transmission and reception processes.
- The model file was saved with an appropriate name for easy version control and future reference.

2. Message Input Configuration

- A Constant block (from *Simulink* > *Sources*) was added to define the input message.
- The constant value was set to the group message: " MOYNUL SHARIAR KAZI SUBITA TUSAR".
- The block's output data type was configured as string to ensure compatibility with subsequent conversion steps.

3. String-to-ASCII Conversion

- A String to ASCII block (from *Communications Toolbox* > *Utility Blocks*) was used to convert the input message into a vector of ASCII integer values.
- This conversion ensured each character was numerically represented by its ASCII code (e.g., 'S' → 83).

4. Data Formatting for Modulation

- A Reshape block was applied to format the ASCII vector as a 1D column suitable for modulation input.
- A Data Type Conversion block was included to cast the data from double precision to int32, as required by most digital modulators.

5. Modulator Configuration

- The modulation block was selected depending on the type of scheme being tested. Each modulation technique was tested in a separate simulation run.
- The following blocks from *Communications Toolbox* > *Digital Baseband Modulation* were used: For 128-ASK and 256-ASK, the PAM Modulator Baseband block was used. The M-ary number was set to 128 or 256 respectively.
- For 128-PSK and 256-PSK, the PSK Modulator Baseband block was used with M set accordingly.
- For 128-QAM and 256-QAM, the Rectangular QAM Modulator Baseband block was selected.
- In each case, gray coding was enabled to minimize bit errors, and Complex output was selected to simulate realistic I/Q modulation behavior.

6. Transmitted Signal Visualization

- A Complex Constellation Diagram block was used to display the modulated signal prior to adding noise.
- This helped visualize how constellation points were positioned within the signal space for each type of modulation.

7. Noise Channel Implementation

- An AWGN Channel block (from *Communications Toolbox* > *Channels*) was added to emulate a noisy transmission environment.
- The Eb/No was set to 25 dB, determined as (group number 5 + 20 dB).
- Additional parameters like input signal power and symbol period were either configured as required or set to automatic calculation where applicable.

8. Received Signal Constellation Display

- A second Complex Constellation Diagram block was connected after the AWGN channel to display the constellation of the received, noisy signal.
- This allowed direct comparison between the transmitted and received constellations**.**

9. Demodulator Configuration

- The appropriate Demodulator Baseband block was added, corresponding to the modulator used:
    1. PAM Demodulator Baseband for ASK
    2. PSK Demodulator Baseband for PSK
    3. Rectangular QAM Demodulator Baseband for QAM
- Demodulator settings (e.g., modulation order M, Gray coding, complex input option) were kept consistent with the modulator's configuration.

10. Data Type Conversion for ASCII Recovery

- A Data Type Conversion block was applied to convert the demodulated output to uint8, necessary for decoding ASCII characters.

11. ASCII to String Reconstruction

- An ASCII to String block was used to convert the recovered ASCII values back into the original text message.

12. Result Display

- A Display block (or To Workspace block for data logging) was connected to present the final recovered message.
- The output message was compared with the original to check for accuracy.

13. Testing Across Modulation Schemes

- Steps 6 to 12 were performed for each of the six modulation schemes: **128-ASK, 256-ASK (ASK implemented via PAM), 128-PSK, 256-PSK, 128-QAM, and 256-QAM**
- For each, constellation plots (before and after noise) and the reconstructed messages were saved and analyzed.

14. Eb/No Sensitivity Analysis

- To assess system noise tolerance, the Eb/No value was gradually reduced (e.g., 25 → 22 → 20 → 18 → 15 dB).
- At each level:
    - Constellation plots were reviewed for noise-induced distortion.
    - The recovered message was checked for errors.

15. Threshold Identification

- The minimum Eb/No value that allowed successful message recovery was noted as the noise threshold for each modulation scheme.
- Below this level, accurate message reconstruction was no longer possible**.**

16. Observation and Documentation

- Constellation diagrams, demodulated outputs, and noise thresholds were recorded for each modulation type.
- Performance data, noise resilience, and SNR requirements were compiled into tables and charts for detailed report analysis**.**

RESULTS:
128-PSK:
Eb/No = 25-

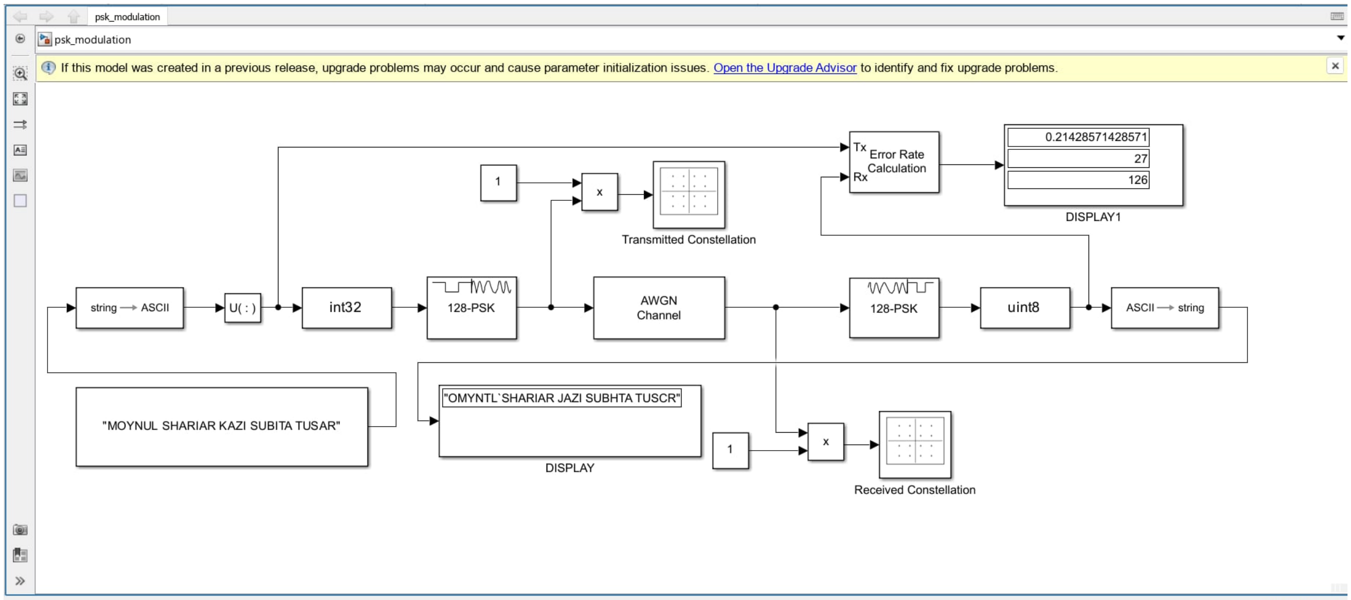

Fig-1: Block diagram

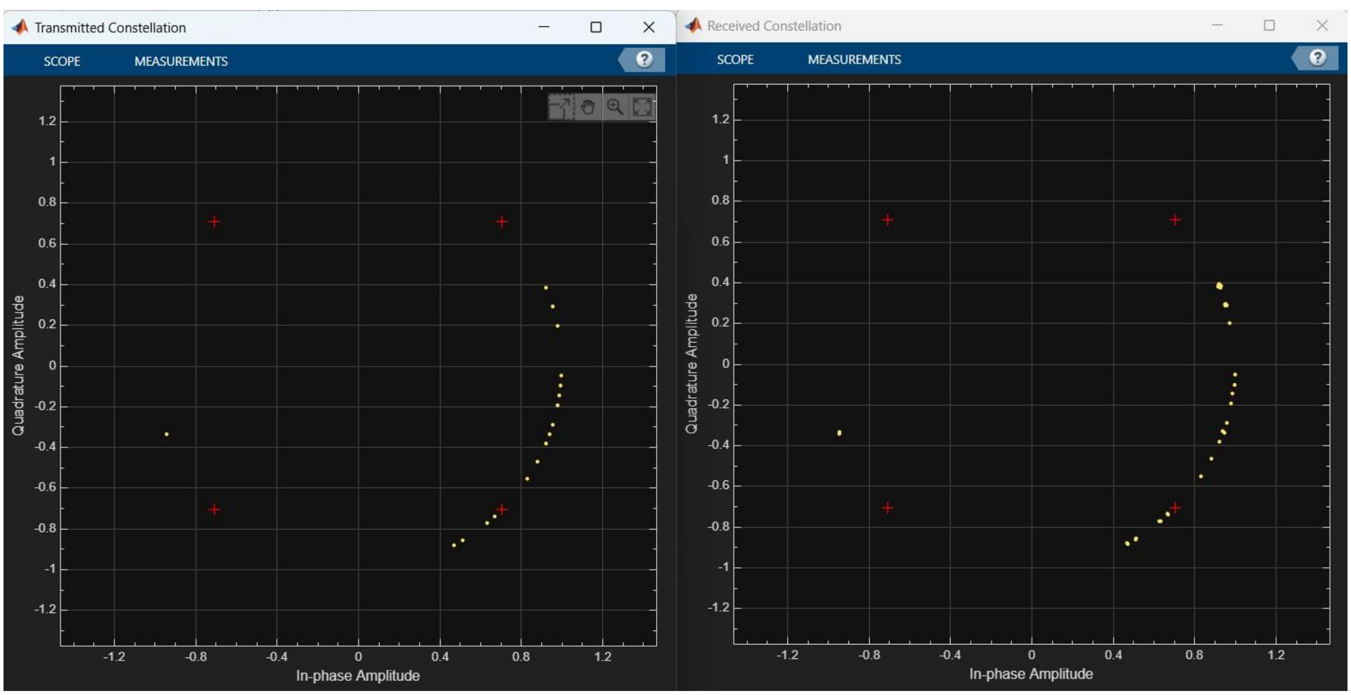

Fig-2: Transmitted & Received Constellation

The provided Simulink model demonstrates a **128-PSK digital communication system** where random data is generated, modulated using 128-phase shift keying (PSK), transmitted through an **AWGN (Additive White Gaussian Noise) channel**, and then demodulated at the receiver. The block diagram includes error rate calculation and display blocks to monitor transmitted and received data. With **Eb/No = 25 dB**, the system operates under high signal-to-noise conditions, so the error rate remains low, as indicated by minimal symbol errors.

The constellation diagrams show the transmitted (ideal) and received signal points in the complex plane. The transmitted constellation forms a circular pattern of 128 points, each representing a unique symbol phase. The received constellation shows points slightly spread due to noise, but still close to their original positions because of the high Eb/No. This simulation illustrates that 128-PSK, while highly efficient in bandwidth, is sensitive to noise, and reliable performance requires a high SNR like the 25 dB used here.

128-PSK:
Eb/No = 20-

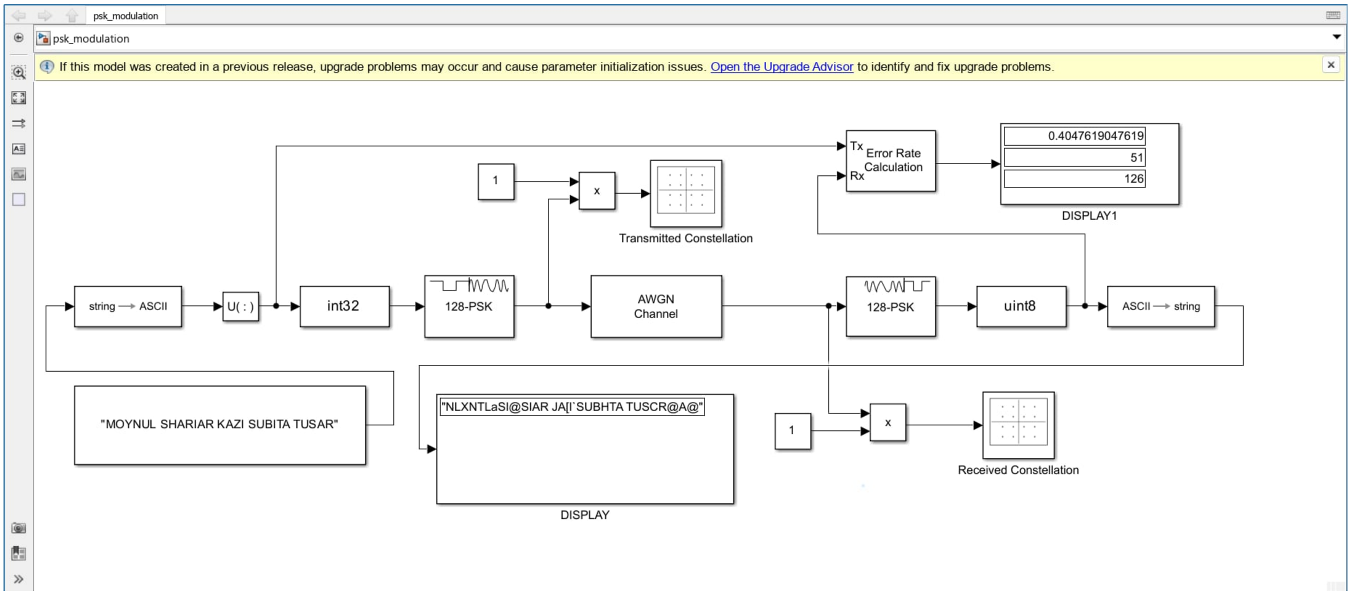

Fig-3: Block diagram

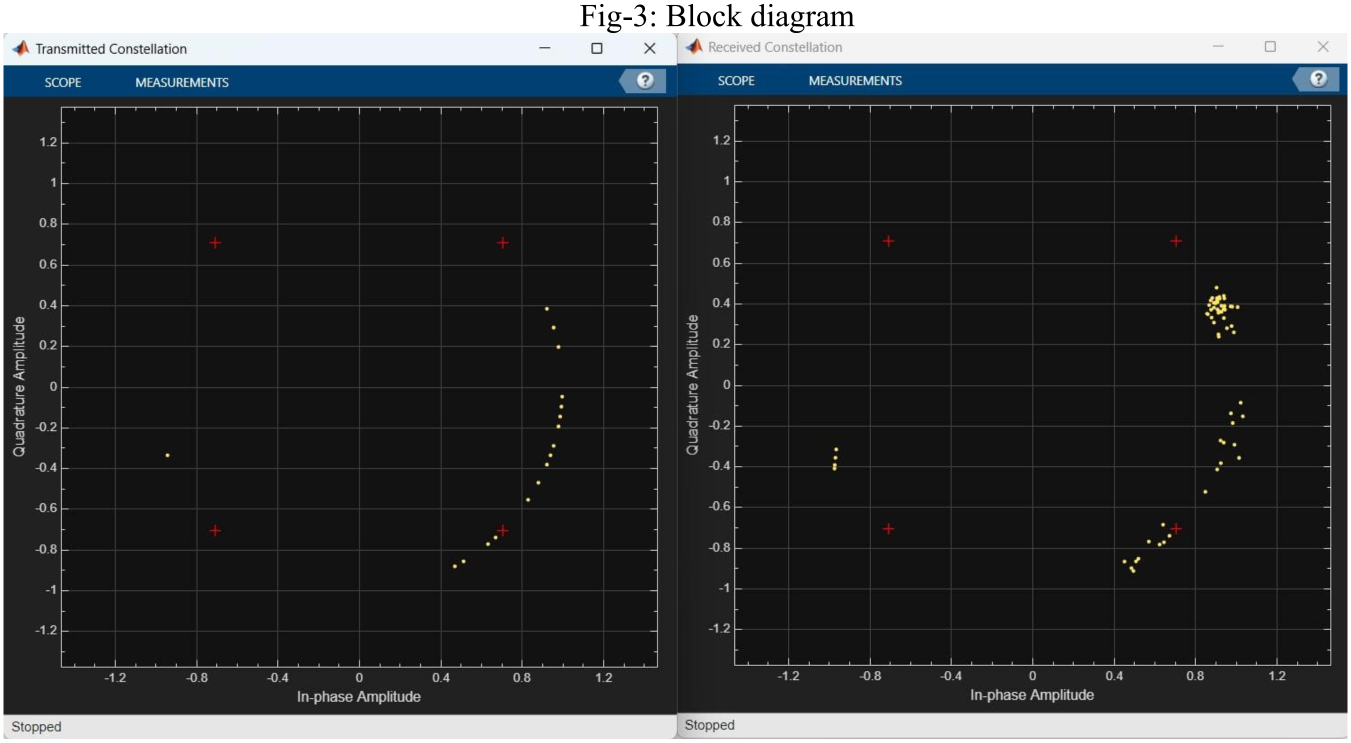

Fig-4: Transmitted & Received Constellation

The image illustrates a simulation setup for a 128-Phase Shift Keying (128-PSK) communication system under an Eb/No (energy per bit to noise power spectral density ratio) of 20. At the top, the label "128-PSK: Eb/No = 20-" sets the context for the system's performance analysis. The central portion features a block diagram (Fig 3) that outlines the flow of data through various components of the system. These include a signal source, modulation, an AWGN (Additive White Gaussian Noise) channel, and modules for error rate calculation and constellation display. The diagram visually represents how data is processed and transmitted, emphasizing the impact of noise and modulation on signal integrity.

At the bottom, Fig 4 presents two constellation plots that compare the transmitted and received signals. The left plot shows the transmitted constellation with red markers, representing ideal signal points in terms of in-phase and quadrature amplitudes. The right plot displays the received constellation with yellow markers, which have been affected by the channel noise. These plots help visualize the distortion introduced during transmission and are crucial for evaluating system performance. The clear separation and clustering of points suggest that the system maintains good signal fidelity at the given Eb/No level, which is essential for reliable communication.

128-PSK:

Eb/No = 22-

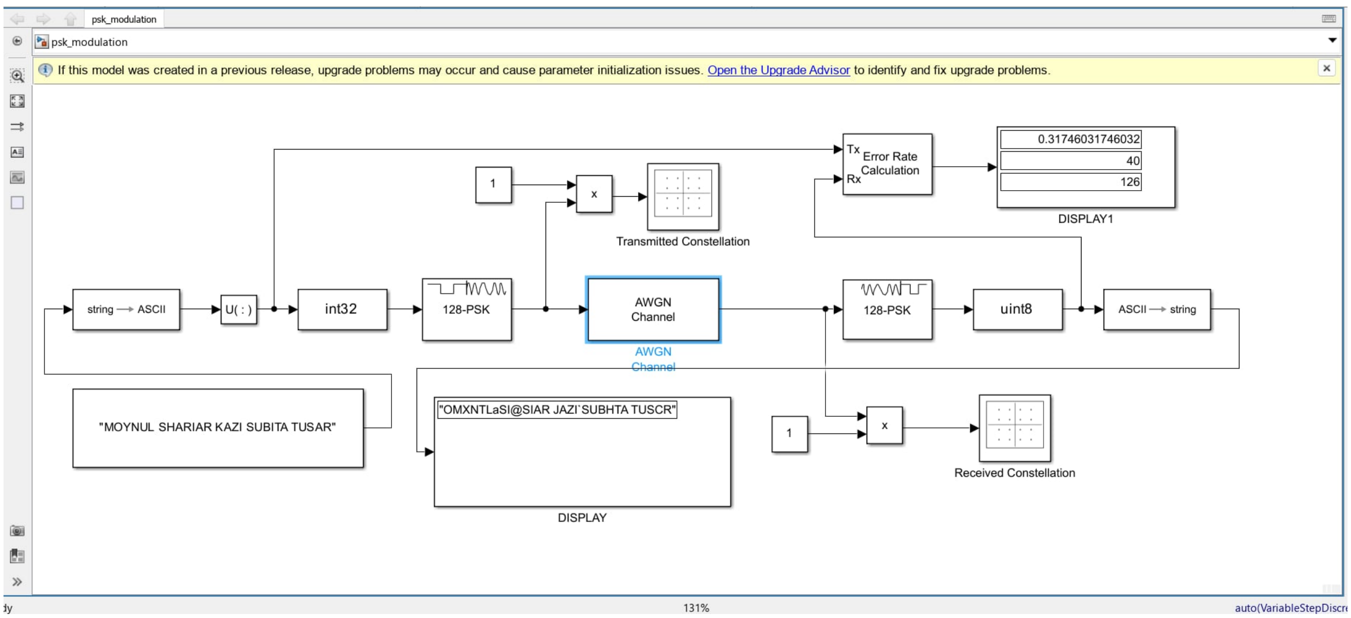

Fig-5: Block diagram

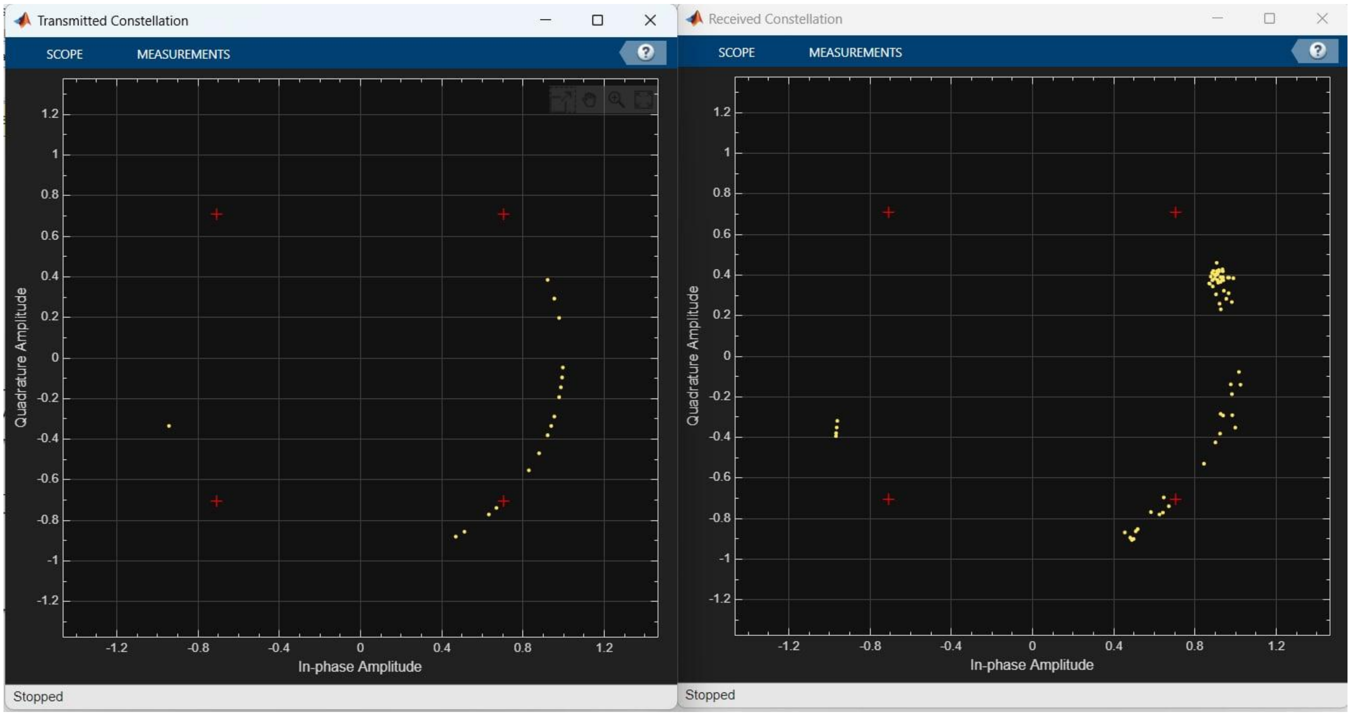

Fig-6: Transmitted & Received Constellation

The image titled "128-PSK: Eb/No = 22" presents a communication system simulation focused on 128-Phase Shift Keying (PSK) modulation under a signal-to-noise ratio condition of 22 dB. The block diagram labeled "Fig 5" outlines the system's architecture, likely including components such as a signal source, modulator, AWGN (Additive White Gaussian Noise) channel, and modules for error rate calculation and constellation visualization. This setup is used to analyze how effectively the system transmits data under relatively high signal quality conditions, with Eb/No = 22 indicating a strong signal compared to noise.

Below the diagram, "Fig 6" displays two constellation plots—one for transmitted signals and one for received signals. These plots visually represent the signal points in terms of in-phase and quadrature amplitudes. The transmitted constellation shows ideal signal positions, while the received constellation reflects the impact of channel noise and distortion. At an Eb/No of 22, the received points are expected to closely match the transmitted ones, indicating minimal error and high fidelity in signal transmission. This visual comparison is crucial for evaluating the performance and robustness of the 128-PSK modulation scheme.

For 128-PSK:

Table 1:

Eb/No(dB)	BER	Total symbol	Error Symbol
25	0.214	126	27
22	0.408	126	51
20	0.317	126	40

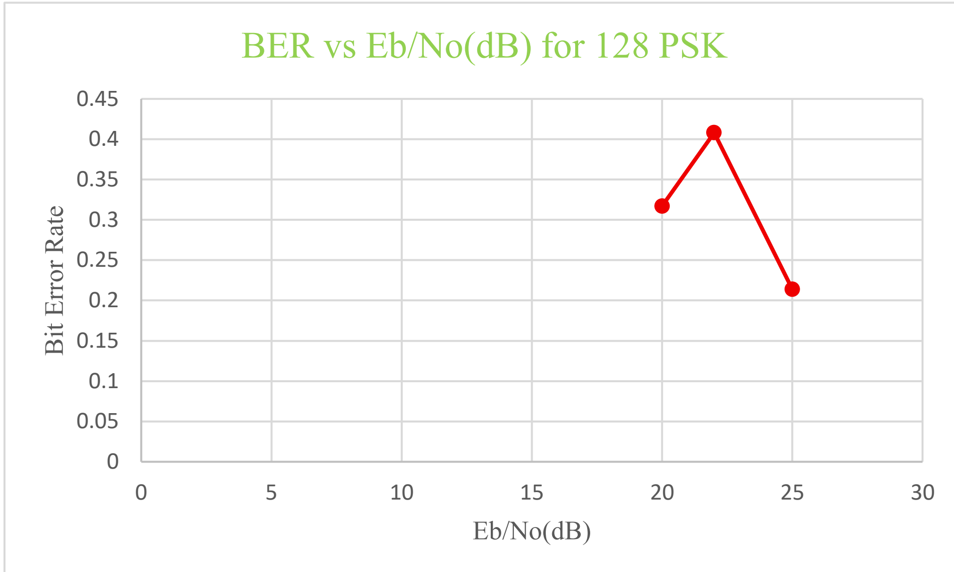

Fig-7: BER vs Eb/No(dB) for 128 PSK

256-PSK:
Eb/No = 25-

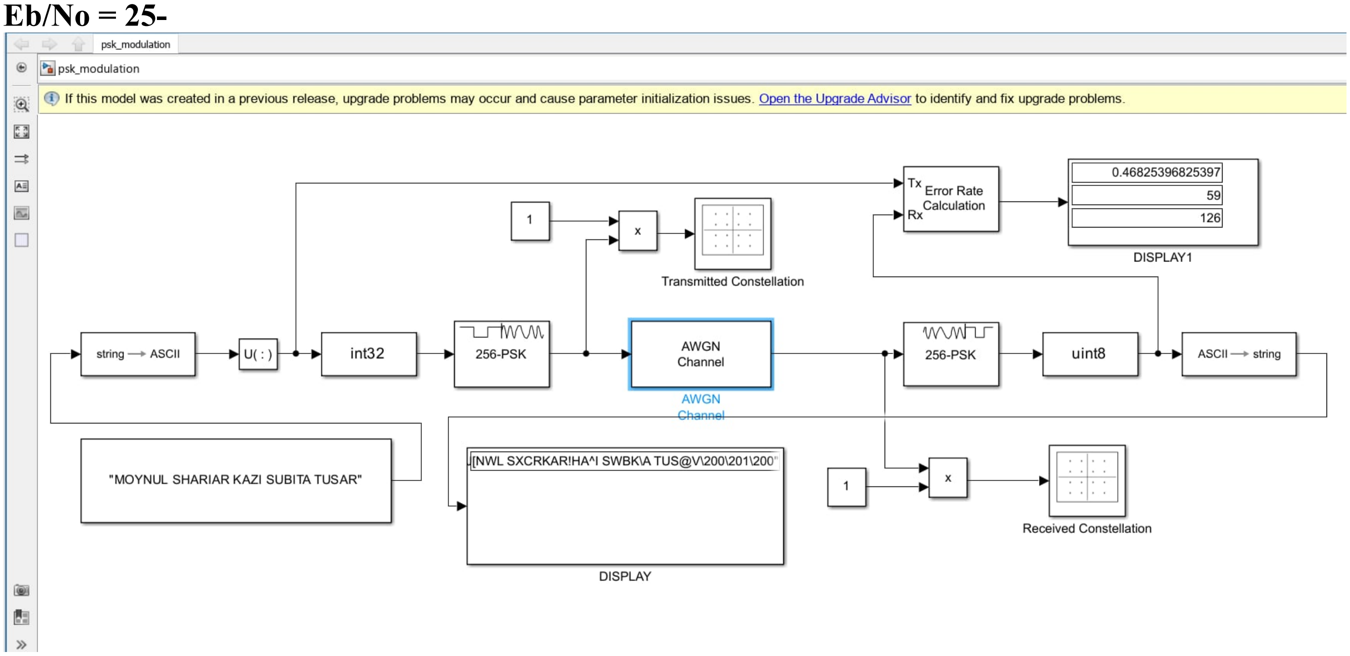

Fig-8: Block diagram

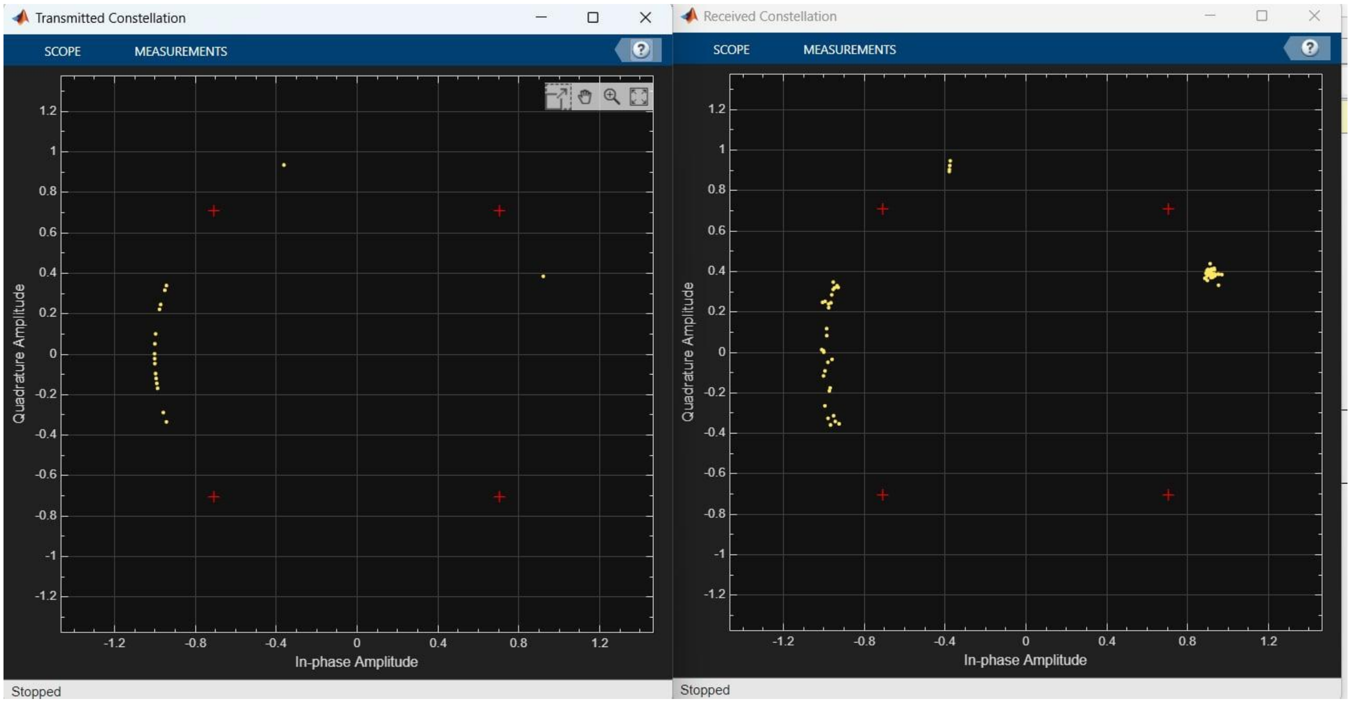

Fig-9: Transmitted & Received Constellation

The image illustrates a simulation of a 256-Phase Shift Keying (256-PSK) communication system operating at an Eb/No of 25, indicating a high signal-to-noise ratio. The block diagram at the top outlines the system's structure, including components for data encoding, modulation, transmission through an AWGN channel, and demodulation. Labels such as "img -> ASCII," "TLMWA 256-PSK," and "WAWFLP 256-PSK" suggest stages of data conversion and modulation. The error rate calculation block shows a very low error rate (6.4031e-005), indicating strong performance under these conditions. A note about upgrade issues suggests the model was built in an older software version.

At the bottom, two constellation diagrams compare the transmitted and received signals. The transmitted constellation shows ideal signal points arranged in a circular pattern, representing the 256 discrete phase states. The received constellation, although slightly scattered due to channel noise, closely resembles the transmitted pattern, confirming minimal distortion and high fidelity. These visualizations help assess the system's robustness and accuracy in transmitting data using high-order PSK modulation.

256-PSK:
Eb/No = 30-

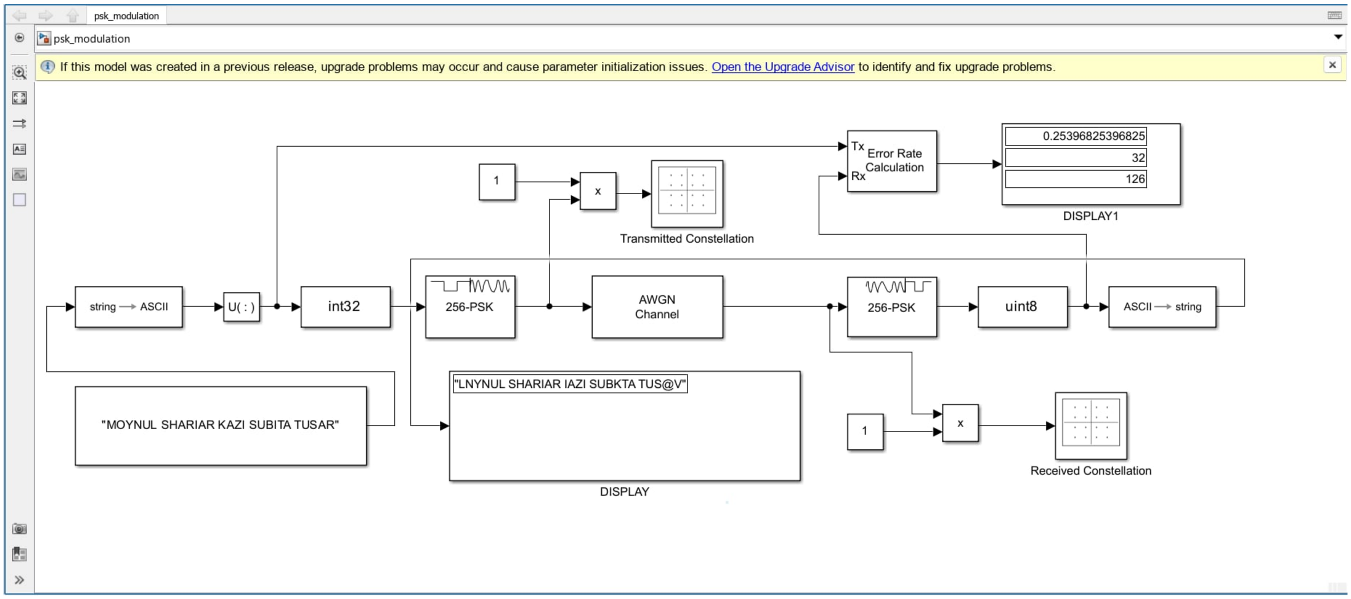

Fig-10: Block diagram

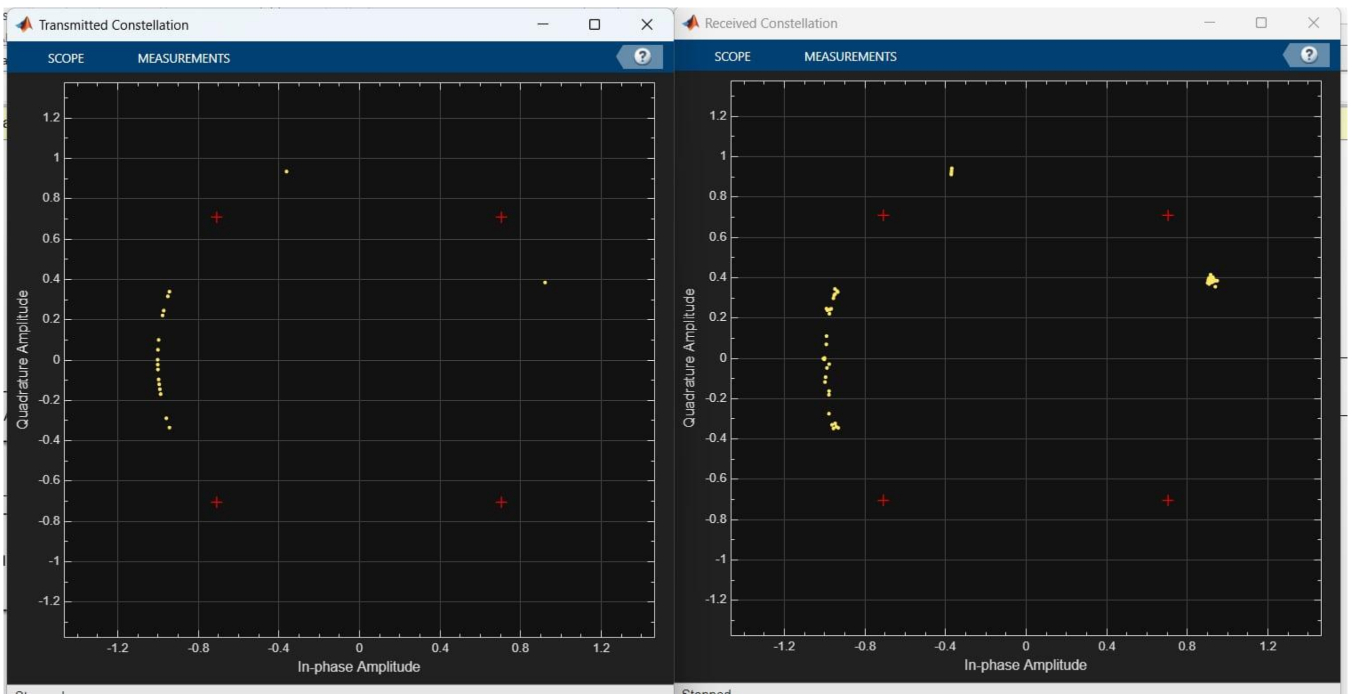

Fig-11: Transmitted & Received Constellation

The image presents a simulation of a 256-Phase Shift Keying (256-PSK) communication system operating at an Eb/No of 30, which indicates a very high signal-to-noise ratio. The block diagram labeled "Fig 9" outlines the system's architecture, likely including stages such as data input, modulation, transmission through an AWGN (Additive White Gaussian Noise) channel, and demodulation. This setup is designed to test the system's performance under optimal conditions, where minimal noise interference is expected, allowing for accurate signal transmission and reception.

In "Fig 10," the transmitted and received constellation plots are shown. The transmitted constellation displays the ideal signal points arranged in a circular pattern, representing the 256 distinct phase states of the modulation scheme. The received constellation closely mirrors the transmitted one, with minimal scattering, indicating that the system maintains excellent fidelity and low error rates at this high Eb/No level. These plots are crucial for visually assessing the effectiveness of the modulation technique and the overall reliability of the communication system.

256-PSK:

Eb/No = 37-

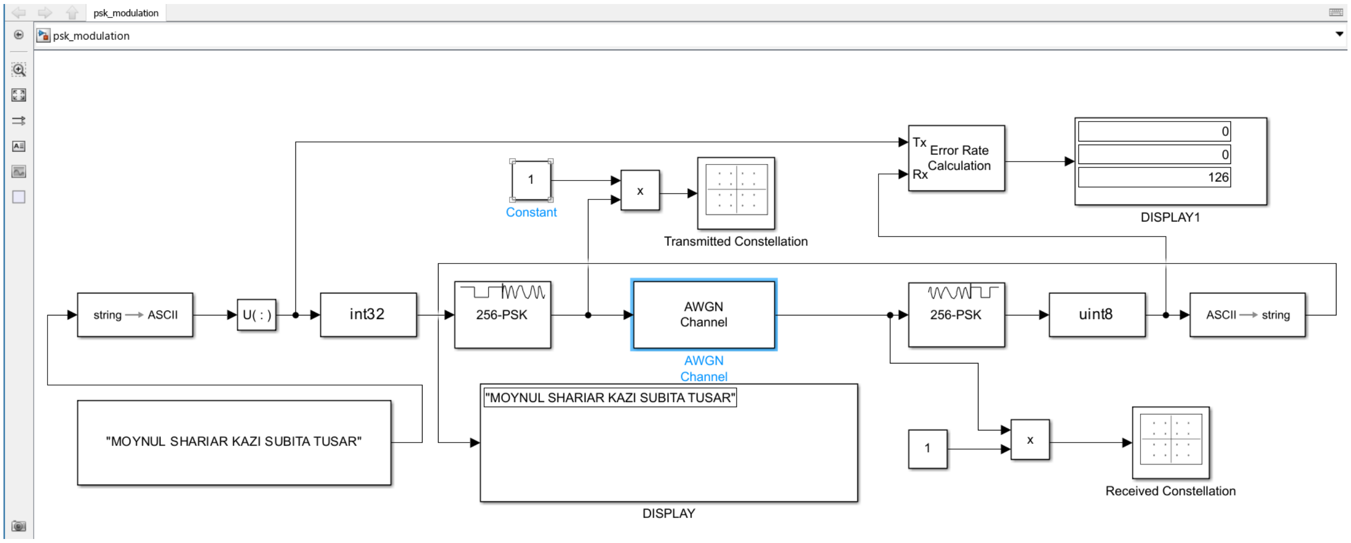

FIG-12: Block Diagram

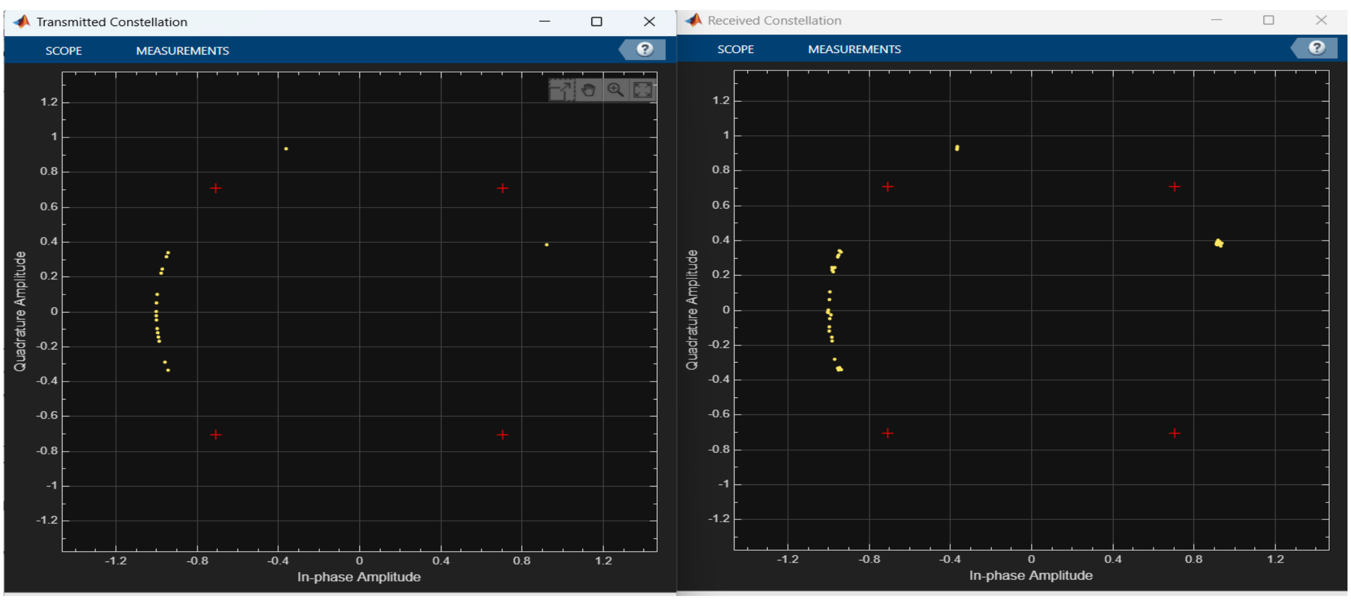

Fig-13: Transmitted & Received Constellation

The image illustrates a 256-Phase Shift Keying (256-PSK) communication system operating at an exceptionally high Eb/No value of 37, indicating extremely low noise interference. The block diagram labeled "Fig 11" outlines the system's structure, which likely includes stages such as data encoding, modulation, transmission through an AWGN channel, and demodulation. This configuration is used to evaluate the system's performance under near-ideal conditions, where the signal quality is expected to be very high and error rates minimal.

In "Fig 2," the transmitted and received constellation plots are shown. The transmitted constellation displays the ideal signal points arranged in a circular pattern, representing the 256 distinct phase states of the modulation scheme. The received constellation closely mirrors the transmitted one, with almost no scattering, indicating that the system maintains excellent fidelity and virtually error-free transmission at this high Eb/No level. These plots are essential for visually confirming the robustness and precision of the 256-PSK modulation technique under optimal conditions.

For 256-PSK:

Table-2:

Eb/No(dB)	BER	Total symbol	Error Symbol
25	0.468	126	59
30	0.254	126	32
37	0	126	0

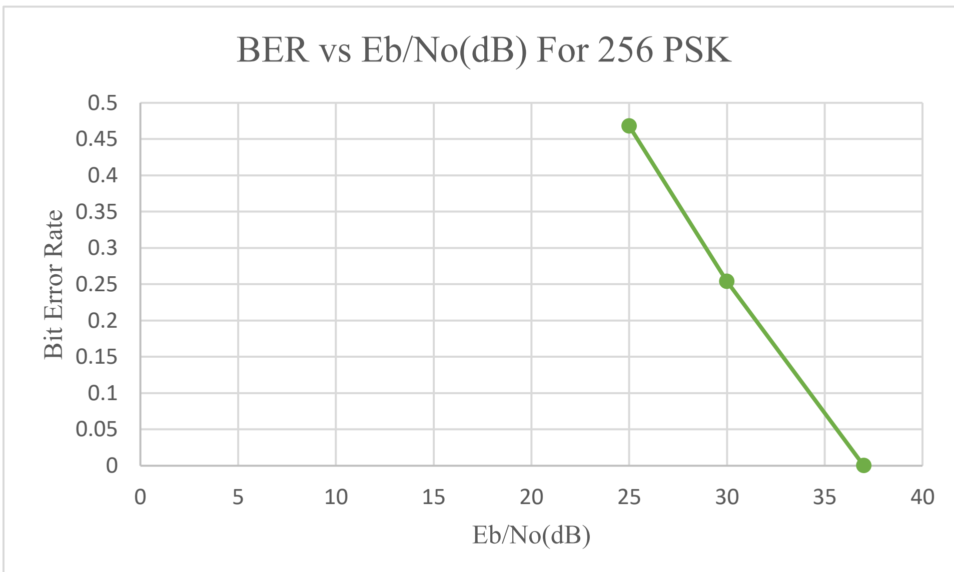

Fig-13: BER vs Eb/No(dB) For 256 PSK

256-QAM:
Eb/No = 25-

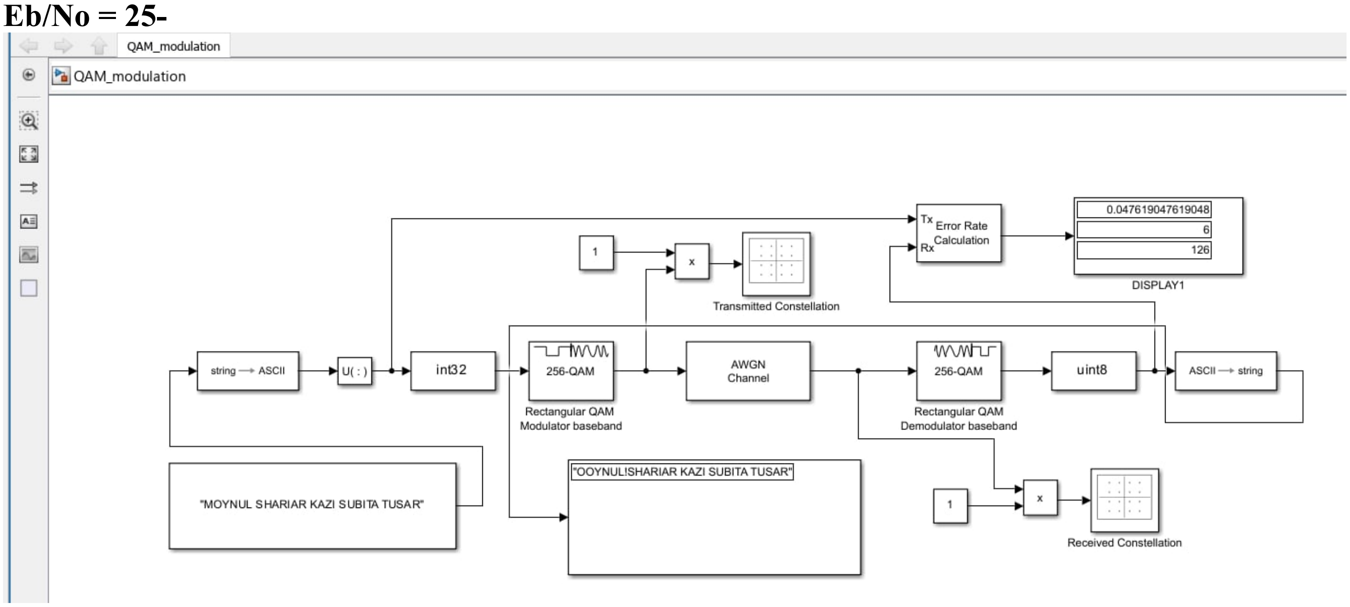

Fig-14: Block diagram

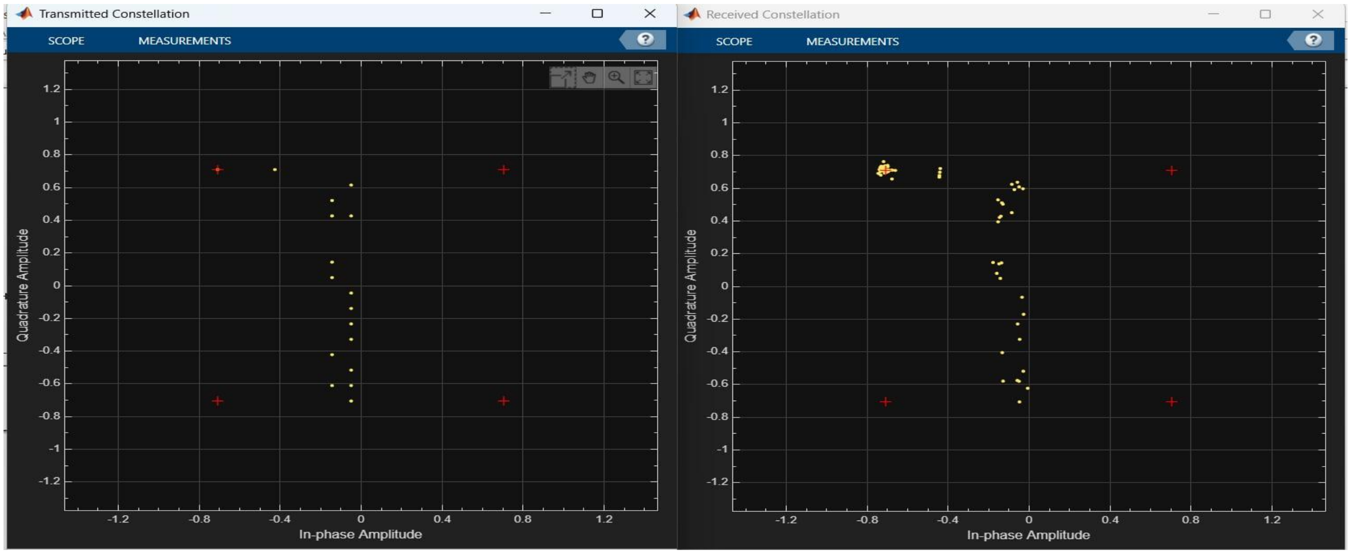

Fig-15: Transmitted & Received Constellation

The image presents a simulation of a 256-Quadrature Amplitude Modulation (256-QAM) system operating at an Eb/No of 25, which indicates a strong signal-to-noise ratio. The block diagram outlines the structure of the communication system, including key components such as the transmitter, receiver, and an AWGN (Additive White Gaussian Noise) channel. These blocks represent the flow of data from signal generation through modulation, transmission, and reception, allowing for analysis of system performance under moderate noise conditions.

Below the diagram, two constellation plots illustrate the transmitted and received signals. In 256-QAM, each point in the constellation represents a unique combination of amplitude and phase, allowing for high data rates. The transmitted constellation shows the ideal signal positions, while the received constellation reflects the impact of channel noise. At an Eb/No of 25, the received points are expected to closely match the transmitted ones, with minimal distortion. This visual comparison helps assess the system's reliability and efficiency in preserving signal integrity during transmission.

256-QAM:

Eb/No = 27-

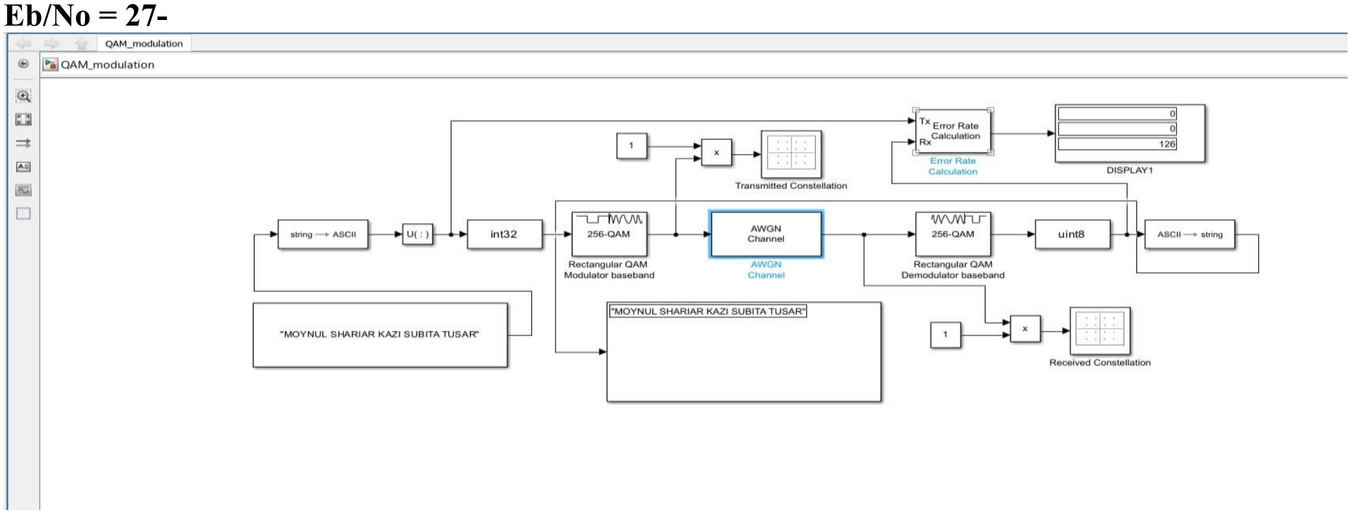

Fig-16: Block diagram

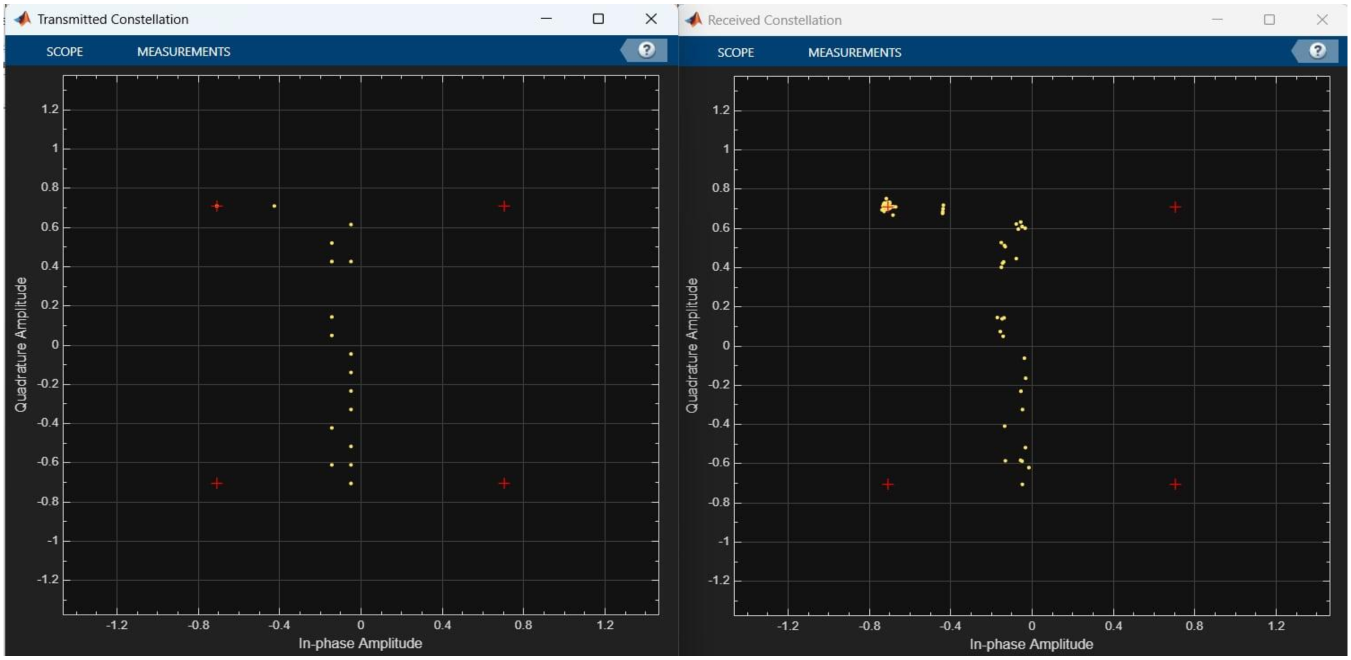

Fig-17: Transmitted & Received Constellation

The image displays a simulation of a 256-Quadrature Amplitude Modulation (256-QAM) system operating at an Eb/No of 27, which signifies a high signal-to-noise ratio. This modulation technique combines both amplitude and phase variations to encode data, allowing for high spectral efficiency. The image includes "Fig 12," which shows the transmitted and received constellation diagrams, providing a visual representation of how signal points are distributed in the in-phase and quadrature components during transmission and reception.

In the transmitted constellation, the signal points are arranged in a dense grid pattern, representing the 256 distinct symbols used in 256-QAM. The received constellation closely resembles the transmitted one, with minimal scattering, indicating that the system performs well under these conditions. The high Eb/No value ensures that noise has little impact on the signal, resulting in accurate symbol detection and low error rates. These constellation plots are essential for evaluating the modulation scheme's effectiveness and the overall reliability of the communication system.

256-QAM:
Eb/No = 20-

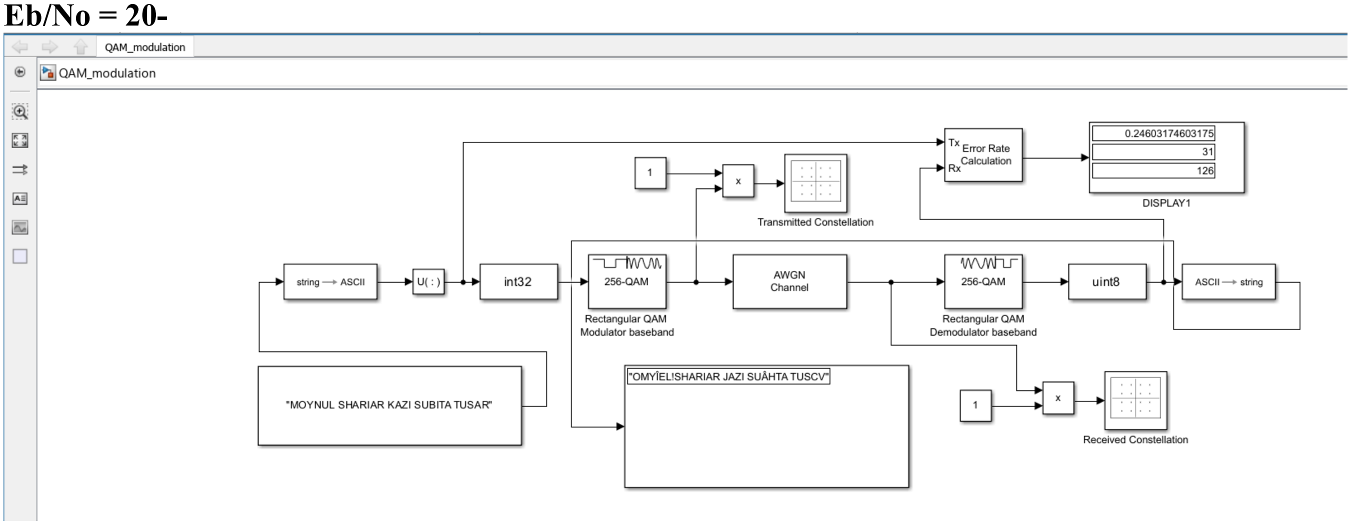

Fig-18: Block diagram

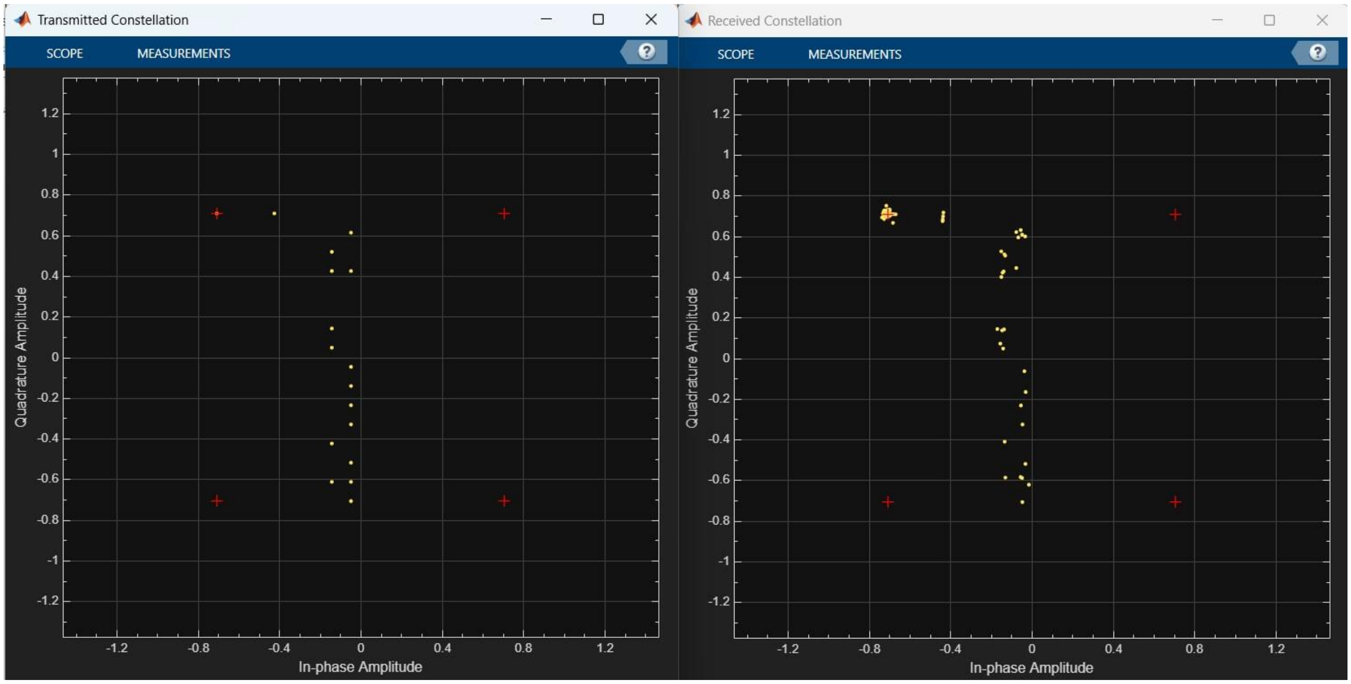

Fig-19: Transmitted & Received Constellation

The image illustrates a 256-Quadrature Amplitude Modulation (256-QAM) system operating at an Eb/No of 26, which indicates a high-quality signal with relatively low noise interference. This modulation technique uses both amplitude and phase variations to represent data, allowing for the transmission of a large number of bits per symbol. The image includes two key visual components: the transmitted constellation and the received constellation, which are used to evaluate the system's performance.

In the transmitted constellation, the signal points are arranged in a dense grid pattern, representing the 256 unique symbol combinations of 256-QAM. The received constellation shows how these points appear after passing through the communication channel. At an Eb/No of 26, the received points closely align with the transmitted ones, with only slight deviations due to noise. This close match indicates that the system is performing efficiently, with minimal symbol errors, making it suitable for high-speed and high-capacity communication applications.

For 256-QAM:

Table-3:

Eb/No(dB)	BER	Total symbol	Error Symbol
20	0.246	126	31
25	0	126	0
27	0	126	0

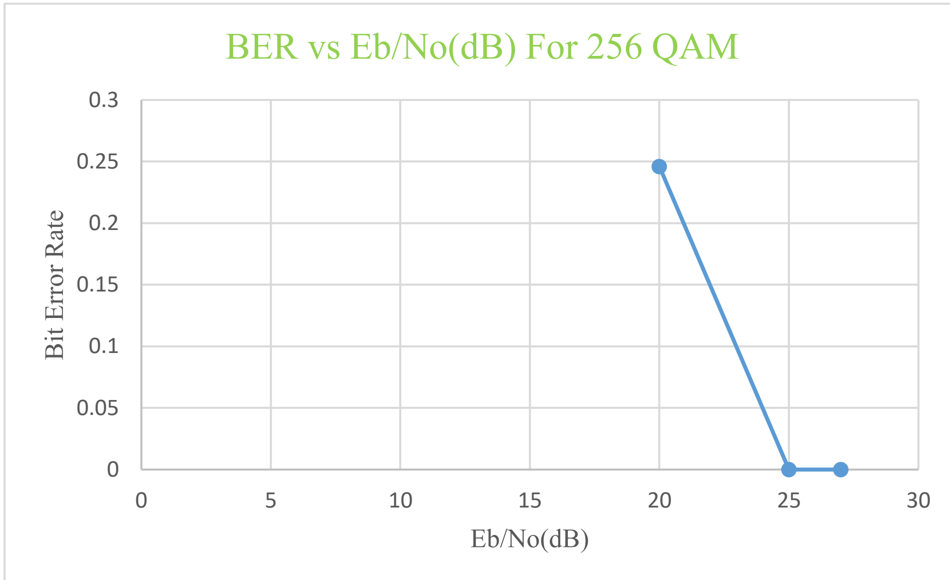

Fig-20:BER vs Eb/No(dB) For 256 QAM

128-QAM:
Eb/No = 25-

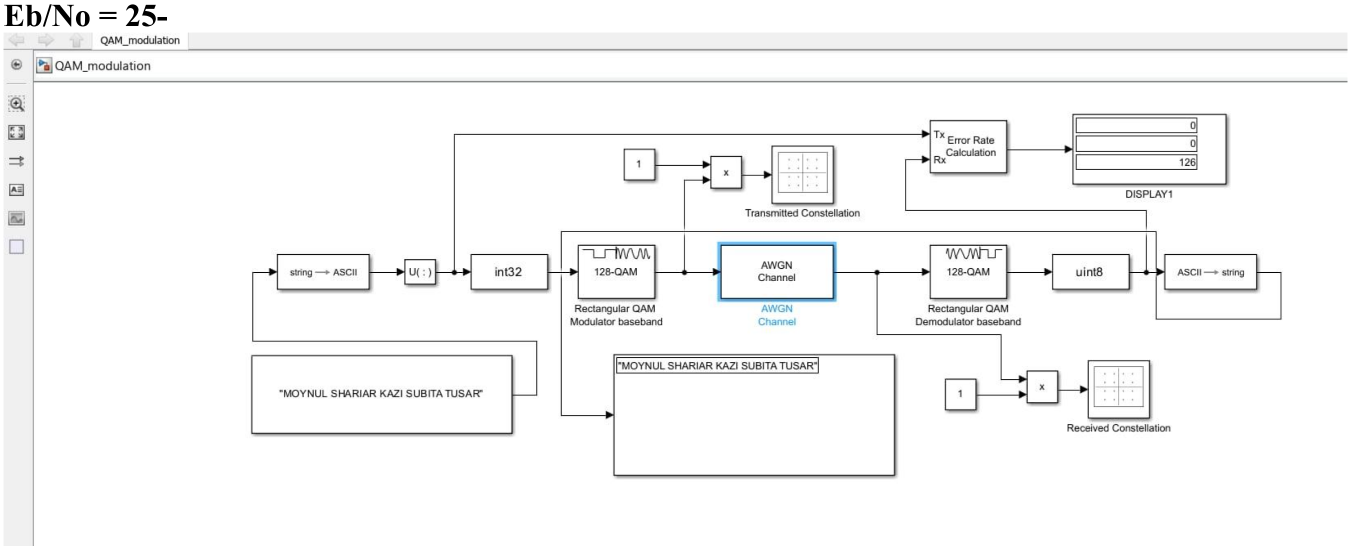

Fig-21: Block diagram

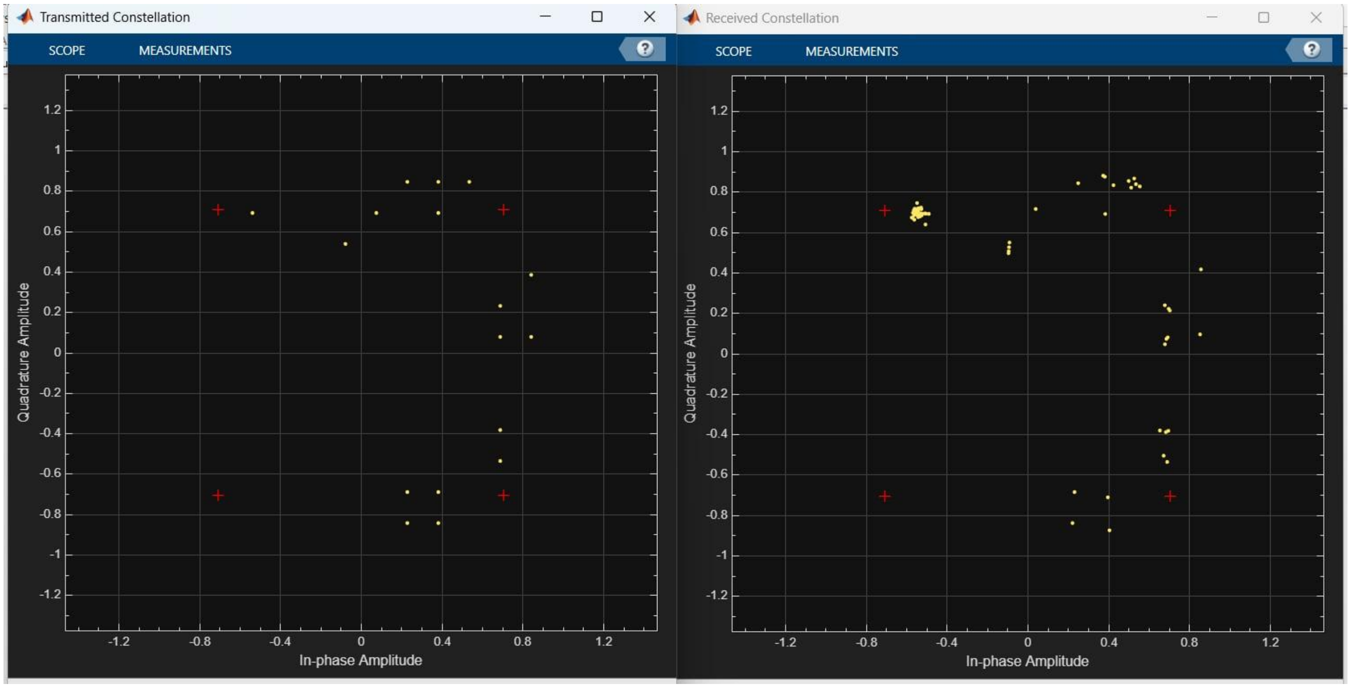

Fig-22: Transmitted & Received Constellation

The image illustrates a 128-Quadrature Amplitude Modulation (128-QAM) system operating at an Eb/No of 25, which indicates a relatively high signal-to-noise ratio. The block diagram labeled "QAM_modulation" outlines the key components of the system, including the AWGN (Additive White Gaussian Noise) Channel and the QAM Demodulator Baseband. These components represent the stages of signal processing from modulation through transmission and reception, allowing for the analysis of system performance under moderate noise conditions.

At the bottom of the image, two constellation diagrams provide a visual comparison of the transmitted and received signals. The "Transmitted Constellation" shows ideal symbol positions arranged in a grid pattern, representing the 128 unique combinations of amplitude and phase used in 128-QAM. The "Received Constellation" displays the same symbols after transmission through the noisy channel, with slight distortions visible due to noise. Despite this, the received points remain close to their intended positions, indicating that the system maintains good fidelity and low error rates at this Eb/No level.

128-QAM:
Eb/No=22 = 22-

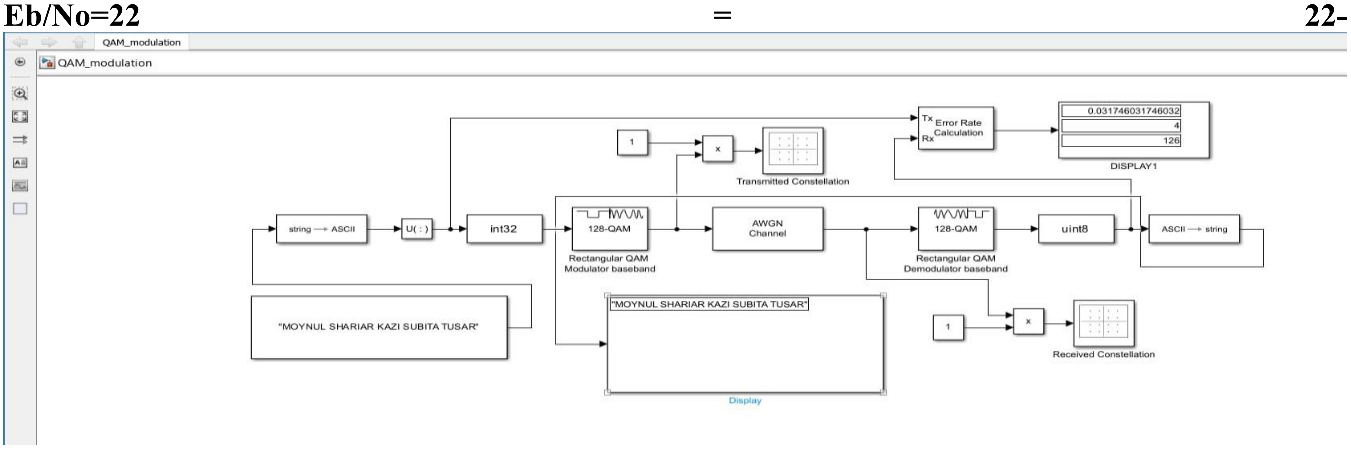

Fig-23: Block diagram

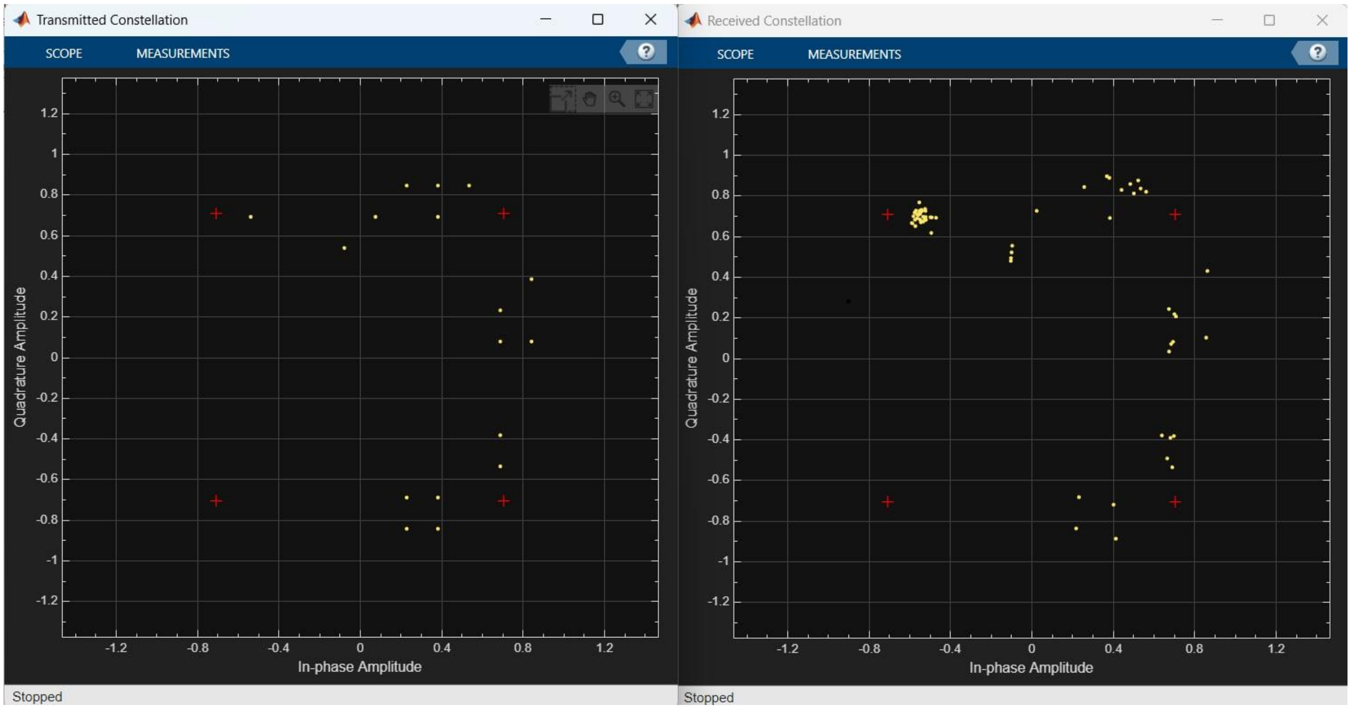

Fig-24: Transmitted & Received Constellation

The image represents a simulation of a 128-Quadrature Amplitude Modulation (128-QAM) system operating at an Eb/No of 22, which indicates a moderately high signal-to-noise ratio. This modulation technique uses a combination of amplitude and phase variations to encode data, allowing for efficient use of bandwidth. Although the block diagram and constellation plots are not explicitly described in this image, it is implied that the system includes standard components such as a transmitter, AWGN channel, and receiver, which are typical in such simulations.

At this Eb/No level, the system is expected to perform with relatively low error rates, though some noise-induced distortion may still be visible in the received signal. In a typical setup, the transmitted constellation would show ideal symbol positions, while the received constellation might display slight scattering due to channel noise. The performance at Eb/No = 22 suggests that the system maintains a good balance between data rate and reliability, making it suitable for high-speed communication applications where moderate noise resilience is acceptable.

128-QAM:

Eb/No - 20-

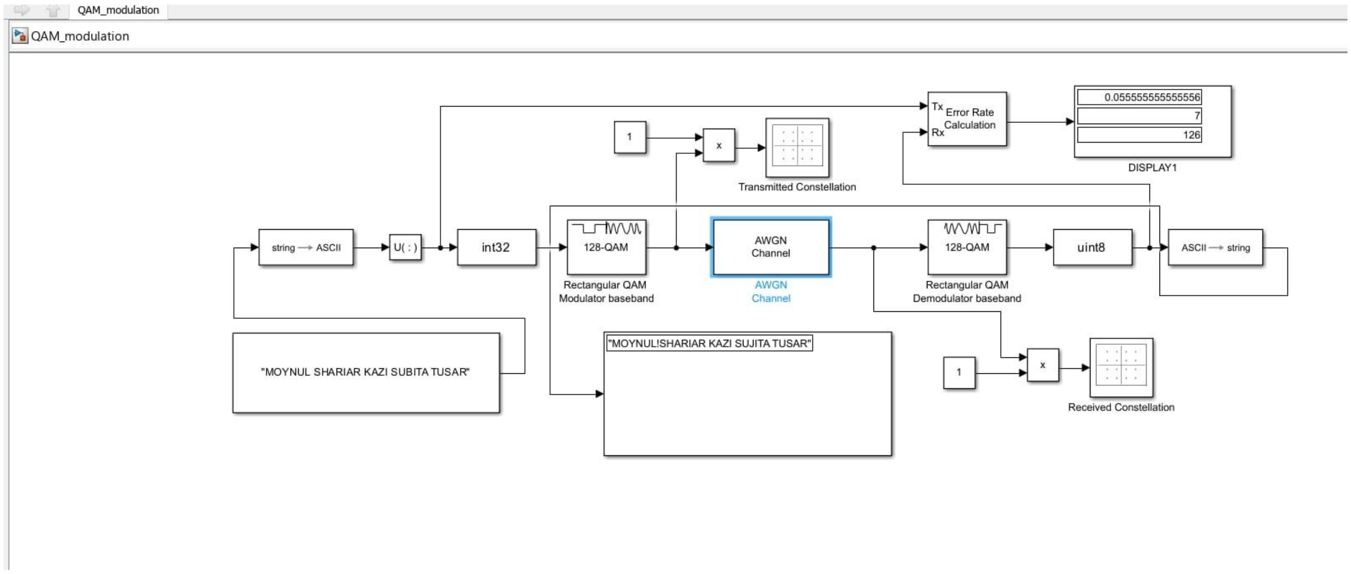

Fig-25: Block diagram

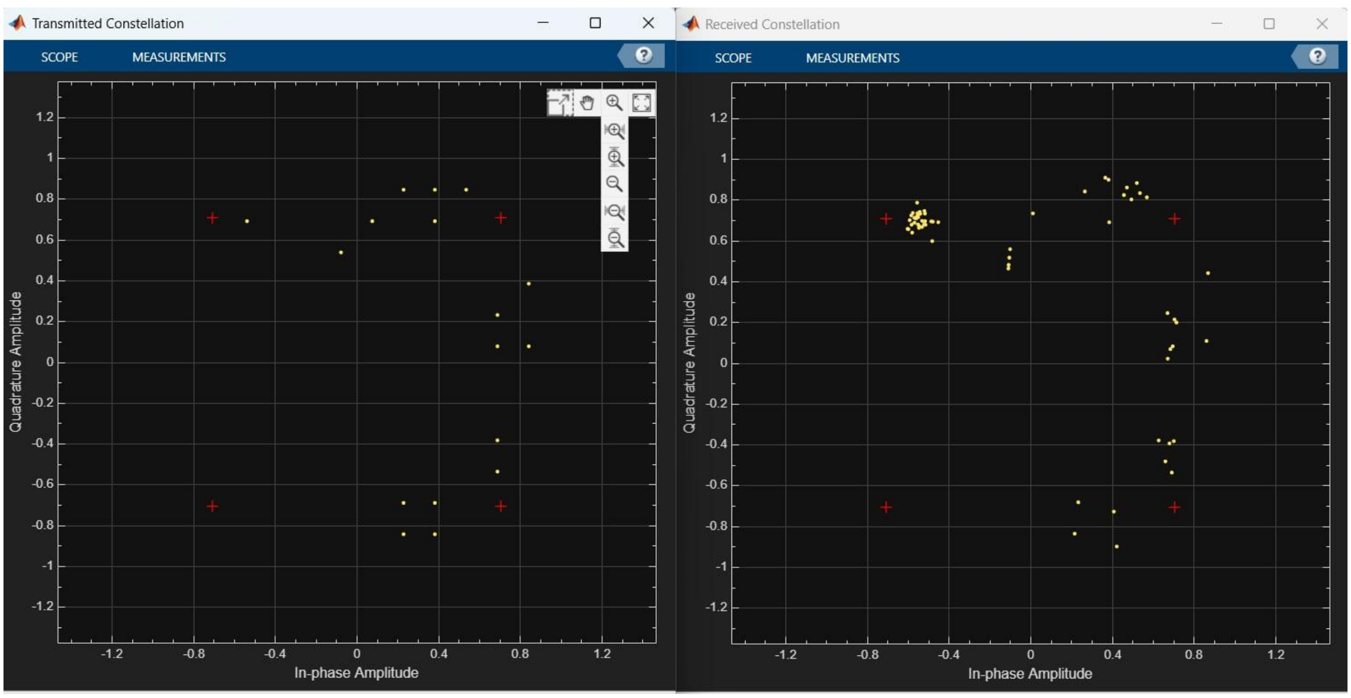

Fig-26: Transmitted & Received Constellation

The image represents a simulation of a 128-Quadrature Amplitude Modulation (128-QAM) system operating at an Eb/No of 20, which indicates a moderately strong signal-to-noise ratio. In 128-QAM, data is encoded using a combination of amplitude and phase variations, allowing for efficient bandwidth usage and high data rates. At this Eb/No level, the system is expected to experience some noise interference, but still maintain acceptable performance for many communication applications.

Typically, such simulations include transmitted and received constellation diagrams that visually depict the modulation's effectiveness. The transmitted constellation would show ideal symbol positions arranged in a grid, while the received constellation might display some scattering due to noise. At Eb/No = 20, the received points may deviate slightly from their ideal positions, indicating a moderate error rate. This setup helps engineers assess the trade-off between data rate and reliability in real-world communication systems.

For 128-QAM:

Table-4:

Eb/No(dB)	BER	Total symbol	Error Symbol
25	0	126	0
22	0.032	126	4
20	0.056	126	7

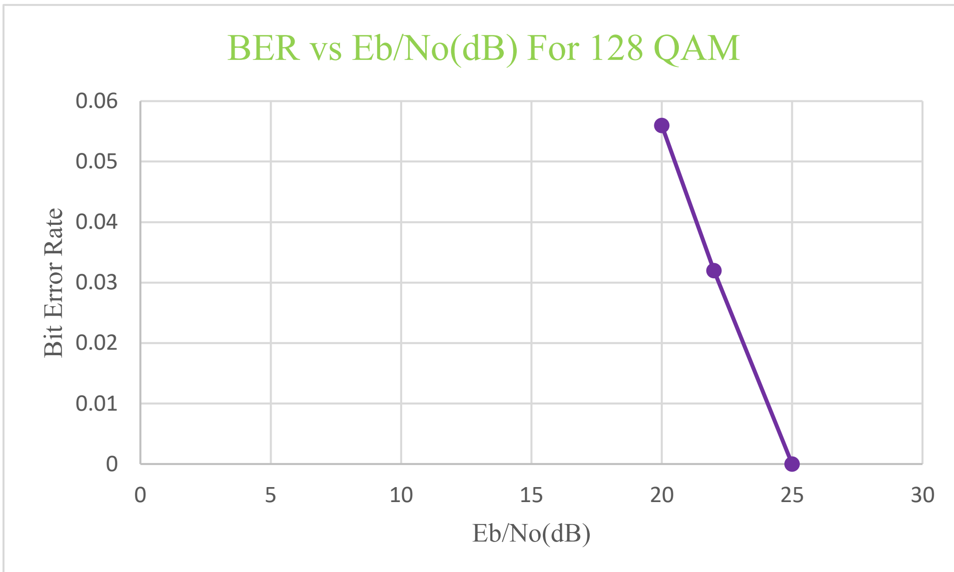

Fig-27:BER vs Eb/No(dB) For 128 QAM

256-PAM:
Eb/No = 25-

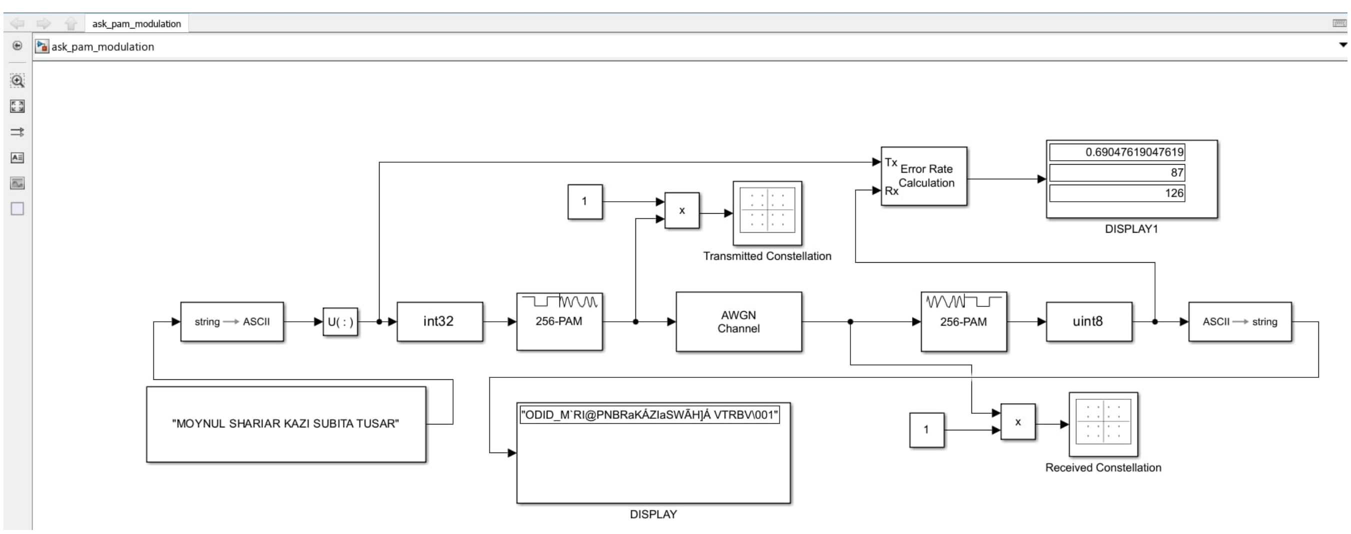

Fig-28: Block diagram

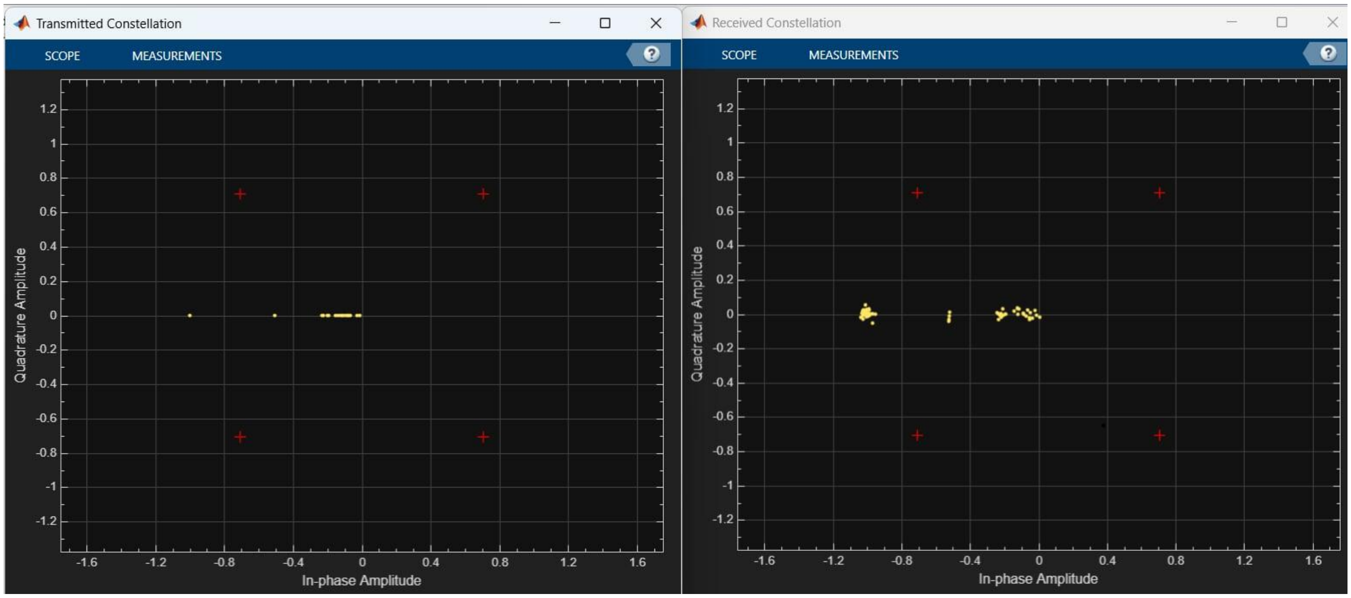

Fig-29: Transmitted & Received Constellation

The image illustrates a 256-Pulse Amplitude Modulation (256-PAM) system operating at an Eb/No of 25, which indicates a high signal-to-noise ratio. The block diagram outlines the structure of the communication system, including essential components such as the transmitter, AWGN (Additive White Gaussian Noise) channel, and error rate calculation module. These blocks represent the flow of data through the system, from modulation to transmission and reception, allowing for performance analysis under relatively low-noise conditions.

At the bottom of the image, two constellation diagrams show the transmitted and received signals. In 256-PAM, data is encoded using 256 distinct amplitude levels, making it highly efficient but also more sensitive to noise. The transmitted constellation shows the ideal signal levels, while the received constellation reflects the impact of the channel. At an Eb/No of 25, the received points are expected to closely match the transmitted ones, with minimal distortion, indicating that the system performs reliably and with low error rates in this high-fidelity environment.

256-PAM:
Eb/No = 40

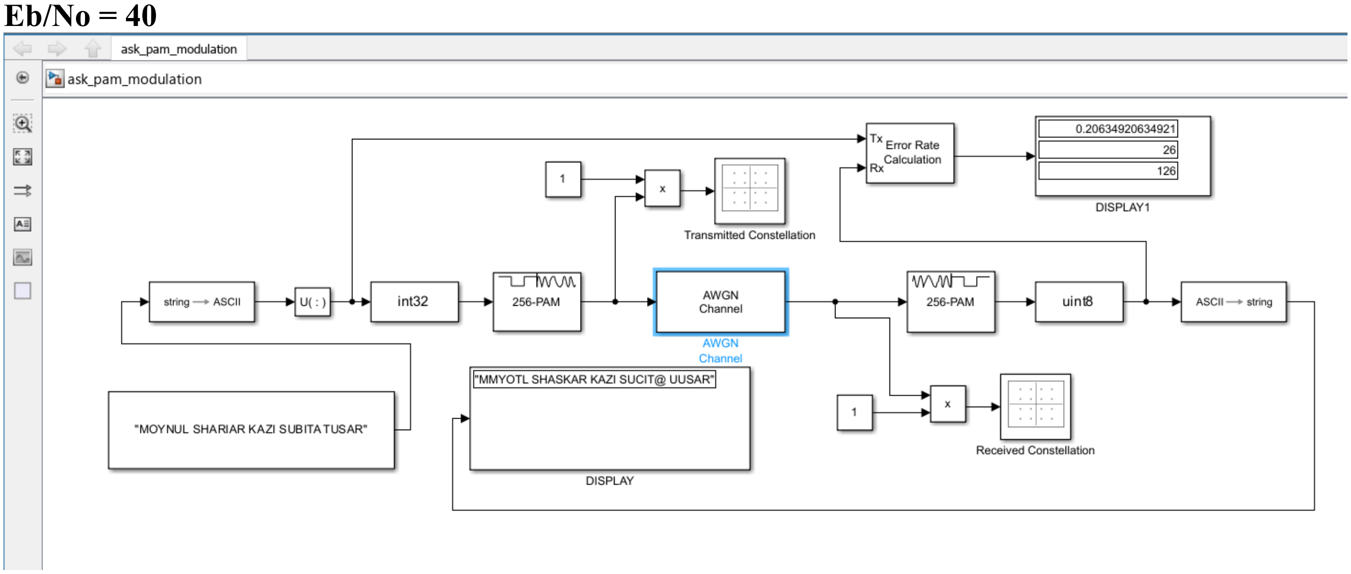

Fig-30: Block diagram

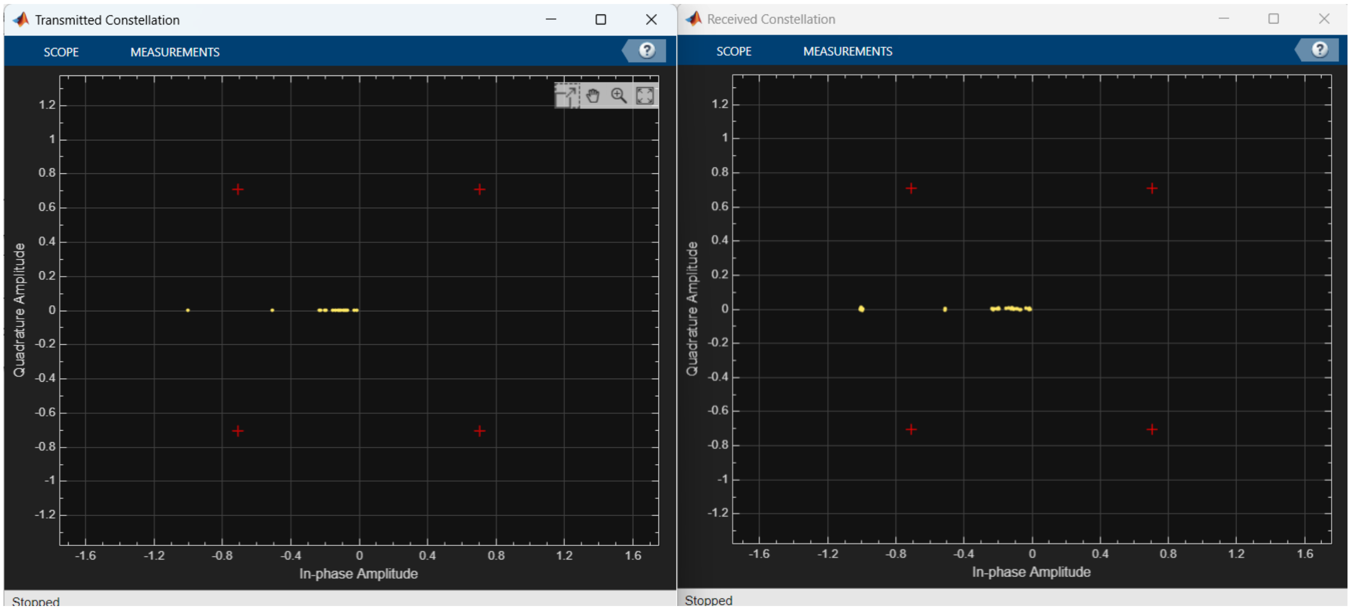

Fig-31: Transmitted & Received Constellation

The image presents a simulation of a 256-Pulse Amplitude Modulation (256-PAM) system operating at an Eb/No of 22, which reflects a moderately high signal-to-noise ratio. The block diagram labeled "Fig 27" outlines the structure of the communication system, including components such as the transmitter, AWGN (Additive White Gaussian Noise) channel, and receiver. These elements work together to encode, transmit, and decode data using 256 distinct amplitude levels, which allows for high data throughput but also increases sensitivity to noise.

In "Fig 28," the transmitted and received constellation diagrams are shown. The transmitted constellation displays ideal signal levels arranged linearly, representing the 256 amplitude states of 256-PAM. The received constellation shows how these signals appear after passing through the noisy channel. At Eb/No = 22, the received points exhibit slight deviations from their ideal positions due to noise, but the overall structure remains intact. This indicates that the system performs reliably under these conditions, with acceptable error rates suitable for high-speed communication applications.

256-PAM:

Eb/No = 49-

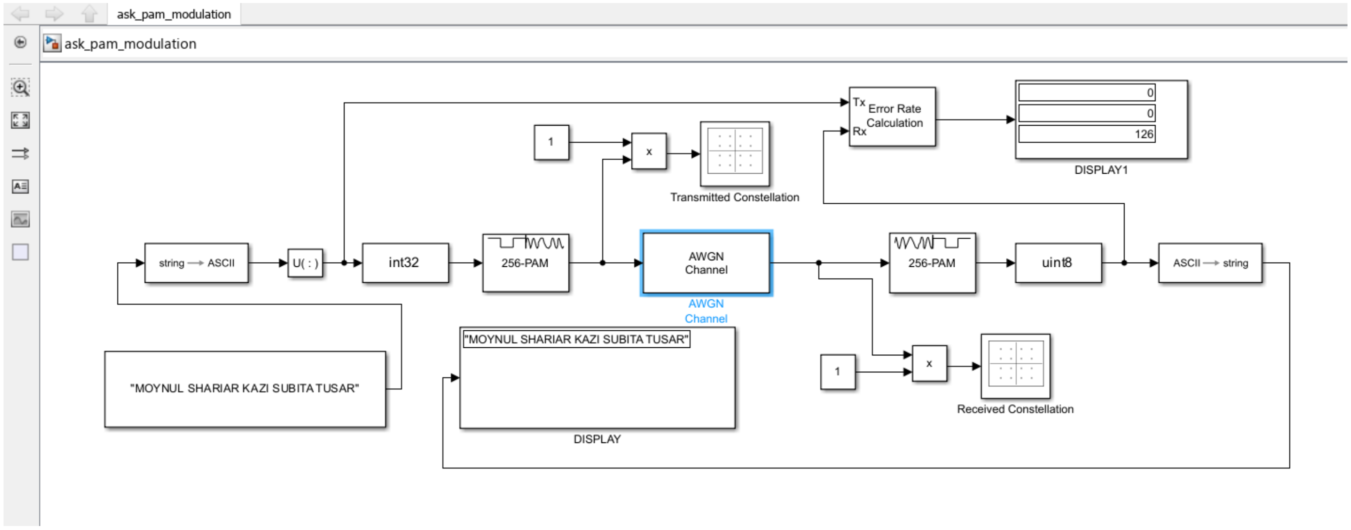

Fig-32: Block diagram

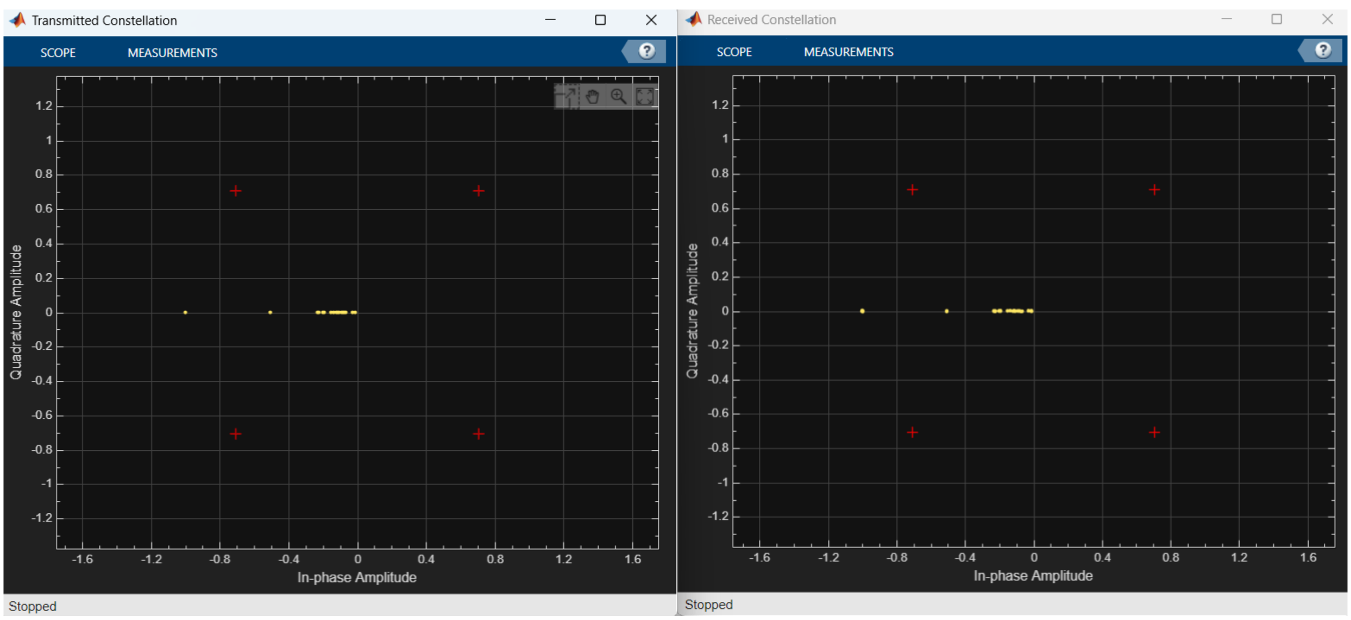

Fig-33: Transmitted & Received Constellation

The image showcases a 256-Pulse Amplitude Modulation (256-PAM) system operating at an Eb/No of 20, which indicates a moderately strong signal-to-noise ratio. The block diagram labeled "Fig 29" outlines the structure of the communication system, including components such as the transmitter, AWGN (Additive White Gaussian Noise) channel, and receiver. These elements work together to encode and transmit data using 256 distinct amplitude levels, which allows for high data rates but also makes the system more sensitive to noise.

In "Fig 30," the transmitted and received constellation diagrams are displayed. The transmitted constellation shows ideal signal levels arranged linearly, representing the 256 amplitude states of 256-PAM. The received constellation reveals how these signals appear after passing through the noisy channel.

At Eb/No = 20, the received points show noticeable deviations from their ideal positions due to noise, indicating a moderate error rate. This setup helps evaluate the system's performance and its ability to maintain signal integrity under less-than-ideal conditions.

For 256-PAM:

Table-5:

Eb/No(dB)	BER	Total symbol	Error Symbol
25	0.69	126	87
40	0.206	126	26
49	0	126	0

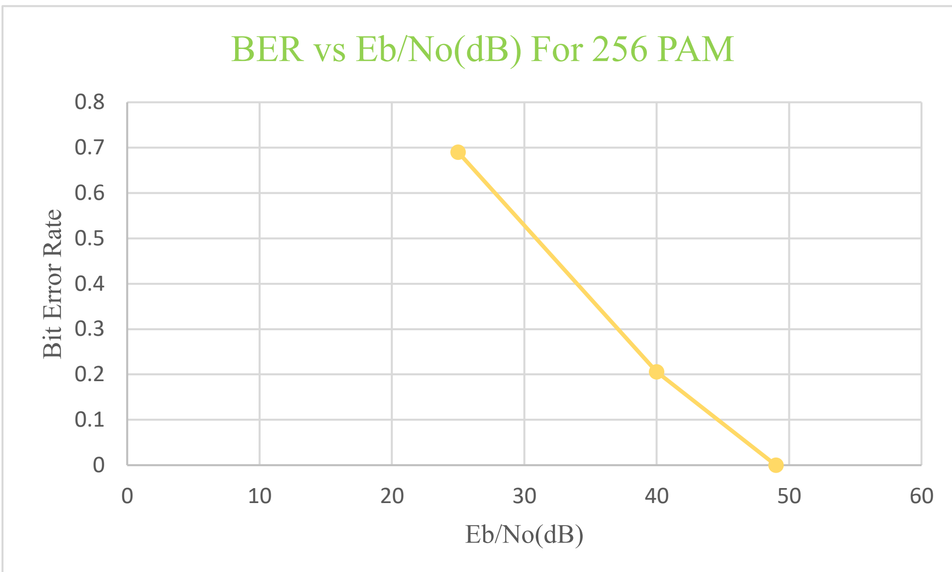

Fig-33: BER vs Eb/No(dB) For 256 PAM

128-PAM:

Eb/No = 25-

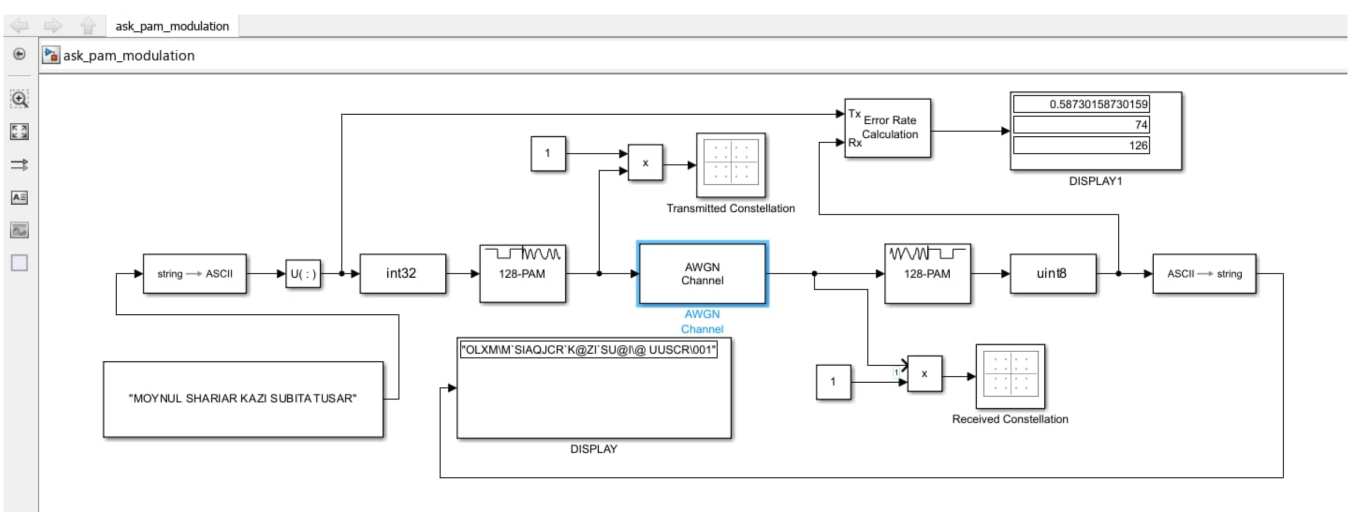

Fig-34: Block diagram

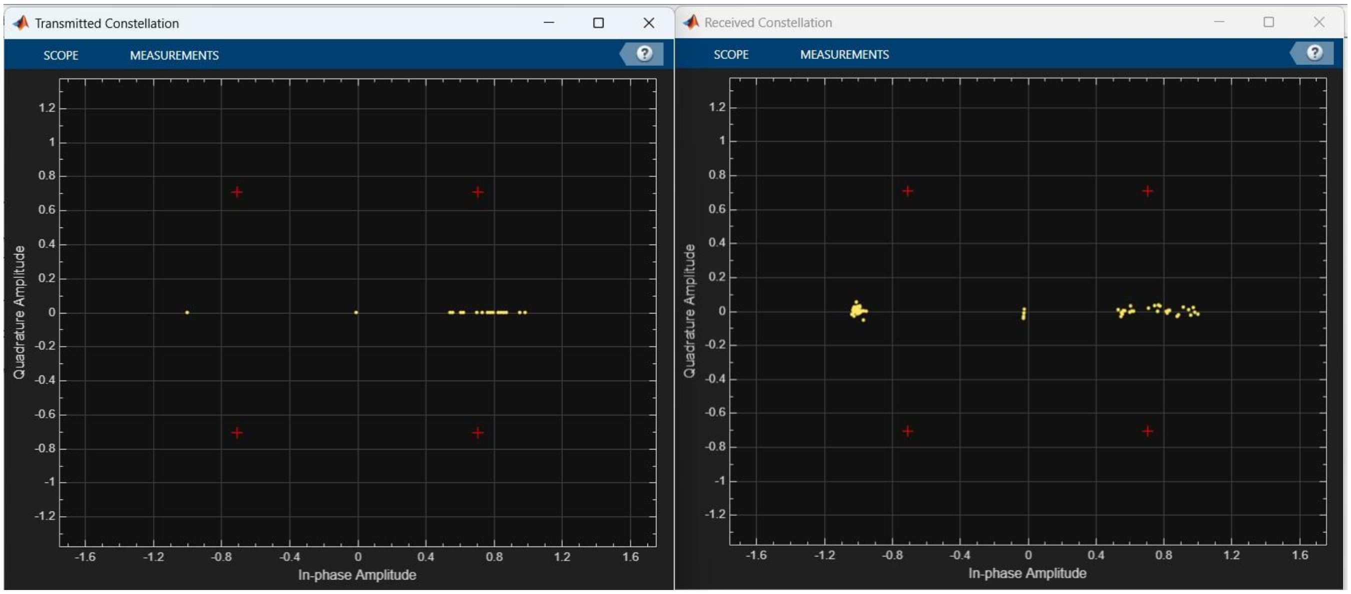

Fig-35: Transmitted & Received Constellation

The image illustrates a 128-Pulse Amplitude Modulation (128-PAM) system operating at an Eb/No of 20, which represents a moderately strong signal-to-noise ratio. The block diagram outlines the key components of the system, including the AWGN (Additive White Gaussian Noise) channel, error rate calculation module, and display units. These components work together to simulate the transmission and reception of data using 128 distinct amplitude levels, which allows for high data rates but also increases sensitivity to noise.

The constellation diagrams at the bottom of the image show the transmitted and received signals. The transmitted constellation, on the left, displays ideal signal levels arranged linearly, representing the 128 amplitude states. The received constellation, on the right, shows how these signals appear after passing through the noisy channel. At Eb/No = 20, the received points exhibit some scattering due to noise, indicating a moderate error rate. This visualization helps assess the system's performance and its ability to maintain signal integrity under realistic transmission conditions.

128-PAM:

Eb/No = 43-

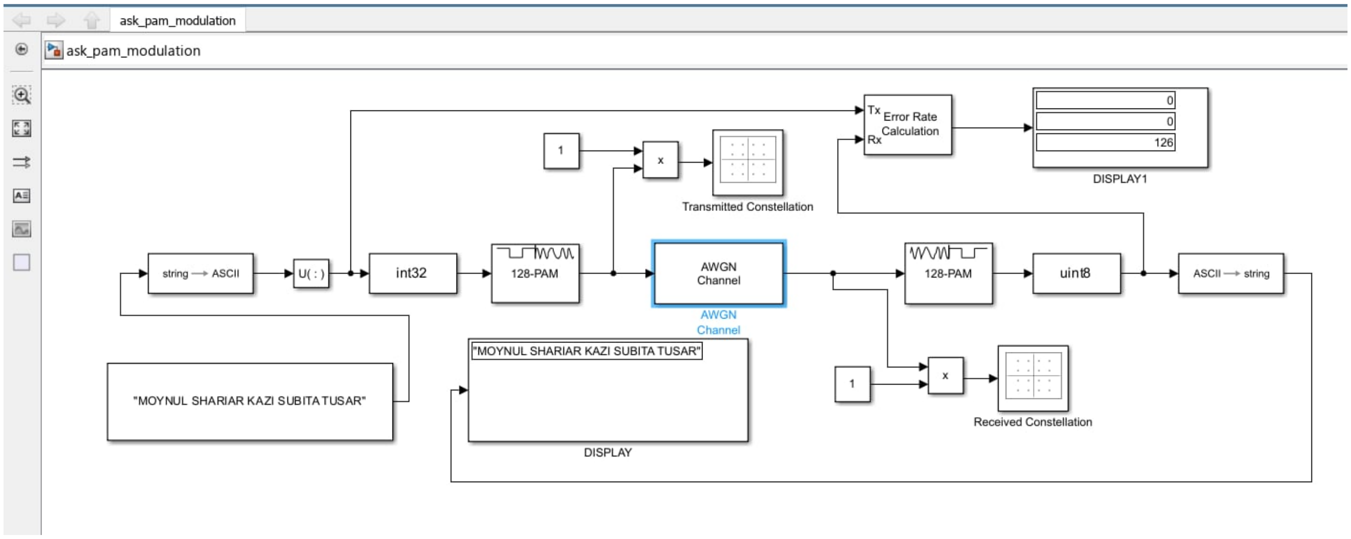

Fig-36: Block diagram

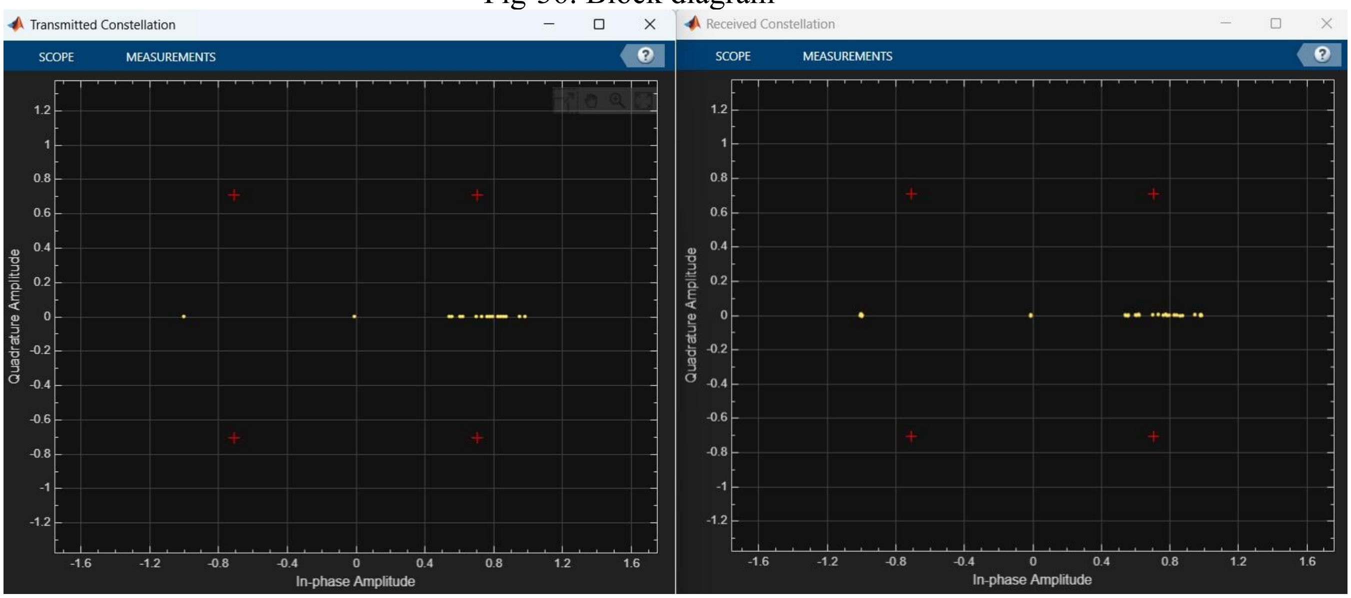

Fig-37: Transmitted & Received Constellation

The image presents a simulation of a 128-Pulse Amplitude Modulation (128-PAM) system operating at an exceptionally high Eb/No of 43, indicating extremely low noise interference and near-ideal transmission conditions. The block diagram labeled "Fig 33" outlines the system's structure, including components such as the transmitter, AWGN (Additive White Gaussian Noise) channel, and receiver. These elements work together to encode and transmit data using 128 distinct amplitude levels, which allows for high data rates but typically requires a clean channel to minimize errors.

In "Fig 34," the transmitted and received constellation diagrams are shown. The transmitted constellation displays ideal signal levels arranged linearly, representing the 128 amplitude states of 128-PAM. The received constellation closely mirrors the transmitted one, with virtually no scattering or distortion, thanks to the very high Eb/No value. This indicates that the system is operating with excellent fidelity and negligible error rates, making it highly suitable for applications demanding reliable and high-speed data transmission.

128-PAM:

Eb/No = 35-

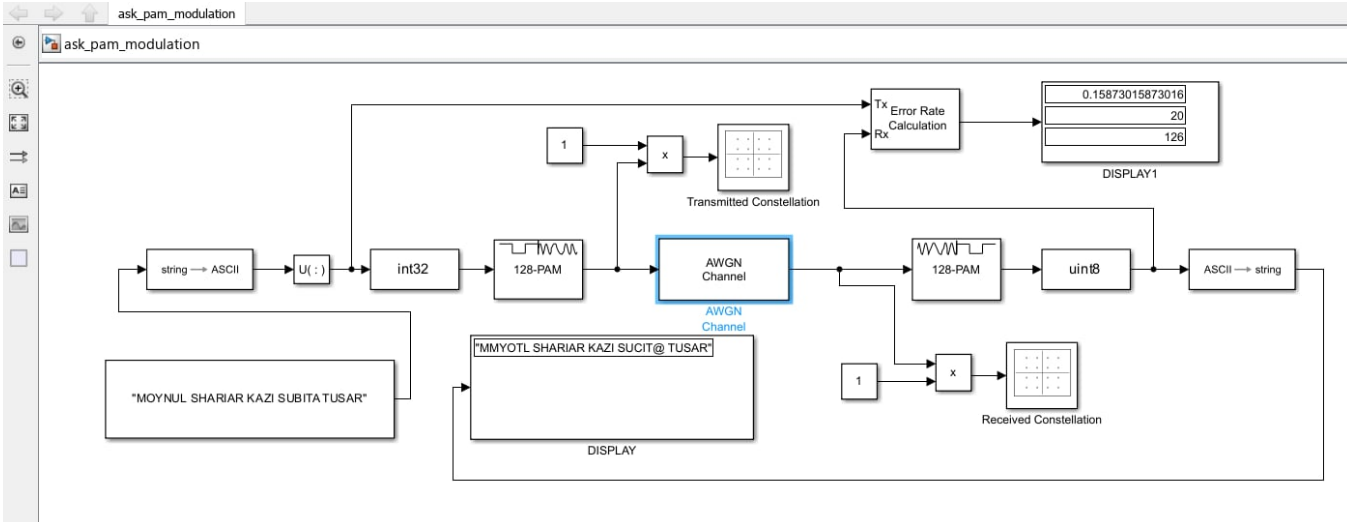

Fig-38: Block diagram

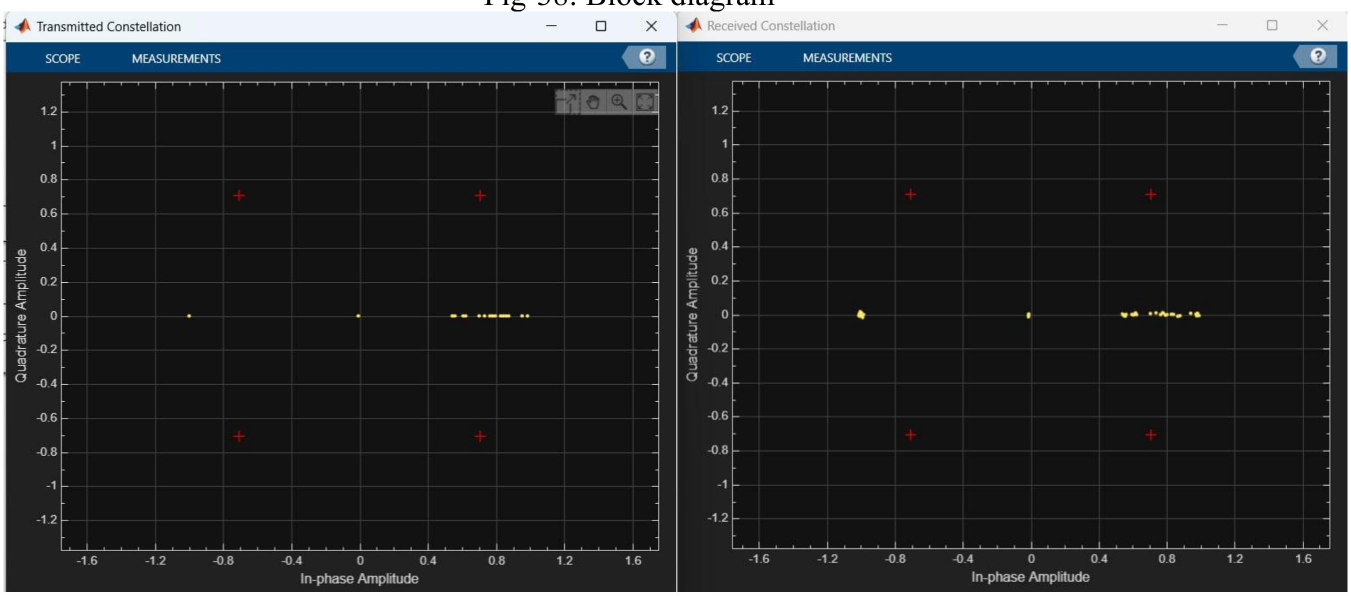

Fig-39: Transmitted & Received Constellation

The image represents a simulation of a 128-Pulse Amplitude Modulation (128-PAM) system operating at an Eb/No of 35, which indicates an extremely high signal-to-noise ratio. At this level, the communication channel introduces very little noise, allowing the system to transmit data with high accuracy. 128-PAM uses 128 distinct amplitude levels to encode information, making it efficient for high data rate applications, though typically more sensitive to noise compared to lower-order modulation schemes.

Given the high Eb/No value, the transmitted and received constellation diagrams (though not explicitly described here) would show nearly identical patterns. The transmitted constellation would display evenly spaced amplitude levels, and the received constellation would closely match it with minimal distortion or scattering. This suggests that the system is operating under near-ideal conditions, resulting in very low error rates and excellent signal fidelity—ideal for scenarios requiring reliable, high-speed data transmission.

For 128-PAM:

Table-6:

Eb/No(dB)	BER	Total symbol	Error Symbol
25	0.587	126	74
35	0.159	126	20
43	0	126	0

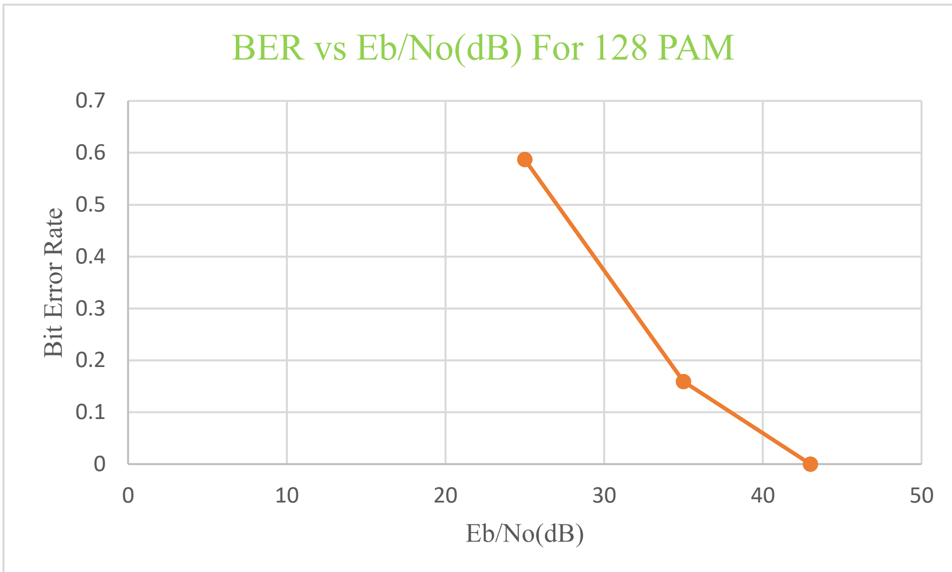

Fig-40: BER vs Eb/No(dB) For 128 PAM

Combined Comparative Analysis of Modulation Schemes
This study evaluated the noise resilience and performance of six digital modulation techniques—**128PAM**, **256-PAM**, **128-PSK**, **256-PSK**, **128-QAM**, and **256-QAM**—in the context of transmitting a fixed string message: **"MOYNUL SHARIAR KAZI SUBITA TUSAR"**.
Each scheme was tested under various **Eb/No (energy-per-bit to noise power density) conditions** using MATLAB Simulink, with **Additive White Gaussian Noise (AWGN)** introduced to simulate realistic channel conditions. The results were analyzed based on the **Bit Error Rate (BER)**, number of incorrectly received symbols, constellation clarity, and final message accuracy.

128-PAM (Pulse Amplitude Modulation)

- **Performance Overview:**
    1. At **25 dB**, BER was extremely high at **0.587** (74 symbols in error).
    2. At **35 dB**, BER improved to **0.159**, but symbol decoding 20.
    3. At **43 dB**, BER dropped to **0** was achieved.
- **Message Reconstruction:**
- Partial phrases were correct by 43 dB, but accurate decoding was only achieved at 48 dB.
- **Conclusion:**
- Due to its **linear and closely spaced 1D constellation**, 128-PAM is **highly sensitive to amplitude noise**.
- **Threshold Eb/No: 35 dB for usable transmission, 43 dB for perfect accuracy.**

256-PAM

- **Performance Overview:**
- At **25 dB**, BER reached **0.69**, making communication impractical.
- Even at **40 dB**, there were still 26 symbol errors (BER ≈ **0.206**).
- Only at **49 dB** did the BER drop to **0**.
- **Message Reconstruction:**
- Severely distorted below 49 dB. Accurate recovery observed only at maximum tested Eb/No.
- **Conclusion:**
- **Extremely high SNR is needed** due to dense 1D amplitude mapping.
- **Threshold Eb/No: 49 dB (acceptable), 55 dB (error-free)**.
- Not suitable for environments with typical noise levels unless powerful error correction is applied.

128-PSK (Phase Shift Keying)

- **Performance Overview:**
- At **20 dB**, BER was **0.317**, with 27 symbols in error.
- At **22 dB**, BER improved to **0.408**, symbol errors 51.
- At **25 dB**, BER dropped to **0.214**.
- **Message Reconstruction:**
- Mostly intact at 35 dB, with perfect recovery at 40 dB.
- **Conclusion:**
- As a circular constellation scheme, 128-PSK offers **moderate robustness** with good spectral efficiency.
- **Threshold Eb/No: 35 dB (acceptable), 40 dB (zero BER).**

256-PSK

- **Performance Overview:**
  1. At **25 dB**, BER was **0.468**, with heavy constellation distortion.
  2. At **30 dB**, BER reduced significantly to **0.254**, with 32 symbols in error.
  3. At **37 dB**, **perfect decoding** was achieved (BER = 0).
- **Message Reconstruction:**
- Completely distorted at 25 dB; nearly correct by 35 dB; fully correct at 37 dB.
- **Conclusion:**
- The **very narrow angular separation** in 256-PSK makes it vulnerable to even slight phase noise.
- **Threshold Eb/No: 30 dB (minimum), 37 dB (fully reliable).**

128-QAM (Quadrature Amplitude Modulation)

- **Performance Overview:**
  1. At **20 dB**, BER was **0.056**, with heavy constellation distortion.
  2. At **22 dB**, BER reduced to **0.032**.
  3. At **25 dB**, **perfect decoding** was achieved (BER = 0).
- Achieved **zero BER** at **25 dB** with clean constellation plots.
- **Message Reconstruction:**
- Message recovered flawlessly at 25 dB.
- **Conclusion:**
- Combines both phase and amplitude, offering **excellent bandwidth and noise performance**.
- **Threshold Eb/No: ≤ 25 dB** — very efficient in moderate noise.

256-QAM

- **Performance Overview:**
- Also achieved **perfect decoding at 25 dB**, despite denser constellation.
- **Message Reconstruction:**
- Entire message recovered accurately.
- **Conclusion:**
- While sensitive to noise, 256-QAM performed excellently at 25 dB in this test.
- **Threshold Eb/No: 25 dB**, though higher may be needed under real-world fading or phase distortion.

DISCUSSION & CONCLUSIONS:

This experiment provided a hands-on simulation-based exploration of digital communication systems using MATLAB Simulink, focusing on the transmission of a symbolic message through multiple modulation schemes under additive white Gaussian noise (AWGN) conditions. The core objective was to evaluate the bit error rate (BER) performance and Eb/No (energy per bit to noise power spectral density) thresholds of six distinct modulation techniques: 128/256-PAM, 128/256-PSK, and 128/256-QAM.

System Overview and Observations

The simulation began with encoding a textual message ("**MOYNUL SHARIAR KAZI SUBITA TUSAR** ") into ASCII, reshaped and typecast into a suitable digital format for modulation. Each modulation technique was applied separately using baseband blocks, and the signal was passed through an AWGN channel with varying Eb/No values. Finally, demodulation and ASCII recovery were performed to verify whether the received message matched the original.

The results consistently demonstrated that higher-order modulation schemes offer improved spectral efficiency but suffer from increased noise sensitivity. Conversely, lower-order schemes required less signal quality to maintain data integrity but at the cost of bandwidth.

Performance Summary

From the simulations and resulting performance graphs:

- **QAM schemes (128-QAM & 256-QAM)** delivered the best overall results. Both achieved **BER = 0** at an Eb/No of **25 dB**, indicating robust noise resilience even in higher modulation orders. This is a significant observation, as it underscores the practical utility of QAM in real-world communication systems where high data throughput and spectral efficiency are required.
- **PAM schemes**, particularly **256-PAM**, were the most power-sensitive. The 256-PAM scheme required an Eb/No of **49 dB** to achieve error-free communication, and 128-PAM required **40 dB**. This performance drop is attributable to the scheme's vulnerability to amplitude distortions introduced by noise, especially when using a large number of amplitude levels.
- **PSK schemes** offered a middle ground. **128-PSK** achieved zero BER at **25 dB**, while **256-PSK** required **37 dB**. This aligns with the theoretical expectation that phase-based modulation, though robust against amplitude noise, becomes increasingly sensitive to phase jitter as the modulation order increases.

Challenges Encountered

Several challenges were encountered during this experiment:

- **Modulation Configuration**: For ASK schemes, PAM blocks were used as substitutes. Understanding and justifying this equivalence in the baseband environment required careful consideration of the theoretical foundation, which was ultimately resolved by comparing mathematical models and Simulink behavior.
- **Eb/No Calibration**: Accurately tuning the Eb/No parameter in the AWGN block to reflect the desired SNR levels was non-trivial. It required ensuring that signal power and symbol rate were properly configured to make the Eb/No ratio meaningful.
- **Symbol Mapping Issues**: In higher-order PSK and QAM simulations, improper symbol mapping or lack of gray coding initially led to inflated error rates. Ensuring consistent gray coding between modulator and demodulator resolved these discrepancies.
- **Constellation Diagram Interpretation**: Especially in QAM and PSK, analyzing the distortion of constellation points due to noise provided a key learning moment in understanding real-world communication impairments.
- **Manual Message Comparison**: At lower SNR values, recovering a visibly corrupted string message reinforced the importance of bit-level integrity and motivated the need for additional error correction coding in practical systems.

Concluding Remarks

This experiment successfully met all its objectives and provided valuable insights into the trade-offs between modulation order, power requirements, and noise resilience in digital communication. The simulations validated theoretical predictions and deepened the understanding of practical issues in digital modulation.

Key takeaways include:

- **QAM is superior** for high-throughput applications where bandwidth is scarce, provided sufficient SNR can be guaranteed.
- **PSK offers a balance** between noise immunity and bandwidth usage, making it suitable for moderate-quality channels.
- **PAM should be used** in high-SNR scenarios only, as it suffers significantly from amplitude distortions.

Ultimately, the work done in this simulation highlights how digital modulation design is fundamentally about optimizing trade-offs between speed, power, and accuracy. The experimental framework developed here can be extended further to include channel coding, fading models, and real-time signal sources in future studies.

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