Experiment No. 7 (IEC2023006) :

Aim:

To analyze the Bit Error Rate (BER) performance of a Quadrature Phase Shift Keying (QPSK) system over an AWGN channel using Simulink and compare simulated BER with theoretical BER.

Theory:

1. **QPSK Modulation :**

   QPSK is a digital modulation technique where **2 bits** are mapped into **one symbol**, represented by:

   $$s_k = A\left[\cos(\theta_k) + j\sin(\theta_k)\right], \quad \theta_k = \frac{\pi}{2}(2k+1)$$

   It provides:

   - Higher spectral efficiency than BPSK
   - Same energy per bit
   - Robust performance in AWGN channels

2. **AWGN Channel :**

   The channel adds noise n(t)~N(0,N0/2)

   Signal received: **r(t)=s(t)+n(t)**

3. **Theoretical BER of QPSK :**

   QPSK BER equals BPSK BER:

   $$P_b = Q\left(\sqrt{2\frac{E_b}{N_0}}\right)$$

   Where:

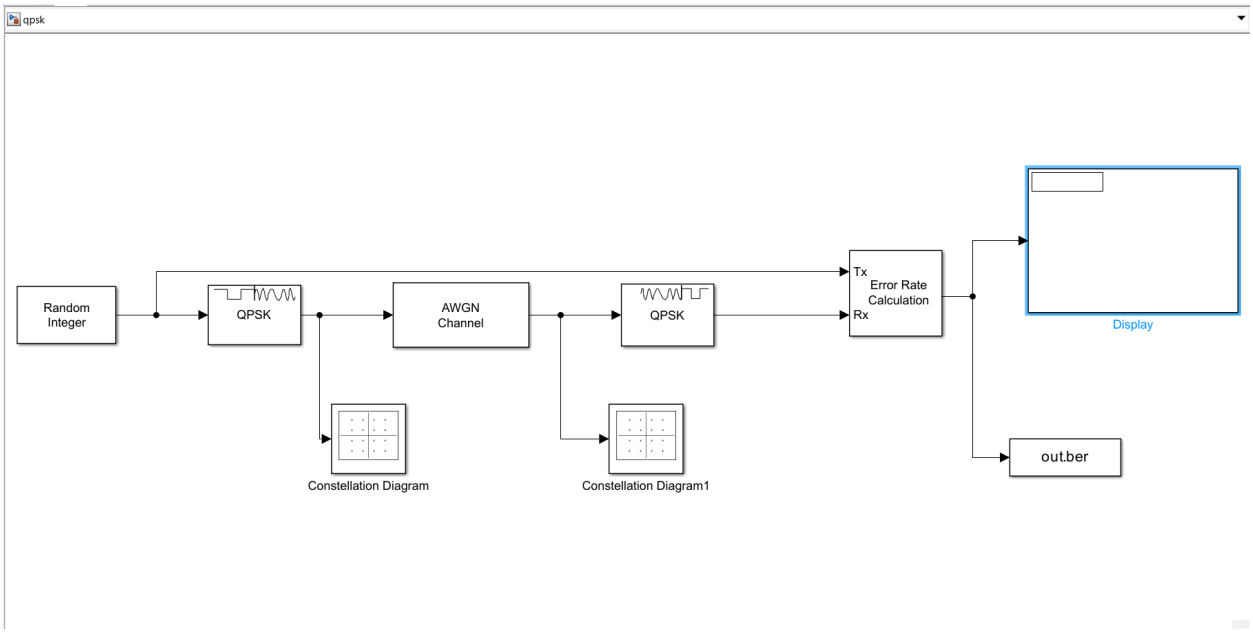
   $$Q(x) = \frac{1}{\sqrt{2\pi}}\int_x^\infty e^{-u^2/2}du$$

Simulink Model Description :

The Simulink model includes:

1. Random Integer Generator : Generates random data symbols (0,1,2,3)
2. QPSK Modulator : Maps integers to QPSK constellation points.
3. AWGN Channel : Adds noise based on selected Eb/No.
4. QPSK Demodulator : Recovers symbols.
5. Error Rate Calculation Block : Compares transmitted and received symbols.

6. Constellation Diagram Blocks : Shows before/after noise scatter.



Simulation Parameters (Theoretical):

Bit Error Rate Analysis*

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Plot	BER Data Set	Eb/N0 (dB)	BER	# of Bits	Confidence Level	Fit	Run Time
☑	theoretical-exact0	0, 1, 2, 3, 4, 5, 6, 7, 8,	0.07865, 0.056282, 0	N/A	N/A	N..	N/A
☑	simulation0	0, 1, 2, 3, 4, 5, 6, 7, 8,	0.307, 0.232, 0.181, 0	1000, 1000, 1000, 1	off	☐	00:00:22
☑	simulation1	0, 1, 2, 3, 4, 5, 6, 7, 8,	0.292, 0.242, 0.193, 0	1000, 1000, 1000, 1	off	☐	00:00:32
☑	simulation2	0, 1, 2, 3, 4, 5, 6, 7, 8,	0.272, 0.23, 0.183, 0.	1000, 1000, 1000, 1	off	☐	00:00:20

Monte Carlo | Theoretical

E_b/N_0 range: 0:20 dB

Channel type: AWGN

Modulation type: OQPSK

Modulation order: 4

Differential encoding

Demodulation type:

Coherent

Channel coding:

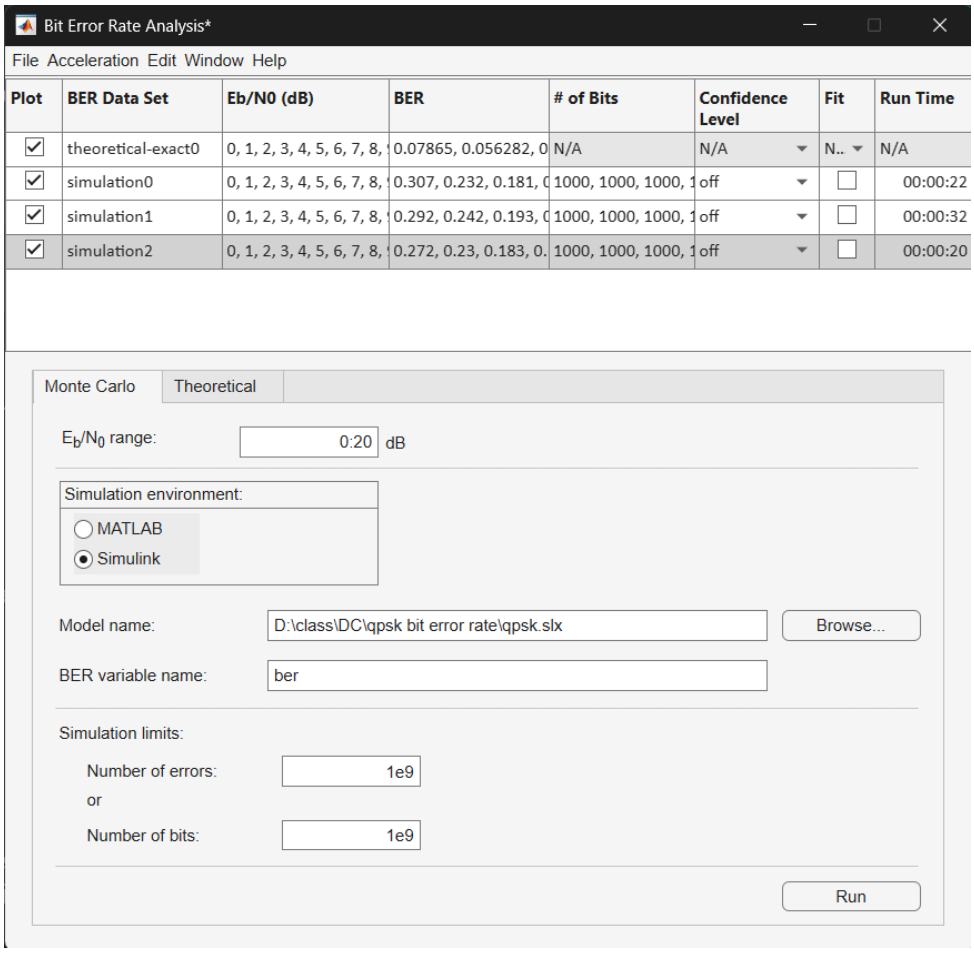
- None
- Convolutional
- Block

Synchronization:

- Perfect synchronization
- Normalized timing error: 0
- RMS phase error (rad): 0

Plot

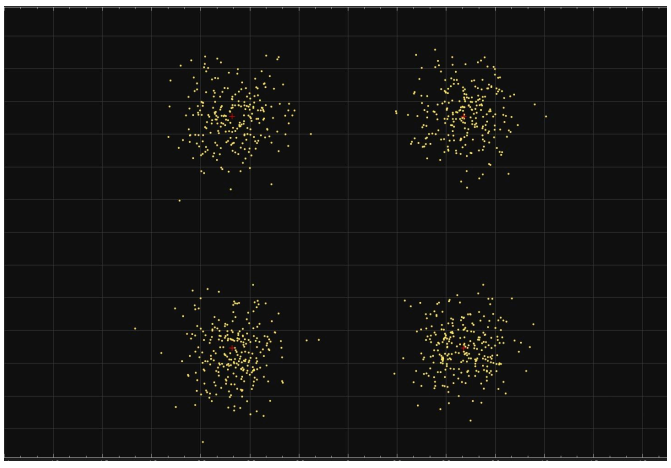
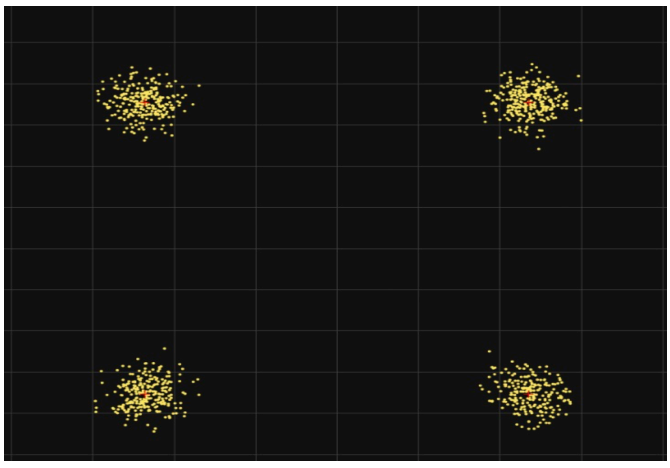
Simulation Parameters (Monte Carlo):



Results :

1. Constellation Plots

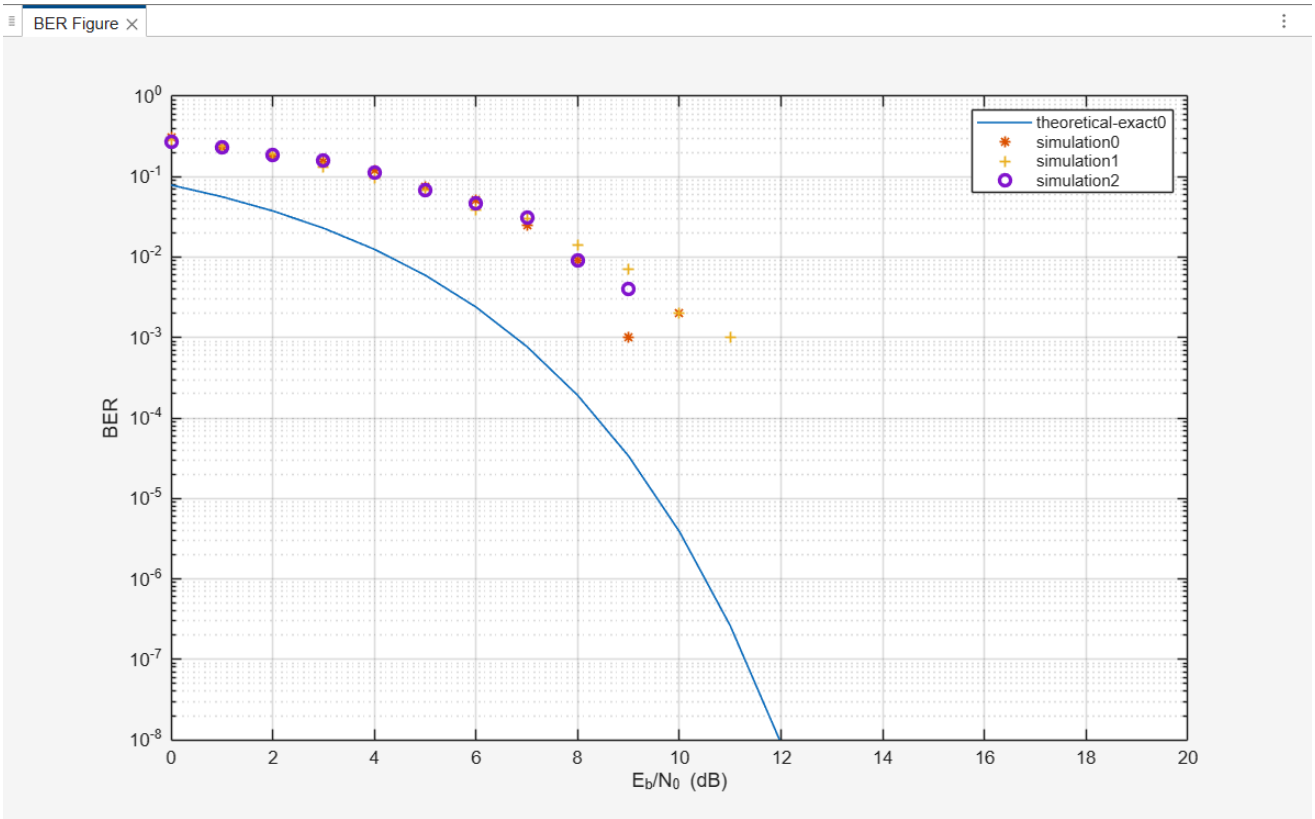
- **High noise:** 4-symbol constellation at QPSK positions at 7db.
- **Low noise:** Clusters spread depending on SNR 20db.

7dB	20dB
	

2. BER Curve

The plotted BER vs Eb/No graph shows:

- BER **decreases exponentially** with increasing Eb/No.
- Simulated BER approaches theoretical BER for **large number of bits**.
- At low SNR (0–5 dB), noise causes significant symbol errors.
- At high SNR (>12 dB), simulation approaches **error-free performance**.



Conclusion :

The experiment successfully demonstrated BER performance of a QPSK system under AWGN conditions.
Simulation results closely follow the theoretical BER curve, validating the QPSK modulation and demodulation process.
Higher SNR significantly improves BER, confirming that QPSK is a robust and bandwidth-efficient modulation scheme.