Instructions

- Answer all questions clearly and completely.
- Use appropriate figures, labels, and legends where necessary.
- Report all calculated probabilities up to 2 decimal places.
- Discuss any observed discrepancies between theoretical and simulated results.

Objective

This lab aims to introduce students to basic MATLAB simulation of binary signaling techniques over an Additive White Gaussian Noise (AWGN) channel. You will simulate the Bit Error Rate (BER) for two modulation schemes and compare with theoretical expectations.

Question 1: BER vs E_b/N_0

You will implement two binary signaling schemes:

- **Polar Signaling:** Map bits using $0 \rightarrow -\sqrt{E_b}$, and $1 \rightarrow +\sqrt{E_b}$
- **On-Off Keying (OOK):** Map bits to $0 \rightarrow 0$, and $1 \rightarrow \sqrt{2E_b}$

Theoretical Bit Error Rates:

$$\text{BER}_{\text{polar}} = Q\left(\sqrt{\frac{2E_b}{N_0}}\right), \quad \text{BER}_{\text{OOK}} = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$$

Steps to Follow

1. Generate a random binary vector of $N = 10^5$ bits using `randi([0 1],1,N)`.
2. Define an array of E_b values from 3 to 10 dB.
3. For each E_b (in linear scale):
   - Generate Gaussian noise with variance $N_0/2 = 1$.
   - For **Polar Signaling**:
     - Map bits to $\pm\sqrt{E_b}$
     - Detection rule: if $r > 0$, decide 1; else 0
   - For **OOK**:
     - Map bits to $1 \to \sqrt{2E_b}$ and $0 \to 0$
     - Use threshold $\gamma = \sqrt{E_b/2}$: if $r > \gamma$, decide 1; else 0
   - Compute simulated BER and theoretical BER using `qfunc()`.
4. **Figure 1:** Plot theoretical and simulated BER vs E_b/N_0 (in dB), both schemes on the same graph.

Question 2: Data Rate vs BER

(a) Assume the received power is $P_r = 10$ mW.

(b) Vary data rate R_b from 500 bps to 5000 bps.

(c) Compute $E_b = \frac{P_r}{R_b}$ for each data rate.

(d) Assume $N_0/2 = 10^{-6}$ W/Hz and compute E_b/N_0 in dB.

(e) Simulate the BER for both Polar and OOK schemes across this data rate range.

(f) **Figure 2:** Plot theoretical and simulated BER vs R_b (in bps), both schemes on the same graph.