Question-2

Interpretations of Observed values

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Interpretation of Observed Values:

1. **Threshold for Reliable Communication:**
    - The values of Eb/N0 corresponding to 10^{-2} and 10^{-5} indicate the minimum signal-to-noise ratio (SNR) needed for reliable communication.
    - A lower Eb/N0 results in more bit errors, making the system vulnerable to noise.
2. **Performance Improvement with Increasing Eb/N0:**
    - Higher Eb/N0 values reduce noise impact, leading to lower bit error rates (BER).
    - Achieving very low BER (such as 10^{-5}) requires substantially higher Eb/N0, though with diminishing returns.
3. **Trade-off Between Power and Performance:**
    - While higher Eb/N0 reduces BER, it demands greater transmission power.
    - The values at 10^{-2} and 10^{-5} demonstrate the power efficiency trade-off—showing the dB cost of achieving lower BER.
4. **Comparison with Theoretical Predictions:**
    - Simulated error rates should align with the theoretical curve.
    - Any deviations may stem from practical limitations such as imperfect noise generation or MATLAB's numerical precision.

The Key take aways:

The observed Eb/N0 values in our BPSK simulation reveal important insights about system performance under noisy conditions.

1. Eb/N0 = 4.38 dB
   At this signal-to-noise ratio (SNR), the system has one bit error per 100 transmitted bits. This operates in a low-SNR range where noise significantly affects performance.

Practical Implications: This SNR level suits scenarios that tolerate moderate error rates. Systems operating at this threshold can use error correction coding (ECC) to improve reliability without increasing transmission power.

Theoretical Context: The theoretical Eb/N0 for BER = 10^{-2} is 4.32 dB (derived from the Q-function). The small difference in simulation results stems from finite sample size (N = 12,000) and Monte Carlo simulation noise.

1. Eb/N0 = 9.79 dB
   At this SNR, the system achieves one bit error per 100,000 transmitted bits—indicating high reliability. This level is essential for fiber optics, deep-space communication, and ultra-reliable 5G/6G links.

Practical Implications: Achieving this SNR requires higher transmission power, advanced coding techniques (LDPC, polar codes), or diversity methods like MIMO.

Theoretical Context: The theoretical Eb/N0 for this BER is 9.59 dB. The difference occurs because low error rates need more samples for accurate estimation. In this region, small SNR changes dramatically affect BER due to the steep curve.

Higher Eb/N0 strengthens signal quality and reduces bit errors, improving system reliability.