Assignment 9: MATLAB code for BER generation of Spread Spectrum QPSK system over fading channel.

Due date: Max. marks: 20

Write a MATLAB code to generate Bit Error Rate (BER) vs Bit-Energy-to-Noise-Power-Spectral-Density ratio ($E_b/N_0$) plot for Spread Spectrum Quadrature Phase Shift Keying (QPSK) system over Rayleigh fading channel (averaged over at least 1000 iterations). Assume system employs a Hadamard sequence of length 4 for spreading data. Fig. 1 depicts a QPSK Spread Spectrum modulator and demodulator system. Referring to the same, answer the following:

Important Note: Refer to the equalizer and channel generation portions of the code provided in tutorial 7 in Week 9 content, and use the same to solve this assignment.

Figure 1: QPSK spread spectrum modulator and demodulator system with fading channel.
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<th>Mathematical notation</th>
<th>MATLAB variable</th>
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</tr>
<tr>
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<td>$Q_{\text{data}}$</td>
</tr>
<tr>
<td>Baseband complex data</td>
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<td>$\text{base}_{\text{sig}}$</td>
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<tr>
<td>Spreading code</td>
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<tr>
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<tr>
<td>Decay parameter for channel</td>
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<td>Channel impulse response without normalization</td>
<td>$c_{\text{un}}$</td>
<td>$\text{imp}<em>{\text{res}</em>{\text{unnorm}}}$</td>
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<tr>
<td>Channel impulse response with normalization</td>
<td>$c_{\text{n}}$</td>
<td>$\text{imp}_{\text{res}}$</td>
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<td>Channel power</td>
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<td>Transmit spread signal after channel</td>
<td>$s'$</td>
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</tr>
<tr>
<td>Received signal</td>
<td>$r$</td>
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<td>Despread signal</td>
<td>$r_d$</td>
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<td>Decoded in-phase data</td>
<td>$\hat{i}$</td>
<td>$\text{decod}<em>{\text{sig}</em>{I}}$</td>
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<tr>
<td>Decoded quadrature data</td>
<td>$\hat{q}$</td>
<td>$\text{decod}<em>{\text{sig}</em>{Q}}$</td>
</tr>
</tbody>
</table>

Table 1: Table of notations.

1. The corresponding multipath delay index vector can be generated using the MATLAB command:
   (2 marks)
   i. $\text{tau}=0:\text{no}_{\text{multipath}}$;
   ii. $\text{tau}=0:\text{no}_{\text{multipath}}-1$;
   iii. $\text{tau}=0:\text{no}_{\text{multipath}}+1$;
   iv. $\text{tau}=1:\text{no}_{\text{multipath}}-1$;

2. For a given decay parameter, the MATLAB command to generate exponential power delay profile of the channel is:
   (2 marks)
   i. $P_{\text{ch}}=1-\exp(-\text{decay}_{\text{para}}*\text{tau})$;
   ii. $P_{\text{ch}}=\exp(\text{decay}_{\text{para}}*\text{tau})$;
   iii. $P_{\text{ch}}=1-\exp(\text{decay}_{\text{para}}*\text{tau})$;
iv. \( \text{PDP} = \exp(-\text{decay\_para} \times \text{tau}) \); 

3. The MATLAB command to generate multipath channel components with Rayleigh distributed amplitude and uniformly distributed phase is:

(2 marks)

i. \( \text{Rayleigh\_amp} = (1/\sqrt{2}) \times (\text{randn}(1, \text{no\_multipath}) + j \times \text{randn}(1, \text{no\_multipath})) \);

ii. \( \text{Rayleigh\_amp} = (1/\sqrt{2}) \times (\text{rand}(1, \text{no\_multipath}) + j \times \text{rand}(1, \text{no\_multipath})) \);

iii. \( \text{Rayleigh\_amp} = (1/\sqrt{2}) \times (\text{rand}(1, \text{no\_multipath} - 1) + j \times \text{rand}(1, \text{no\_multipath} - 1)) \);

iv. \( \text{Rayleigh\_amp} = (1/\sqrt{2}) \times (\text{randn}(1, \text{no\_multipath} - 1) + j \times \text{randn}(1, \text{no\_multipath} - 1)) \);

4. The MATLAB command to generate channel impulse response (without normalization) is:

(2 marks)

i. \( \text{imp\_res\_unnorm} = \text{Rayleigh\_amp} \times \text{PDP} \);

ii. \( \text{imp\_res\_unnorm} = \text{Rayleigh\_amp} \times \sqrt{\text{PDP}} \);

iii. \( \text{imp\_res\_unnorm} = \text{Rayleigh\_amp} \times \sqrt{\text{PDP}} \);

iv. \( \text{imp\_res\_unnorm} = \text{Rayleigh\_amp} / \sqrt{\text{PDP}} \);

5. The MATLAB command to calculate the net power of the channel multipath components (of the channel generated in question no. 4) is:

(2 marks)

i. \( \text{ch\_power} = \text{sum}((\text{imp\_res\_unnorm})^2) \);

ii. \( \text{ch\_power} = \text{sum}(\text{abs(imp\_res\_unnorm)}) \);

iii. \( \text{ch\_power} = \text{sum}(\text{abs(imp\_res\_unnorm})^2) \);

iv. \( \text{ch\_power} = \text{sum}(\text{imp\_res\_unnorm}) \);

6. The effect of multipath channel on transmitted data \( s \) can be captured using MATLAB command:

(2 marks)

i. \( \text{conv(tx\_data, imp\_res)} \);

ii. \( \text{tx\_data} \times \text{imp\_res} \);

iii. \( \text{kron(tx\_data, imp\_res)} \);

iv. \( \text{tx\_data} \times \text{imp\_res} \);

7. For a decay parameter, \( \alpha = 1.2 \) and number of multipath components, \( l = 4 \), the BER vs EbNo (averaged over atleast 10000 iterations) plot is approximately:

(4 marks)
i.

![Graph of BER vs. Eb/No in dB for the first scenario. The y-axis represents BER on a logarithmic scale, ranging from $10^{-2}$ to $10^0$. The x-axis represents Eb/No in dB, ranging from -2 to 12. The graph shows a decreasing trend as Eb/No increases.]

ii.

![Graph of BER vs. Eb/No in dB for the second scenario. The y-axis represents BER on a logarithmic scale, ranging from $10^{-4}$ to $10^0$. The x-axis represents Eb/No in dB, ranging from -2 to 10. The graph shows a decreasing trend as Eb/No increases.]
iii. 

iv. 

[Graphs showing BER vs. Eb/No in dB for different ranges of Eb/No]
8. For a decay parameter, $\alpha=2.5$ and number of multi-path $l=4$, the BER vs EbNo (averaged over at least 10000 iterations) plot is approximately:

(4 marks)

i.

![Graph 1](image1)

ii.

![Graph 2](image2)