Assignment 10: MATLAB code for BER generation of Spread Spectrum MU 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 multi-user (MU) Spread Spectrum Quadrature Phase Shift Keying (QPSK) system over Rayleigh fading channel (averaged over at least 1000 iterations). Assume that the system employs Hadamard sequences of length 4 for spreading data. Fig. 1 depicts typical QPSK Spread Spectrum modulator. Fig. 2 incorporates Fig. 1 as transmitter for respective users and depicts a single (desired) user demodulator over a fading channel. 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.
In-phase detection
Quadrature detection
BER calculation
Despread

Fig. 1: Block diagram for individual user spread spectrum (SS) signal generation

User 1 SS signal
User 2 SS signal
User 3 SS signal

Fig. 2: Block diagram of a multiuser SS transmitter and single user receiver system over fading channel

Bipolar In-phase stream generation
Bipolar quadrature stream generation
Complex operator, j

$t_{sig}$

Fading Channel
Despread

In-phase detection
Quadrature detection

BER calculation

$\hat{i}$

$\hat{q}$
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mathematical notation</th>
<th>MATLAB variable</th>
</tr>
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<tr>
<td>Number of baseband data samples</td>
<td>$N_s$</td>
<td>no_sample</td>
</tr>
<tr>
<td>Number of user</td>
<td>$N$</td>
<td>$N$</td>
</tr>
<tr>
<td>In-phase bipolar data for user $x$</td>
<td>$i_x$</td>
<td>$I_{\text{data.mat}}(x,:)$</td>
</tr>
<tr>
<td>Quadrature bipolar data for $x$</td>
<td>$q_x$</td>
<td>$Q_{\text{data.mat}}(x,:)$</td>
</tr>
<tr>
<td>Baseband complex spread data for user $x$</td>
<td>$s_x^*$</td>
<td>$\text{base.sig.mat}(x,:)$</td>
</tr>
<tr>
<td>Spreading code for user $x$</td>
<td>$s_x$</td>
<td>$\text{code_mat}(x+1,:)$</td>
</tr>
<tr>
<td>Transmitted multiuser signal</td>
<td>$t_{\text{sig}}$</td>
<td>$\text{comb.tx.sig}$</td>
</tr>
<tr>
<td>Number of multipath components</td>
<td>$l$</td>
<td>no_multipath</td>
</tr>
<tr>
<td>Multipath delay index vector</td>
<td>$\tau$</td>
<td>tau</td>
</tr>
<tr>
<td>Decay parameter for channel</td>
<td>$\alpha$</td>
<td>decay_para</td>
</tr>
<tr>
<td>Power delay profile vector</td>
<td>$P(\tau)$</td>
<td>PDP</td>
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<tr>
<td>Complex channel with Rayleigh amplitude and uniformly distributed phase</td>
<td>$c_{\text{amp}}$</td>
<td>Rayleigh_amp</td>
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<tr>
<td>Channel impulse response without normalization</td>
<td>$c_{\text{un}}$</td>
<td>$\text{imp.res.unnorm}$</td>
</tr>
<tr>
<td>Channel impulse response with normalization</td>
<td>$c_{\text{n}}$</td>
<td>$\text{imp.res}$</td>
</tr>
<tr>
<td>Channel power</td>
<td>$P_{\text{ch}}$</td>
<td>$\text{ch.power}$</td>
</tr>
<tr>
<td>Transmit spread signal after channel</td>
<td>$s'$</td>
<td>$\text{tx.data.ch}$</td>
</tr>
<tr>
<td>AWGN channel noise</td>
<td>$n$</td>
<td>$n_{\text{AWGN}}$</td>
</tr>
<tr>
<td>Received signal</td>
<td>$r$</td>
<td>rec_data</td>
</tr>
<tr>
<td>Despread signal</td>
<td>$r_d$</td>
<td>despread_data</td>
</tr>
<tr>
<td>Decoded in-phase data</td>
<td>$\hat{i}$</td>
<td>$\text{decod.sig.I}$</td>
</tr>
<tr>
<td>Decoded quadrature data</td>
<td>$\hat{q}$</td>
<td>$\text{decod.sig.Q}$</td>
</tr>
</tbody>
</table>

Table 1: Table of notations.

1. If the bipolar binary data of two users is stored row-wise in a matrix, the MATLAB command to select the in-phase data of user 2 is:

   (2 marks)
   
   i. $I_{\text{data.mat}}(2,:) = 2*(\text{rand}(1,\text{no.samples}) \geq 0.5) - 1$;
   
   ii. $I_{\text{data.mat}}(2,:) = 2*(\text{rand}(1,\text{no.samples}) \geq 0.5) - 2$;
   
   iii. $I_{\text{data.mat}}(:,2) = 2*(\text{rand}(1,\text{no.samples}) \geq 0.5) - 2$;
   
   iv. $I_{\text{data.mat}}(:,2) = 2*(\text{rand}(1,\text{no.samples}) \geq 0.5) - 1$;

2. The MATLAB command to spread data of user 1 using the code generated in the second row of the Hadamard matrix is:

   (2 marks)
   
   i. $\text{base.sig.mat}(1,:) = \text{kron}(I_{\text{data.mat}}(1,:)+j*Q_{\text{data.mat}}(1,:),\text{code_mat}(1,:))$;
   
   ii. $\text{base.sig.mat}(1,:) = (I_{\text{data.mat}}(1,:)+j*Q_{\text{data.mat}}(1,:)).*\text{code_mat}(2,:)$;
iii. \( \text{base} \_\text{sig} \_\text{mat}(1,:) = \text{kron}((\text{I}_\text{data} \_\text{mat}(1,:)+j*\text{Q}_\text{data} \_\text{mat}(1,:)),\text{code} \_\text{mat}(2,:)); \)

iv. \( \text{base} \_\text{sig} \_\text{mat}(1,:) = (\text{I}_\text{data} \_\text{mat}(1,:)+j*\text{Q}_\text{data} \_\text{mat}(1,:))\.*\text{code} \_\text{mat}(1,:); \)

3. The power of the combined multi-user transmitted data can be calculated using the MATLAB command:

(2 marks)

i. \( \text{pow} \_\text{txdata} = \text{sum}((\text{comb} \_\text{tx} \_\text{sig}).^2); \)

ii. \( \text{pow} \_\text{txdata} = \text{sum}((\text{comb} \_\text{tx} \_\text{sig}).^2)/\text{N}; \)

iii. \( \text{pow} \_\text{txdata} = \text{sum}((\text{comb} \_\text{tx} \_\text{sig}).^2); \)

iv. \( \text{pow} \_\text{txdata} = \text{sum}((\text{comb} \_\text{tx} \_\text{sig}).^2)/\text{N}; \)

4. The sum power of the multipath components (without normalization) can be calculated using the MATLAB command:

(2 marks)

i. \( \text{ch} \_\text{power} = \text{sum}((\text{abs}(\text{imp} \_\text{res} \_\text{unnorm})); \)

ii. \( \text{ch} \_\text{power} = \text{sum}((\text{abs}(\text{imp} \_\text{res} \_\text{unnorm})).^2); \)

iii. \( \text{ch} \_\text{power} = \text{sum}((\text{abs}(\text{imp} \_\text{res} \_\text{unnorm})).^2); \)

iv. \( \text{ch} \_\text{power} = \text{sum}((\text{imp} \_\text{res} \_\text{unnorm})^2); \)

5. The multi-user spread spectrum signal contaminated with noise through the fading channel is:

(2 marks)

i. \( \text{rec} \_\text{data} = \text{comb} \_\text{tx} \_\text{sig}+\text{noise}; \)

ii. \( \text{rec} \_\text{data} = \text{comb} \_\text{tx} \_\text{sig} \.*\text{imp} \_\text{res}+\text{noise}; \)

iii. \( \text{rec} \_\text{data} = \text{conv}\((\text{comb} \_\text{tx} \_\text{sig}),\text{imp} \_\text{res})+\text{noise}; \)

iv. \( \text{rec} \_\text{data} = \text{comb} \_\text{tx} \_\text{sig} \.*\text{imp} \_\text{res}+\text{noise}; \)

6. For a \( \text{decay} \_\text{para}=1.2 \), the average exponential power delay profile versus multipath delay index vector is approximately:

(3 marks)
7. Assume 2 number of users. User 1 spreading code corresponding to second row of the Hadamard matrix and user 2 spreading code corresponding to third row of the Hadamard matrix. The BER vs Eb/No plot for user 1 is approximately: (4 marks)

i.

![BER vs Eb/No plot for user 1](image1)

ii.

![BER vs Eb/No plot for user 2](image2)
8. Assume 3 number of users. User 1 spreading code corresponding to second row of the Hadamard matrix, user 2 spreading code corresponding to third row of the Hadamard matrix, and user 3 spreading code corresponding to fourth row of the Hadamard matrix. The BER vs Eb/No plot for user 1 is approximately:

(i) 

![Graph of BER vs Eb/No for user 1]

(ii) 

![Graph of BER vs Eb/No for user 2]
iii.

![Graph](image1)

iv.

![Graph](image2)