Assignment 12: MATLAB code for BER generation of Spread Spectrum MU QPSK with Kasami codes 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) with Kasami spreading codes over Rayleigh fading channel (averaged over at least 1000 iterations). Assume that the system either employs Hadamard sequences of length 16 or Kasami code with length 15 for spreading data. Assume a multi-user scenario with maximum 3 users. 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: Note: Use the equalizer and the channel generation codes provided in tutorial 7 from week-9. Use Kasami codes generated in assignment 4 from week-4.
<table>
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<tr>
<th>Parameter</th>
<th>Mathematical notation</th>
<th>MATLAB variable</th>
</tr>
</thead>
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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>$I_{\text{data	extunderscore mat}}(x,:)$</td>
</tr>
<tr>
<td>Quadrature bipolar data for $x$</td>
<td>$q_x$</td>
<td>$Q_{\text{data	extunderscore mat}}(x,:)$</td>
</tr>
<tr>
<td>Baseband complex spread data for user $x$</td>
<td>$s_x^s$</td>
<td>$\text{base	extunderscore sig	extunderscore mat}(x,:)$</td>
</tr>
<tr>
<td>Spreading code for user $x$</td>
<td>$s_x$</td>
<td>$\text{code	extunderscore mat}(x+1,:)$</td>
</tr>
<tr>
<td>Transmitted multiuser signal</td>
<td>$t_{\text{sig}}$</td>
<td>$\text{comb	extunderscore tx	extunderscore sig}$</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>$\text{tau}$</td>
</tr>
<tr>
<td>Decay parameter for channel</td>
<td>$\alpha$</td>
<td>$\text{decay	extunderscore para}$</td>
</tr>
<tr>
<td>Power delay profile vector</td>
<td>$P(\tau)$</td>
<td>PDP</td>
</tr>
<tr>
<td>Complex channel with Rayleigh amplitude and uniformly distributed phase</td>
<td>$c_{\text{amp}}$</td>
<td>Rayleigh_amp</td>
</tr>
<tr>
<td>Channel impulse response without normalization</td>
<td>$c_{\text{un}}$</td>
<td>imp_res_unnorm</td>
</tr>
<tr>
<td>Channel impulse response with normalization</td>
<td>$c_{\text{n}}$</td>
<td>imp_res</td>
</tr>
<tr>
<td>Channel power</td>
<td>$P_{\text{ch}}$</td>
<td>ch_power</td>
</tr>
<tr>
<td>Transmit spread signal after channel</td>
<td>$s'$</td>
<td>$\text{tx	extunderscore data	extunderscore ch}$</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>$r_{\text{d}}$</td>
<td>despread_data</td>
</tr>
<tr>
<td>Decoded in-phase data</td>
<td>$\hat{i}$</td>
<td>$\text{decod	extunderscore sig	extunderscore I}$</td>
</tr>
<tr>
<td>Decoded quadrature data</td>
<td>$\hat{q}$</td>
<td>$\text{decod	extunderscore sig	extunderscore Q}$</td>
</tr>
</tbody>
</table>

Table 1: Table of notations.

1. Hadamard code of length 16 can be generated using the MATLAB command:

   (1 mark)

   i. code_mat=hadamard(16);
      spread_code=code_mat(3,:);

   ii. code_mat=hadamard(16);
       spread_code=code_mat(1,:);

   iii. code_mat=hadamard(16);
        spread_code=code_mat(17,:);

   iv. code_mat=hadamard(16);
       spread_code=code_mat(0,:);

2. Select the second row of the Hadamard matrix as the code for simulation. This can be accomplished using the MATLAB command:

   (1 mark)
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

i. spread_code=code_mat(1,:);
ii. spread_code=code_mat(2,:);
iii. spread_code=code_mat(:,2);
iv. spread_code=code_mat(:,1);

3. Refer to Fig. 3, the Kasami code obtained by bit wise 'XOR' operation of the generated m-sequence and the circularly shifted decimated sequence with shift amount 6 is:
(2 marks)
i. 111001100000100.

Figure 3: Linear Feedback Shift Register
ii. 010100001101001.

iii. 101011100010101.

iv. 101001101101101.

4. Refer to Fig. 3, the Kasami code obtained by bit wise 'XOR' operation of the generated m-sequence and the circularly shifted decimated sequence with shift amount 7 is:

(2 marks)

i. 111010010010110.

ii. 101011100010101.

iii. 101111101010111.

iv. 010100001101001.

5. For the Hadamard code 1 -1 -1 1 1 -1 1 1 -1 1 1 -1 1 1 -1 1, the periodic auto correlation sequence is:

(3 marks)

Hint: Periodic autocorrelation and crosscorrelation functions are defined as:

\[ \phi_{auto}(\nu) = \sum_{m=0}^{M-1} c^i_m c^i_{m+\nu} \]

\[ \phi_{cross}(\nu) = \sum_{m=0}^{M-1} c^i_m c^j_{m+\nu}, \]

where \( c^i_m \) denotes \( m \)-th sample of \( i \)-th spreading code with length \( M \). It should be noted that \( c^i_{m+\nu} = c^i_n \) if \( rem(m + \nu, M) = n \), where \( rem(x, y) \) is the remainder of the division of \( x \) by \( y \).
i.

ii.
iii.

iv.
6. For the Kasami code 1 -1 -1 -1 1 1 1 -1 1 1 1 1, the periodic auto correlation sequence is:

(3 marks)

i.

![Graph 1](image1)

ii.

![Graph 2](image2)
7. Assume 2 number of users. Consider two systems which uses Hadamard codes and Kasami codes for spreading, respectively. In system 1, User 1 spreading code corresponding to 2-nd row of the Hadamard matrix and user 2 spreading code corresponding to 8-th row of the Hadamard matrix. Whereas in System 2, User 1 spreads its data using the Kasami code '1 1 1 -1 1 1 -1 -1 -1 -1 1 1 -1 -1 -1' and User 2 spreads its data using the Kasami code '1 -1 -1 -1 1 -1 1 1 1 1 1 1'. Compare BER vs Eb/No plots for user 1 corresponds to Kasami with Hadamard codes (assume a Rayleigh multi-path channel with decay_para=1.2, and no_multipath=4).

(4 marks)

i.

![BER vs Eb/No plot](image)

ii.
iii.

iv.
8. Assume 3 number of users. Consider two systems which uses Hadamard codes and Kasami codes for spreading, respectively. In system 1, User 1 spreading code corresponding to 2-nd row of the Hadamard matrix, user 2 spreading code corresponding to 8-th row of the Hadamard matrix, and user 2 spreading code corresponding to 11-th row of the Hadamard matrix. Whereas in System 2, User 1 spreads its data using the Kasami code '1 1 1 -1 -1 1 1 -1 -1 -1 -1 -1 -1 -1 -1', User 2 spreads its data using the Kasami code '1 -1 -1 -1 1 -1 1 1 1 1 1 1 1 1 1 1', and User 3 spreads its data using the Kasami code '-1 1 -1 1 -1 -1 -1 -1 1 1 1 1 1 1 1 1'. Compare BER vs Eb/No plots for user 1 corresponds to Kasami with Hadamard codes (assume a Rayleigh multi-path channel with decay\_para=1.2, and no\_multipath=4).

(4 marks)
i. 

![Graph 1](image1.png)

ii. 

![Graph 2](image2.png)
iii.

iv.