HW 2: Error Rate Evaluations for Baseband Systems

due November 12

1. You are given a simulation package that evaluates the Monte Carlo performance of the QPSK modulation in the baseband and that plots the bit error probability (BER) as a function of signal to noise ratio (SNR) or E_s/N_0. Study the code, and complete the detection part, that is missing. Run the code. Notice what happens if you decrease or increase the parameters *ferlim* or the *max-nframe*. Modify the code and run it again so that it simulates the BER performance versus E_b/N_0. What is the difference?

   Modify the code so that it simulates the symbol error rate (SER) performance of QPSK as a function of both SNR and E_b/N_0. In all cases justify that the detector that is used is the maximum likelihood detector. Now, generate a single graph with 8 curves:

   - SER vs SNR: simulation: red line with an 'x' marker, theory: no line with a square marker,
   - SER vs E_b/N_0: simulation: red line with an 'o' marker, theory: no line with a diamond marker,
   - BER vs SNR: simulation: blue line with an 'x' marker, theory: no line with a square marker,
   - SER vs E_b/N_0: simulation: blue line with an 'o' marker, theory: no line with a diamond marker.

   Compare the results. Do the BER and SER simulation results match with the theory?

2. Now modify the MATLAB Monte-Carlo simulation package so that it implements a transmission system employing BPSK. Assume that the BPSK signals are transmitted over an AWGN channel with zero mean and variance $N_0/2$. Also assume that the receiver is a maximum-likelihood (ML) detector. Run your code to obtain the bit-error rate (BER) as a function of E_b/N_0. Now, generate a single graph with 2 curves:

   - BER vs E_b/N_0: simulation: red line with an 'x' marker, theory: no line with a square marker.

   Compare your simulation result with the theoretical values. Do they match? How does the BER vs E_b/N_0 performances of BPSK and QPSK compare? Are they the same or different?

3. Repeat part (2) for 8-PSK communication, but obtain the BER as a function of SNR. Employ uniform and gray mapping for bit-to-symbol conversions. Is there a difference in the BER performance due to mapping?

4. Repeat part (2) for 4-PAM communication, but obtain the BER as a function of SNR. Employ uniform and gray mapping for bit-to-symbol conversions. Is there a difference in the BER performance due to mapping?

5. Repeat part (2) for a transmission scheme using 16-QAM (use rectangular constellation), but obtain the BER as a function of SNR. Employ uniform and Gray-mapping for bit-to-symbol conversions. Is there a difference in the BER performance due to mapping?

   Hint for 4) and 5): Notice that in your QPSK simulation code, the average symbol energy is set to unity. The SNR value is obtained by changing the noise variance. Previous constellations all had unit energy but in 16-QAM and 4-PAM, different constellation points have different amplitudes and energies. Therefore you need to normalize the constellation points so that the average constellation energy is equal to 1.

   Plotting for 3, 4) and 5): For each part, generate a single graph with 4 curves:

   - Uniform mapping: simulation: red line with an 'x' marker, theory: no line with a square marker,
   - Gray mapping: simulation: blue line with an 'x' marker, theory: no line with a diamond marker.

6. Repeat part (2) for binary FSK. Generate a single graph with 2 curves:
   - BER vs E_b/N_0: simulation: red line with an 'x' marker, theory: no line with a square marker.
7. In the end put all BER curves together to see which modulation method is the best!!!

Instructions on Figures, Report and Submission:

You should prepare a report, where all your explanations, graphs and results are included. You are also required to turn in your MATLAB source codes. Your source code has to be understandable (commenting, meaningful variable names etc). At the due date, submit your report and your Matlab codes (5 m-files in total, one for each constellation). All submissions are on MOODLE, paper copies will not be accepted. Late submission is penalized with 10% per day. You should create your graphs by following the instructions given in each part and also given below. In order to save time, you may prefer to do your plots with a plotter function, that you will create.

1. All BER/SER curves will be semi-logarithmic.
2. Name each curve, show the legend and make sure the legend does not block the curves. (*semilogy(...,'DisplayName',CurveName)*).
3. Axes have to be squared (*axis square*).
4. Background has to be gridded (*grid on*).
5. Set the font size of the figure to 14 (*set(gcf,'FontSize',14)*).
6. Label both axes. No need for a title, instead caption the figures in your report.
7. Make sure your curves go down to at least 10^{-4} BER level.
8. Limit the axes appropriately (no blank spaces).