KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
COLLEGE OF COMPUTER SCIENCES & ENGINEERING
COMPUTER ENGINEERING DEPARTMENT
COE-341 – Data and Computer Communication
Matlab Programming Assignment #2: Digital Information Analog Signals Modulation – Due Date June 14th, 2009 – In Class.

- The **objective** of this programming assignment is to familiarize the students with Matlab programming as a tool for analyzing modulation schemes and reinforce the understanding of concepts and techniques that are part of the course. In specific, the aim of this programming assignment is to simulate the QPSK modulation/demodulation scheme, and to plot the constellation diagram for the received signal for low and high noise power relative to the signal power. The assignment also requires that students calculate the symbol error rate and bit error rate empirically. Some of the required functionalities are already built in Matlab's communication's toolbox. It is not the objective of this assignment to introduce the communication's toolbox, but rather to implement the required functions without using the toolbox.

- The instructor will give the needed hints and guidelines to complete the Matlab coding in class.

- The deliverable for this programming assignment is a zipped file with the student's ID and Last Name (e.g. NNNNNNNN_LASTNAME_FIRSTNAME.ZIP). The zipped file should contain at least two Matlab files: Problem_1.m and Problem_2. The zip file may contain a third Matlab file called Problem_3.m. The Matlab files produce the required outputs described below. The code is *also* graded for *clarity and style*. Therefore, use a clean and clean coding style that is rich with comments.

- The zipped file should be sent to Eng. Fahd AbdelHamid (fahd@kfupm.edu.sa) ccing the instructor ashraf@kfupm.edu.sa before the deadline of the assignment.

Problem Statement (40 points + 20 bonus points):

(1) **(20 points)** QPSK signal constellation

Generate a stream of *random* binary bits and encode those into QPSK symbols whose energy is given by $A^2/2$ joules. The received (baseband) signal is the generated symbols plus random noise.

a) For a sequence of 100 symbols plot the received signal constellation points (scatter plot) when the Eb/N0 is given equal to 5 dBs. Comment on scattered plot.

b) For a sequence of 100 symbols plot the received signal constellation points (scatter plot) when the Eb/N0 is given equal to 10 dBs. Comment on scattered plot.

The student should submit a Matlab code named "Problem_1.m" that generates the random binary bits, performs the QPSK modulation, adds the noise, and produces two signal constellation figures: one for part (a) and another for part (b).

(2) **(20 points)** QPSK demodulation

Given the received signal constellation for QPSK, the demodulator divides I-Q plane into 4 quadrants (refer to figure at end of quiz statement):

1. The first quadrant: I and Q are positive ➔ symbol is $s_1(t) = A\cos(2\pi f_c t + \pi/4)$ and two information bits are "11".

2. The second quadrant: I is negative and Q is positive ➔ symbol is $s_2(t) = A\cos(2\pi f_c t + 3\pi/4)$ and two information bits are "01".

3. The third quadrant: I and Q are negative ➔ symbol is $s_3(t) = A\cos(2\pi f_c t - 3\pi/4)$ and two information bits are "00".

4. The fourth quadrant: I is positive and Q is negative ➜ symbol is $s_4(t) = A\cos\left(2\pi f_c t - \pi/4\right)$ and two information bits are "10".

a) Implement the above demodulation rule using Matlab and estimate the *symbol error rate* (SER) for Eb/N0 equal to 2 dB and 10 dB.

b) Extend your Matlab code to compute the estimate for the *bit error rate* (BER) for Eb/N0 equal to 2 dB and 10 dB.

The student should submit a Matlab code names "Problem_2.m" that generates the random binary bits, performs the QPSK modulation, adds the noise, performs the demodulation, and estimates the SER and BER for the given Eb/N0 numbers. The code prints the SER and BER estimates (calculations) to the screen.

3) (**20 point – bonus**) Using the code developed above to produce a figure that contains the following curves:

   1. SER computed empirically versus Eb/N0
   2. SER computed analytically versus Eb/N0.
   3. BER computed empirically versus Eb/N0.
   4. BER computed analytically versus Eb/N0.

For this part you need to take 10 or more points on the x-axis (the Eb/N0 axis) to produce a smooth curve. Note that the BER curve versus Eb/N0 should be similar to the BER curve shown in textbook page 147 Figure 5.4 (the curve denoted by QPSK). Use the "semilogy" to plot the error rate logarithmically. Note for all curves, the Eb/N0 is taken in dBs.

The student should search for the analytic formulas that specify the SER or BER curves. If the work is sound, the empirical curves should match the corresponding analytical ones.

The student should submit a Matlab code names "Problem_3.m" that for a vector of Eb/N0 values, generates the random binary bits, performs the QPSK modulation, adds the noise, performs the demodulation, and estimates the SER and BER for every Eb/N0 values in the vector. The code plot the empirical SER and BER curves on a log scale versus the Eb/N0 values in dB using "Markers". The code also evaluates the SER and BER formulas and plots the results on the same curve using solid lines. Limit the x-axis to be from 0 dB to 14 dB while the y-axis is limited from 10^{-7} to 1.
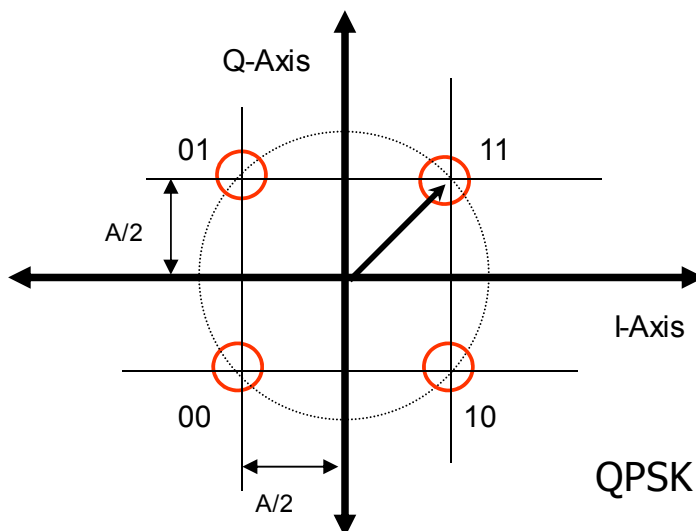

Figure P1: QPSK signal constellation.