# Project: Signal Constellations and A Priori Probabilities

## Objective:

As part of the assessment of the course, the project aims at testing students' understanding on the course materials, and providing students a chance to realize the theories taught in the class. In this project, the performance of a simple communication system will be simulated and compared with theoretical analysis.

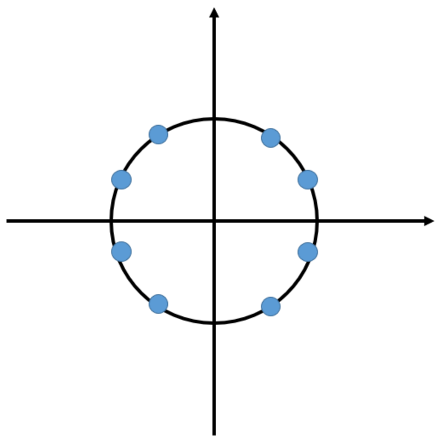
## Instruction:

Simulation programs in this project should be written using MATLAB.

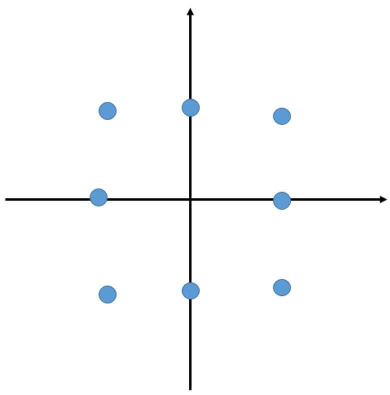
## Signal Constellations:

Consider the following 8PSK or 8QAM signal constellations in Figure below. The constellations are supposed to have the same minimum distance $r$ which is set according to the specified symbol energy $E_s$ (note that the constellations are not drawn to scale in the figure).

Divide the last digit of your student ID by 2, and get the remainder. **If the remainder is i , the Constellation i is your signal constellation.**



(0)



(1)

## A Priori Probabilities:

In this project, the signals are not equally likely. Use the following set of probabilities.

$P(S_1) = 0.2$ $P(S_2) = 0.3$ $P(S_3) = 0.1$ $P(S_4) = 0.08$

$P(S_5) = 0.1$ $P(S_6) = 0.12$ $P(S_7) = 0.05$ $P(S_8) = 0.05$

## System Simulation Model:

In this project, the performance of an 8PSK or 8QAM modulation scheme will be evaluated by computer simulation. Here is a brief description of the system:

1. The data source generates 8PSK or 8QAM symbols according to a specified set of *a priori* probabilities;
2. The channel model is AWGN;

## Task 0 – Minimum Distance Detector

1. Suppose minimum distance detector is used at the receiver. Please draw the receiver block diagram and the associated decision region.
2. Write a MATLAB function to simulate the SER of the aforementioned system using your signal constellation. Plot the simulation results and the nearest neighbor union bound as a graph of SER versus $E_s/N_0$ in dB. It suffices to plot the $E_s/N_0$ in increments of 2dB and SER should be at least as low as $10^{-4}$ .

## Task 1 – SER Optimal Detector

1. Due to the unequal *a priori* probabilities for the data symbols, the minimum distance detector in Task 0 is not the optimal receiver. Using the theories we have learnt , propose an optimal receiver for your signal constellation. Draw the block diagram.
2. Write a MATLAB function to visualize the decision regions of your proposed detector.

   **Input:**

   1. Coordinates of the signal points in the constellation;
   2. *a priori* probabilities of the signals;

   **Output:**

   1. A diagram of decision regions of the specified signal constellation with indicated signal points.

## Task 2 – SER Simulation using Optimal Detector

Write a MATLAB program to simulate the SER performance of the aforementioned system using your signal constellation. Assume the receiver has perfect knowledge of the source statistics or *a priori* probabilities. Plot the simulation results, the standard union upper bound and the nearest neighbor's union upper bound as a graph of SER versus $E_s/N_0$ in dB. It suffices to plot the values of $E_s/N_0$ in increments of 2dB. To obtain meaningful simulation results, the SER should be at least as low as $10^{-4}$. Compare the simulation results with the minimum distance detector.

## Task 3 – Bit Mapping Design（Choose to do the problem）

Try your best to find a bit-to-symbol labeling scheme such that bit error rate (BER) is minimized in your constellation. Write a MATLAB program to simulate the BER performance of the system with 1) the best labeling scheme you can find, and 2) random labeling. Plot the simulation results, the union upper bound for both cases as a graph of BER versus $E_s/N_0$ in dB. Describe and justify your method on how to find this labeling scheme.

## Deliverables:

A soft copy of the project report and soft copies of all the programs should be compressed as a zipped file and uploaded to the course website before the due date. Note that all the programs should be well documented. You are supposed to write a `readme` file to introduce your functions and instruct the running method (make sure your programs can be successfully run).

## Important Notice:

Besides the functionality of simulation programs, originality of the solution and implementation is a crucial grading factor. To maintain fairness, the university's zero tolerance policy will be enforced. **Plagiarism in any form will be considered as cheating, and will be given 0 mark for the project**. To avoid unnecessarily confusion, please provide detailed citations to the sources of references whenever you adopt some materials from a book, an article, or a website.