Final Project

Part 1

1.1 Gram-Schmidt Orthogonalization:

- Write a Matlab function “[phi1,phi2]=GM_Bases(s1,s2)”
  - The function calculates the Gram-Schmidt orthonormal bases functions (phi1 & phi 2) for two input signals (s1 & s2)
  - The inputs s1 and s2: are two $1\times N$ vectors that represent the input signals
  - The outputs phi1 & phi2: are two $1\times N$ vectors that represent the two orthonormal bases functions (using Gram-Schmidt). If s1 & s2 have one basis function, then phi2 is $1\times N$ zero vector

1.2 Signal Space representation:

- Write a matlab function “[v1,v2]=signal_space(s, phi1,phi2)”
  - The function calculates the signal space representation of input signal s over the orthonormal bases functions (phi1 & phi 2)
  - The inputs s: is a $1\times N$ vectors that represent the input signal
  - The inputs phi1 & phi2: are two $1\times N$ vectors that represent the two orthonormal bases functions .
  - The output [v1,v2]: is the projections (i.e. the correlations) of s over phi1 and phi2 respectively.

1.3 Effect of AWGN on signal space representation

Now consider the signals

$r_1(t) = s_1(t) + w(t);\qquad r_2(t) = s_2(t) + w(t)$

Where $w(t)$ is a zero mean AWGN with variance σ^2

1.4 Requirements of Part 1

1. Use your "GM_Bases" function to get the bases functions of $s_1(t)$ & $s_2(t)$ Figure 1.1. Plot the obtained bases functions

2. Use your "signal_space" function (along with the bases from 1) to get the signal space representation of $s_1(t)$ & $s_2(t)$ in Figure 1.1. Plot the signal space representation

3. Generate samples of $r_1(t)$ and $r_2(t)$ using $s_1(t)$ & $s_2(t)$ in Figure 1.1 and random noise samples (for example 50 or 100 sample). Use your "signal_space" function (along with the bases from 1) to plot the signal points of the generated samples of $r_1(t)$ and $r_2(t)$ at $\frac{E}{\sigma^2} = -5$ dB, 0 dB, 10 dB (each $\frac{E}{\sigma^2}$ in a different figure), where E is the energy of $s_1(t)$ or $s_2(t)$ (**use "scatter" in Matlab**)
4. How does the noise affect the signal space? Does the noise effect increase or decrease with increasing σ^2?

<u>Notes:</u> Each figure should have a legend and the axes should be properly labelled with proper font size. All curves should have line width of 2.
The signal points in the scatter plots in 3 should be clear and visible. Use different colours for the points of $r_1(t)$ and $r_2(t)$

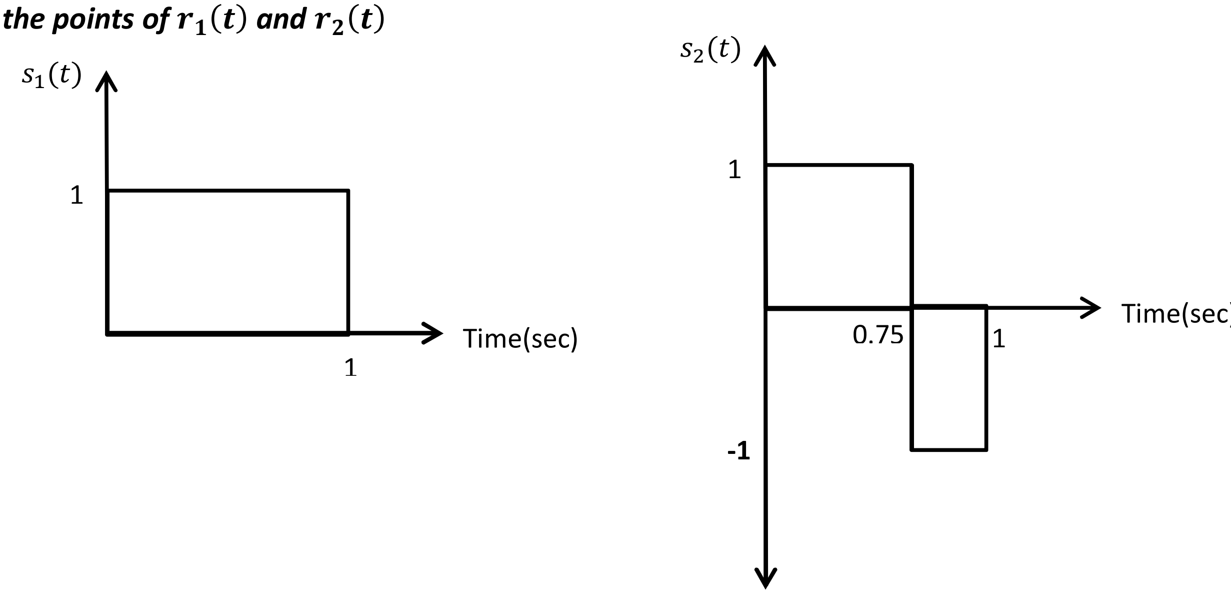


Figure 1.1

Part 2

2.1 Description

The purpose of this part is the simulation and analysis of the Bit Error Rate (BER) of different modulation schemes of a digital communication system. Figure 2.1 shows a simple block diagram of the communication system. It consists of a mapper, a channel, and a demapper

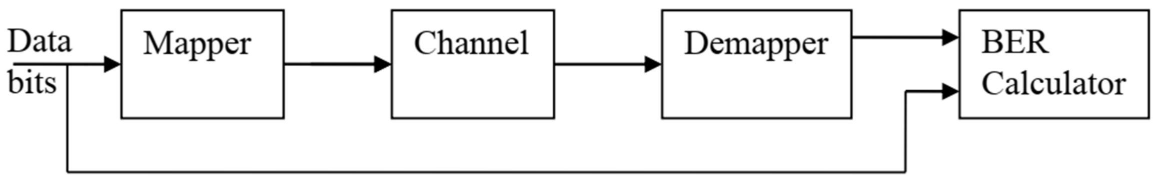


Figure 2.1: Communication System

The Mapper

The first block in the communication system under consideration is the mapper. The mapper takes the I/P data bits “for example, 100,000 randomly generated bits” and produces the symbols to be transmitted on the channel. The modulation schemes under consideration are the BPSK, QPSK, 8-QAM, and 16-PSK systems. Figure 2.2 shows the signal constellations of these modulation schemes

The Channel

The channel is an AWGN channel. In this model, the channel just adds noise to the transmitted signal (i.e. no distortion). In MATLAB, the command “randn” should be used to generate the AWGN

The DeMapper

The simple demapper in the model under consideration will take the output of the channel and decide on the symbol transmitted. The output bit stream of the receiver is compared to the input bit stream and the BER is calculated.

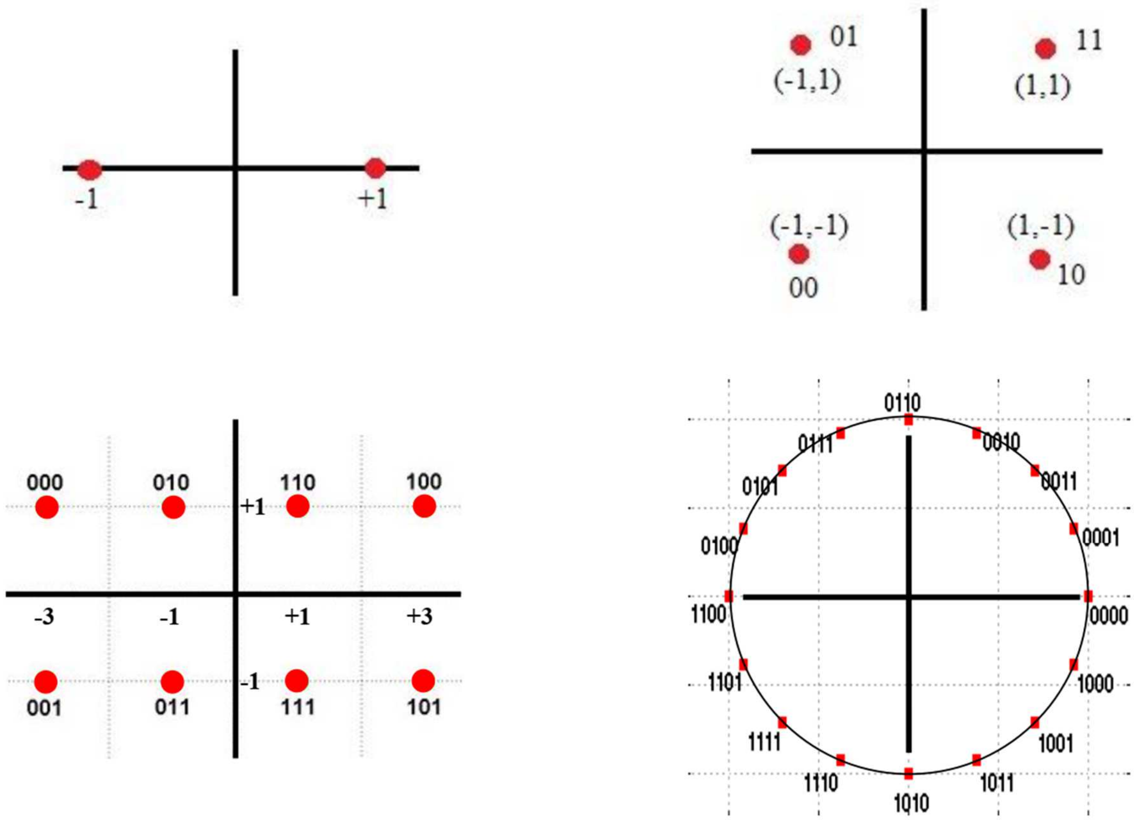


Figure 2.2 BPSK, QPSK, 8-QAM, and 16-PSK constellations

<u>2.2 Requirements of Part 2</u>

1- Use **Matlab** to simulate and calculate the BER of the four modulation schemes in Figure 2.2. **All simulations are done on the baseband equivalent system, with no carriers**.

2- Sketch the four constellations in Figure 2.2 with the decision regions of each symbol marked.

3- Derive the theoretical BER of the BPSK, QPSK, and 8QAM and a tight upper bound to the BER of the 16PSK.

4- Plot the curves for the simulated BER Vs E_b/N_0 for the four modulation schemes in a single graph. The BER should be on the vertical axis (in log scale). E_b/N_0 should be on the horizontal axis in dB (from -4 to 16 dB with step 2 dB). Use “semilogy” in Matlab to plot the BER on y-axis with log scale. ***Please note that we’re asking for the Bit error rate NOT the symbol error rate.***

5- On the same graph in step 4, plot the curves of the theoretical BER versus E_b/N_0 for the BPSK, QPSK, 8QAM and the tight upper bound of the 16PSK. The BER should be on the vertical axis (in log scale). E_b/N_0 should be on the horizontal axis in dB (from -4 to 16 dB with step 2 dB). Use “semilogy” in Matlab to plot the BER on y-axis with log scale. ***Please note that we’re asking for the Bit error rate NOT the symbol error rate.***

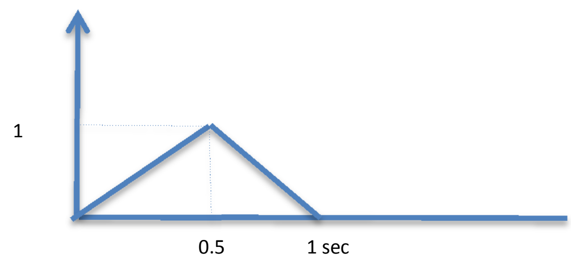
6- You are designing a system that uses M-ary PSK. The required bit rate is 0.5Mbps and the available BW is 0.5 MHz centered at a carrier frequency 5 MHz. It is required that the SNR (E_b/N_0) doesn’t exceed 5 dB and the BER doesn’t exceed 10^{-2}. Knowing that the bandwidth of a passband modulation is twice the symbol rate (i.e. $BW = 2R_s$), which of the above PSK modulation schemes (BPSK, QPSK, and 16-PSK) could be used? Why?

Note: ***Use solid lines for your simulated BERs curves, dashed lines for the theoretical BERs curves, and different colours for different modulation schemes. The figure should have a legend and the axes should be properly labelled with proper font size. All curves should have line width of 2.***

Part 3

If a transmitter uses the below shape as a transmit pulse. A receiver uses a matched filter.

(a) Use MATLAB to generate 10 random bits 1 or 0
(b) Use BPSK by mapping the bits to 1 or -1
(c) Sample the filters at 10 times the bit rate (0.1 sec)
(d) Draw the output of the transmitter
(e) Assume no noise, and draw the output of the receiver
(f) Sample the output of the receiver starting to demodulate the bits



Submission Requirements

1. You should submit a .pdf report that **fulfils the requirements of all three parts (in the same order of the requirements).** The report should include:
    - **a)** All the required results, comments, and answers to questions
    - **b)** All the required figures
    - **c)** All the required sketches and theoretical analysis
    - **d)** All codes as appendices (with comments that clearly explain the code and variables).
    - **e)** The role of each team member.
2. The report should use the given template.
3. The figures in your report should be **clear**. **All figures** should have **a clear legend and the axes should be properly labelled with proper font size.**
4. The theoretical analysis along with the decision regions of part 2 (whether you scan your hand analysis or use word/latex for the equations features) should be **clear, neat, and easily readable.** **Do NOT write equations on word or any text editor as text, you should use a proper equation editor or feature. DO NOT use pale pencil/pen and do not scratch**
5. Your comments and answers should be clearly typed not scanned. They should be **"concise"** and do not exceed 3 lines (each).
6. Please keep your report **neat, clean, and organized**.
7. **You are responsible** for the clarity and visibility of your figures, analysis, comments, code, etc.

Submission Policy

Groups: You should work in groups 3-5 students per group.

Submission: You should submit your report as a single uncompressed pdf file on the Google classroom of the course (Communication ELC306B with code "folysw5"). You should use the given report template.

Plagiarism: Students must not copy any material from any reference (without proper citation) or any another group's project. Plagiarism check shall be carried and the project will be considered invalid (fail) in case of plagiarism.

Deadline: May, 31, 2020 at 10:00 PM

Late submission is not allowed