Communications and Information Engineering Program
Communications Theory and Systems
CIE 337 - Spring 2020
Final Assessment - Due May 19, 2020

DESCRIPTION

In this project, you will design and implement digital communication systems, calculate the average error probabilities and generate eye diagrams of a number of PAM signaling schemes.

INSTRUCTIONS

1) This assessment is composed of 5 parts, equally weighted.
2) This is an **individual assessment**.
3) Assessment reports (including design solutions, source codes, figures or comments) are **not to be shared with others**, neither before nor after submission.
4) **Any copied reports**, either fully or partially, will receive **0 points**. This applies to both the original and the copy. Students who have duplicate reports will be subject to **Academic penalty** for violating Academic Integrity rules.
5) **No late submissions** are allowed. This will be strictly enforced.
6) In submission, you have to submit .m files separately. In addition, figures should be submitted in .fig format and should be included in the .pdf report. Reports should be comprehensive and readable on their own.
7) Your solutions for the design parts should be clear and including complete steps.
8) **The .pdf report is the main document** to be evaluated, *i.e.* no credit is given for the source codes. However, source codes will be checked against plagiarism.
9) Each part has its grading criteria.

SUBMISSION

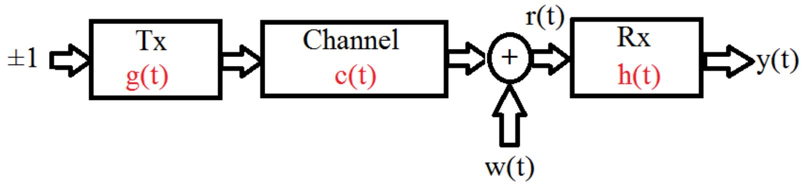
You are required to submit, by the due date, the following on Classroom:

1) A single .pdf file representing the whole assessment report, and including a cover page.
2) A single .zip folder, including 5 sub-folders, each including the deliverables of each part.

Both the file and the folder should be named: CIE337_Spring2020_201XXXXX, where 201XXXXX is your student ID.

Part 1: Matched Filters

Consider the digital communication system shown in the following figure. It is required to design an optimum ISI-free communication system. Assume that the channel has an impulse response $c(t) = 0.5\delta(t)$, and the the noise $w(t) \sim \mathcal{N}\left(0, \frac{N_0}{2}\right)$ is AWGN.



1) The following pulse-shaping filter $g(t)$ is used

$$g(t) = \begin{cases} +2t/T_b, & 0 \leq t \leq T_b/2 \\ 1, & T_b/2 \leq t \leq T_b \\ 0, & \text{otherwise} \end{cases}$$

   Draw the impulse response, $h(t)$, of the optimum receiver. Label your figure properly.
2) In the absence of AWGN, plot the output of the optimum receiver, $h_1(t)$, after the sampler, when the polar input signal is $\{-1, 1, -1, -1, 1\}$.
3) If the receiver filter has the following impulse response, instead of the optimum filter:

$$h_2(t) = \begin{cases} 1, & T_b/2 \leq t \leq T_b \\ 0, & \text{otherwise} \end{cases}$$

   Plot the output of the receiver after the sampler, in the absence of AWGN, when the polar input signal is $\{-1, 1, -1, -1, 1\}$.
4) In the presence of AWGN, which filter, $h_1(t)$ or $h_2(t)$, achieves a better performance. Justify your answer.
5) Is this system ISI-free? Why?

Deliverables - Part 1

Include in your .pdf report:

1) The required figures. These should be plotted using Matlab.
2) Solution steps and justification of each question.

Grading Criteria

Grading of this part will depend on:

- **60%:** Completeness and correctness of solution.
- **20%:** Clarity of figures, and proper labeling.
- **20%:** Report writing and organization.

PART 2: THEORETICAL ERROR PROBABILITY

It is required to calculate theoretical error probability of the system in the previous part. Polar RZ signaling is used to transmit symbols '1' and '0'. The pulse amplitude is $\pm A$.
Assuming that symbol '1' has a transmit probability of p, find an expression for the average error probability at the optimum receiver output.

Express the error probability in terms of the $\mathcal{Q}$-function, where

$$\mathcal{Q}(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-\frac{t^2}{2}} dt$$

Assume that the decision device threshold is λ.

Deliverables - Part 2

Include in your .pdf report:

1) All solution steps.
2) Expression of the average error probability as a function of $E_b = A^2 T_b$, λ and p.
3) Derive the optimum value of λ.
4) Plot, using Matlab, the average error probability vs E_b/N_0 for $p = 0.1, 0.5$ and 0.9 all on the same figure.
   Note that λ is a function of p.

Grading Criteria

Grading of this part will depend on:

- **60%:** Completeness and correctness of solution.
- **20%:** Clarity of the required figure, with proper legend and labeling.
- **20%:** Report writing and organization.

PART 3: EYE DIAGRAMS IN NOISE-FREE SYSTEMS

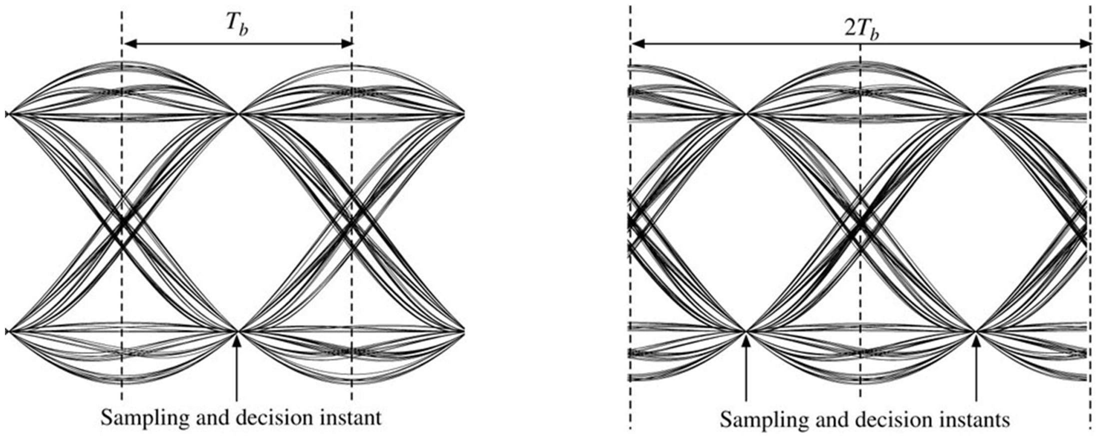
Write a Matlab function that generates eye diagrams for a DCS that uses polar NRZ, ideal Nyquist, raised-cosine and square root raised-cosine pulse shapes in PAM.

It is required to do such simulations for binary signaling as well as for 8-level PAM signaling.

Your function should allow the user to enter the following as inputs:

- Pulse shape type (NRZ, Ideal Nyquist Pulse, Raised-Cosine or Square Root Raised-Cosine Pulse)
- Number of PAM levels (Binary or 8-level)
- Duration of Eye Diagram (T_s or $2T_s$)

In this part, generate 300 equiprobable bits.



(a) (b)

Deliverables - Part 3

Deliver, electronically, the following in a .zip file

1) Source code (.m files) of the function.
2) Source code of the main script used to generate the eye diagrams.
3) Eye diagram figures (.fig files) for all possible cases (Total of 16 cases).
4) Comment on the eye diagrams to explain the effect of ISI in the different scenarios.
5) A .pdf file of the whole report, including the figures, properly labeled and titled. The report should also include your comments.

Grading Criteria

Grading of this part will depend on:

- **50%:** Completeness and correctness of deliverables (as per the .pdf report)
- **30%:** Clarity of figures, and proper labeling (as per the .pdf report)
- **20%:** Report writing and organization.

Part 4: Eye Diagrams in Noisy Systems

Write a modified Matlab function that generates eye diagrams for each DCS in Part 3, assuming that the system is subject to AWGN $\sim \mathcal{N}\left(0, \frac{N_0}{2}\right)$. Your function should allow the user to enter the value N_0. In this part, generate 300 equiprobable bits, and the same number of noise samples.

Test Cases

Generate the eye diagrams for the cases in the following table:

	Case 1	**Case 2**	**Case 3**	**Case 4**
Pulse Shape	Ideal Nyquist	Raised-Cosine	Ideal Nyquist	Raised-Cosine
PAM	Binary	Binary	Binary	Binary
E_b/N_0	0 dB	0 dB	10 dB	10 dB

Deliverables - Part 4

Deliver, electronically, the following in a .zip file

1) Source code (.m files) of the function.
2) Source code of main script used to generate the eye diagrams.
3) Eye diagram figures (.fig files) for all possible cases (Total of 4 cases).
4) Comment on the eye diagrams to explain the effect of **ISI** as well as the effect of **Noise** in the different scenarios.
5) A .pdf file of the whole report, including the figures, properly labeled and titled. The report should also include your comments.

Grading Criteria

Grading of this part will depend on:

- **50%:** Completeness and correctness of deliverables (as per the .pdf report)
- **30%:** Clarity of figures, and proper labeling (as per the .pdf report)
- **20%:** Report writing and organization.

PART 5: ERROR RATE CALCULATION

For the case of a DCS system using **raised-cosine** pulse shape and binary PAM signaling, find by simulation the average error rate as a function of the signal-to-noise ratio E_b/N_0.

Also, for the case of a DCS system using polar NRZ pulse shape and binary PAM signaling, find by simulation the average error rate. Then, plot the theoretical average error rate obtained in Part 2 for comparison. In this part, assume that $p = 0.5$.

Note that in this part, you have to generate 10^5 bits, with $p = 0.5$. You also have to generate the AWGN according to its given properties.

Deliverables - Part 5

Deliver, electronically, the following in a .zip file

1) Source code (.m files).
2) A figure of the average error rates on a logarithmic scale (total 3 curves on the same plot).
3) A .pdf file of the whole report, including the figures, properly labeled and titled. The report should also include your comments.

Grading Criteria

Grading of this part will depend on:

- **50%:** Completeness and correctness of deliverables (as per the .pdf report)
- **30%:** Clarity of figures, and proper labeling (as per the .pdf report)
- **20%:** Report writing and organization.