Spring 2025 EE 445S Real-Time Digital Signal Processing Laboratory Prof. Evans

Homework #5 ***Steepest Descent, Frame Synchronization, and Baseband Transmitter***

Assigned on Saturday, March 29, 2025, at 4:00pm
Due on Friday, April 4, 2025, by 11:59pm

Homework submitted after 11:59pm will be subject to a penalty of 2 points per minute late.

Reading: Johnson, Sethares & Klein, chapters 6, 9 and 10

Problem 5.1 introduces steepest descent which we will use to adapt system parameters in the receiver to estimate and track carrier frequency and phase offset, symbol timing period and offset, gain control and equalizer coefficients. Problem 5.2 simulates baseband processing for a pulse amplitude modulation system. Problem 5.3 asks you to evaluate implementation complexity for pulse shaping.

Office hours for the teaching assistants and Prof. Evans; **bold** indicates a 30-minute timeslot.

Time Slot	***Monday***	***Tuesday***	***Wednesday***	***Thursday***	***Friday***
10:30am	**Evans (ECJ 1.312)**		**Evans (ECJ 1.312)**		
11:00 am	Evans (ECJ 1.312)		Evans (ECJ 1.312)		
12:00 pm					Evans coffee hours (EER Cafe)
1:00 pm			Evans (EER 6.882 & Zoom)		Evans coffee hours (EER Cafe)
2:00 pm			Evans (EER 6.882 & Zoom)	Barati (TBA)	
3:00 pm				**Barati (TBA)**	
3:30 pm				**Eun (TBA)**	
4:00 pm				**Eun (TBA)**	**Eun (EER 1.810)**
4:30 pm			**Barati (EER 1.810)**	**Eun (TBA)**	**Eun (EER 1.810)**
5:00 pm			**Barati (EER 1.810)**		**Eun (EER 1.810)**
5:30 pm			**Barati (EER 1.810)**		

NOTE: In your solutions, please put all work for problem 1 together, then all work for problem 2 together, etc.

Please submit any MATLAB code that you have written for the homework solution

As stated on the course descriptor, "Discussion of homework questions is encouraged. Please be sure to submit your own independent homework solution."

Homework #5 Hints

A ***Hamming window*** is an even symmetric pulse about the midpoint with endpoints having value 0.08. The Matlab command for the Hamming window is `hamming`. The amplitude values of the causal Hamming window of length N samples is defined as

$$w[n] = 0.54 - 0.46 \cos(2 \pi n / (N - 1)) \text{ for } n = 0, 1, ..., N\text{-}1.$$

The group delay of a Hamming pulse of length N samples is $(N\text{-}1)/2$ samples.

5.1 Steepest Descent. 30 points.

Johnson, Sethares & Klein, exercise 6.23, page 117, but use $J(x) = x^2 - 14x + 49$. Derive the adaptive equations for x to find the minimum value of $J(x)$. For part (a), use values of μ of -0.01, 0.00, 0.01, 0.1, 1.0, 10.0. For parts (b) and (c), use μ of 0.01.

The objective function J(x) has the form of a least squares problem because we can factor the objective function into $J(x) = (x - 7)^2$. *That is, we're trying to find x that minimizes the squared distance to the desired answer of 7. This is also called a least squares problem. For the rest of the semester, we'll be making heavy use of the adaptive least mean squares approach in this problem to solving a wide variety of least squares problems, esp. as related to compensating for impairments experienced by propagating signals. Examples in a communication receiver include carrier frequency and phase recovery, symbol synchronization, automatic gain control and channel equalization. We'll explore those subsystems in homework assignments #6 and #7.*

5.2 Frame Synchronization. 40 points.

Johnson, Sethares & Klein, exercise 9.6, page 177. For the marker in part (b), please use a pseudo-noise sequence of length 31 samples.

This problem relates to homework problems 4.2 and 4.3.

5.3 Baseband PAM Transmitter. 30 points.

For a baseband pulse amplitude modulation (PAM) transmitter, please compare the implementation complexity of two approaches for interpolation: (a) upsampling followed by a finite impulse response (FIR) pulse shaping filter and (b) polyphase FIR filter bank, by completing the table on slide 13-14. Draw block diagrams for both approaches. Lecture 13 slides 8 through 16 might also be helpful.

Please read the online hints for homework #5.

Homework #5 Hints