The University of Texas at Austin
Dept. of Electrical and Computer Engineering
Midterm #2

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Date: December 5, 2014 Course: EE 445S

Name: ____
Last, First

- The exam is scheduled to last 50 minutes.
- Open books and open notes. You may refer to your homework assignments and the homework solution sets. You may not share materials with other students.
- Calculators are allowed.
- You may use any standalone computer system, i.e. one that is not connected to a network. **Disable all wireless access from your standalone computer system**.
- Please turn off all cell phones and other personal communication devices.
- All work should be performed on the quiz itself. If more space is needed, then use the backs of the pages.
- **Fully justify your answers unless instructed otherwise**. When justifying your answers, you may refer to the Johnson, Sethares & Klein textbook, the Welch, Wright and Morrow lab book, course reader, and course handouts. Please be sure to reference the page/slide number and quote the particular content you are using in your justification.

Problem	Point Value	Your score	Topic
1	21		Energy Detection
2	27		Communication Performance
3	30		Echo Cancellation
4	22		Transceiver Design
Total	100		

Problem 2.1. *Energy Detection*. *21 points*.

Energy detection is useful in a wide variety of signal processing applications.

Definition of energy for a causal discrete-time signal $r[m]$ follows:

$$Energy = \sum_{m=0}^{\infty} |r[m]|^2$$

Several linear time-invariant energy detectors are given below. Assume all initial conditions are zero.

For each energy detector, input $x[m]$ is the instantaneous power $|\, r[m]\, |^2$. Output is $y[m]$.

Give the transfer function for each system and give the primary advantage and disadvantage of each.

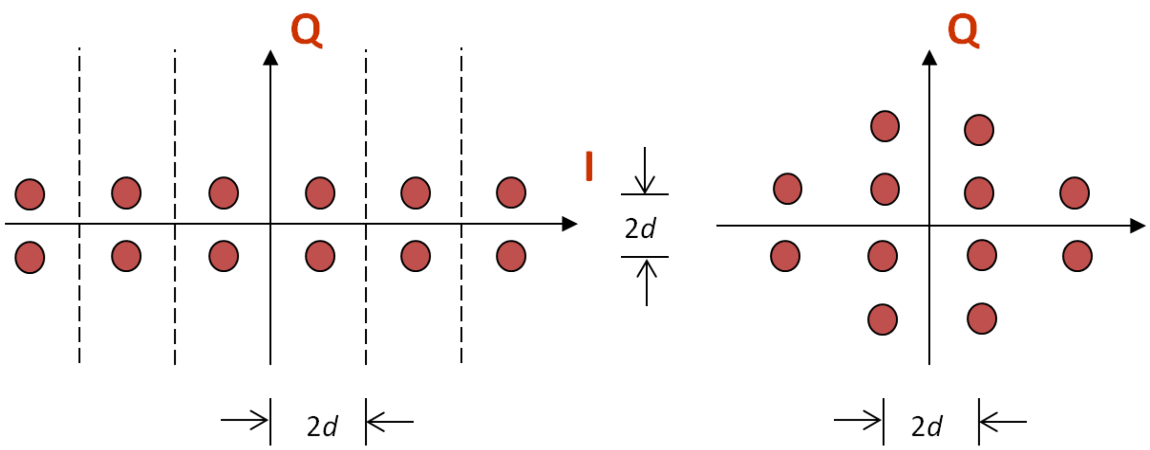
(a) Running sum: $y[m] = y[m-1] + x[m]$. *7 points*.

(b) Sum of current input and previous M-1 inputs: $y[m] = x[m] + x[m-1] + \ldots + x[m-(M-1)]$. *7 points*.

(c) Weighted combination using constant c where $0 < c < 1$: $y[m] = c\, y[m-1] + (1-c)\, x[m]$.

Problem 2.2 *Communication Performance*. *27 points*.

Consider the two 12-QAM constellations below. Constellation spacing is $2d$.



Energy in the pulse shape is 1. Symbol time T_{sym} is 1s. The constellation on the left includes the decision regions with boundaries shown by the I axis, Q axis and dashed lines.

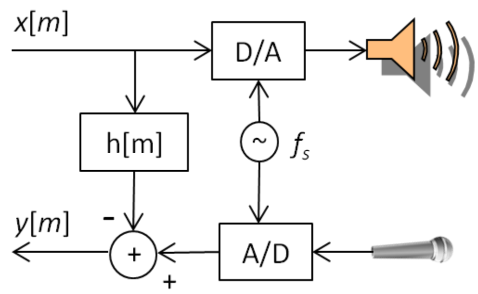
	Left Constellation	Right Constellation
(a) Peak power	$26\ d^2$	
(b) Average power	$12.67\ d^2$	
(c) Number of type I regions	0	
(d) Number of type II regions	8	
(e) Number of type III regions	4	

Draw the decision regions for the right constellation on top of the right constellation. *3 points*.

Fill in each entry (a)-(e) in the above table for the right constellation. Each entry is worth *3 points*.

Which of the two constellations would you advocate using? Why? *9 points*.

Problem 2.3. *Echo Cancellation*. *30 points*.



A block diagram of a speakerphone is shown to the right.

During a phone call, the received speech plays out over the speaker. The sound from the speaker is captured by the microphone, and the caller will hear an echo of his/her voice.

$x[m]$ is a reference signal. It is either the digitized speech from the other person on the call or a training signal.

$h[m]$ is the impulse response of a finite impulse response filter.

The analog-to-digital (A/D) and digital-to-analog (D/A) converters are synchronized by use of a common sampling clock. The A/D and D/A converters quantize to B bits per sample.

Design the finite impulse response (FIR) filter to reduce echo by using an adaptive method.

(a) Give a reference signal for $x[m]$ to use for training $h[m]$. Why did you choose it? *6 points*.

(b) During training, the ideal value for $y[m]$ is 0, which would mean that all echo has been removed.

i. Give an objective function $J(y[m])$ to be minimized. *9 points*.

ii. Give the update equation for the vector $\vec{h}$ of FIR coefficients. *9 points*.

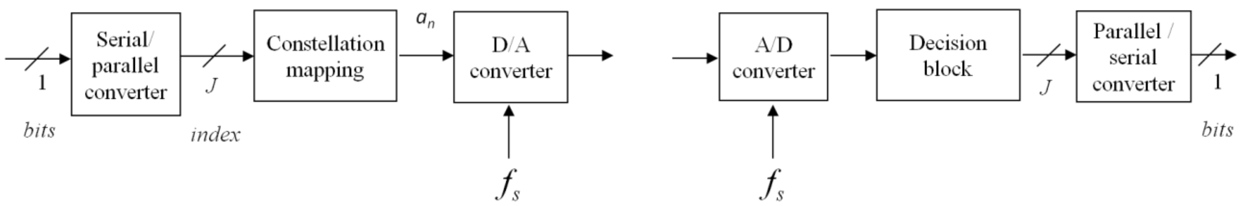
iii. What values would you recommend for the step size μ? *6 points*.

Problem 2.4. *Transceiver Design*. *22 points*.

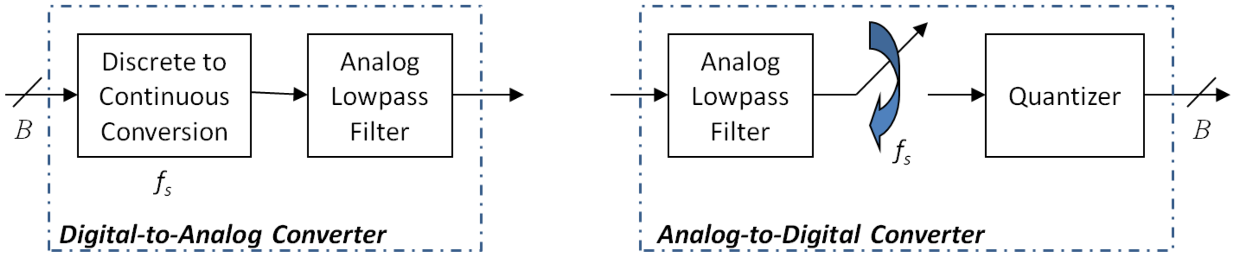
In certain discrete-time baseband transceivers, we remove the pulse shaping filter in the transmitter and the matched filter in the receiver to reduce complexity.

We also remove the upsampler in the transmitter and downsampler in the receiver.

Here is the resulting transmitter (left) and receiver (right) for baseband pulse amplitude modulation:



Here are block diagrams for the analog-to-digital (A/D) and the digital-to-analog (D/A) converters:



(a) What is the formula relating the symbol rate f_{sym} and the sampling rate f_s? *4 points*

(b) Consider a channel model of only additive spectrally-flat Gaussian noise.

i. Which block in the block diagrams acts as a pulse shaping filter? In what way? *4 points*.

ii. Which block in the block diagrams acts as a matched filter? In what way? *4 points*.

iii. How close does the matched filter you identified in part (b)-ii above come to the optimal matched filter? *4 points*.

(c) Consider a binary phase shift keying (BPSK) system, a.k.a. two-level Pulse Amplitude Modulation, with symbol amplitudes of $-d$ and $+d$. Give a formula for d. Why? *6 points*.