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

Prof. Brian L. Evans

Date: December 4, 2015 Course: EE 445S

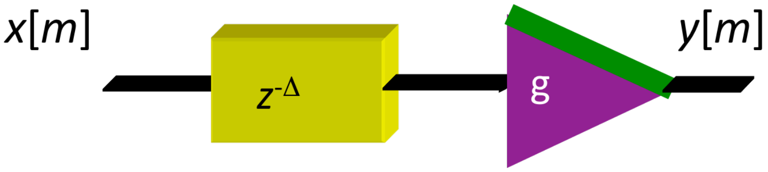
Name: ________________________________________________
Last, First

- 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 smart phones and other personal communication devices.
- Please remove headphones.
- 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 (JSK) textbook, the Welch, Wright and Morrow (WWM) lab book, course reader, and course handouts. Please be sure to reference the page/slide number and quote the particular content in your justification.

| Problem | Point Value | Your score | Topic |
|---|---|---|---|
| 1 | 21 | | Ideal Channel Model |
| 2 | 27 | | QAM Communication Performance |
| 3 | 28 | | Narrowband Interference |
| 4 | 24 | | Potpourri |
| Total | 100 | | |

**Problem 2.1.** *Ideal Channel Model. 21 points.*

Consider the following block diagram of an ideal channel model:



Assume that the delay $\Delta$ is positive and the gain $g$ is not zero.

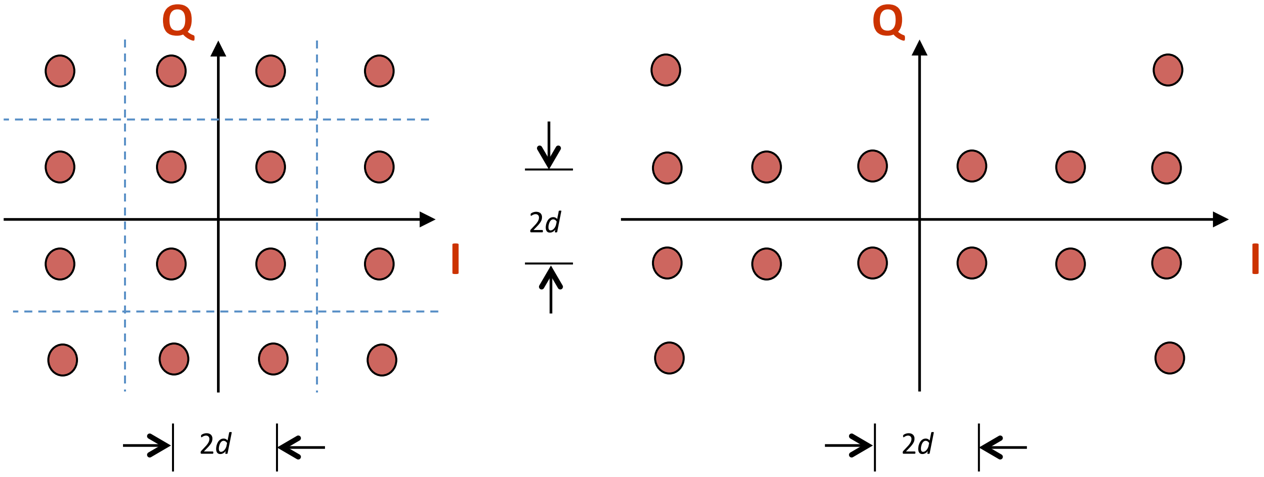
(a) Give an algorithm to recover $x[m]$ from $y[m]$ assuming that the values of $\Delta$ and $g$ are known. *6 points.*

(b) For a pseudo-noise training sequence known to the transmitter and receiver, give an algorithm for the receiver to estimate the delay $\Delta$ and gain $g$. *9 points.*

(c) Given a sequence of -1 and +1 values, how could you verify whether or not it is a maximal length pseudo-noise sequence? *6 points.*

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

Consider the two 16-QAM constellations below. Constellation spacing is $2d$.



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

| | Left Constellation | Right Constellation |
|---|---|---|
| (a) Peak transmit power | $18d^2$ | |
| (b) Average transmit power | $10d^2$ | |
| (c) Number of type I regions | 4 | |
| (d) Number of type II regions | 8 | |
| (e) Number of type III regions | 4 | |
| (f) Probability of symbol error for additive Gaussian noise with zero mean & variance $\sigma^2$ | $3Q\left(\frac{d}{\sigma}\right)-\frac{9}{4}Q^2\left(\frac{d}{\sigma}\right)$ | |

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

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

Which of the two constellations would you advocate using? Why? Please give at least two reasons. *6 points*.

**Problem 2.3.** *Narrowband Interference. 28 points.*

Consider a baseband pulse amplitude modulation communication system in which the narrowband interference is stronger than the transmitted signal and additive noise at the receiver input.

Design a causal second-order adaptive infinite impulse response (IIR) filter to remove the interference:

- Zero locations are at $\exp(j\ \omega_0)$ and $\exp(-j\ \omega_0)$
- Pole locations are at $r\ \exp(j\ \omega_0)$ and $r\ \exp(-j\ \omega_0)$

Relationship between input $x[m]$ and output $y[m]$ is

$y[m] = x[m] - (2\cos\omega_0)\, x[m-1] + x[m-2] + (2\, r \cos\omega_0)\, y[m-1] - r^2\, y[m-2]$

To guarantee stability, we will set the pole radius $r$ to a constant value so that $0 < r < 1$.

We will adapt the frequency location of the notch, $\omega_0$.

(a) Determine an objective function $J(y[m])$. *6 points.*

(b) What initial value of $\omega_0$ would you use? Why? *6 points*

(c) Compute the partial derivative of $y[m]$ with respect to $\omega_0$. You may assume that the partial derivative of $y[m]$ with respect to $\omega_0$ is 0 for $m < 0$. *6 points.*

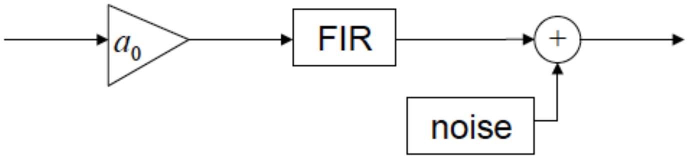
(d) Based on your answers in (a), (b), and (c), derive an update equation to adapt $\omega_0$. *6 points.*

(e) For the answer in (d), what value of the step size would you recommend? Why? *4 points.*

**Problem 2.4.** *Potpourri*. *24 points*

In a communication receiver, a finite impulse response (FIR) channel equalizer may be designed by various methods. For this problem, the channel equalizer will operate at the sampling rate.

Consider the following channel model:



Here, $a_0$ represents time-varying fading gain and the FIR filter models the channel impulse response.

(a) Describe why the channel impulse response is modeled by a finite impulse response. *6 points*.

Wireless channels –

Wired channels –

(b) Describe what a channel equalizer tries to do. *6 points*.

Time domain –

Frequency domain –

(c) When the transmitter is transmitting a known training sequence, would you recommend using a least squares method or an adaptive least mean squares method for the channel equalizer? Please justify your answer for each criteria below. *6 points*.

Communication performance –

Implementation complexity –

(d) If the noise contained a narrowband interferer in the transmission band, would a separate notch filter be needed in addition to the channel equalizer? Why or why not? *6 points*.