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

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Date: May 4, 2018 Course: EE 445S

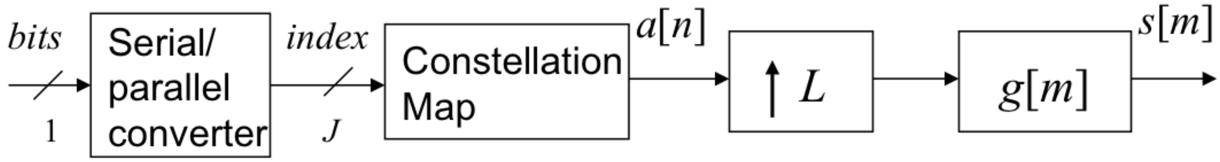
Name: ____
Last, First

- 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	24		Baseband Pulse Amplitude Modulation
2	28		QAM Communication Performance
3	24		QAM Constellation Derotation
4	24		Potpourri
Total	100		

Problem 2.1. *Baseband Pulse Amplitude Modulation. 24 points.*

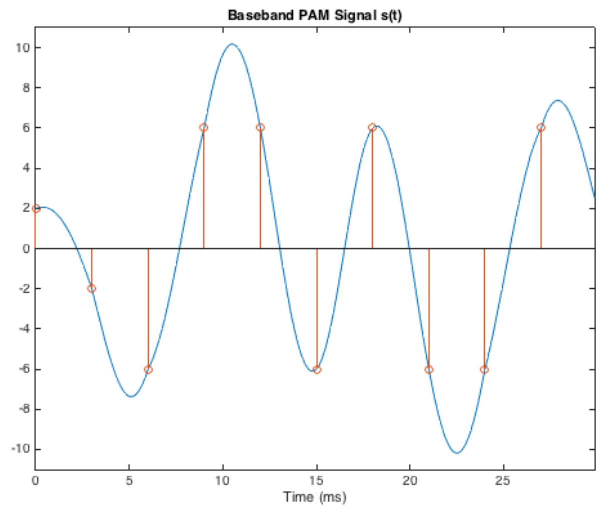
A baseband pulse amplitude modulation transmitter is described as



where

$a[n]$ symbol amplitude	f_s sampling rate	f_{sym} symbol rate	$g[m]$ pulse shape
J bits/symbol	L samples/symbol	N_g symbol periods in a pulse shape	

For $N_g = 4$ and $L = 20$, a plot is shown below for 10 symbol periods over 0 to 30 ms of $s[m]$ after it had passed through a digital-to-analog converter, and the symbol amplitudes $a[n]$ are shown as a stem plot:



(a) What is the value of J, the number of bits per symbol? Why? *3 points.*

(b) If the spacing between constellation points is $2d$, what is the value of d? Why? *3 points.*

(c) Draw a constellation map with Gray coding. *3 points.*

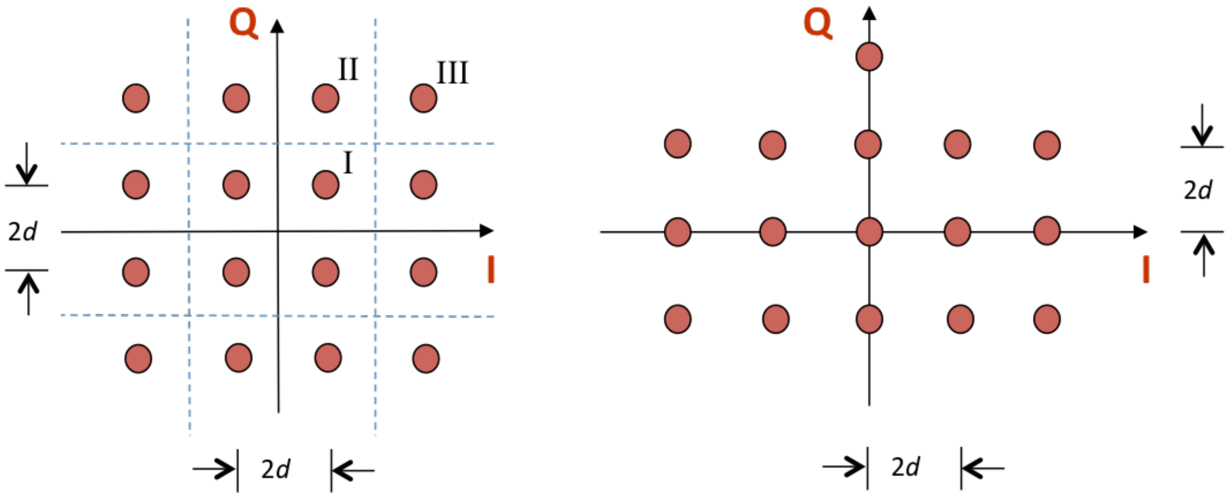
(d) Accurately compute the symbol time, T_{sym}, in milliseconds. *3 points.*

(e) Give a formula for the pulse shape, $g[m]$. How many samples are in $g[m]$? *6 points.*

(f) Infer an upper bound on the amplitude of $s[m]$ as a function of d, J and N_g. *6 points.*

Problem 2.2 *QAM Communication Performance. 28 points.*

Consider the two 16-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 in-phase (I) axis, quadrature (Q) axis and dashed lines.

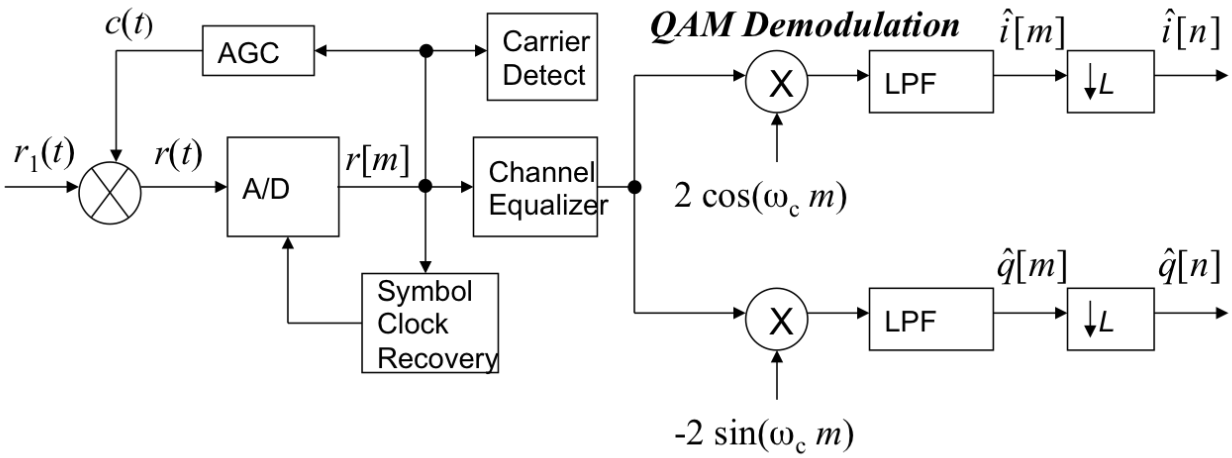
Each part below is worth 3 points. **Please fully justify your answers.**

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

(h) Consider using the constellations in upconverted QAM. In the QAM receiver, how would the Costas loop for the phase locked loop perform for the right constellation vs. the left constellation? *7 points.*

Problem 2.3. *QAM Constellation Derotation. 24 points.*

A baseband Quadrature Amplitude Modulation (QAM) receiver is given below



where $\hat{\imath}[n]$ and $\hat{q}[n]$ are the received in-phase and quadrature symbol amplitudes at symbol index *n*.

At the receiver, the QAM constellation may rotate due to a mismatch in the carrier frequencies.

A phase locked loop running at the sampling rate could track the time-varying phase that is due to the carrier frequency mismatch.

An alternative is to derotate the constellation at the symbol rate by multiplying the complex symbol $\hat{\imath}[n] + j\,\hat{q}[n]$ by $e^{j\theta}$, i.e. $i[n] + j\,q[n] = (\hat{\imath}[n] + j\,\hat{q}[n])e^{j\theta} = (\hat{\imath}[n] + j\,\hat{q}[n])(\cos\theta + j\sin\theta)$:

$$i[n] = \hat{\imath}[n]\cos\theta - \hat{q}[n]\sin\theta \quad \text{and} \quad q[n] = \hat{q}[n]\cos\theta + \hat{\imath}[n]\sin\theta$$

We will adapt the phase offset θ based on the error vector magnitude $e[n]$ in the decision device, i.e.

$$e^2[n] = (i[n] - \hat{\imath}[n])^2 + (q[n] - \hat{q}[n])^2$$

(a) Give an objective function $J(e[n])$. *6 points.*

(b) Derive the update equation for θ_{k+1}, where *k* is a symbol index. *9 points.*

(c) What range of values would you recommend for μ? *3 points.*

(d) This method can work with or without a training sequence. If you were to use a training sequence, which one would you use? Why? *6 points.*

Problem 2.4. *Potpourri. 24 points*

(a) What is the primary advantage of using symbol amplitudes of $-3d$, $-d$, d and $3d$ for 4-level pulse amplitude modulation instead of d, $3d$, $5d$, and $7d$? *6 points.*

(b) How will fifth-generation (5G) cellular communication systems be able to provide 10 times the average and peak bit rates of fourth-generation (4G) cellular communication systems? *6 points.*

(c) For each communication subsystem below, advocate using either a discrete-time digital implementation or a continuous-time analog implementation.

i. Baseband processing. *3 points.*

ii. Upconversion to carrier frequencies greater than 1 GHz. *3 points.*

(d) In the automatic gain control (AGC) block diagram given below, the analog-to-digital converter outputs $r[m]$ which is a signed integer of B bits. Give a formula that uses $r[m]$ and the adapted gain $c(t)$ to create a floating-point approximation of $r_1(t)$. This type of floating-point analog-to-digital conversion is used in practice, e.g. in cellular basestations. *6 points.*