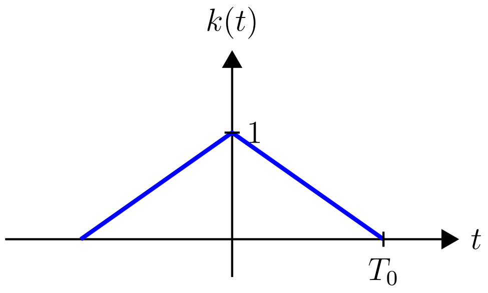
Last Name(s):	Grades
First (Middle) Name(s):	1
ID Number: .... Group:	2
Signature	3

Exercise 1

A baseband communication system uses transmitter and receiver filters whose joint response, $k(t)$, is shown in the figure



where T_0 is a design parameter.

a) Assuming an ideal channel, $h(t) = \delta(t)$, and a 4-PAM constellation, calculate the maximum bit rate of the system for a transmission free of Inter-Symbol Interference (ISI).

b) Consider in this section that $T_0 = T/2$, where T is the symbol duration, the constellation is a 2-PAM with normalized levels, white and equiprobable symbols, and the channel is $h(t) = \delta(t) - 1/4\ \delta(t-T)$. Calculate the probability of error when the noise is white, Gaussian and with variance σ_z^2.

(1.5 points)

Exercise 2

A baseband digital communication system has the following equivalent discrete channel

$$p[n] = \delta[n] + c\,\delta[n-1] - 0.5\,\delta[n-2].$$

The constellation is a 2-PAM with normalized levels, symbols are white and equiprobable, and thermal noise has power spectral density $N_0/2 = 10^{-1}$.

a) Design the optimal memoryless symbol-by-symbol detector for $c = -0.75$ (i.e., get the delay for the decision and the decision regions).

b) Considering $c = 1$, design a linear equalizer without limitation of coefficients with the minimum mean square error (MMSE) criterion and obtain its error probability. Explain how the optimal delay would be chosen, although you don't need to calculate it.

c) From now on, consider $c = 0$.

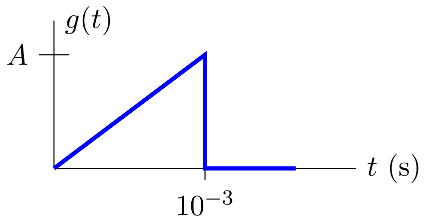
   I) Design a linear equalizer of 3 coefficients with the zero forcing (ZF) criterion and delay $d = 1$.

   II) Get the error probability for equalizer $w[n] = \delta[n] + 0.5\,\delta[n-1]$, assuming it has been designed for a delay $d = 0$.

REMARK: If an integral is involved in some answer, it is not necessary to solve it.
(2.5 points)

Exercise 3

A communication system uses a CPM modulation with unit amplitude, $x(t) = \sin(\omega_c t + \theta(t, \mathbf{I}))$, modulation index 3 and the normalized transmitter filter given in the figure below



a) For a full-response modulation in a 4-ary system ($I[n] \in \{\pm 1, \pm 3\}$):

  I) Calculate the maximum possible bit rate, clearly explaining how it was obtained.

  II) Find the value of the constant A.

  III) Calculate the mean energy per symbol of this system.

b) For the previous system, draw the phase tree for two symbol intervals.

c) Now we have a partial-response modulation, also in a 4-ary system.

  I) If it is possible to transmit only at a rate that is double or half the rate of the full-response system, choose the option that you consider most appropriate, clearly explaining why.

  II) For the chosen option, the first symbols of the sequence to be transmitted are

m	0	1	2
$I[m]$	$+1$	-1	$+3$

  Plot the individual contribution of each of these three symbols to the term $\theta(t, \mathbf{I})$, appropriately labeling both axes of the figure.

(2 points)

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Exercise 4

A digital communication system is designed to transmit at a bit rate of 4 Mbits/s using a 4-PAM constellation, the first symbols of which are shown below

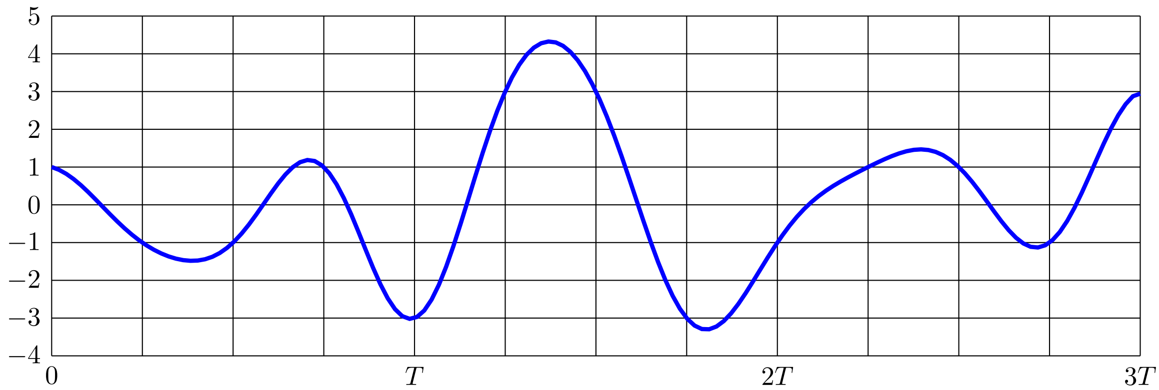
n	0	1	2	3	4	5	6	7
$A[n]$	$+3$	$+1$	-1	-3	$+3$	$+1$	-1	-3

a) If a direct sequence spread spectrum modulation is used, with spreading factor $N = 4$, spreading sequence $x[m] = \delta[m] - \delta[m-1] - \delta[m-2] + \delta[m-3]$ and a transmitter filter at chip rate $g_c(t) = h_{RRC}^{\alpha,T_c}(t)$, with roll-off factor $\alpha = 0.25$, for a baseband transmission:

I) Calculate the bandwidth of the modulated signal.

II) Obtain the first 8 samples of the discrete time sequence at chip rate, $s[m]$, $m \in \{0, 1, \cdots, 7\}$.

III) If the output of the receiver filter at chip rate, $f_c(t) = g_c(-t)$, is the signal shown in the figure below, calculate the following observations at symbol rate: $q[0]$ and $q[1]$.



b) Now an OFDM modulation with $N = 4$ carriers is used. The carrier frequency is 200 MHz and the equivalent discrete channel at $T/(N + C)$ is

$$d[m] = \delta[m] - \delta[m-2].$$

I) Transmitting without cyclic prefix, obtain the sequence of samples $s[m]$ corresponding to the transmission of the 8 symbols $A[n]$ given above, and calculate the bandwidth of the modulated signal.

II) Obtain the length of the cyclic prefix to transmit without ISI and ICI using the minimum bandwidth, calculate this bandwidth, and obtain the samples $\tilde{s}[m]$ to transmit in that case.

(2 points)

Exercise 5

Consider the following two codes of rate 1/2:

- A linear block code with generator matrix

$$G = \begin{bmatrix} 0 & 0 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 0 & 1 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 \end{bmatrix}.$$

- A convolutional code with generator matrix

$$G(D) = \left[\ 1+D \quad D+D^2\ \right].$$

a) For the linear block code:

I) Find the minimum Hamming distance.

II) Obtain the parity-check matrix and the syndrome table.

III) Decode the following received word using syndrome-based decoding:

$$\mathbf{r} = [\ 1 \quad 0 \quad 1 \quad 1 \quad 1 \quad 0\ ].$$

b) For the convolutional code:

I) Obtain the trellis diagram.

II) Find the minimum Hamming distance.

III) Assuming that the initial and final state are the zero state, i.e., $\psi_0 = [\ 0 \quad 0\ ]$, decode the message using the Viterbi algorithm when the received message is

$$\mathbf{r} = [\ 00 \quad 11 \quad 11 \quad 11 \quad 01\ ].$$

c) Which of the two codes can correct more errors?

(2 points)