1. Consider each of the systems with the input-output difference equation given as follows:

   (1) $y[n] = x[n] - x[n-1]$
   (2) $y[n] = \sum_{k=0}^{n} x[k]$
   (3) $y[n] = nx[n]$
   (4) $y[n] = 2x[n-1]$

   Answer the following questions:

   (a) (6%) Which of the four systems are linear ? You should justify your answer.
   (b) (7%) Which of the four systems are time-invariant ? You should justify your answer.
   (c) (7%) Find the unit impulse response $h[n]$ for those systems that are both linear and time-invariant.

2. Consider a system which is a cascade of two linear time-invariant (LTI) systems.

   (a) (8%) Let the first LTI system have the input-output difference equation given by $y[n] = x[n] + \frac{5}{6}x[n-1]$ and the second LTI system have the system function $H_2(z) = 1 - 2z^{-1} + z^{-2}$. Find the system function of the overall cascade system.
   (b) (12%) Let the first LTI system be a general finite impulse response (FIR) filter. Determine the conditions on the system function $H_1(z)$ of first LTI system if $H_2(z)$ is to be a stable and causal inverse filter for $H_1(z)$.

3. Consider the following wireless communication technologies: (1) Bluetooth (2) WiMAX (3) UWB (4) HSDPA (5) WiFi

   Answer the following questions:

   (a) (2%) Which one is designed for local area networking?
   (b) (2%) Which one is designed for broadband wireless access over wide range area?
   (c) (2%) Which one is used for "Wireless USB" technology?
   (d) (2%) Which one is an evolutionary improvement for the UMTS-based 3G networks?
   (e) (2%) Which one is designed for low data rate connections over short distances?

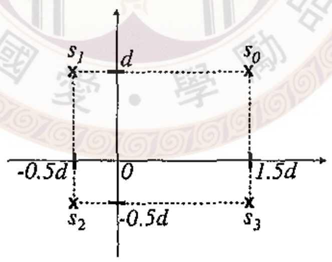

Figure 1: Signal constellation 1

4. Consider the signal constellation in Fig.1 using the following symbol mapping.

Bits: b_0b_1	Symbol s_i
00	s_0
10	s_1
01	s_2
11	s_3

   Assume that each bit equals to 0 or 1 with equal probability $\frac{1}{2}$. Given that the channel is AWGN with a power spectral density (PSD) of $\frac{N_0}{2}$, and the receiver makes the decision based on the minimum distance (MD) decision rule.

   (a) (5%) Derive and express the symbol error probability by d, N_0, and Q-function (or erfc).
   (b) (5%) Derive and express the bit error probability of the **first bit** b_0 by d, N_0, and Q-function (or erfc).
   (c) (5%) Find the $\frac{E_b}{N_0}$ required to achieve a bit error probability of 10^{-5} for the **second bit** b_1, where E_b denotes the transmitted energy per bit. Note: $Q(4.265) = 10^{-5}$.

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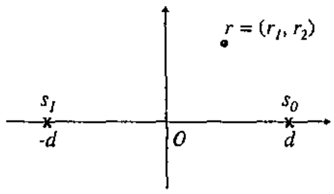

Figure 2: Signal constellation 2

5. Consider the signal constellation in Fig.2 . The probability of s_0 being transmitted is p and the probability of s_1 being transmitted is $1-p$, $p \neq \frac{1}{2}$. Assume that the receiver knows the symbols are unequally likely to be transmitted and it also knows the exact value of p. Given that the channel is AWGN with a PSD of $\frac{N_0}{2}$, the receiver makes decision based on the maximum aposteriori probability (MAP) decision rule. Let $r = (r_1, r_2)$ denote the match filter output at the receiver.

   (a) (5%) Derive and express the decision rule of the receiver using d, N_0, r_i, s_i (not necessarily using all). The decision rule has to be simplified to its simplest form.

   (b) (5%) Given that $p = \frac{1}{4}$ and $\frac{d}{N_0} = 2$, plot the decision region for each symbol according to the MAP decision rule. You should label your figure clearly and correctly without any ambiguity.

   (c) (5%) Now consider the signal constellation in Fig. 3. The probability of each symbol being transmitted is given as follows.

s_i	s_0	s_1	s_2	s_3
$P(s_i)$	$\frac{1}{6}$	$\frac{2}{6}$	$\frac{1}{6}$	$\frac{2}{6}$

   The channel is AWGN and we assume that the receiver knows the exact values of $P(s_i)$ and makes decision based on the MAP rule. Given that $\frac{d}{N_0} = 2$, plot the decision region for each symbol according to the MAP decision rule. You should label your figure clearly and correctly without any ambiguity.

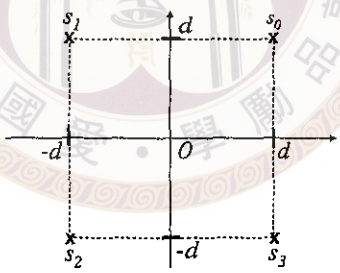

Figure 3: Signal constellation 3

6. Consider a convolutional code with generators $\mathbf{g_1} = [101]$, $\mathbf{g_2} = [111]$. Assume that trellis termination is not applied in encoding and the encoder always starts with the zero state.

   (a) (5 %) Explain why convolutional code has the word "convolutional" in its name?

   (b) (5 %) Please plot the trellis diagram of this code. You should specify the associated input/output bits for each branch.

   (c) (5 %) Given the demodulator output $\mathbf{y} = 11010011$, please find the **hard decision** decoding result for the decoder. You should show the decoding process.

   (d) (5 %) If BPSK is used for modulation with the signal constellation shown in Fig.4.

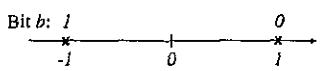

Figure 4: Signal constellation 4

   Given the match filter output values of eight BPSK symbols $\mathbf{r} = [0.3, 0.5, -0.1, -0.1, -0.2, -0.5, -0.3, 0.4]$, please find the **soft decision** decoding result for the decoder. You should show the decoding process.

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