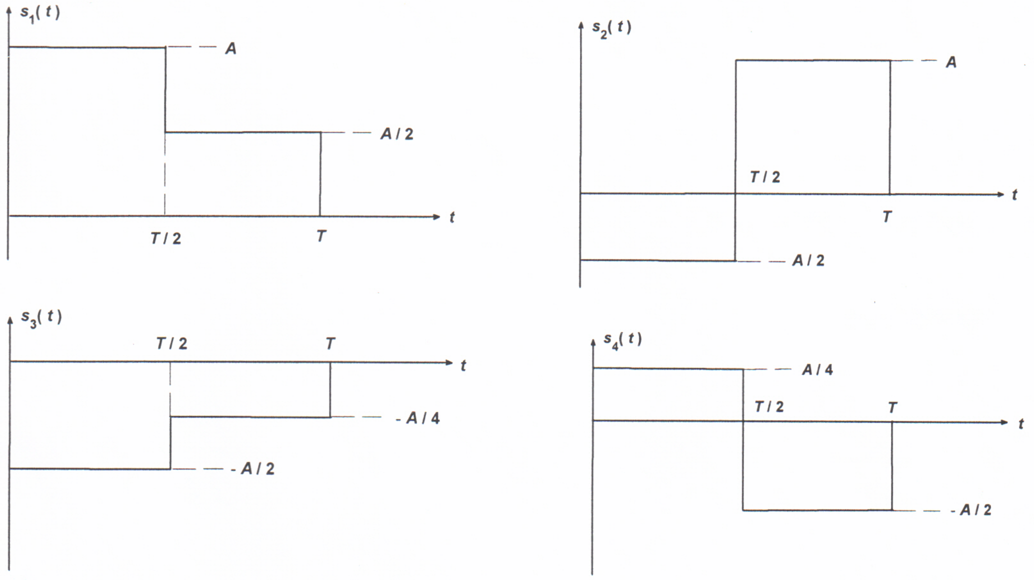
Çankaya University – ECE Department – ECE 376

Student Name :
Student Number :

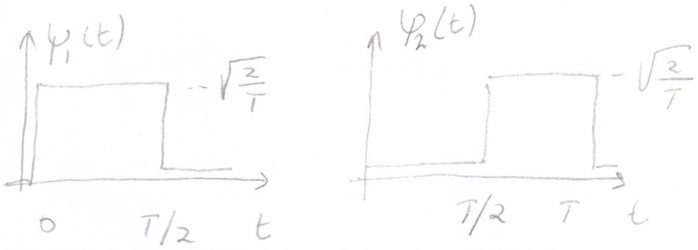
Open source exam
Duration : 2 hours

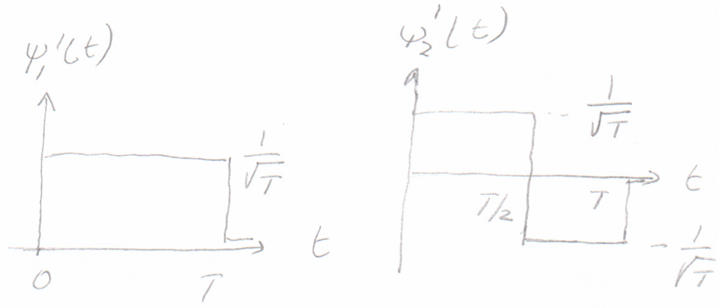
Questions

1. (70 Points) The four signals $s_1(t)$, $s_2(t)$, $s_3(t)$ and $s_4(t)$ are given as below. Determine the parameters M and N and what type of modulation (i.e., ASK, PSK, QAM, FSK), is represented by these signals and. Find set of $\psi_i(t)$ **orthogonal** basis functions for $s_1(t)$, $s_2(t)$, $s_3(t)$ and $s_4(t)$. Draw the signal constellation diagram, showing the position, the length of vectors $\mathbf{s}_1$, $\mathbf{s}_2$, $\mathbf{s}_3$ and $\mathbf{s}_4$ and the distance between them. Comment whether the spacings between the end points of $\mathbf{s}_1$, $\mathbf{s}_2$, $\mathbf{s}_3$ and $\mathbf{s}_4$ are maximized, if not suggest ways to improve it by indicating this optimum arrangement on the constellation diagram. Draw the receiver diagram as correlator and MF, find the output from the MF detector, if $s_3(t)$ is transmitted and compare this output to the output obtained from the correlator.



Solution: For $s_1(t) \cdots s_4(t)$ signals, $M=4$ and $N=2$ is sufficient to represent all waveforms. Thus the basis functions are





Alternative set

Writing $s_1(t) \cdots s_4(t)$ and s vectors [Taking $\varphi_1(t), \varphi_2(t)$ as basis functions]

$$s_1(t) = A \times \sqrt{\frac{T}{2}}\,\varphi_1(t) + \frac{A}{2}\sqrt{\frac{T}{2}}\,\varphi_2(t)$$

$$s_1 = \left[A\sqrt{\frac{T}{2}},\ \frac{A}{2}\sqrt{T/2} \right]$$

$$s_2(t) = -\frac{A}{2}\sqrt{\frac{T}{2}}\,\varphi_1(t) + A\sqrt{\frac{T}{2}}\,\varphi_2(t)$$

$$s_2 = \left[-\frac{A}{2}\sqrt{\frac{T}{2}},\ A\sqrt{\frac{T}{2}} \right]$$

$$s_3(t) = -\frac{A}{2}\sqrt{\frac{T}{2}}\,\varphi_1(t) - \frac{A}{4}\sqrt{\frac{T}{2}}\,\varphi_2(t)$$

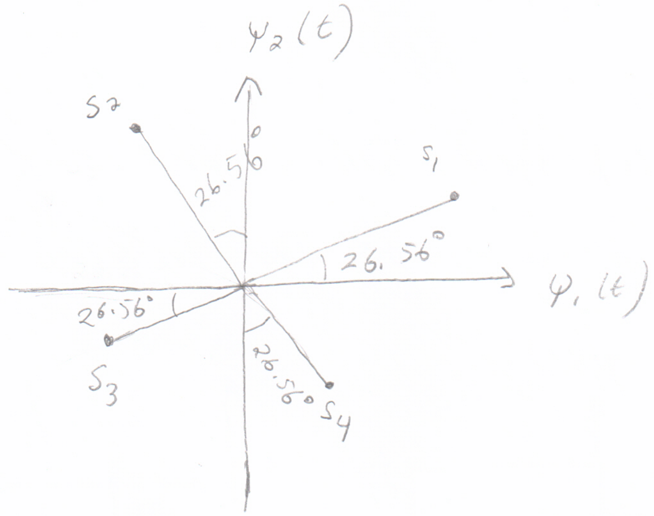
$$s_3 = \left[-\frac{A}{2}\sqrt{\frac{T}{2}},\ -\frac{A}{4}\sqrt{T/2} \right]$$

$$s_4(t) = \frac{A}{4}\sqrt{\frac{T}{2}}\,\varphi_1(t) - \frac{A}{2}\sqrt{\frac{T}{2}}\,\varphi_2(t)$$

$$s_4 = \left[\frac{A}{4}\sqrt{\frac{T}{2}},\ -\frac{A}{2}\sqrt{\frac{T}{2}} \right]$$

Length and energies of signal vectors

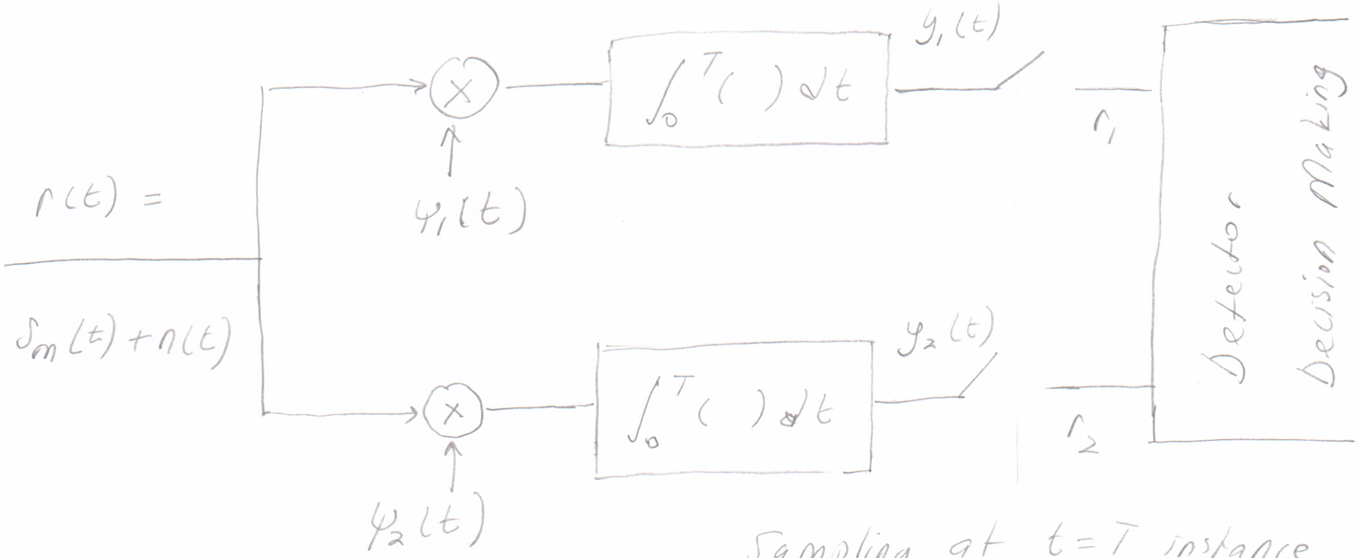
$$\|s_1\|^2 = \frac{5A^2T}{8} = \|s_2\|^2,\quad \|s_3\|^2 = \frac{5A^2T}{32} = \|s_4\|^2$$



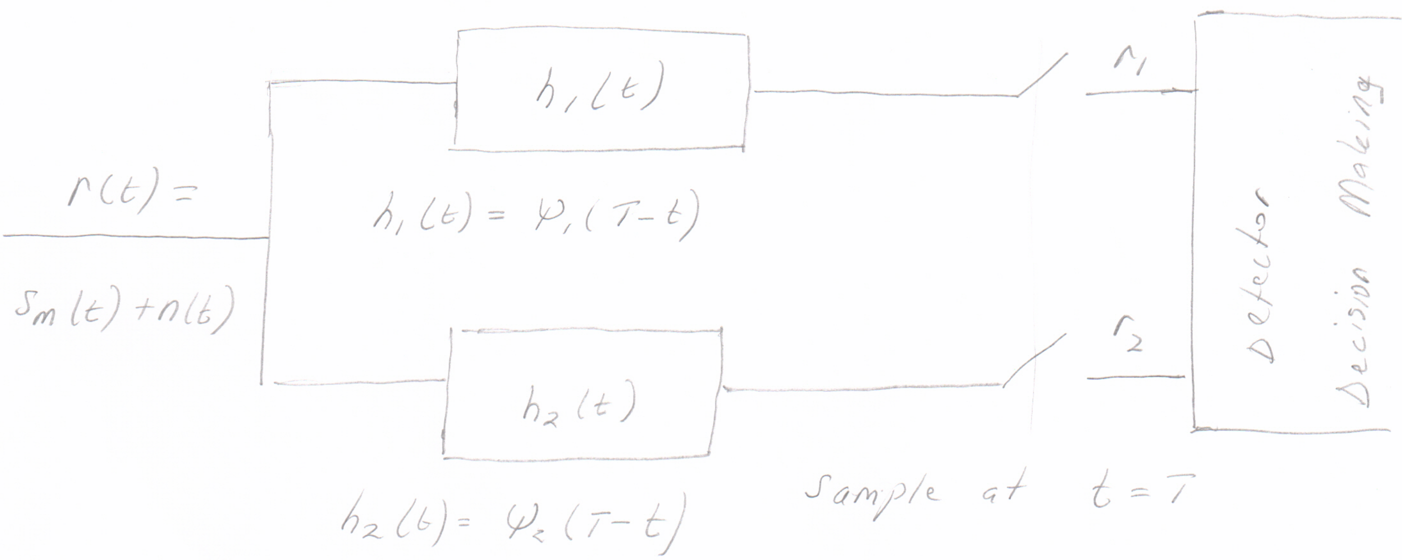
This is QAM, since singnal vector lengths of $s_1 \cdots s_4$ are different, additionally spacings between signal vectors seem to be optimom, since signal vectors are distributed at 90° wrt to adjacent ones. But if $M=4$, a more reasonable approach is to make signals have equal energies

In this case, the shown constellation converts into PSK, in any case for $M=4$ it is not logical use QAM.

Correlator Type of Receiver



MF (Matched Filter) Type of Receiver



Both for the correlator and the MF, if

$s_3(t)$ is transmitted from the transmitter

$$r_1 = \int_0^T s_3(t)\,\varphi_1(t)\,dt + \int_0^T n(t)\,\varphi_1(t)\,dt$$

$$= -\int_0^{T/2} \frac{A}{2} \times \sqrt{\frac{2}{T}}\,dt + n_1 = -\frac{A}{2}\sqrt{\frac{T}{2}} + n_1$$

$$r_2 = \int_0^T s_3(t)\,\varphi_2(t)\,dt + \int_0^T n(t)\,\varphi_2(t)\,dt$$

$$= -\frac{A}{4}\sqrt{\frac{T}{2}} + n_2$$

2. (30 Points) Answer the following questions as **True** or **False.** For the **False** ones give the correct answer or the reason. For the **True** ones justify your answer.

a) In receiver, demodulation fails, when the phase of the locally generated carrier is different from that of the carrier in received signal by 180^0 : False demodulation fails when the two carriers are different by 90°.

b) We can have orthogonality only along time axis : False, we can also have orthogonality along frequency axis (amoung non-overlapping frequency components or frequency bands)

c) The difference between PSK and QAM cannot be seen by looking at the constellation diagram : True, in PSK, all vector lengths are the same, but in QAM we will encounter signal vectors of unequal lengths.

d) At the output of the MF receiver, the characteristics of AWGN input noise changes : False At the output of MF receiver, the noise remains to be AWGN.

e) An optimum receiver makes a decision in favour of the signal that maximizes the value of correlation metrics, $\mathbf{C}(\mathbf{r},\mathbf{s}_m)$: True, The decision of an optimum receiver is based on selecting s_m which maximizes $C(r, s_m)$, thus the signal vector closest to r is chosen.