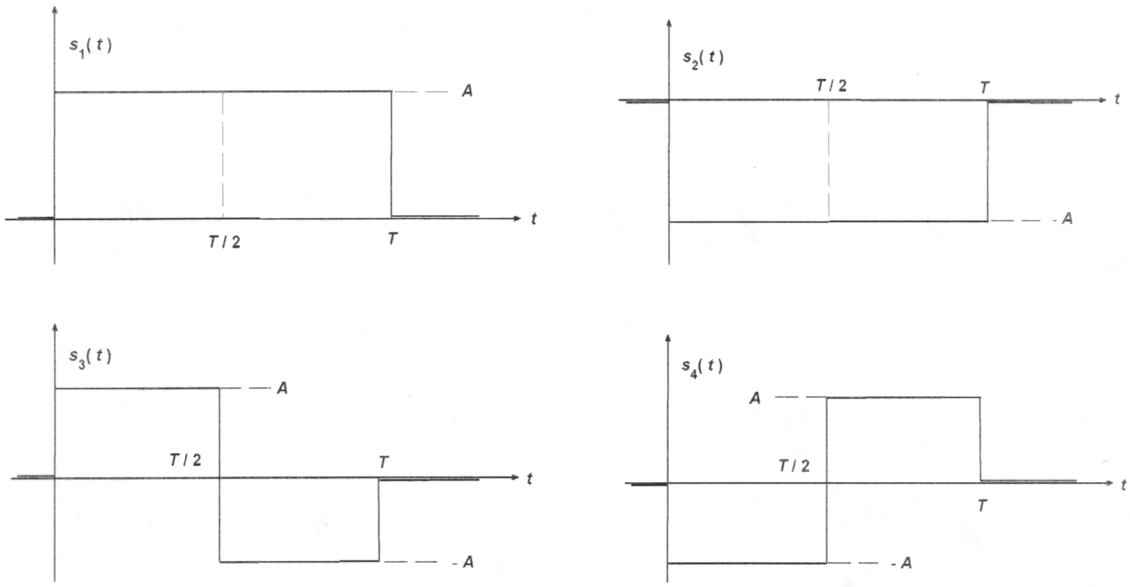
Çankaya University – ECE Department – ECE 588

Student Name :
Student Number :

Duration : 2 hours
Open book exam

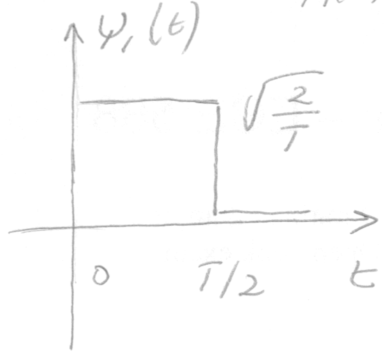
Questions

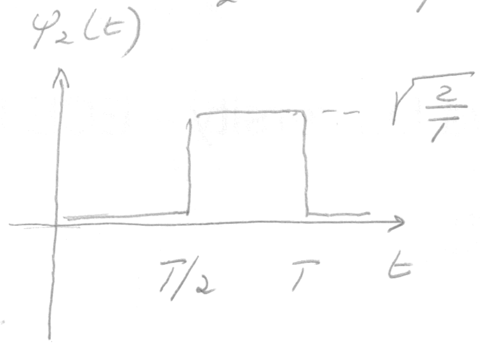
1. (70 Points) The following waveforms as shown below, $s_1(t)$, $s_2(t)$, $s_3(t)$ and $s_4(t)$ are given. For these waveforms find and plot orthonormalized basis functions $\psi_1(t)$ ... $\psi_N(t)$ and also determine N. Plot all $s_m(t)$ $m = 1...4$ signals on the signal space (constellation) diagram. Write for $\mathbf{s_m}$ (vectors), find the energy in each $\mathbf{s_m}$. Suggest what type of modulation $s_m(t)$ waveforms represent commenting on the efficiency of this representation. What is the minimum number of $s_m(t)$ signals to achieve a more efficient modulation ? Draw the receiver diagram incorporating correlator and MF (Matched Filter). Find the output from this receiver if $s_1(t)$ was transmitted.



Solution: It is clear that the waveforms $s_1(t)$ -- $s_4(t)$ can be (normalized) represented by two basis funtions divided into time slots of $0 \rightarrow T/2$ and $T/2 \rightarrow T$. Thus $\psi_1(t)$ and $\psi_2(t)$ will become

$\varphi_1(t) = \sqrt{\frac{2}{T}} \quad 0 < t < T/2, \quad \varphi_2(t) = \sqrt{\frac{2}{T}} \quad T/2 < t < T$



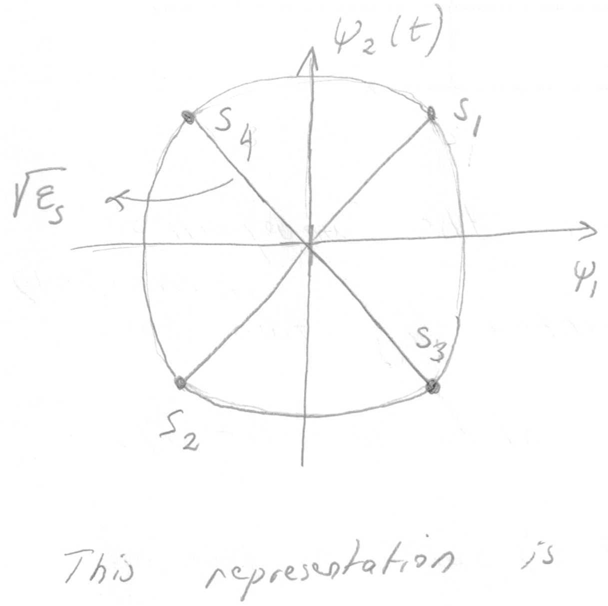


The s_m vectors in terms of coefficients of $\varphi_1(t)$ and $\varphi_2(t)$ making up the expressions of $s_1(t) \cdots s_4(t)$

$$\begin{array}{ccc} & \varphi_1(t) & \varphi_2(t) \\ s_1 = & \left[A\sqrt{\frac{T}{2}}, \right. & \left. A\sqrt{\frac{T}{2}} \right] \end{array}, \quad s_3 = \left[-A\sqrt{\frac{T}{2}}, -A\sqrt{\frac{T}{2}} \right]$$

$$s_2 = \left[-A\sqrt{\frac{T}{2}}, -A\sqrt{\frac{T}{2}} \right], \quad s_4 = \left[-A\sqrt{\frac{T}{2}}, A\sqrt{\frac{T}{2}} \right]$$

Constellation diagram accordingly



Length of each vector is the same, so this is PSK modulation

$N = 2, \quad \mathcal{E}_s = A^2 T$

This representation is efficient, since there are $\pi/2$ angular spacing between signal vectors.

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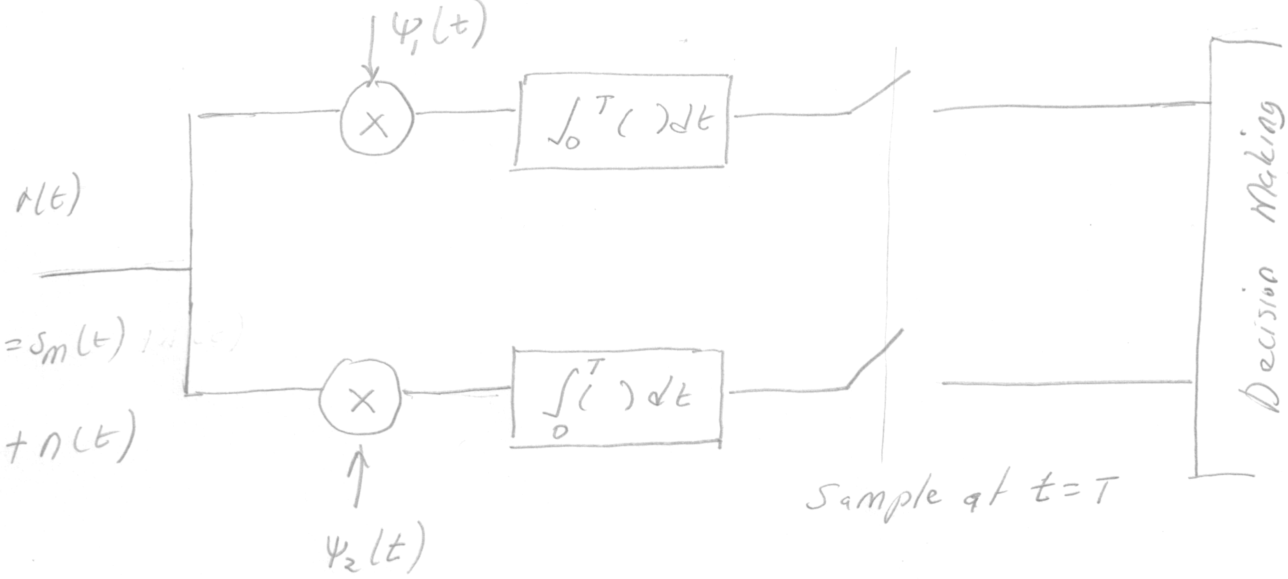
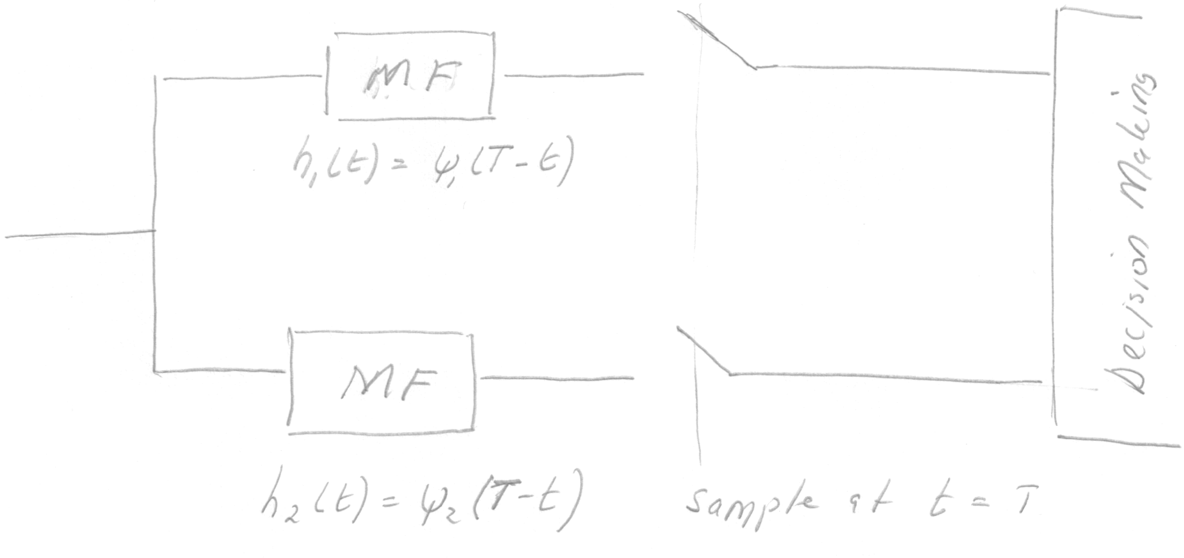
Receiver diagram incorporating correlator



Receiver diagram incorporating MF



If $s_1(t)$ is transmitted the OP (in both cases) shall be as follows for signal and noise parts

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For signal part

$$y_1 = \int_0^T s_1(t)\, \varphi_1(t)\, dt = A\sqrt{\frac{2}{T}}\, t \Big|_0^{T/2} = A\sqrt{\frac{T}{2}}$$

$$y_2 = \int_0^T s_1(t)\, \varphi_2(t)\, dt = A\sqrt{\frac{2}{T}}\, t \Big|_{T/2}^{T} = A\sqrt{\frac{T}{2}}$$

For noise part

$$n_1 = \int_0^T n(t)\, \varphi_1(t)\, dt \quad , \quad n_2 = \int_0^T n(t)\, \varphi_2(t)\, dt$$

Hence the vector going into the decision box is

$$r = \left[A\sqrt{\frac{T}{2}} + n_1 \, , \, A\sqrt{\frac{T}{2}} + n_2 \right] \quad \text{or}$$

$$r = \left[\sqrt{\frac{\mathcal{E}_s}{2}} + n_1 \, , \, \sqrt{\frac{\mathcal{E}_s}{2}} + n_2 \right]$$

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) PSK is two dimensional, while QAM is three dimensional : Both PSK and

True False

QAM are two dimensional. In QAM, there is the additional property that length of signal vectors may vary.

b) The performance of correlator and matched filter is the same : True

Since they are just two differents ways of implementing optimum detection, their performances are identical

c) Given the same symbol duration (T), PSK signal needs more bandwidth than ASK signal : False, if PSK and ASK use the same symbol duration, their bandwidth acquirements are the same.

d) $\mathbf{C}(\mathbf{r}, \mathbf{s}_m)$ values give us the distances from the received vector $\mathbf{r}$ to each signal $\mathbf{s}_m$ in the constellation : False, $C(r, s_m)$ values give us the correlation (similarity) between received vector r and s_m signals. $D(r, s_m)$ values give us distances.

e) $\mathbf{D}(\mathbf{r}, \mathbf{s}_m)$ calculations are used at the output of matched filter : True if the output of MF is refering to Decision making box where we make decisions based on $D(r, s_m)$ [or $C(r, s_m)$] values.