*Wendesday 12 March 2014; Time: 13h30 à 15h20*
*No notes allowed; no calculator allowed*

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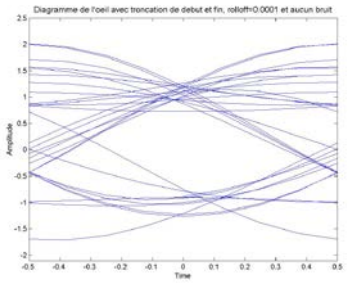
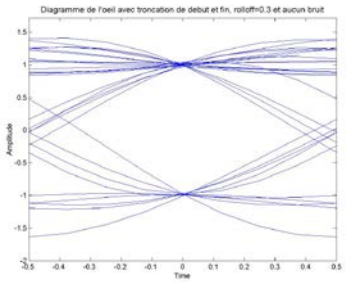
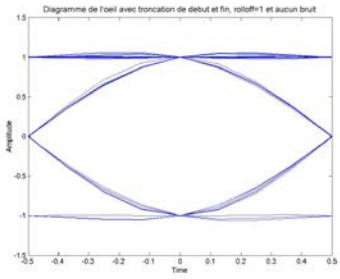
## Problem 1 (25 points out of 100)

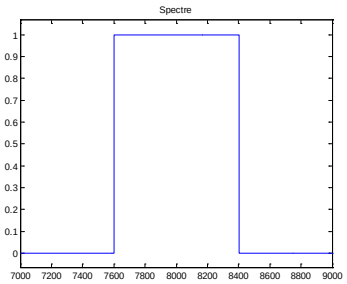
A. (10 points) For the three « raised cosine » pulses illustrated, give advantages/disadvantages making reference to the following graphs :

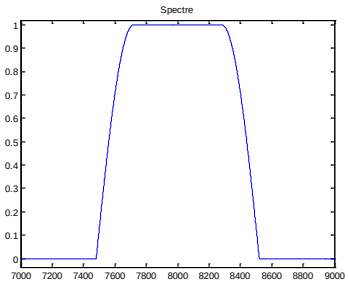
rolloff=0 rolloff=0.3 rolloff=1

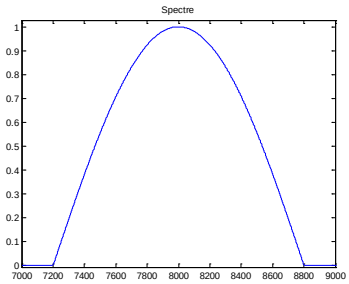


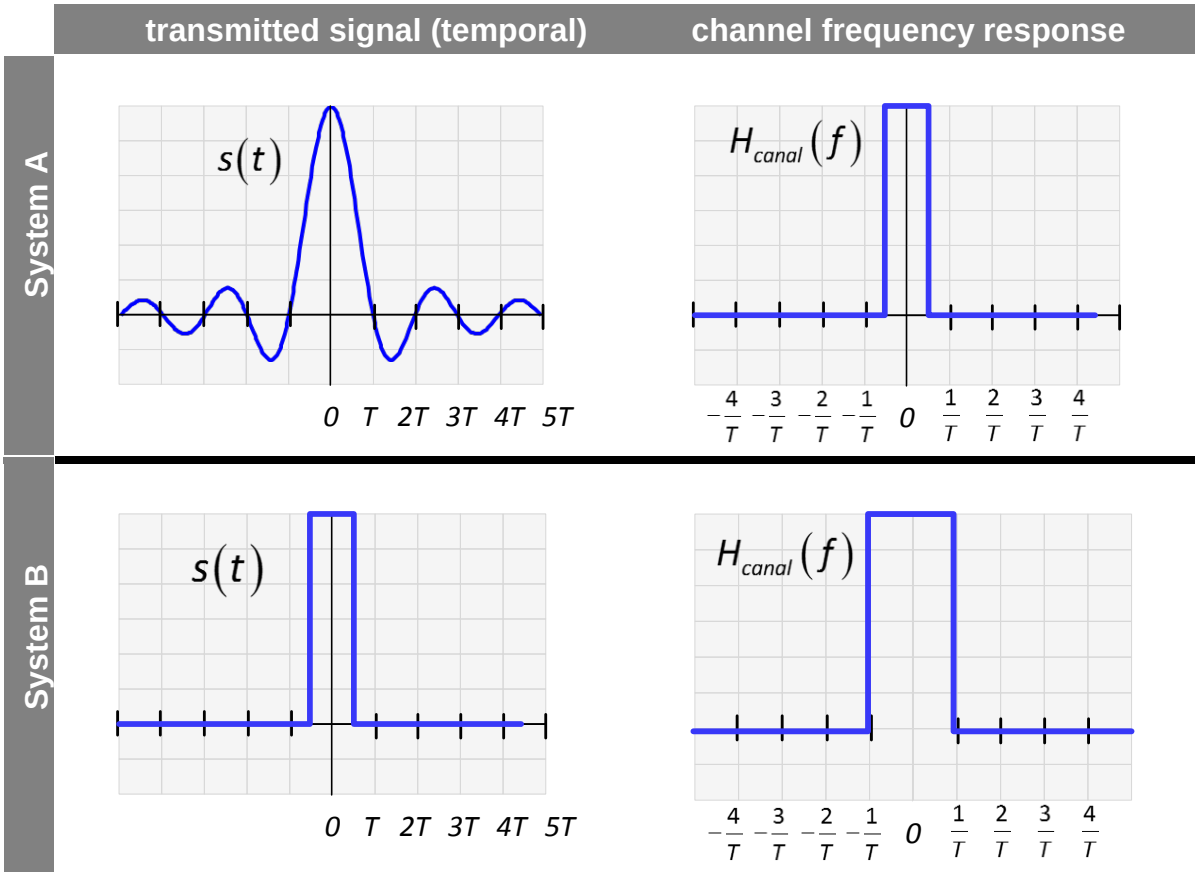




B. (5 points) What is the ideal Nyquist pulse and in what sense is it optimal?

C. (10 points) Which of the following two systems suffer the most from intersymblol interference (ISI), and why?




## Problem 2 (20 points)

For the signals

$$s_1(t) = 1, \qquad 0 \le t \le 1$$
$$s_2(t) = \cos 2\pi t, \quad 0 \le t \le 1$$
$$s_3(t) = \cos^2 \pi t, \quad 0 \le t \le 1$$

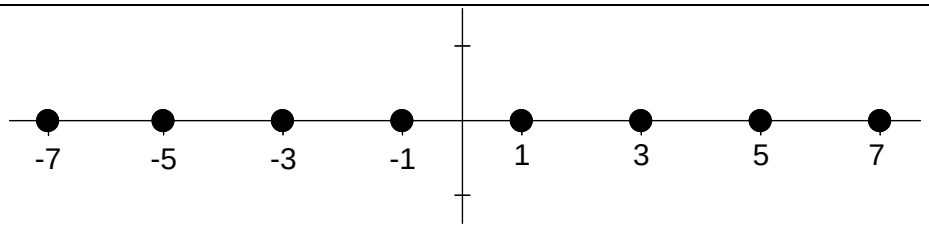
A. (10 points) Do the signals have the same energy? What is the average energy per bit?

B. (10 points) Give an orthogonal basis for the three signals.

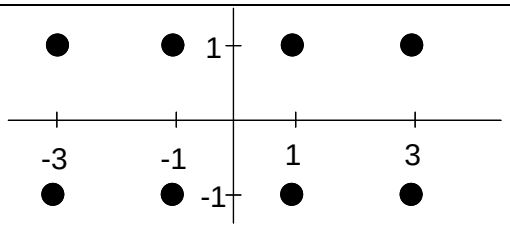
## Problem 3 (55 points out of 100)

The following are 4 constellations of 8 symbols with average energy per symbol $E_s$ :

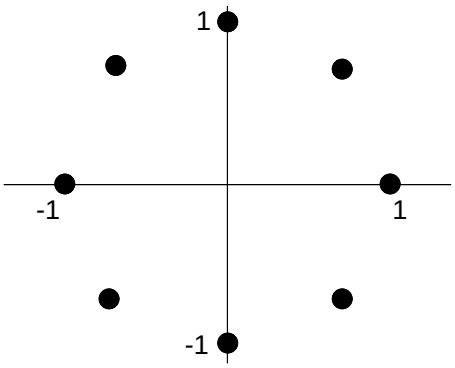
**A**




**B**




**C**




**D**

Hypercube in 8 dimensions; constellation points at

| | | | |
|---|---|---|---|
| $\left(\sqrt{E_s},0,0,0,0,0,0,0\right)$ | $\left(0,\sqrt{E_s},0,0,0,0,0,0\right)$ | $\left(0,0,\sqrt{E_s},0,0,0,0,0\right)$ | $\left(0,0,0,\sqrt{E_s},0,0,0,0\right)$ |
| $\left(0,0,0,0,\sqrt{E_s},0,0,0\right)$ | $\left(0,0,0,0,0,\sqrt{E_s},0,0\right)$ | $\left(0,0,0,0,0,0,\sqrt{E_s},0\right)$ | $\left(0,0,0,0,0,0,0,\sqrt{E_s}\right)$ |

A. (10 points) Give the correspondence between the four constellations and the modulations 8PSK, 8QAM, 8PAM, and 8FSK.

B. (5 points) How can we tell that only constellation D has coordinates given in signal space?

C. (10 points) Suppose that 1 Mb/s of data is transmitted with an ideal Nyquist pulse. What is the bandwidth (in Hz) for each constellation and the spectral efficiency for coherent detection (in b/s/Hz)?

D. (10 points) Calculate the signal space coordinates for constellations A and B.

E. (5 points) Find the error probability as a function of $E_b/N_0$ for constellation A using the approximation derived from the union bound.

F. (5 points) Find the loss in dB with respect to QPSK for constellation A.

G. (10 points) Place the constellation A in the following graph.