Final exam in
Digital Communications
on October 15, 2007, 8–13.

Department of Electrical and Information Technology
Lund University

- During this final exam, you are allowed to use a calculator, the textbook, and Tefyma (or equivalent).
- Each solution should be written on a separate sheet of paper.

  Please add Your name on each sheet.
- Show the line of reasoning clearly, and use the methods presented in the course.

  If You use results from the textbook, add a reference in Your solution.
- If any data is lacking, make reasonable presumptions.
- If You want or if You do not want Your result to appear on the department's web site, please write so on the cover page of the exam.

Good Luck!

Problem 1: Determine for each of the five statements below if it is true or false.
Observe! As usual, motivations to your answers should be given.

Assume a conventional M-ary baseband PAM system. The pulse shape is denoted $g(t)$.

a) Assume that $g(t) = g_{tri}(t)$ with duration $T_s/5$. "If the bit rate is 300 kbps and $M = 8$ then the one-sided width of the mainlobe is 1 MHz."

b) Assume that $g(t) = g_{hcs}(t)$ with duration T_s and $T_s = 0.25\mu s$. "If M is increased from 16 to 64 then the bandwidth efficiency is increased and the bandwidth is decreased."

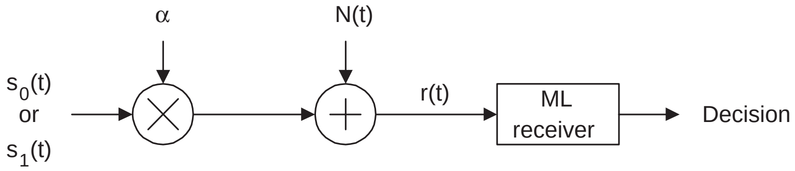
c) Assume a conventional AWGN channel, and ML receiver. "If $M = 64$ and $\mathcal{E}_b/N_0$ is 37 dB then $P_s \approx 4 \cdot 10^{-11}$."

d) "If $g(t) = g_{rec}(t)$ with amplitude A and duration $T_s/2$, and $M = 2$, then the average signal power equals $A^2/2$."

e) "If $M = 32$ then the energy efficiency is the same as for 1024-QAM with the same pulse $g(t)$."

(10 points)

Problem 2: Assume the binary communication system below.



The signal alternatives $s_0(t)$ and $s_1(t)$ are equally likely, and the average sent signal power $\bar{P}_{sent}$ has a given constant value. The parameter α describes the influence of the communication link, and $N(t)$ is AWGN with $R_N(f) = N_0/2$. A requirement is that the bit error probability equals 10^{-6}. $\mathcal{E}_b$ denotes the average received signal energy per information bit.

For the given communication link above it is known that if the bit rate is 96 kbps then $\mathcal{E}_b/N_0$ is 13 dB and $P_b = 10^{-6}$.

Assume now that the communication distance is changed, which changes α.

a) Which bit rates must be used if the communication distance is changed such that:

i) α is decreased to $\frac{\alpha}{5}$. ii) α is increased to 5α.

b) Compare the energy efficiency with binary antipodal signals.

c) Determine a detailed block diagram of the receiver which contains only one correlator.

(10 points)

Problem 3: Assume that the received signals $\{z_\ell(t)\}_{\ell=0}^{M-1}$ are conventional bandpass M-ary PAM signals. Also assume that a hcs pulse with amplitude A and duration $T = T_s/2$ is used. It is given that the 99.5% communication bandwidth equals 1 MHz. The communication is disturbed by AWGN $N(t)$ with power spectral density $R_N(f) = N_0/2$, and the ML receiver is used. It is given that the ratio $\bar{P}_z/N_0 = 4 \cdot 10^7$.

a) Explain why the symbol error probability in this case can be upper bounded by $2Q(\sqrt{d_{\min}^2 \mathcal{E}_b/N_0})$.

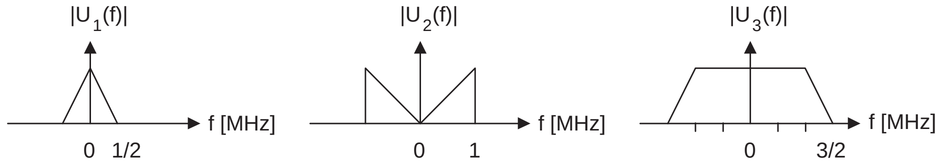
b) Determine the highest bit rate that can be used if the symbol error probability must not exceed (use the upper bound in a)).

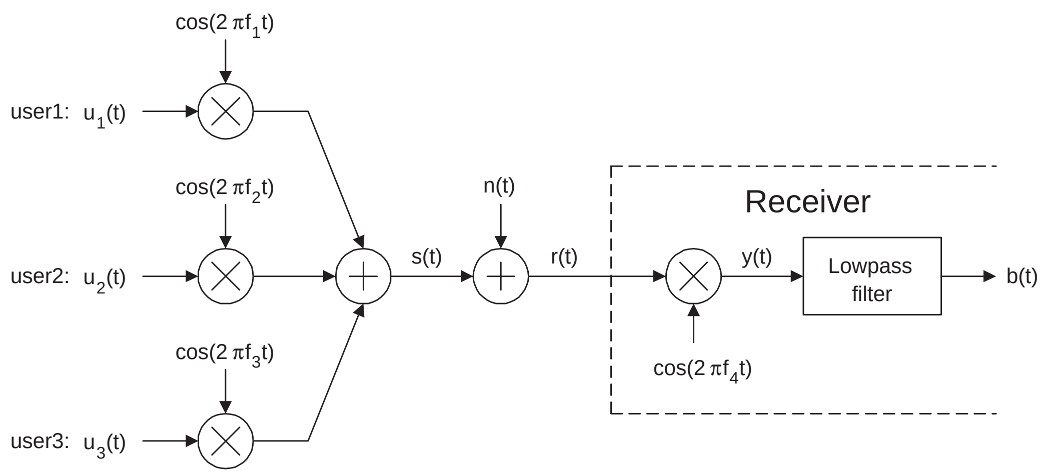
i) $2 \cdot 10^{-3}$ ii) $2 \cdot 10^{-12}$

(10 points)

Problem 4:

a) In the three-user digital communication system below, the frequency content in the user information signals $u_1(t)$, $u_2(t)$ and $u_3(t)$ are:





It is known that $f_1 = 65.7$ MHz and $f_3 = 61.7$ MHz. The disturbance $n(t) = \cos(2\pi f_A t) + \cos(2\pi f_B t)$ where $f_A = 62.7$ MHz and $f_B = 65.3$ MHz.
Only frequencies up to 1.5 MHz pass the lowpass filter. It is required that 60 MHz $\leq f_2 \leq$ 67 MHz.

Note that detailed calculations are not required below. However, the frequency content must be clearly seen in the figures.

i) Determine a suitable choice of f_2.

ii) Sketch the frequency content in $r(t)$ (use the value of f_2 in i)).

iii) Sketch the frequency content in $y(t)$ and in $b(t)$ if $f_4 = 61.7$ MHz. (Use the value of f_2 in i)). Conclusions?

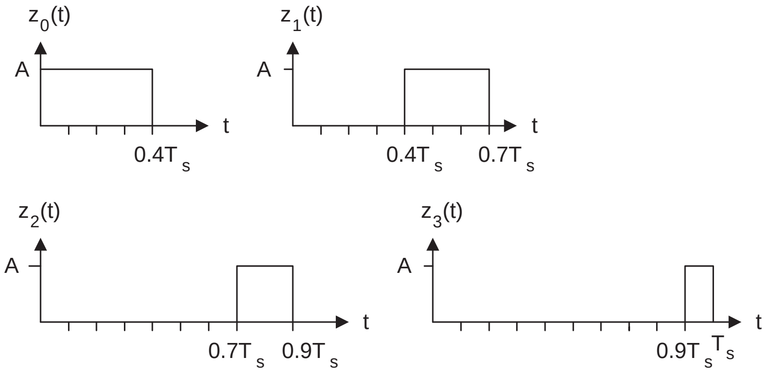
b) Assume that we want to communicate over a communication link that consists of an N-ray channel (i.e. multi-path) and AWGN.

i) Explain possible consequences due to the N-ray channel.

ii) Explain the statement:
"By using sent signal alternatives that are zero in a time interval at the end of the symbol interval $0 \leq t \leq T_s$ we can avoid overlapping signals after the N-ray channel."

(10 points)

Problem 5: In a specific application only signals with a constant amplitude can be used. Consider the 4-ary signal constellation below (equally likely signals):



AWGN $N(t)$ with power spectral density $N_0/2$, and the ML receiver is assumed.

i) Assume a "good" communication link, and calculate the value of the union bound in this case when $\mathcal{E}_b/N_0$ is 12[dB].

ii) Compare the energy efficiency with 4-ary PPM signals. Conslusions?

iii) The union bound can always be written in the form:

$$cQ\left(\sqrt{d_{\min}^2 \mathcal{E}_b/N_0}\right) + c_1 Q\left(\sqrt{d_1^2 \mathcal{E}_b/N_0}\right) + \ldots$$

Determine all coefficients $c, c_1, \ldots$ and all normalized squared Euclidean distances $d_{\min}^2, d_1^2, \ldots$

(10 points)