Final exam in Digital Communications (ETT051) on October 20, 2009, 08–13.

Department of Electrical and Information Technology
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- 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.

a) "A binary PAM signal constellation can never be orthogonal"

b) Assume a conventional M-ary bandpass PAM system. Also assume that $g(t) = g_{hcs}(t)$ with duration $3T_s/4$. "If the bit rate is 800 kbps and $M = 32$ then the width of the mainlobe is 400 kHz."

c) Assume a conventional M-ary PSK system that uses $g(t) = g_{rc}(t)$ with duration T_s, a conventional AWGN channel, and ML receiver. "If $M = 64$ and $\mathcal{E}_b/N_0$ is 30.4 dB then $P_s \approx 2 \cdot 10^{-8}$."

d) "QPSK is better than BPSK. "

e) "The dominating term in the union bound can never be equal to $(M-1)Q(\sqrt{d^2_{\min}\mathcal{E}_b/N_0})$."

(10 points)

Problem 2: Assume a binary communication system that uses equally likely signal alternatives $s_0(t)$ and $s_1(t)$. The received signal alternatives are $z_0(t) = \alpha s_0(t)$ and $z_1(t) = \alpha s_1(t)$, where α is a fixed and given channel parameter. These signals are disturbed by AWGN noise $N(t)$ with power spectal density $R_N(f) = N_0/2$. It is also given that the ML receiver is used.

The signal $s_0(t) = g_{rec}(t)$, and $s_1(t) = 2g_{rec}(t)$, where the pulse $g_{rec}(t)$ has amplitude A and duration T. It is also given that the bit rate is 600 kbps, and that the average signal power after the channel is $\bar{P}_z$.

A requirement is that the bit error probability is at most 10^{-12}.

Another requirement is that the width of the mainlobe of $g_{rec}(t)$ equals 1.6 MHz.

Determine requirements on the ratios A^2/N_0 and $\bar{P}_z/N_0$.

Would these requirements change if the pulse $g_{rec}(t)$ where changed to $g_{hcs}(t)$ with the same amplitude A and duration T_1?

How good is the energy efficiency?

(10 points)

Problem 3: Assume that the received signal alternatives $\{z_\ell(t)\}_{\ell=0}^{M-1}$ are conventional M-ary PAM signals. Also assume that a $g_{rc}(t)$ pulse with amplitude A and duration $T = T_s/2$ is used, where T_s is fixed and given. The communication is disturbed by AWGN $N(t)$ with power spectral density $R_N(f) = N_0/2$, and the ML receiver is used. The ratio $\bar{P}_z/N_0$ is fixed and given.

The symbol error probability can in this case be upper bounded by $P_s \leq 2Q(\sqrt{d_{\min}^2 \mathcal{E}_b/N_0})$. Furthermore, it is known that if $M = 8$ then $P_s \leq 2Q(169.03)$.

Determine the highest bit rate that can be used if the symbol error probability must not exceed $2 \cdot 10^{-11}$.

Also explain if, in general, there are any advantages to use QAM instead of bandpass PAM.

(10 points)

Problem 4:

a) Here we consider a three-user digital communication system. The information carrying user signals are denoted $u_1(t)$, $u_2(t)$ and $u_3(t)$, respectively, and they are baseband (low-frequency) signals. The width of the mainlobes of the user information signals $u_1(t)$, $u_2(t)$ and $u_3(t)$ are: 800 kHz, 400 kHz and 400 kHz, respectively.

The transmitted multi-user signal is denoted $s(t)$, and
$s(t) = u_1(t)\cos(2\pi f_1 t) + u_2(t)\cos(2\pi f_2 t) + u_3(t)\cos(2\pi f_3 t)$

The received multi-user signal is denoted $r(t)$, and
$r(t) = \alpha s(t) + n(t)$
where α is a given channel parameter, and $n(t)$ denotes a disturbance.

The receiver first constructs the signal denoted $y(t)$ as
$y(t) = r(t)\cos(2\pi f_4 t)$
and the desired information carrying signal is then obtained by filtering $y(t)$ in a properly designed low-pass filter.

It is known that $f_1 = 7.6$ MHz, $f_2 = 8.4$ MHz, and $f_3 = 9.2$ MHz. The disturbance is $n(t) = \cos(2\pi f_A t) + \cos(2\pi f_B t)$ where $f_A = 8$ MHz and $f_B = 9$ MHz.

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

i) Sketch the frequency content in $r(t)$.

ii) Sketch the frequency content in $y(t)$ if $f_4 = 8.6$ MHz.
What are your conclusions concerning the choice of $f_4 = 8.6$ MHz in the receiver?

b) Explain in detail:

i) What ISI is and when it occurs.

ii) Possible consequences of ISI.

iii) Methods to reduce the effects of ISI.

(10 points)

Problem 5:

a) In a specific application four signal alternatives are used. Equally likely signal alternatives, AWGN channel and ML reception is assumed.

It is given that all signal alternatives $z_i(t)$ have the same energy, here denoted E. The signals $z_0(t)$, $z_2(t)$ and $z_3(t)$ are all orthogonal to each other, while $z_1(t) = -z_0(t)$.

Find an expression for the union bound in this case.

What are, in general, the advantages and disadvantages with the union bound?

b) Determine in detail the specific operations performed by the specific ML-receiver that is used in Problem 2, and illustrate with a detailed block-diagram of the receiver. The simpler(=low complexity) implementation the better.

(10 points)
