Final exam in

Digital Communications (ETT051)

on October 29, 2014, 14–19.

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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.

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) Assume a conventional M-ary PSK system. Also assume that $g(t) = g_{tri}(t)$ with duration $3T_s/4$. "If the bit rate is 190 kbps and $M = 32$ then the width of the mainlobe is 203 kHz."

b) "16-QAM is better than 16-PSK."

c) Assume a conventional 8-ary PAM system that uses $g(t) = g_{rc}(t)$ with duration $5T_s/6$, a conventional AWGN channel, and ML receiver. "If $\mathcal{E}_b/N_0$ is 16.805 dB then $P_s \approx 1.89 \cdot 10^{-4}$."

d) "It is not possible to improve the receiver in Figure 4.8 on page 241 in the compendium such that the symbol error probability is decreased."

e) "With $M = 2$ and equally likely signal alternatives $s_0(t) = -s_1(t) = g_{tri}(t)$ with amplitude A and duration $9T_b/10$ the average signal power is $3A^2/5$."

(10 points)

Problem 2: Assume a binary communication system that uses equally likely signal alternatives, a conventional AWGN channel, and an ML receiver.

i) It is given that $z_0(t) = g_{rec}(t)$ with amplitude A and duration T. It is also given that $z_1(t) = 2z_0(t)$. Furthermore, A^2T/N_0 is 14.832 dB.

Calculate the bit error probability.

ii) Here, $z_0(t)$ is the same as in i), but the signal alternative $z_1(t)$ is changed to $z_1(t) = g_{rec}(t)$ with amplitude A and duration $T/4$. A^2T/N_0 is the same as in i).

Calculate the bit error probability.

iii) Calculate the difference in energy efficiency, in dB, for the signal alternatives in i) and ii). Which has best energy-efficiency?

What are your comments on the results obtained?

(10 points)

Problem 3:

a) Conventional bandpass M-ary PAM signals are sent from a transmitter, and $T_s = 10^{-5}$ s. The pulse used is $g(t)$.

It is known that the communication channel is a multi-path channel with 5 signal paths (5-ray channel), and the maximum delay is $4 \cdot 10^{-6}$ s.

A requirement is that the bandwidth $W_{99.9}$ is at most 1 MHz.

Specify in detail a suitable pulse $g(t)$.

b) In the error probability analysis of M-ary systems we use the union bound.

i) Explain the advantages, the more the better, of using the union bound.

ii) Calculate the value of the union bound for a 4-ary base-band PAM signal constellation that uses the pulse $g_{hcs}(t)$, and the equally likely amplitudes -1,0,1,2. It is given that $\mathcal{E}_b/N_0 = 13.5$.

(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: 200 kHz, 600 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 $f_1 = 25$ MHz, $f_2 = 25.6$ MHz, and $f_3 = 26.2$ MHz. The disturbance is $n(t) = \cos(2\pi f_A t) + \cos(2\pi f_B t)$ where $f_A = 25.2$ MHz and $f_B = 26$ 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 $f_4 = 26.1$ MHz.

iii) The choice of $f_4 = 26.1$ MHz is not a correct choice but it can occurr due to a malfunction in the receiver. Determine the bandwidth of the lowpass filter if instead $f_4 = 26.2$ MHz, which is an example of a correctly chosen frequency.

b) i) Explain what ISI is, when it may appear, and why ISI is of interest.

ii) Assume an M-ary PAM communication system that uses equally likely signal alternatives, a conventional AWGN channel, and the receiver given in Figure 4.8 on page 241 in the compendium. It is clear that if M is large than the number of correlators in this receiver gets large. However, since M-ary PAM is used here, the receiver can in this case be simplified to contain only one correlator.

Start with Figure 4.8 and determine an equally good receiver for M-ary PAM that contains only one correlator.

(10 points)

Problem 5: Consider a conventional communication link that contains attenuation and AWGN (with power spectral density $N_0/2$). The ML receiver is assumed to be used.

The 99 % definition of bandwidth is here used and it is required that the bandwidth efficiency must not be smaller than 4.5 bps/Hz. The carrier frequency is 5 Ghz.

The symbol error probability is required to be at most $7.596 \cdot 10^{-8}$.

The duration of the pulse used should be equal to the symbol time.

The communication distance of the communication link is such that the communication system must be able to operate with an $\mathcal{E}_b/N_0$ that is close to 35.5 dB.

Analyse the requirements given above and determine a communication system solution in detail that satisfies all requirements.

(10 points)