Final exam in

Digital Communications, Advanced Course (ETTN01)

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on December 13, 2011, 08–13.

- During this final exam, you are allowed to use a calculator and the textbook.
- 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 always, motivations to your answers should be given.

a) " A rate 5/6 encoder in combination with 64-ary QAM has the same bandwidth efficiency as uncoded 32-ary PSK."

b) "The so-called eye-diagram is the same as a one-dimensional signal space."

c) "Diversity always saves bandwidth."

d) "The location of the decision regions for 16-ary PSK are not sensitive to a Gaussian distributed multiplication factor."

e) "A sequence of uncoded conventional 8-PAM signal alternatives that uses a pulse with duration $T = 2T_s$ can be represented as a path in an 8-state trellis."

(10 points)

Problem 2:

Consider a communication link that uses the eight equally likely signal alternatives given below ("tr" means transpose).

$\mathbf{z_0} = -\mathbf{z_7} = (-2a, 0)^{tr}$
$\mathbf{z_1} = -\mathbf{z_6} = (-2a, 2a)^{tr}$
$\mathbf{z_2} = -\mathbf{z_5} = (-2a, -2a)^{tr}$
$\mathbf{z_3} = -\mathbf{z_4} = (0, 2a)^{tr}$

where a is a positive value. AWGN and ML symbol receiver are assumed.

a)

i) Make a detailed figure that clearly shows the decision regions for message 0 and message 1.

ii) Determine d^2_{min} if $a = 1/7$.

b)

Assume that message 6 is sent.

Calculate the probability that the receiver makes a symbol error in this case if $a^2/N_0 = 5.5$.

c)

Assume that message 6 is sent.

Calculate the probability that the receiver decides message 5 in this case if $a^2/N_0 = 5.5$.

(10 points)

Problem 3:

a)

For a given conventional communication link it is found that if the communication bandwidth is $W = 5$ MHz, then the capacity equals $C = 50$ Mbps (the notation follows the compendium).

Change now only the communication bandwidth W, and calculate and sketch how the capacity C then changes versus C/W, for $1 \leq C/W \leq 4$.

b)

Explain in detail with your own words:

i) What is meant by "waterfilling"?

ii) Why is the result of "waterfilling" important?

iii) How can the "waterfilling" idea approximatly be implemented in practice?

(10 points)

Problem 4:

a)
Consider the transmitter in Figure 8.6a) in the compendium.

Over a $5T_s$ time interval it is known that the sent sequence of signal alternatives is: s_1, s_4, s_2, s_5, s_4.

However, due to noise, the sequence decision produced by the Viterbi Algorithm(VA) contains the corresponding sequence: s_1, s_6, s_4, s_1, s_4.

Determine how many information bit errors that are made by the receiver over this $5T_s$ time interval.

b)

i) Determine the squared Euclidean sequence distance between the two sequences given in a).

ii) Explain in detail how the so-called squared Euclidean distance increments:

- are obtained in the receiver

- are used by the VA

(10 points)

Problem 5:
Consider a MIMO communication system with N_t transmitting antennas and N_r receiving antennas, as is illustrated in Problem 5.34 in the compendium.

Each transmitting antenna uses a conventional M-ary QAM signal constellation (as is considered in Subsection 5.1.6 in the compendium, $M = 4, 16, 64, ...$ etc), and the N_t constellations are identical.

The signals from the N_t antennas are sent during the same time interval, and it has the duration T_s, $T_s = 10^{-6}$ (sec).

Here we consider the uncoded case which means that all input bits to the N_t antennas are independent and equally likely (this is an example of so called spatial multiplexing).

Slow Rayleigh fading, AWGN, and ML reception is assumed. Furthermore, all individual channel links are assumed to be statistically independent.

In this problem the symbol error probability for the system described above can be approximated by;

$P_s \approx M^{N_t}(\frac{1}{d^2_{min}\mathcal{E}_b/(2N_rN_0)})^{N_r}$

where

$\mathcal{E}_b$ is the average received signal energy per information bit.

N_0 is the conventional AWGN parameter.

d^2_{min} is the minimum normalized squared Euclidean distance for the M-ary QAM signal constellation used above.

R_b is the total bit rate from the transmitter, and $R_b = 8$ Mbps.

a)

Assume that $M = 256$, $N_t = 1$ and $P_s \approx 10^{-5}$.

How large must then $\mathcal{E}_b/N_0$ be, in dB, for the cases $N_r = 1$, $N_r = 4$ and $N_r = 8$, respectively.

What are your conclusions?

b)

Other choices of M and N_t will give the same bit rate as in a).

For all such possible choices of M and N_t, calculate P_s if $\mathcal{E}_b/N_0$ is 23 dB and $N_r = 8$.

Which choice do you recommend to use for the bit rate $R_b = 8$ Mbps if 8 receiving antennas are used.

(10 points)