Final exam in

Digital Communications, Advanced Course (ETTN01)

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on January 12, 2015, 14–19.

- 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 2/3 encoder in combination with 64-ary bandpass PAM has a smaller bandwidth efficiency than a rate 7/8 encoder with 16-ary QAM."

b) "The so-called eye-diagram is measured with an oscilloscope (with memory) directly after the correlator in the receiver"

c) "If M-QAM is used at each sub-carrier, and if the number of sub-carriers is large then the bandwidth efficiency of uncoded OFDM only depends on M and the ratio T_{CP}/T_{obs}."

d) "Channel knowledge is not needed at the receiver if the channel is slowly Rayleigh fading."

e) "The receiver in Figure 5.8a on page 341 in the compendium is the optimal receiver regardless of if coding is used or not in the transmitter."

(10 points)

Problem 2:

a) Consider a communication link where the eight equally likely received signal alternatives are represented in a two-dimensional signal space as:

$\mathbf{z_0} = (3a, 4a)^{tr}, \mathbf{z_1} = (7a, 4a)^{tr}, \mathbf{z_2} = (5a, 6a)^{tr}, \mathbf{z_3} = (3a, 8a)^{tr}$
$\mathbf{z_4} = (5a, 8a)^{tr}, \mathbf{z_5} = (7a, 8a)^{tr}, \mathbf{z_6} = (5a, 10a)^{tr}, \mathbf{z_7} = (5a, 12a)^{tr}$

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

Assume that message 1 is sent. Calculate the probability that the receiver decides that message 4 was sent, if $a^2/N_0 = 4$.

b) Consider a communication link where the two equally likely received signal alternatives are represented in a four-dimensional signal space as:

$\mathbf{z_0} = (a, 2a, a/2, a/4)^{tr}$
$\mathbf{z_1} = (-a/4, a, -a/2, a/2)^{tr}$

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

Calculate the bit error probability if $\mathcal{E}_b/N_0$ is 12.6 dB.

(10 points)

Problem 3:

a)

i) Suggest a combination of encoder and M-ary nodulation scheme that has the same bandwidth efficience as the uncoded 16-PSK scheme in Figure 5.17 on page 369 in the compendium, but has an improved energy efficiency.

Also, how much is it in principle possible to improve the energy efficiency, for the same bandwidth efficiency, compared with the uncoded 16-PSK scheme in Figure 5.17.

ii) Explain in detail the purpose of waterfilling, and also give an example when waterfilling cannot be used.

b)
Explain in detail with your own words:

i) Explain what is meant by "a (slowly) Rayleigh fading channel", and how this channel changes the transmitted signal?

ii) Explain possible advantages if the channel is random and frequency-selective.

iii) Describe several communication methods (the more the better) which makes it possible to obtain a diversity gain at the receiver.

(10 points)

Problem 4:

a) Consider an OFDM signal with 700 sub-carriers, and with sub-carrier separation 7.5 kHz. Furthermore, 16-QAM is used at each subcarrier, and the duration of the cyclic prefix is 5% of the receivers observation interval.

The notation in the lecture notes should be used!

i) Determine a suitable sampling frequency.
ii) In case of no coding, determine the bit rate.
111) Determine the frequency-domain sample X_0, i.e. the first value of the input-sequence to the IDFT.

b) Consider the same K=8 and N=12 OFDM-example as in the lecture notes.

However, here we investigate the consequences of a technical error in the transmitter.

The error means that the input sequence to the IDFT is:
$X_0 = 12a_0, X_1 = 12a_1, X_2 = 12a_2, X_3 = 12a_3, X_4 = 12a_4, X_5 = 12a_5, X_6 = 12a_6, X_7 = 12a_7$ and $X_8 = X_9 = X_{10} = X_{11} = 0$.

which clearly is different compared to the correct sequence given in the lecture notes.

Determine the consequences of this error on the transmitted high-frequency OFDM signal. Consider in particular that the QAM symbols are now carried at other sub-carriers.

(10 points)

Problem 5:

a) Consider a MIMO communication system according to problem 5.34 in the compendium. It is here assumed that independent binary antipodal PAM signals are sent from each of six transmitting antennas. All channel parameters are here assumed to be real, and the number of receiving antennas is also 6.

i) Calculate the value r_4 obtained after the 4:th receiving antenna. Determine if it is a good idea to make a decision of the sent bits based only on the value of r_4.

ii) Explain in detail the steps performed by the ML receiver to obtain the decisions of all six transmitted bits.

b) Consider two mobile users, each having two transmitting antennas. User 1 transmits QPSK from each antenna, and user 2 transmits 16-QAM from each antenna. The two users transmit simultanously in the same symbol interval and within the same bandwidth.

The base station has eight receiving antennas.

Make a model of this communication situation and explain how the base staion may recover the four bits from user 1, and the eight bits from user 2.

(10 points)
