Final exam in

Digital Communications, Advanced Course (ETTN01)

on December 14, 2010, 08–13.

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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 always, motivations to your answers should be given.

a) " A rate 3/4 encoder in combination with 256-ary QAM has the same bandwidth efficiency as a rate 2/3 encoder in combination with 512-ary PSK."

b) "For a rate 2/3 encoder in combination with 16-ary PAM, approximatly 2.67 information bits are sent in each symbol interval."

c) "For a conventional non-random SISO AWGN channel, bit rates up to 1.5 Mbps are suitable if $P_z/N_0 = 10^6$."

d) "The decision regions for 64-ary PSK are not sensitive to a Rayleigh distributed signal attenuation, but the bit error probability is."

e) "If the transmitter does not know the communication channel, then diversity does not help."

(10 points)

Problem 2:

a)

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

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

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

i) Make a detailed figure that clearly shows the decision regions for message 4 and message 5.

ii) Determine d^2_{min}.

b)

Binary PSK signals are sent over a SIMO communication link using 4 receiving antennas (see problem 5.34 in the compendium). AWGN and ML symbol receiver are assumed.

For a specific channel outcome it is known that the received noisy vector $\mathbf{r}$ is

$$\mathbf{r} = (-0.2a, -0.3a, 0.1a, -0.1a)^{tr} = (-0.4, 0, -0.6, 0.4)^{tr} d + (w_1, w_2, w_3, w_4)^{tr}$$

where $d = -a$ or $d = +a$.

i) Determine the decision made by the receiver.

ii) For this specific channel outcome determine an expression for P_b containing only a and N_0 as unknown parameters.

(10 points)

Problem 3: Consider a communication link with parameters $W = 5$ MHz, and P_z/N_0 such that the maximum bandwidth efficiency $C/W = 4$ bps/Hz (the notation follows the compendium).

a) Assume that P_z/N_0 has the same value as above. Calculate the capacity and the maximum bandwidth efficiency if the bandwidth used is increased to $4W$.

b) Assume here that the bandwidth used is $W = 5$ MHz. Calculate the value of P_z/N_0 that is required to obtain the same capacity as in a).

c) In a) and b) two methods to achieve the same capacity are illustrated. Explain advantages and disadvantages with each method.

(10 points)

Problem 4:

a) Consider the transmitter in Figure 8.2a) in the compendium, and assume that its starting state is state number 13. Furthermore, assume that the first input bit is a 0, the second input bit is a 0, and that the third input bit is a 1.

i) Determine the path in the trellis, and the sequence of output signal alternatives.

ii) Would there be any advantages to replace QPSK with 16-QAM? Any disadvantages?

b) Assume that the transmitter in Figure 8.2a) in the compendium is used in a communication link.

Determine in detail the mathematical calculations made by the Viterbi algorithm at state 5.

(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.

The distance between the transmitter and the receiver is denoted L (unit meter).

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 value of M is chosen in an adaptive way depending on the quality of the channel.

The signals from the N_t antennas are sent during the same time interval, and it has the duration T_s.

T_s is a given constant.

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 bit error probability for the system described above is approximated by;

$P_b \approx 2^{N_t log_2(M)}/y^{N_r}$

where

$y = (3/2) \cdot (log_2(M)/(M-1)) \cdot (a/L^3) \cdot (P_t/N_0)/R_b$

and

a is related to the communication channel and it is a given constant.

P_t is the total average transmitted signal power, and it is a given constant.

N_0 is the conventional AWGN parameter and it is a given constant.

R_b is the total bit rate from the transmitter.

In this problem it is required that the bit error probability P_b for the system described above may not exceed 10^{-6}. This can be formulated as:

$2^{N_t log_2(M)}/y^{N_r} \leq 10^{-6}$

Within the constraints given above we want to find the maximal possible communication distance, denoted L_{max}, that can be used for different values of N_t and N_r. We are also interested in the corresponding bit rate when $L = L_{max}$, denoted $R_{b,L_{max}}$.

Determine L_{max} and $R_{b,L_{max}}$ for the two cases below:

i) $N_t = N_r = 1$

ii) $N_t = 2$ and $N_r = 4$

iii) For the case ii) above: Determine the maximal bit rate that can be used when the communication distance is reduced to $L = L_{max}/16$.

What are your comments and conclusions?

(10 points)