Dept. Signal Processing and Acoustics
S-88.4176 Signal Processing in Wireless Communications (6 cr)

Write in each answer paper your name, department, student number, the course name and code, and the date. Number each paper you submit and denote the total no. of pages. 4 problems, 23 points total. Exam problems in English only. Please feel free to answer in Finnish or English. No additional material is allowed in the exam.

1. (1p each) Define/describe/discuss *briefly* the following concepts:

(a) Channel coherence bandwidth

(b) Rayleigh fading channel

(c) Pairwise error probability

(d) Transmit diversity vs. transmit beam-forming

(e) Random vector quantization

2. (6p) Consider the following 3-transmitter antenna space-time block code

$$\mathrm{X} = \begin{pmatrix} x_1 & x_2 & -x_3 \\ -x_2^* & x_1^* & -x_4^* \\ x_3 & x_4 & x_1 \\ -x_4^* & x_3^* & x_2^* \end{pmatrix}$$

(a) What is the rate of the code?

(b) What is the diversity of the code?

(c) Is the code orthogonal or non-orthogonal?

(d) Is there a way to improve the diversity of the code?

3. (6p) Consider two closed-loop transmit diversity systems with two transmit and one receive antenna. The systems are

System I: Transmit from the strongest antenna, i.e., from $\max\{|h_1|, |h_2|\}$.

System II: Apply co-phasing algorithm where the transmit weights are selected such that the channel observed in the receiver becomes

$$\max\{|\frac{1}{\sqrt{2}}(h_1 + h_2)|, |\frac{1}{\sqrt{2}}(h_1 - h_2)|\}$$

Both systems require a one-bit feedback message

Consider the performance of Systems I and II in three different scenarios:

(a) Channels h_1 and h_2 are independent identically distributed complex Gaussian random variables.

(b) The channels are independent non-identically distributed complex Gaussian random variables such that $\mathrm{E}\{|h_1|\} < \mathrm{E}\{|h_2|\}$.

(c) The channels are non-independent identically distributed complex Gaussian random variables such that $\mathrm{E}\{h_1^* h_2\} = \rho$, $\rho > 0$.

The task is to rank the performance of Systems I and II in all three scenarios. Which one of the two systems performs best in each scenario and why?

4. (6p) Consider a multiuser MIMO system with 2 transmitter antennas and two single-antenna users. The channels between the transmitter and receiver antennas are $h_{11} = 1$, $h_{21} = 1$, $h_{12} = -2$, and $h_{22} = 4$, where h_{ij} refers to a channel from antenna i to user j. Noise power σ^2 is the same in the both receivers

(a) Write down the sum rate of the system when the transmitter applies *zero-forcing*

(b) How much does the signal-to-noise ratio (SNR) decrease due to zero-forcing?

(c) Suppose that both users employ binary phase-shift keying (BPSK) modulation. How can you modify the transmitted signals such that signal-to-interference ratio (SIR) in the receivers is ∞, i.e. there is no multiuser interference, and SNR does not degrade?