ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
School of Computer and Communication Sciences

Handout 11 Modern Digital Communications
Midterm Exam November 5, 2025

Name:

Note:

- You have 2 hours to work on the exam.
- The exam is closed book, but you are allowed one sheet (one single-sided A4 page) of handwritten notes, with NO processing (plain and pure handwriting on paper). Resources from the internet as well as code written outside this exam are not allowed (unless the code is written on the sheet of handwritten notes).
- The code will be evaluated according to the usual criteria, namely correctness, speed, form, and readability. Short comments that allow us to follow what you are doing will improve readability.
- The problems can be solved in any order.
- You will upload (to Moodle) your solution to the problems that require writing MATLAB or Python code. Do so in a single archive.

To get started with the exam, do the following:

1. Close all the windows and programs on your laptop.
2. Launch the MATLAB/Python editor and close all the tabs (previously written code).
3. From Moodle, download the file `mdc_midterm_2025.zip`. Unzip the file to create the directory `mdc_midterm_2025`. For the rest of the exam you are required to work inside that directory. The MATLAB/Python files for Problem n, are found in subfolder pn.
4. Turn your WiFi off until you are ready to upload your solutions.
5. Wait until you receive the go-ahead signal.

Problem 1. 14 points (MATLAB/Python)

In this problem you are asked to make use of the eye diagram in order to determine when you should sample the matched filter output for minimizing the error probability at the receiver. We consider the usual symbol-by-symbol on a pulse train communication system where the channel introduces an unknown delay of q samples, where q is a positive integer smaller than 25. The transmitted symbols are drawn from a 4-QAM constellation and the upsampling factor (samples per symbol) is 50. You are given the samples at the output of the matched filter, before down-sampling, in the file `mf_output.mat`.

Please write your code in the script `p1.m[py]`.

1. Plot the eye diagrams corresponding to the real, imaginary and absolute value of the samples at the output of the matched filter.
2. Estimate q based on one of the eye diagrams plotted before (choose the method that you find more convenient to code).
3. Use q to downsample `mf_output` and do a scatterplot of the received symbols. You should obtain a noisy 4-QAM constellation.

Problem 2. 12 points (MATLAB/Python)

The samples of a preamble sequence are given to you in the file `preambleSequence.mat`.
We receive a delayed and Doppler affected version of it, and its samples are stored in `rx_preambleSequence.mat`.
The sampling time T_s is the same for both signals. The Doppler frequency f_d is some value in the interval $[-1000, 1000]$ Hz.

Please write your code in the script `p2.m[py]`.

1. Estimate f_d with a resolution of 10 Hz, and the delay.
2. Correct the Doppler, remove the delay and do a scatterplot of the received samples. You should obtain a BPSK (± 1 values) constellation.

Problem 3. 14 points (Paper and Pencil)

Consider a symbol-by-symbol on a pulse train communication system. $R(t)$ and $Y(t)$ are the signals at the input and the output of the matched filter, respectively. Let $p(t) = \sum_{k=0}^{L-1} b_k \psi(t - kT)$ be a preamble signal, where b_k are complex symbols, T is the symbol period and $\psi(t)$ is the pulse shaping function. The matched filter is assumed to be $h_{\text{MF}}(t) = \psi^*(-t)$. Let $T = NT_s$, where N is a positive integer and T_s is the sampling time.

1. Show that the output of the matched filter is

$$Y(t) = \langle R(\alpha), \psi(\alpha - t) \rangle.$$

2. Compute $\rho(v) = \langle R(t), p(t - v) \rangle$ and show that

$$\rho(mT_s) = \sum_k b_k^* Y(mT_s + kT).$$

3. Rewrite the formula above as a correlation between the discrete (sampled) version of $Y(t)$ and a sequence $\{\hat{b}_k\}$ (which you should say what it is).