ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
School of Computer and Communication Sciences

Handout 11 Modern Digital Communications
Midterm Exam November 9, 2022

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. 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_2022.zip`. Unzip the file to create the directory `mdc_midterm_2022`. 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. 13 points (Paper and Pencil)

Consider the communication system of Figure 1. Assume that $h(t) = \delta(t)$, $N(t) = 0$ and $h_{\mathrm{MF}}(t) = \psi^*(-t)$.

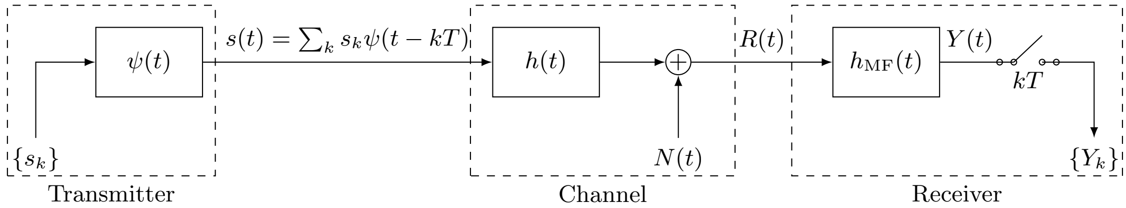

Figure 1: Communication System of Interest

1. Compute the output of the matched filter ($Y(t)$) and express it as a function of the inner product between $R()$ and $\psi()$. For the inner product, you should use the notation $\langle \cdot, \cdot \rangle$ as we did in class.
2. Let $c(\alpha) = \int R(t) s^*(t - \alpha) dt$. Compute $c(\alpha)$ as a function of $\{s_k\}$ and $Y()$.
3. Let $T = NT_s$, for some positive integer N, where T_s is the sampling time. Let $c[m] := \sqrt{T_s} c(mT_s)$ be the samples of $c(\alpha)$, where the scaling factor $\sqrt{T_s}$ was introduced for the reasons explained in class. Compute $c[m]$ as a function of $\{s_k\}$ and $Y[\ ]$ (the sampled version of $Y()$).
4. Express $c[m]$ as the correlation between $Y[\,]$ and a modified sequence $\{\hat{s}_k\}$ (obtained from $\{s_k\}$). Specify the sequence $\{\hat{s}_k\}$.
5. Express $c[m]$ as the convolution between $Y[\,]$ and a modified sequence $\{p_k\}$ (obtained from $\{\hat{s}_k\}$). Specify the sequence $\{p_k\}$.

Problem 2. 14 points (MATLAB/Python)

Consider again the communication system of Figure 1. Assume that $h(t) = \delta(t)$, $h_{\mathrm{MF}}(t) = \psi^*(-t)$ and $N(t)$ is complex-valued AWGN with zero mean and variance $\frac{N_0}{2}$ per real-valued dimension.

Please follow the instructions in the script `p2.m[py]`.

Problem 3. 13 points (MATLAB/Python)

The files `caPulse.mat` and `caPulseDelayedWithDoppler.mat` contain the samples of a C/A pulse and its delayed and Doppler affected version, respectively. The sampling time T_s is the same for both signals. We are interested in estimating the Doppler frequency and the delay by using a new method which is detailed in the script `p3.m[py]`.

Please follow the instructions in the script `p3.m[py]`.