ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

School of Computer and Communication Sciences

Handout 11 Modern Digital Communications

Midterm Exam November 10, 2021

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_2021.zip`. Unzip the file to create the directory `mdc_midterm_2021`. 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 $h(t) = \delta(t)$ and that $N(t)$ is complex-valued AWGN with zero mean and variance $\frac{N_0}{2}$ per real-valued dimension.

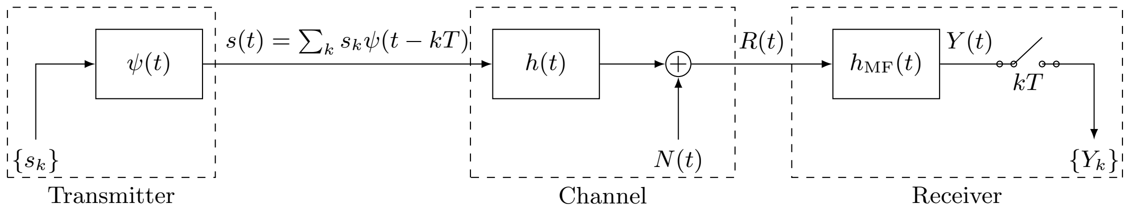

Figure 1: Communication System of Interest

1. Choose and specify $\psi(t)$ such that $\{s_k\}$ are the samples of $s(t)$, i.e., $s_k = s(kT)$. The signal $s(t)$ should be reconstructable (in the sense of the sampling theorem) from the sequence $\{s_k\}$.
2. Draw $\psi(t)$ and $\psi_{\mathcal{F}}(f)$ (the Fourier transform of $\psi(t)$), labelling appropriately the X/Y axis.
3. Let $s_{\mathcal{F}}(f)$ be the Fourier transform of $s(t)$. Specify f_{min}, f_{max} as a function of T such that the support of $s_{\mathcal{F}}(f)$ is contained in the interval $[f_{min}, f_{max}]$.
4. Check if your chosen $\psi(t)$ is a Nyquist pulse. (Hint: You might want to do that in the frequency domain.)
5. What are the advantages and disadvantages of choosing $\psi(t)$ as at point 1?
6. Specify $h_{\text{MF}}(t)$.
7. What is the variance of the noise at the output of the matched filter?
8. Assume that you truncate $\psi(t)$ at the length $100T$ (total length) and you sample it at $T_s = T/10$. Let $\psi_{\mathcal{F}}[k]$ be the DFT of this sampled $\psi[n] = \psi(nT_s)$. Assume you would like to plot $\psi_{\mathcal{F}}[k]$. Specify the labelling of the frequency axis.

Problem 2. 13 points (MATLAB/Python)

The file `rx_signal.mat` contains the samples of a signal at the output of the channel. The transmitted data symbols are drawn from a 4-QAM constellation and they are preceded by a preamble of BPSK symbols. The preamble symbols are stored in the file `preamble.mat`. The transmitted symbols (preamble and data symbols) are pulse shaped with a rectangular pulse of amplitude 1 and using 5 samples per pulse. The sampling time is $T_s = 10^{-5}$ seconds. We assume that the channel delays the transmitted signal. The transmitted signal is also affected by Doppler, a rotation by a fixed phase, and complex-valued AWGN.

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

PROBLEM 3. 14 points (MATLAB/Python)

The file `rx_signal_gps.mat` contains the samples of a received GPS signal. The signal is real valued, and sampled using 4 samples per chip (as in class). We would like to decode the bits transmitted by satellite 3. The samples of the C/A pulse of this satellite are stored in the file `ca_code.mat` (again, using 4 samples per chip). Due to a malfunction, the satellite is using only 1 C/A pulse (as opposed to 20) for transmitting a bit. We assume that the received signal is delayed and affected by real-valued AWGN. There is no Doppler, nor rotation by a fixed phase.

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