ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

School of Computer and Communication Sciences

Handout 11 — Modern Digital Communications

Midterm Exam — November 6, 2019

Name:

Note:

- You have 1h45 min to work on the exam.
- The exam is closed book, but you are allowed one sheet (one single-sided A4 page) of handwritten notes and the printed reference card. 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 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 MATLAB and close all the tabs (previously written code).
3. From Moodle, download the file `mdc_midterm_2019.zip`. Unzip the file to create the directory `mdc_midterm_2019`. For the rest of the exam you are required to work inside that directory. The MATLAB 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. 12 points (MATLAB)

This problem is about coherent detection of AM signals. All we ask is to write the code that, at the receiver, creates a copy of the carrier which is in phase with the carrier of the AM signal. (The frequency is known). Please follow the instructions in the script `p1.m`.

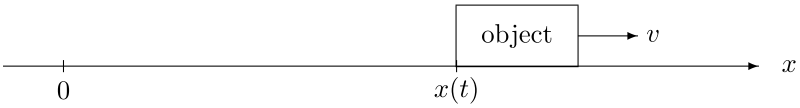
Problem 2. 12 points (MATLAB)
The goal of this problem is to compare the performance of two bit-by-bit on a pulse train of the form

$$\sum_i s_i \psi(t - iT)$$

for two different Nyquist pulses (ψ_1 and ψ_2) of the same duration, one of which is a wideband pulse. The symbols s_i are from a binary PSK constellation. The pulse train is transmitted over the AWGN channel. The samples of the two waveforms, ψ_1 and ψ_2, are stored in the files `psi1.mat` and `psi2.mat`.

Follow the directions given in the script `p2.m`. Answer the questions directly in the file (as comments).

PROBLEM 3. 16 points (MATLAB / Paper and Pencil)
This problem has a MATLAB part and a paper-and-pencil part. The setup, described below, is the same for both parts, but you can work on each part independently.



We are in a one-dimensional world as shown. You are positioned at the origin ($x = 0$) and you transmit a signal $s(t)$, an echo of which comes back to you after it reflects on an object that moves at a constant speed v. Let $x(t) = x_0 + vt$ be the position of the object at time t.

MATLAB part, (10 points). For the MATLAB part, open the script p3.m where you have step-by-step instructions on constructing $s(t)$ and processing the echo to determine a delay and a Doppler shift.

Paper and Pencil part, (6 points). For the paper-and-pencil part answer the following questions. (The first two questions can be answered independently.)

1. Suppose that what you send at $t = 0$ comes back at $t = T_d$. This means that the signal traveled a distance cT_d. At what time was the object at distance $\frac{cT_d}{2}$?
2. The signal that you transmit is a high-frequency signal with center frequency f_c. You determine that the echo is centered at frequency $f_c + f_d$. What is the speed v (or a good approximation of it) of the moving object as a function of f_d and c (speed of light), where a positive v means that the object is moving away from you? No need to provide a proof, you may use what you have learned in class and the following hint.

   Hint: To get a good approximation of v by leveraging on what you have learned about the GPS, consider the following two questions: (i) what is the center-frequency-shift perceived by a receiver sitting on the moving object? (ii) If the moving object receives the signal at this new center frequency and sends back to you an identical copy, what is the center frequency of what you receive?
3. Using your answer to the previous two questions, write an expression for $x(t)$ as a function of T_d, f_d, and c.