ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
School of Computer and Communication Sciences

Software-Defined Radio:	Midterm
A Hands-On Course	October 31, 2012

Name:

Note:

- You have 1 h 30 min to work at the midterm.
- The exam is closed book (no notes allowed). You are only allowed to use the workstations in the laboratory (not your own laptops). Resources from the internet as well as code written outside this exam are not allowed.
- There are five problems that can be solved in any order.
- The first three problems require a handwritten solution that we will take at the end of the exam. The rest requires writing MATLAB code that you will upload on Moodle.
- 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.

Good luck!

Problem 1. (10 p.)

(a) The following question is of fundamental importance in making the link between the continuous-time and the discrete-time world. Let $N(t)$ be white Gaussian noise of power spectral density P. Let $g(t)$ be an arbitrary function. Describe the statistic of the object that results from the operation $\langle N(t), g(t) \rangle$.

(b) For some integer `n`, let `z=randn(1,n)` and let `p` be an arbitrary real-valued $1 \times n$ vector. Describe the mathematical object simulated by `z * p'`.

(c) You are given the formula for a function $\psi : [-T_0, T_0] \to \mathbb{R}$ that has unit norm and you know that the function $\psi(t)$ is orthogonal to $\psi(t - kT)$ for every integer k and some known T. You sample the function $\psi(t)$ at intervals of T_s seconds and stick the samples into a MATLAB vector `psi`. Does `psi` have unit norm and if not how do you scale it so that it will? Let `normpsi` be the normalized `psi`.

(d) Now let `normpsi2=[normpsi,normpsi]` and consider

```
q=conv(normpsi2,fliplr(conj(normpsi))).
```

Assume that $T_0/T = n$ and $T/T_s = m$, with n and m known integers. Determine `length(q)` and describe at which position(s) `q` has value 1 and at which it has value 0.

Problem 2. (5 p.) Arrange the operations presented below in order to decode the bits transmitted by a GPS satellite. Specify which operations are performed for all the satellites and which are performed only for the visible satellites.

(a) Determine the start of the first bit

(b) Update tau and the Doppler shift

(c) Find the start of the first received C/A code and the Doppler shift

(d) Find a phase shift approximately equal to `pi` in the received signal

(e) Estimate the next 5 bits

(f) Refine the Doppler shift estimation

(g) Estimate the first 5 bits

Problem 3. (5 p.) The graphic in Figure 1 shows the result of

```
plot(abs(fftshift(fft(s)))),
```

where `s` is a vector obtained from sampling a continuous time signal with the sampling frequency $F_s = 1500$ Hz. The x-axis is labeled with the sample indices. The Fast Fourier Transform was computed with 1000 points. Which of the following signals can generate such a spectrum? For the selected signals specify the value of the f-parameters (but do *not* specify the A-parameters).

(a) $s(t) = Ae^{2\pi jft}$

(b) $s(t) = A\cos(2\pi ft)$

(c) $s(t) = A_1\sin(2\pi f_1 t) + A_2\sin(2\pi f_2 t)$, with $f_1 \neq f_2$

(d) $s(t) = A_1\sin(2\pi 100t) + A_2\sin(2\pi 900t)$

(e) $s(t) = A_1 e^{2\pi j f_1 t} + A_2 e^{2\pi j f_2 t}$, with $f_1 \neq f_2$

(f) $s(t) = A\sin(2\pi ft)$

(g) $s(t) = 100t + 900t$

(h) $s(t) = A_1\sin(2\pi 100t) + A_2\sin(2\pi 900t)$

(i) $s(t) = A_1 e^{2\pi f_1 t} + A_2 e^{2\pi f_2 t}$, with $f_1 \neq f_2$

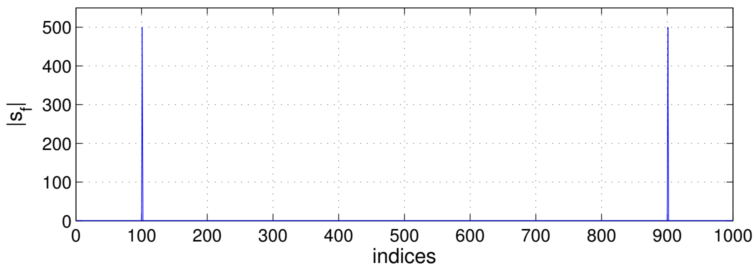

Figure 1: Signal spectrum

For the following two problems you need to use Matlab. Download the `midterm_2012.zip` file from Moodle, complete the requested functions and upload them on Moodle before the end of the exam.

Problem 4. (10 p.) The matlab file `psk.m` from the folder `p4` contains the header given below. Open the file and complete as instructed in the header.

```
% Simulate binary uncoded PSK transmition over the AWGN channel
% Specific instructions:
%
% Set NrBits to E5;
% Set Es_sigma2 to 3 dB
% Produces a binary random sequence of length NrBits taking values in {0,1}
% Map the bit sequence into a symbol sequence where 0 --> 1 and 1 --> -1
% Create the output of the AWGN channel that has the symbol sequence as input
% The energy per symbol over the noise variance shall be Es_sigma2 in dB
% Determine the bit sequence estimate (maximum likelihood decoding)
% Compute the error probability
```

Problem 5. (10 p.) For this exercise you need the files from the folder `p5`. The file `codeDelay.m` contains the header given below. Open the file and complete as instructed in the header.

```
% Load data.mat.
% Knowing that satellite 9 has Doppler frequency 1030 Hz,
% find the first sample that contains the start of the C/A code of satellite 9.
```