ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE

School of Computer and Communication Sciences

Software-Defined Radio:	Midterm
A Hands-On Course	November 2, 2011

Name:

Note:

- You have 1 h 30 min to work at the midterm.
- There are three problems that can be solved in any order.
- The code has to be written using only *built-in* Matlab functions (no toolbox functions). Resources from the internet as well as code written (by you or someone else) outside this exam are not allowed.
- You are only allowed to use the workstations in the laboratory (not your own laptops).
- Write short comments that allow us to follow what you are doing.
- The exam is closed book.
- The first two problems require a handwritten solution that we will take at the end of the exam. The third problem requires writing Matlab code: please upload your code on Moodle.
- The code will be evaluated according to the usual criteria, namely correctness, speed, form, and readability.

Good luck!

Problem 1.

(a) Consider the signal $s(t)$ with support from 0 to T_p. Let $s_1[n]$ be obtained from $s(t)$ by sampling at multiples of T_s and $s_2[n]$ obtained from $s(t)$ by sampling at multiples of $T_s/2$. T_s is small enough that the sampling theorem is met and, in addition, $T_p = NT_s$.

What is the relation between the norm of $s_1[n]$ and $s_2[n]$? Relate the norm of $s(t)$ and that of $s_1[n]$.

By norm of a signal $\underline{\mathbf{s}} = [s[0], s[1], \cdots s[N-1]]$ we consider the value

$$norm = ||s[n]||^2 = \sum_{i=0}^{N-1} s^2[i]$$

(b) Consider the 4QAM mapping with the following constellation symbols

```
map_4qam=[-1+1i, -1-1i, 1+1i, 1-1i];
```

Write down the Matlab code which encodes the source sequence

```
source=[1 0 3 3 2 1 0 1 0 1 1]
```

into a sequence of symbols from the 4QAM constellation.

(c) The graphic in Figure 1 shows the result of

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

where `s` is a discrete signal sampled with $F_s = 400$ Hz. The x-axis labels represent sample indices. What is the bandwidth of the signal from edge to edge? What is the minimum frequency with which we can sample this signal so that there will be no aliasing? What are the frequencies (in Hz) corresponding to indices 1, 400 and 800? The Fast Fourier Transform was computed with 800 points.

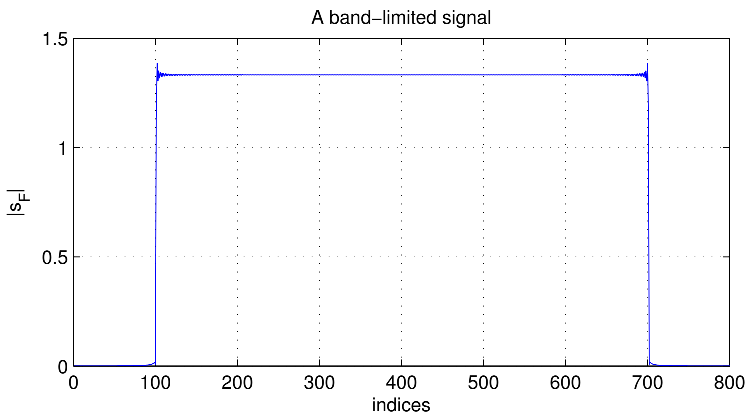

Figure 1: Band-limited signal

Problem 2.

(a) The following Matlab sequence contains one or several errors. Identify and correct them. The comments (lines starting with %) are considered to be correct.

The vector `bits` contains 1200 bits from a data signal. The data is grouped into frames of 250 bits, each starting with the preamble [1111100000]. Find the start of the first frame. You may assume that the preamble is present only at the start of each frame.

```
preamble=[1 1 1 1 1 0 0 0 0 0];

%switch from values of 0 and 1 to -1 and 1
bits_new=2*bits-1;
preamble_new=2*preamble-1;

%compute the correlation between bits and preamble
c=xcorr(bits_new, preamble_new);

%find the maximum value
[max_c, pos]=max(abs(c));

%pos is the position where the first frame starts
```

(b) **Matlab exercise**

Implement the function `z=my_demod(y)` which demodulates vector `y` by finding which element from the constellation in Figure 2 is closest (from the Euclidian distance point of view) to each element of `y`. Output `z` has the same dimensions as `y`. The possible values for `z` are specified in Figure 2.

Example:

```
z=my_demod([1 1i 0.9 -0.9+0.1*1i 1+0.9*1i])
z =
     1     2     1     3     1
```

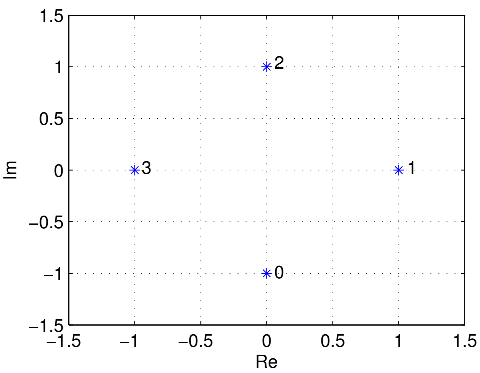

Figure 2: Signal constellation

Problem 3. Matlab exercise

A sequence of bits is encoded by a convolutional encoder of rate `r`. The result is converted to 4QAM symbols and sent over an AWGN channel. The transmitted symbols are denoted by `tx`. The noise-affected received symbols are denoted by `rx`. Both `tx` and `rx` have been stored in the file `signals_midterm.mat`. Complete the function skeleton provided in `checkSNR.m` by implementing the following parts.

(a) Complete the first part of the function to check the input parameter `r` which is optional. If it is not specified, it is assumed to have value 1. If specified, it should have values between 0 and 1. An error message should be provided otherwise.

(b) Starting from `tx` and `rx`, determine the signal to noise ratio, E_s/σ^2, expressed in decibels. E_s is the energy per symbol and σ^2 is the noise variance. The corresponding Matlab variable is `Es_N0`. Remember that `rx=tx+noise`.

(c) Determine E_b/σ^2 in decibels, where E_b is the energy per uncoded bit for the transmitted signal. The corresponding Matlab variable is `Eb_N0`. If you did not solve the previous question, you can consider `Es_N0`=5 dB.