Name:

Note:

- You have 1 h 45 min to work at the exam.
- 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 is a MATLAB part and a paper-and-pencil part.
- 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.
- Start by downloading from Moodle and unzipping the file `sdr_midterm_2014.zip` with all the data required for the different problems. The files for Problem n, $n = 1, 2, 3$, are found in subfolder pn.
- You will upload to Moodle your solution to the problems that require writing Matlab code. Do so in a single archive.
- The MATLAB problems (Problems 1, 2, and 3) can be solved in any order.
- The last problem (Problem 4) is solved without the computer. It will be handed out 15 minutes before the end.

Problem 1. 12 p. (MATLAB)

Suppose that the siren of a police car is 1 KHz (measured when the car is not moving). A driver being chased by the police records the siren's sound, sampling it at $F_s = 10^4$ samples per second, and stores the result in the vector `siren` obtained by loading `siren.mat`.

(a) Plot the absolute value of the frequency spectrum of `siren`, with the x-axis labeled in Hz.

(b) Who is faster, the chased car or the police? Justify your answer.

(c) What is the relative speed between the two cars? Hint: The formula $f = f_0(1 \pm v/c)$ might be useful, where f_0 is the frequency of the siren, f is the frequency heard by the chased driver, $c = 343$ m/s is the speed of sound, and v is the speed difference, with positive sign if the police is going faster, and negative sign otherwise.

Problem 2. 9 p. (MATLAB)

By loading `probe.mat` and `reply.mat` you obtain the signals `probe` and `reply`, respectively. The signal `probe` contains the samples of a baseband equivalent signal transmitted by a radar. This signal bounces on an obstacle and a delayed, attenuated and noisy version of the signal comes back to the radar. The samples of the baseband equivalent return signal are stored in `reply`.

Determine the distance separating the radar and the obstacle. You can assume that neither the radar nor the obstacle are moving, that signals are traveling at the speed $c = 3 \times 10^5$ Km/s, and that the samples are taken at the sampling rate $F_s = 1$ Msps.

Problem 3. 14 p. (MATLAB) The purpose is to transmit an image over a simulated AWGN channel using a M-QAM constellation. Implement the following functions called by the script `p3.m` .

(a) `function [bits] = my_img2bit(img_name)`. It converts an image to a sequence of bits.

(b) `function [symbols, constellation] = my_mapper(bits, M)`. It maps a sequence of bits into a sequence of symbols taking values in a M-QAM constellation. It returns the symbol sequence and the constellation. Specifically, it shall carry out the following tasks:

   (i) Check if the input M is the square of an integer power of 2 (e.g. 4, 16, 64, ...). Print an error message and stop the program if it is not the case.

   (ii) Generate a unit-norm constellation vector named `constellation` of size 1xM.

   (iii) Map the bit-vector into a symbol vector.

(c) `function [estim_tx_bits] = my_demapper(r,constellation)`. It finds the maximum likelihood symbol sequence that corresponds to the received (noisy) sequence `r` and it outputs the corresponding bit sequence.

The following MATLAB functions may be useful: `imread`, `reshape`, `bi2de`, `de2bi`.

If your functions work correctly, the script should return a BER around 0.08 (with `Es_N0_dB = 10;` and `M = 16;`)

Problem 4. 5 p. (Paper and Pencil) Let a be a real-valued vector that contains the real-valued vector b, i.e., a has the form a_1, b, a_2 for some vectors a_1 and a_2. Suppose that the maximum of the correlation between a_1 and b and that between a_2 and b is small compared to the squared norm of b.

(a) Draw a qualitative plot of the result of `xcorr(a,b)`. Note: the help for `xcorr` is available.

(b) Describe the length of a_1 as a function of the result of the MATLAB operation `[t,u]=max(xcorr(a,b))`. Note: the help for `max` is available.

(c) Draw a qualitative plot of the result of `xcorr(b,a)`.

(d) Describe the length of a_1 as a function of the result of the MATLAB operation `[v,w]=max(xcorr(b,a))`.