COMP.SGN.100 Introduction to Signal Processing,
Exercise 9, 4.-5.10.2021

Pen & paper task solutions should be submitted to Moodle at least one hour before your exercise session. Matlab tasks are done during the exercise session.

Task 1. *(Pen & paper)* The impulse response of a filter is $h(n) = \delta(n) + \delta(n-2)$. Calculate the expressions of the phase response and group delay for this filter. Hint: Take $e^{-i\omega}$ as a common factor in the frequency response.

Task 2. *(Pen & paper)* The aim is to design an FIR filter by the window design method. The system has the sampling rate 16000 Hz and is intended to pass the frequencies lower than 4000 Hz and to eliminate the frequencies higher than 5000 Hz.

(a) Calculate, what the frequencies are when normalized by the sampling rate, and the normalized width of the transition band.

(b) How many coefficients (N) are needed when using

i. rectangular,
ii. Hanning,
iii. Hamming,
iv. Blackman

window?

Task 3. *(Matlab)* Create a vector containing the impulse response of the ideal low-pass filter truncated between $-20 \leq n \leq 20$ (41 coefficients) when the cut-off frequency $f_c = 0.3$ (Nyquist frequency $= 0.5$). Plot the amplitude response (`help sinc`). Conversion to the Matlab presentation should be done carefully. In the end result, the passband should be at zero decibels.

(a) What is approximately the attenuation of the first (the leftmost) oscillatory peak in the stopband?

(b) Do the same when the truncation is between $-30 \leq n \leq 30$. What happens to the first oscillatory peak?

(c) What happens when the number of coefficients is further increased? Can the stopband attenuation be improved by increasing the number of coefficients?

Task 4. *(Matlab)* Design using Matlab's `fir1` command a filter satisfying the following requirements:

Passband	[0 kHz, 4 kHz]
Stopband	[5 kHz, 8 kHz]
Passband ripple	0.1 dB
Minimum stopband attenuation	30 dB
Sampling frequency	16 kHz

Plot the impulse response (`impz`) and the amplitude and phase responses (`freqz`).

Task 5. *(Matlab)* Load Matlab's test signal `handel` to variable `y` with the command `load handel`. The sampling frequency of the signal is 8192 Hz. Design using the window design method filters with the order 50 and the following pass- and stopbands.

(a) Passband $0 - 1000$ Hz and stopband $1200 - 4096$ Hz (low-pass filter).

(b) Passband $1800 - 4096$ Hz and stopband $0 - 1500$ Hz (high-pass filter).

(c) Passband $2000 - 3000$ Hz and stopbands $0 - 1500$ Hz and $3500 - 4096$ Hz (band-pass filter).

(d) Passbands $0 - 500$ Hz and $3000 - 4096$ Hz and stopband $750 - 2500$ Hz (band-stop filter).

Plot the amplitude responses of the filters (`freqz`). Filter the signal with the above filters and listen to the results.