SGN-11006, Basic Course in Signal Processing

Exercise 9.

The first 3 problems should be solved and returned before the deadline: **21.11 at 4pm**. Submit your solutions either through Moodle or in the postbox #527 next to the room TC421. Matlab part is checked during the exercise sessions.

21.11 – 25.11.2016

Problem 1: An FIR LTI discrete-time system is described by the difference equation:

$$y[n] = a_1 x[n+k+1] + a_2 x[n+k] + a_2 x[n+k-2] + a_1 x[n+k-3]$$

where $y[n]$ and $x[n]$ denote, respectively, the output and the input sequences. Determine the expression for its frequency response $H(e^{j\omega})$. For what values of the constant k will the system have a frequency response $H(e^{j\omega})$ that is a real function of ω. (2 points)

Problem 2: Consider a causal IIR transfer function:

$$H(z) = \frac{(5z+6)(2z-3)}{(z-0.3)(z+0.2)} \tag{1}$$

Is it minimum-phase? If it is not minimum-phase, then construct a minimum-phase transfer function $G(z)$ such that $|G(e^{jw})| = |H(e^{jw})|$. Determine their corresponding impulse responses, $g[n]$ and $h[n]$. (4 points)

Problem 3: A causal LTI FIR discrete-time system is characterized by an impulse response $h[n] = a_0\delta[n] + a_1\delta[n-1] + a_2\delta[n-2] + a_3\delta[n-3] + a_4\delta[n-4] + a_5\delta[n-5] + a_6\delta[n-6]$, where $a_{0..6}$ are real constants. For what values of the impulse response samples will its frequency response $H(e^{jw})$ have a constant group delay?

(4 points)

Problem 4: (Matlab) (MATLAB) Design the linear-phase FIR filter of type (N - the last digit of the student number)

- N=[0, 3, 5] - HPF: F_{pass} = 1500 Hz, F_{stop} = 1000 Hz, δ_p = 0.01, δ_s = 0.05;
- N=[2, 4, 6, 8] - BPF: F_{stop1} = 1000 Hz, F_{pass1} = 1400 Hz, F_{pass2} = 2000 Hz, F_{stop2} = 2400 Hz, δ_p = 0.05, δ_s = 0.01;
- N=[1, 7, 9] - BSF: F_{pass1} = 1000 Hz, F_{stop1} = 1400 Hz, F_{stop2} = 2000 Hz, F_{pass2} = 2400 Hz, δ_p = 0.05, δ_s = 0.01;

using the functions `firpmord` and `firpm` (HINT: for function `firpmord(..., A, ..., ...)` define `A=[1 0]`). What is the filter order? Check if the designed FIR filter is optimum: compare δ_p with the output parameter `ERR` of function `firpm`. In case the FIR is not optimum - optimize it! Plot the impulse response, magnitude and phase using the outer function `plot_fir` (available from the course web-site). (4 points)

Problem 5: (Matlab) Use the outer function `MAG_fir (b, fextr, f0, a0, Fs)` (available from the course web-site) to plot the magnitude of your linear-phase FIR filter, ideal magnitude and the Chebyshev's alternance (maxima and minima) points. The optimum order of the designed filter should be $R = 2m-3$, where m - is the number of the Chebyshev's alternance points. Check it!

(HINT: use `fextr=res.fextr`) (3 points)

Problem 6: (Matlab) Create a signal with low and high frequency components and plot its spectrum. Then filter the signal using the designed FIR filter. Plot the spectrum of the filtered signal (use `subplot`) and rationalize your results.

(HINT: use the same vector of frequences f as specified in the function `MAG_fir` when calculating frequency response using `freqz`) (3 points)