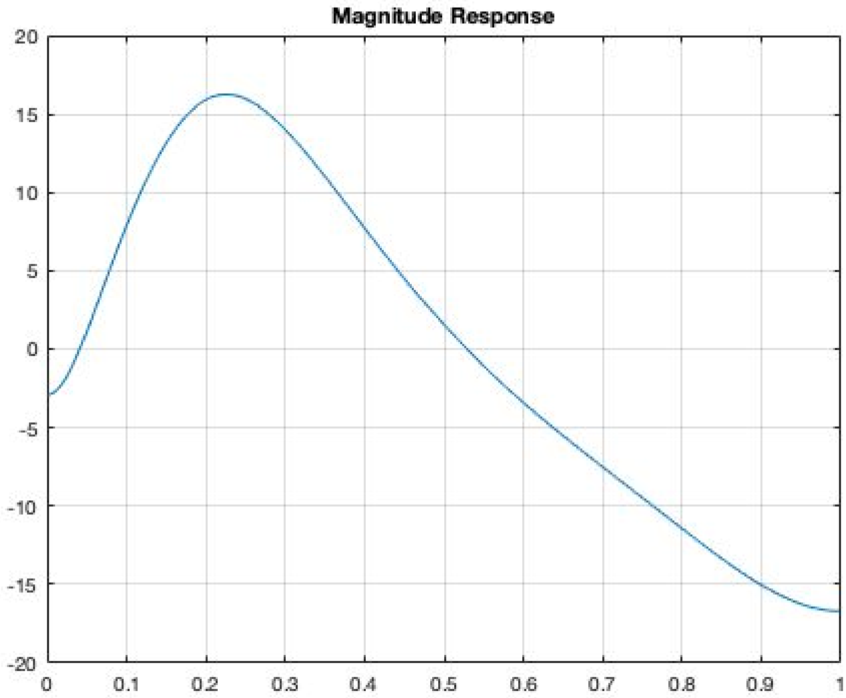
EE 274 DSP 1 / CoE 197E Semester SY 2020-2021
Pole-zero placement and FIR Filter Design

Instructions: You are to submit a pdf document containing the answers to the questions in this exercise. Submit your pdf together with the m-files as a zip file and submit via UVLe before the deadline.

A. Pole-Zero Placement.

For the given magnitude response, design a filter using pole-zero placement, that meets the desired response within +/- 0.5 dB. The x-axis is normalized frequency.

a. Draw the pole and zero locations of your filter
b. Draw the magnitude response of your filter
c. What is the frequency response H(ω) of your filter?



B. Properties of Various Windowing Function

The unit impulse response *h(n)* obtained using the windowing method in designing FIR filters can be expressed as $h(n) = h_d(n)w(n)$

$$h_d(n) = \frac{sin\left[\omega_c\left(n - \frac{M-1}{2}\right)\right]}{\pi\left(n - \frac{M-1}{2}\right)}, \text{ for } 0 \le n \le M-1, n \ne \frac{M-1}{2}$$

where

and w(n) is the window function.

For the case where *M* is selected to be odd,

$$h_d\left(\frac{M-1}{2}\right) = \frac{\omega_c}{\pi}, \text{ for } n = \frac{M-1}{2}.$$

For the filter lengths $M = 31$, 61 and 121 and $\omega_c = 0.5\pi$, generate the FIR filter coefficients using the following window functions

a. Rectangular
b. Bartlett
c. Hanning
d. Hamming
e. Kaiser with β =1, 4, 9
f. Blackman

Plot the magnitude response and determine the approximate transition width of the main lobe and peak sidelobe (in dB). Fill up the table below. Normalize your filter such that $|H(\omega = 0)| = 1$.

Window name	Transition width (in π radians)				Peak Sidelobe (in dB)		
	Exact value	M=31	M=61	M=121	M=31	M=61	M=121
Rectangular	$\frac{1.8\pi}{M}$						
Bartlett	$\frac{6.1\pi}{M}$						
Hanning	$\frac{6.2\pi}{M}$						
Hamming	$\frac{6.6\pi}{M}$						
Blackman	$\frac{11\pi}{M}$						

(include a three row for the Kaiser window with β =1, 4, 9
)

C. Design a digital FIR lowpass filter with the following specifications.

Choose an appropriate window function from the table above. Determine the impulse response and provide a plot of the frequency response of the designed filter.

$$\omega_p = 0.2\pi$$
$$\omega_s = 0.3\pi$$
$$R_p = 0.25 \text{ dB},$$
$$A_s = 50 \text{ dB}$$

Notes:
1. From the given specifications, we can determine the type of window to be used (i.e. peak sidelobe of a window function corresponds to the minimum stopband attenuation it can provide).
2. The filter length M can be determined using the transition width of the chosen window function.
3. Although the passband ripple is not to be used in the design, we have to check if the actual ripple from the design is indeed within the given tolerance.

Plot the magnitude response of your filter and show that it meets the specifications. As with any filter design, your implicit design is to minimize the number of multiplications and additions to implement the filter. Explain your methodology in the filter design.

D. Frequency Sampling (Grad Students only)

The following are frequency samples of H(ω).

$$H(k) = \begin{cases} (-1)^k, & 0 \le k \le 7 \\ 0.5, & k = 8 \\ 0, & 9 \le k \le 23 \\ 0.5, & k = 24 \\ (-1)^k, & 25 \le k \le 31 \end{cases}$$

Using frequency sampling method, design a FIR filter with real coefficients h(n). Plot the frequency response of your filter and measure the width of the transition band of your filter and measure the passband and stopband ripple heights. Note: Frequency sampling is done using fir2().

a. What is the order of the FIR filter? Is the filter linear phase?
b. Compare the transition bandwidth, passband and stopband ripple heights of FIR filters design using windowing method and frequency sampling methods of the same filter order.
c. What is the main advantage of using frequency sampling methods with windowing methods?