NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

EC3093D Digital Signal Processing Lab

Winter Semester 2023-24

Experiment No. 5: FIR Filter design (Tool – MATLAB)

Part A: FIR Filter Design using Window Method

1. Compute the impulse response of the following filters and plot the filter functions. (10 Marks)
   a. Ideal Low pass filter
   b. Ideal High pass filter
   c. Ideal Band pass filter
   d. Ideal Band reject filter

2. Find the Main Lobe Width (MLW) and Side Lobe Attenuation (SLA) of the following window functions used in the design of FIR filters. You can compute the window function w[n] and the magnitude spectrum W(ω) to find the required parameters. Plot the window function w[n] and its spectrum W(ω) for N=15 and N=55, where N is the length of the window and give appropriate comments based on your results. (10 Marks)
   a. Rectangular Window
   b. Bartlett (Triangular) Window
   c. Hanning Window
   d. Hamming Window
   e. Blackman Window

3. Design a linear Phase Type 1 FIR filter with the following specifications using window method. Choose appropriate window function based on the given specifications and compute the order of the filter. Plot the window function, ideal impulse response and implulse response of the designed filter. Plot the magnitude and phase spectrum of the designed filter and verify that the given specifications and linear phase property is met. (40 Marks)
   a. Pass band edge frequency = 1000Hz; Stop band edge frequency = 1500Hz
      Minimum stop band attenuation = 50 dB; Maximum pass band attenuation = 0.9 dB
      Sampling Frequency = 8000Hz

   b. Pass band edge frequency = 1500Hz; Stop band edge frequency = 1000Hz
      Minimum stop band attenuation = 50 dB; Maximum pass band attenuation = 0.9 dB
      Sampling Frequency = 8000Hz

4. An FIR filter having the following specifications is to be designed using window method. Design the given filter using Rectangular, Hamming and Blackman windows. Plot the window function, ideal impulse response and implulse response of the designed filter. Also plot the magnitude and

phase spectrum of the designed filter. Compare the performance of the filters designed using different windows and give appropriate comments based on your results. (20 Marks)

$$-1 \le \left|H(e^{j\omega})\right|_{dB} \le 0 \qquad \text{for} \qquad 0.2\pi \le \omega \le 0.5\pi$$
$$\left|H(e^{j\omega})\right|_{dB} \le -60 \qquad \text{for} \qquad 0 \le \omega \le 0.15\pi \text{ and } \; 0.7\pi \le \omega \le \pi$$

5. Generate a composite signal by adding sinusoids of different frequencies (200Hz, 500Hz, 1000Hz, 2000Hz, 4000Hz). Compute the output of the filters designed in Qns. 3 and 4 by giving the composite signal as input and verify the design. (20 Marks)

Part B: FIR Filters – Properties and Alternate Design Methods

1. **MATLAB functions for the design of FIR filters**:
   - Familiarize various MATLAB functions for the design of FIR filters. Eg. firpmord, firpm, fir1, fir2, freqz etc.
   - You can design the filters given in part A using MATLAB functions and compare the responses.
2. **Linear Phase FIR Filters**: Many applications require the use of digital filters with linear phase. It is always possible to design an FIR transfer function with an exact linear phase response. Such a transfer function corresponds either to a symmetric impulse response defined by $h[n] = h[N - n]$, $0 \le n \le N$, or an antisymmetric impulse response defined by $h[n] = -h[N - n]$, $0 \le n \le N$, where N is the order of the transfer function and the length of h[n] is N + 1. There are four types of such transfer functions: Type 1: Symmetric Impulse Response with Odd length. Type 2: Symmetric Impulse Response with Even Length. Type 3: Antisymmetric Impulse Response with Odd Length. Type 4: Antisymmetric Impulse Response with Even Length.
   - Study the importance of linear phase filters and identify some applications which require this property.
   - Study the characteristics of all four types of linear phase FIR filters. Whether all types of filters can be used for the design of LPF, HPF, BPF and BRF?
   - The impulse response coefficients of four FIR filters are given below in b1, b2, b3 and b4. Identify the types of these filters. Write a program to plot the impulse response coefficients and zero locations for these four filters:
     b = [1 -8.5 30.5 -63]; b1 = [b 81 fliplr(b)]; b2 = [b 81 81 fliplr(b)]; b3 = [b 0 -fliplr(b)]; b4 = [b 81 -81 -fliplr(b)];
3. **Frequency sampling method of FIR filter design:**
   - Study the basics of FIR filter design using frequency sampling method. What are the possible ways of tuning the filter parameters to meet the given specification?
   - Design a lowpass FIR filter using frequency sampling technique having cut-off frequency of $\pi/2$ rad/sample. The filter should have linear phase and length of 17.
4. **Design of FIR filters with Kaiser window:**
   - Study the design of FIR filters using Kaiser window.

- Find an expression for the impulse response h(n) of a linear phase low pass FIR filter using Kaiser window to satisfy the following magnitude response specifications for the equivalent analog filter. Implement the filter in MATLAB using functions `kaiserord` `and fir1.` Plot the spectrum.

Stopband attenuation: 40 dB	Passband ripple: 0.01 dB
Transition width: 1000 π rad/sec	Ideal cutoff frequency: 2400 π rad/sec
Sampling frequency: 10 KHz	

References:

1. Oppenheim and Schafer, Discrete Time Signal Processing. Pearson education, Prentice Hall, 2003. ‘
2. Sanjit K. Mitra , Digital Signal Processing, Tata Mc-Graw Hill, 2004
3. Sanjit K. Mitra , Digital Signal Processing Laboratory Using MATLAB’ McGraw-Hill, 1999