LNMIIT
The LNM Institute of Information Technology
The LNM Institute of Information Technology
DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

Experiment No. # 9
Digital Filter Design: Windowing, Linear phase FIR

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1) **Aim:**
   a) Digital Filter Design.

2) **Software used:**
   a) MATLAB.

3) **Theory**
   a) J. Proakis and D. Manolakis, Digital signal processing: principles, algorithms, and applications

4) **Procedure**
   a) **Windowing Based design: Rectangle, Hamming, Blackman**

      i) Let's consider a low pass filter, whose response is given by

$$H_d(w) = e^{\left(-j\cdot w\cdot\left(\frac{M-1}{2}\right)\right)} \cdots, 0 \leq |w| \leq w_c \tag{1}$$
$$H_d(w) = 0, \cdots Otherwise.$$

      where M is corresponding delay in time domain.

      ii) The corresponding filter impulse response can be found by

$$h_d(n) = \frac{1}{2\pi}\int_{-w_c}^{w_c} e^{\left(-j\cdot w\cdot\left(n-\frac{M-1}{2}\right)\right)}dw \tag{2}$$

      and is given by

$$h_d(n) = \frac{sin\left(w_c\left(n-\left(\frac{M-1}{2}\right)\right)\right)}{\left(\pi\left(n-\left(\frac{M-1}{2}\right)\right)\right)} \tag{3}$$

      iii) This impulse response is windowed using the windows mentioned below.
         A) Rectangle Window: $w(n) = 1$
         B) Hamming Window: $w(n) = 0.42 - 0.5\cdot cos(\frac{2\pi n}{M-1}) + 0.08\cdot cos(\frac{4\pi n}{M-1})$
         C) Blackman Window: $w(n) = 0.54 - 0.46\cdot cos(\frac{2\pi n}{M-1})$
         where $n = 0, 1, \cdots M-1$

      iv) The finite impulse response $h(n)$ is then windowed impulse response given by

$$h(n) = h_d(n)\cdot w(n) \tag{4}$$

      where n = 0,1,2, ... $M-1$.

b) **Filtering Hamming sound using filtering:**

   i) Let's read an audio file and sample it using 32 Khz. Let's also consider this audio file has a hamming sound or Hiss having frequency greater than ($\frac{\pi}{2}$) 8 KHz. Follow the steps and remove the hissing sound.

   ii) Steps:
   - Take 256 samples of the audio file and locate the hissing frequency (Approximately at 66^{th} and 192^{th} sample).
   - Use the low pass filter designed in previous exercise, having cut off frequency $\frac{\pi}{2}$ i.e (or ideal filter having ones for first 64 samples and zeros for next 64 sample over a span of 0 to π frequency).
   - Multiply the filter response and spectrum of audio signal for N= 256 samples.
   - Repeat above step for the whole audio file.
   - Check whether hiss sound removed and also conclude for distortion audible if any.

c) **Notch Filtering of Hiss:**

   i) Let's read an audio file and sample it using 32 Khz. Let's also consider this audio file has a hissing sound at 8 KHz. Follow the steps and remove the hissing sound.

   ii) Steps:
   - Take 8 samples of the audio file and locate the hissing frequency (Approximately at 3^{rd} and 7^{th} sample).
   - Design a notch filter at frequency $\frac{\pi}{4}$ i.e (By placing complex conjugate pairs of zeros at $\pm\frac{\pi}{4}$ frequency).
   - Convolve the impulse response $h(n)$ with the distorted file Or Multiply the filter response $H(w)$(Having zero values at corresponding frequencies) and spectrum of audio signal for $N = 8$ samples. Here the transfer function $H(w)$ and the impulse response $h(n)$ having complex conjugate zeros at frequencies $\frac{\pi}{4}$ is given by

$$H(Z) = (1 - exp(j \cdot \frac{\pi}{4})Z^{-1})(1 - exp(-j \cdot \frac{\pi}{4})Z^{-1}) = 1 - 2\cos(\frac{\pi}{4})Z^{-1} + Z^{-2} \quad (5)$$

$$h(n) = [1, -2\cos(\frac{\pi}{4}), 1] \quad (6)$$

   - Check whether hiss sound removed and also conclude for distortion audible if any.

5) **Tasks and Observations:**

   a) Window Based Filtering: Use Eq.(1),(2),(3),(4)

      i) Simulate vaious window(rectangle, hamming, blackman's) based Low pass FIR filter with cutoff frequncies $w_c = \frac{\pi}{2}, \frac{\pi}{4}, \frac{\pi}{6}$, show the frequncy response of the windowing functions and plot the magnitude(in dB), phase response of the designed FIR filter.

      ii) Simulate vaious window(rectangle, hamming, blackman's) based High pass FIR filter with cutoff frequncies $w_c = \frac{\pi}{2}, \frac{\pi}{4}, \frac{\pi}{6}$, show the frequncy response of the windowing functions and plot the magnitude, phase response of the designed FIR filter.

      iii) Simulate vaious window(rectangle, hamming, blackman's) based band pass FIR filter with cutoff frequncies $w_c(low) = \frac{\pi}{4}$, $w_c(high) = \frac{\pi}{2}$, show the frequncy response of the windowing functions and plot the magnitude, phase response of the designed FIR filter.

   b) Remove the hissing sound using above generated filter.

   c) Remove the hissing sound using Notch filter.

   d) Repeat the experiment in simulink.

6) Plot all the signals in all of the above steps and justify them.

7) **Conclusion** Write/plot your own.