EE-386 Digital Signal Processing lab

Experiment No: 7

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Problem:1

Window Functions

1. Explore the following windows: (a) Rectangular (b) Hamming (c) Hanning.

2. Plot the spectrum of the window (if $\alpha = 1$ use Hanning window, if $\alpha = 2$ use Blackman window, if $\alpha = 3$ use Hanning window) signal for different lengths. Use a 1024 point DFT and normalise the magnitude by the actual lengths (Say $N = 100, 200, 300$).

Solution:

1)Using the suitable window functions we can plot the time domain features of the windows. From the time domain analysis of windows we can get information regarding the capture area of the window, windowing endpoints which gives us information regarding how much the spectral leakage is suppressed in the frequency domain and their effect on main lobe. (Refer Fig.1)

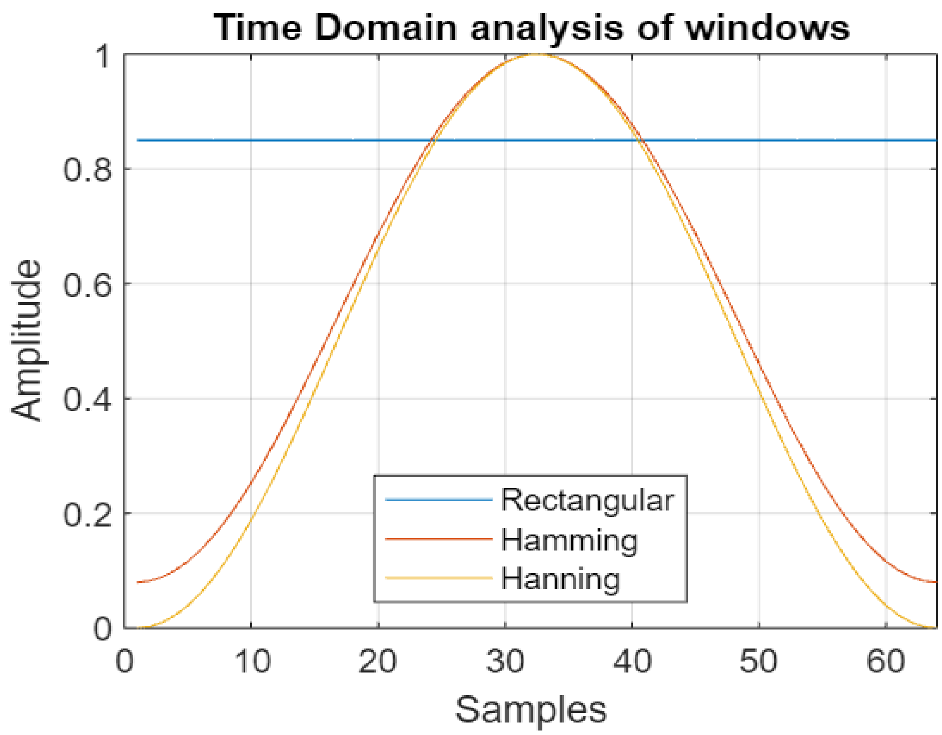

Fig.1

2) Taking FFT of all the above mentioned windows we can do frequency analysis of the windows and get the characteristics such as roll off/on rate of the suppression of side lobes (spectral leakage) and their impact on main lobe, we can get the proper conditions to select a specific window based on the application we need it for and get a trade-off between frequency resolution and spectral leakage suppression. The frequency responses of rectangular, hamming and hanning are plotted. (Refer Fig .2)

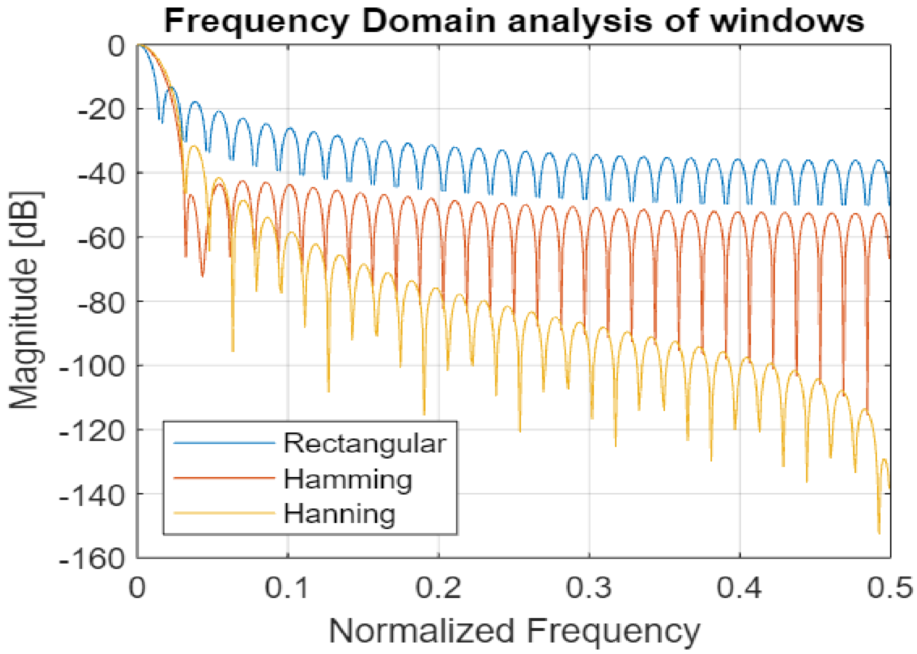

Fig .2

Problem:2

FIR filter design

Design digital low pass FIR filter using rectangular and (if $\alpha = 1$ use Hanning window, if $\alpha = 2$ use Blackman window, if $\alpha = 3$ use Hanning window) functions for a cut-off frequency of $\omega c = \pi/\alpha+1$ rad/sample. Select the window length for all the window functions to be 21.

1. Plot the impulse response of the two filters.
2. Perform a bode analysis on the two filters and comment on them.

Solution:

// Impulse responses:

The lowpass FIR filter can be designed using the **fir1** function which takes order, cutoff frequency and window with its length as input parameters. From Fig.3 we can visualise the impulse responses of the rectangular and hanning windowed filters. The impulse response of a filter basically signifies the time domain characteristics of that filter for an impulse input. For a FIR filter the impulse response is finite and attenuates to zero quickly. This response gives us an idea about how that particular filter behaves to different inputs and time domain characteristics such as linearity, time invariance and stability. (Refer Fig.3)

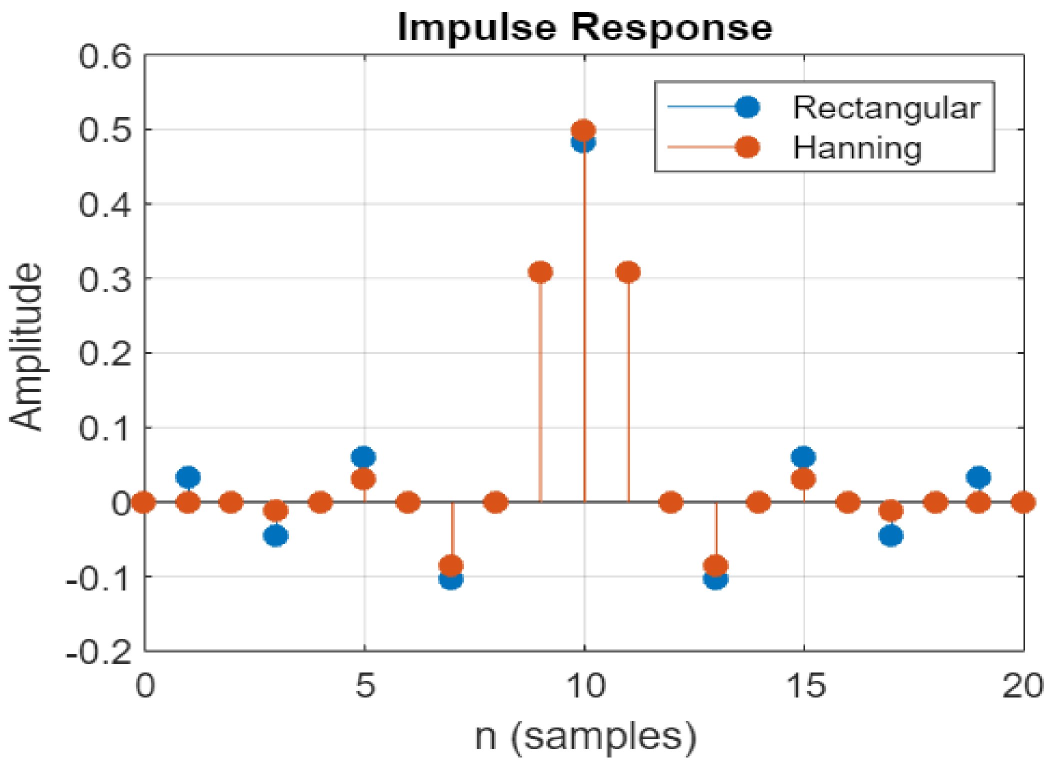

Fig.3

// Bode analysis:

The bode plot of a filter is the frequency domain visualisation of impulse response of a filter. This gives us some idea of basic parameters like magnitude plot which depicts the filter's gain, phase plot implies the phase shifts of the filter responses at different frequencies, cutoff frequency, filter type (low, high, bandpass) and stability of the filter. The bode plot of rectangular, hanning, hamming and blackman windowed lowpass filters is analysed. (Refer Fig.4).

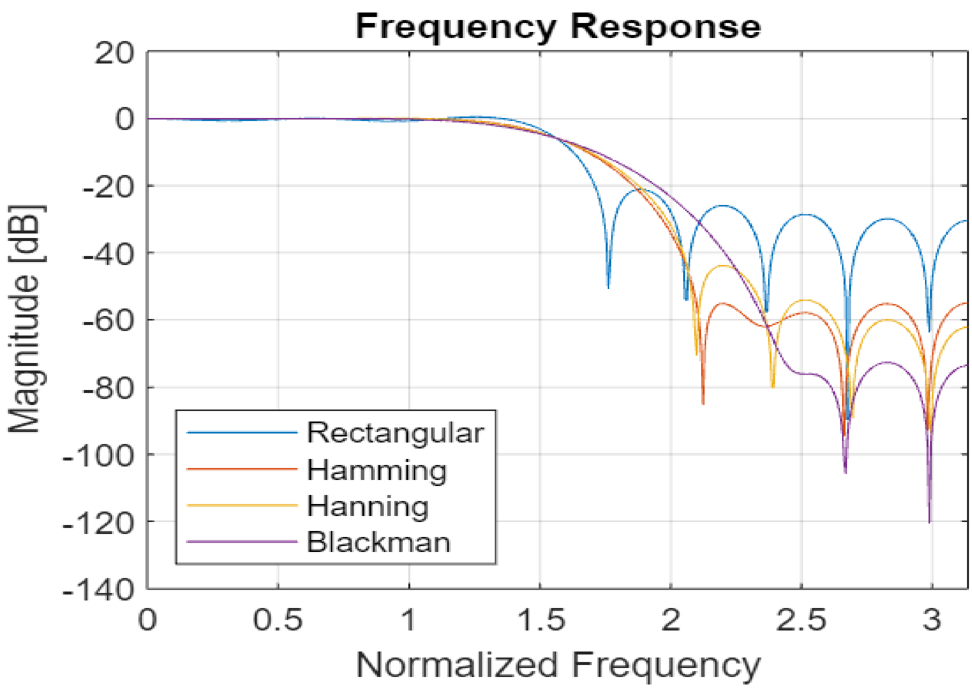

Fig.4

Problem: 3

Filtering using FIR filters

Plot the spectrogram of the *instrua.wav* (same as Exp. 5 & 6). Use any window of your choice and sample duration for the window. Design a digital FIR filter (using windowing) to only extract the fundamental (the first major peak excluding $\omega = 0$) and remove the rest including $\omega = 0$. Write it into a .wav file and listen. Also plot the spectrogram to ensure that you only have the fundamental. You may use the same specs that you have used in Exp. 6.

Solution:
The instru1.wav file is selected for this analysis. The spectrograms and pitch extraction are done as specified in Exp.6 (Refer Fig.5 and Fig.6).

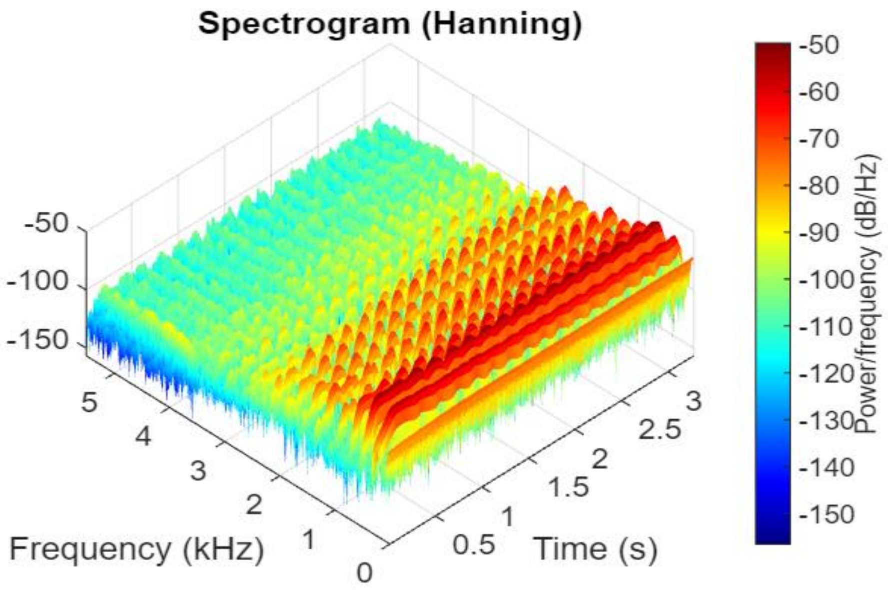

Fig.5

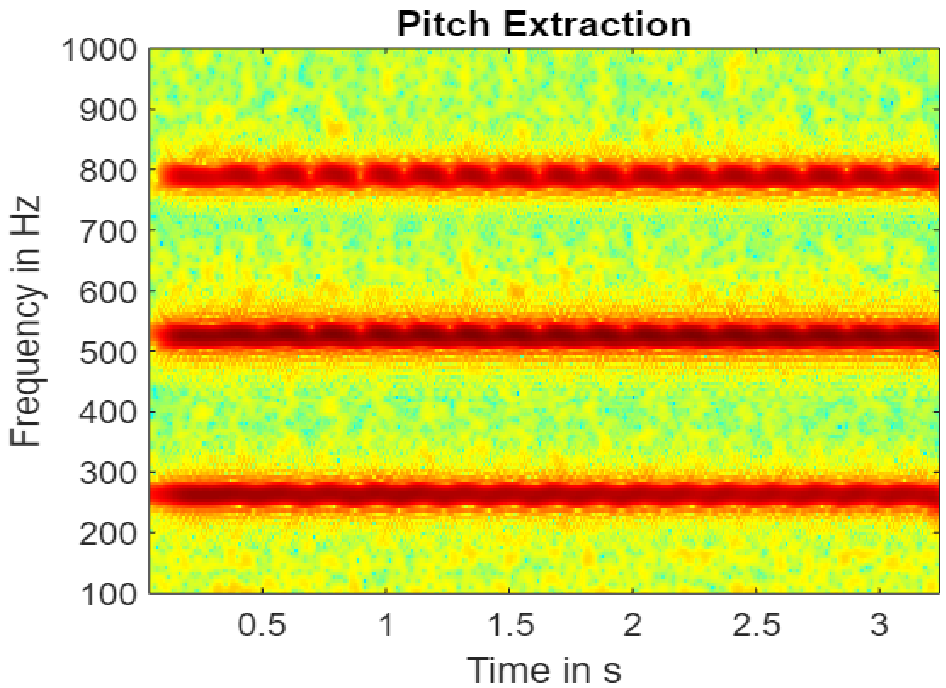

Fig.6

From Fig.6 we can conclude that the fundamental frequency lies in the range of 400-600Hz, hence we need to design a bandpass FIR filter for this purpose. The **fir1** function is used and a Chebyshev window of size 100 is chosen for this design. A bandpass filter for the range 400-600Hz is designed and the signal is filtered using the **filtfilt** command. From Fig.7 we can visualize the frequency response of the digital FIR filter and the attenuation ripple is set at 60dB. (Refer Fig.7)

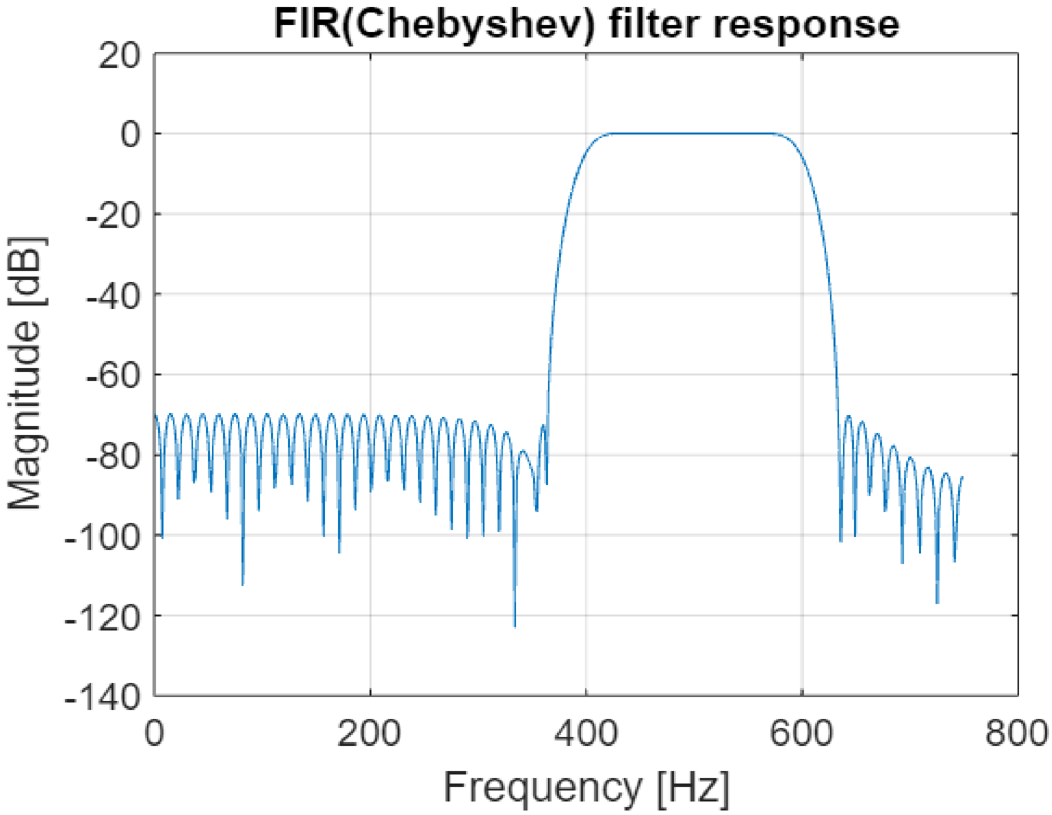

Fig.7

The spectrogram of the filtered signal is plotted in Fig.8. From the plot we can visualize that the frequency components excluding the bandpass region (400-600 Hz) has been satisfactorily suppressed but we can see that the magnitude of the signal has been reduced, as from the frequency response we can see the gain of the filter reducing as the frequencies increase which is evident from the filtered signal spectrogram also respectively. (Refer Fig.8)

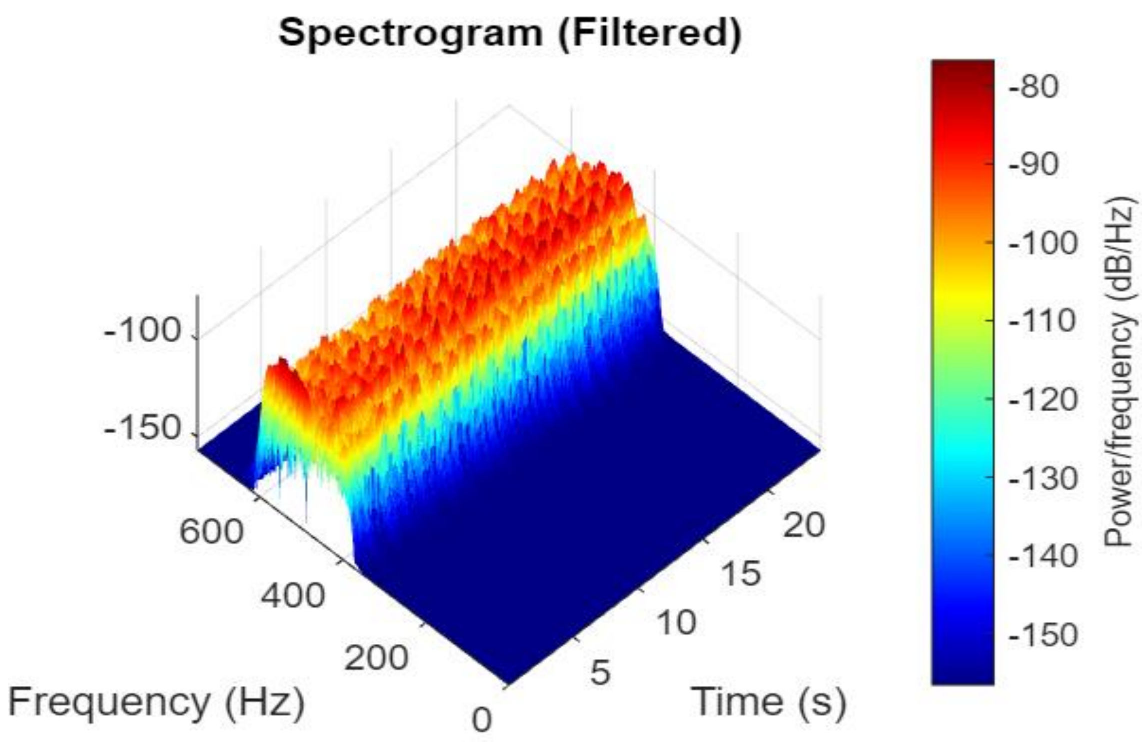

Fig.8

Problem: 4

Differentiate between the time-domain windowing and the window-based FIR filter design. Can you give a descriptive comparison of the same?

// Time-Domain Windowing:

Time-Domain windowing is used on finite duration signals where spectral leakage is prominent i.e. fundamental frequency components spreading in the neighbouring frequencies of the signal and imposes a challenge for further frequency analysis. So, the main role of a window here is to reduce signal amplitude to zero at its edges and reduce the spectral leakage where accurate frequency analysis has to be carried out like in audio processing.

// Window-Based FIR filter design:

In window-based FIR filter design the filter is multiplied with a suitable window so as to improve the frequency response characteristics such as response shape and roll off/on characteristics, attenuation levels, linear phase characteristics without disturbing the finite impulse response characteristics.

Code Repository: https://github.com/Launnish2001/Digital-Signal-Processing.git