DSP Lab Report

Experiment 7

Aim:

1. To explore the generation of rectangular, Hamming and Hanning window in matlab.
2. To plot the frequency spectrum of different time domain windows.
3. To design a digital low-pass FIR filter using different windows and plot their impulse response and bode.
4. To extract only the fundamental component of an instrument using a band-pass FIR filter.
5. To differentiate between time domain windowing and window-based FIL filter design.

Code:

Q1)

```
% number of points in windows
N = 125;

% plotting different windows
figure();

subplot(3,1,1);
plot(rectwin(N));
title('Rectangular Window');
xlabel('samples');
ylabel('y(n)');

subplot(3,1,2);
plot(hamming(N));
title('Hamming Window');
xlabel('samples');
ylabel('y(n)');

subplot(3,1,3);
plot(hanning(N));
title('Hanning Window');
xlabel('samples');
ylabel('y(n)');
```

Q2)

```
% a = 3, hanning window

% defining the lengths for different hanning winows
N1 = 100;
N2 = 200;
N3 = 300;

% getting the hanning windows
x1 = hanning(N1);
x2 = hanning(N2);
x3 = hanning(N3);

N = 2048;
k = 0:N-1;

% taking the 1024 point DFTs of different windows
DFT1 = fft(x1,N);
DFT2 = fft(x2,N);
DFT3 = fft(x3,N);

% plotting the frequency spectrums
figure();

plot(k/N,abs(DFT1)/N1,'r');
hold on;

plot(k/N,abs(DFT2)/N2,'b');
hold on;

plot(k/N,abs(DFT3)/N3,'g');
hold on;

legend('100 pts','200 pts','300 pts');
title('Frequency Spectrums');
xlabel('Normalized f');
ylabel('Normalized abs(DFT)');
```

Q3)

```
% a = 3, rectangular and hanning windows

% M = 21, so N = 20

% defining cutoff frequency
Wc = 1/(1+3);
N = 20;

% desinging the FIR filters using different windows.
B1 = fir1(N,Wc,rectwin(21));
B2 = fir1(N,Wc,hanning(21));

% plotting the Impulse response of filters
figure();
stem(0:(size(B1,2)-1),B1,'r');
hold on;
stem(0:(size(B2,2)-1),B2,'g');
legend('Rectangular','Hanning');
title('Impulse Response');
xlabel('samples');
ylabel('h(n)');

% ploting the bode
figure();
freqz(B1);
title('Rectangular window');

figure();
freqz(B2);
title('Hanning window');
```

Q4)

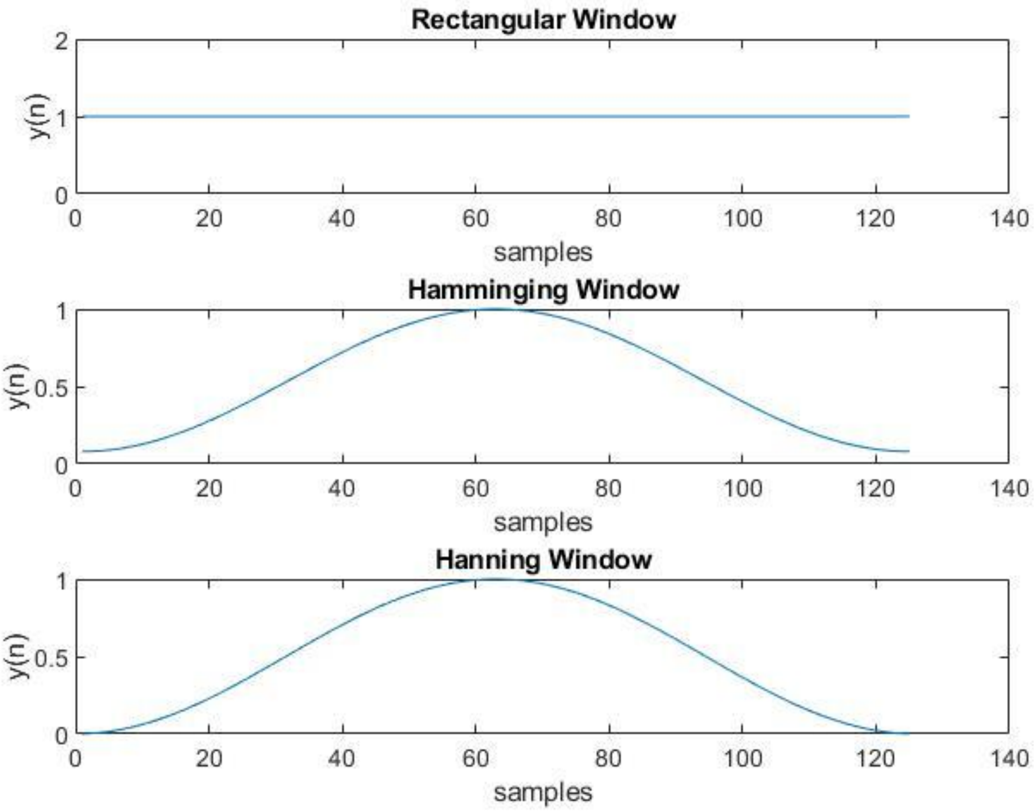
```
% loading the audio file
[x,Fs] = audioread('instru3.wav');

% plotting the spectrogram of original audio
figure();
spectrogram(x,blackman(500),10,[],Fs);
title('Original Audio');
```

```
% setting the cut-off frequencies for band-pass filter
f1 = 695;
f2 = 900;

% desinging the filter
N = 300;
B = fir1(N,[f1*2/Fs,f2*2/Fs],blackman(N+1));
A = 1;

% filtering the signal
y = filter(B,A,x);

audiowrite('instru_.wav',y,Fs);

% plotting the spectrogram of processed audio
figure();
spectrogram(y,blackman(500),10,[],Fs);
title('Filtered Audio');
```

Graphs and Observations:

Q1)

Graphs –



Observations –

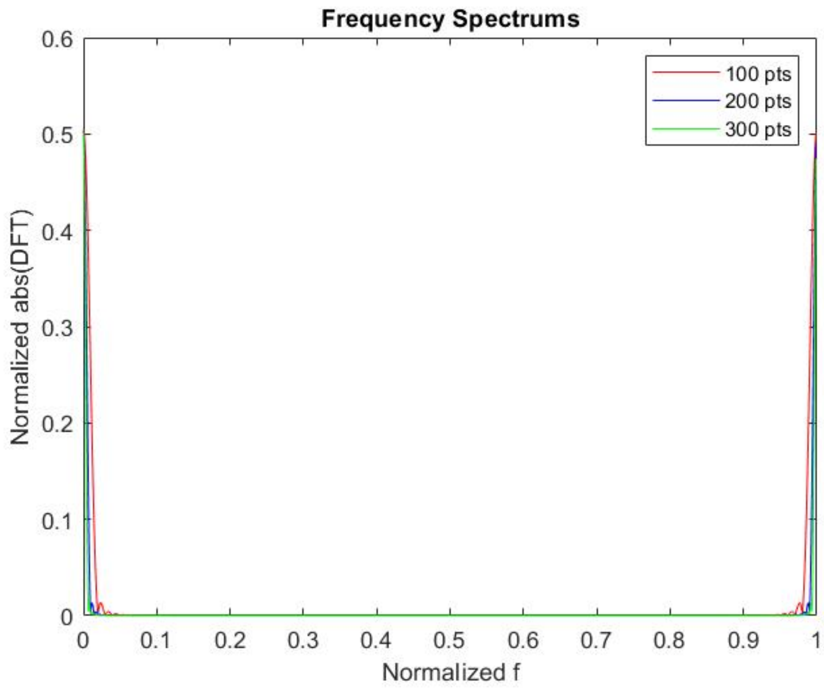
The functions for plotting time domain windows are as follows:

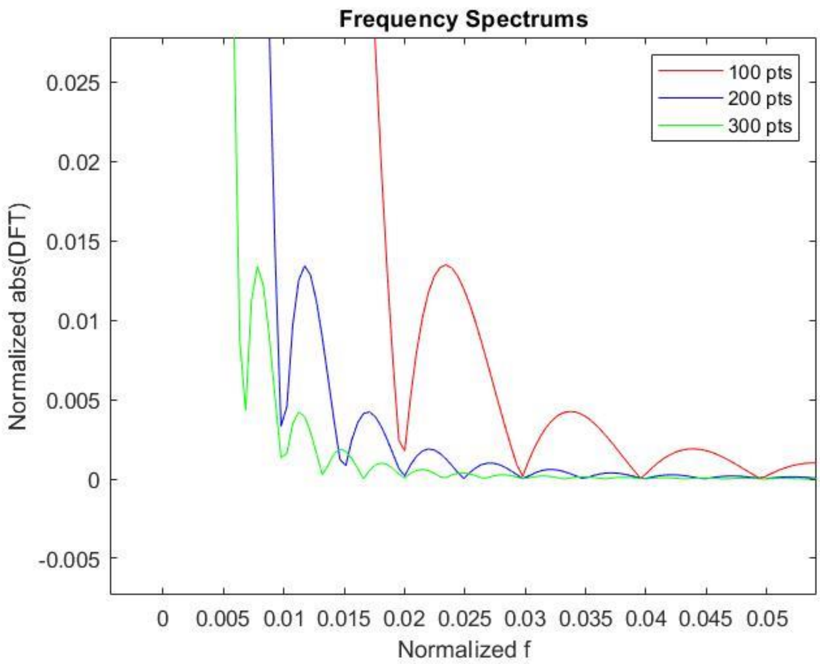
- Rectangular – rectwin(N)
- Hamming – hamming(N)
- Hanning – hanning(N)

where N stands for number of samples.

Q2)

Graphs –



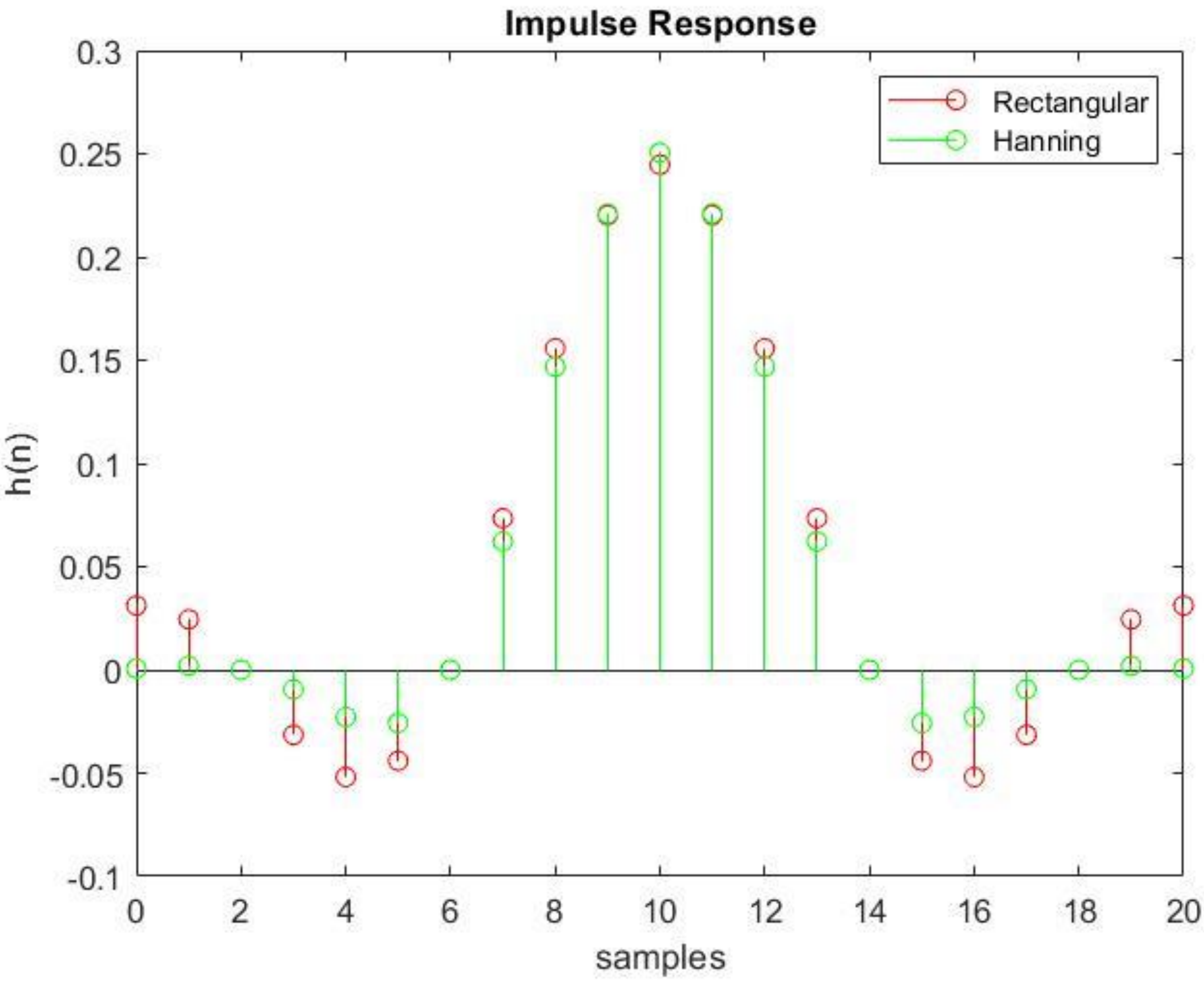


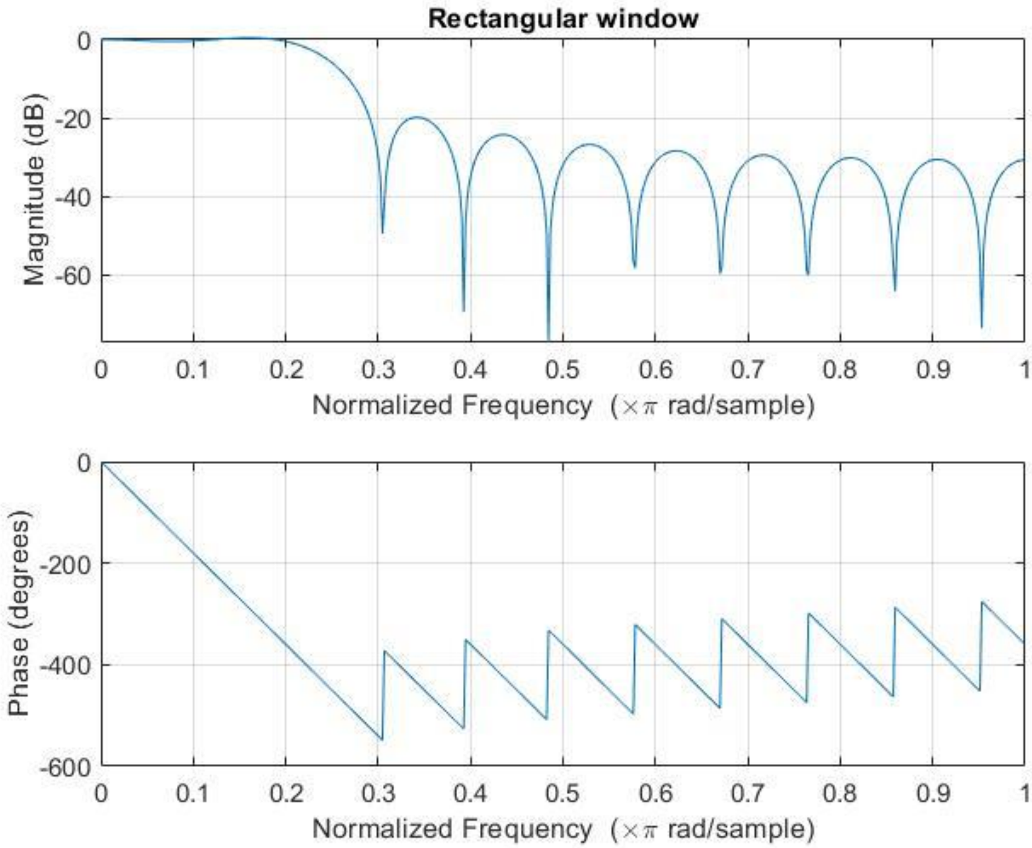
Observations –

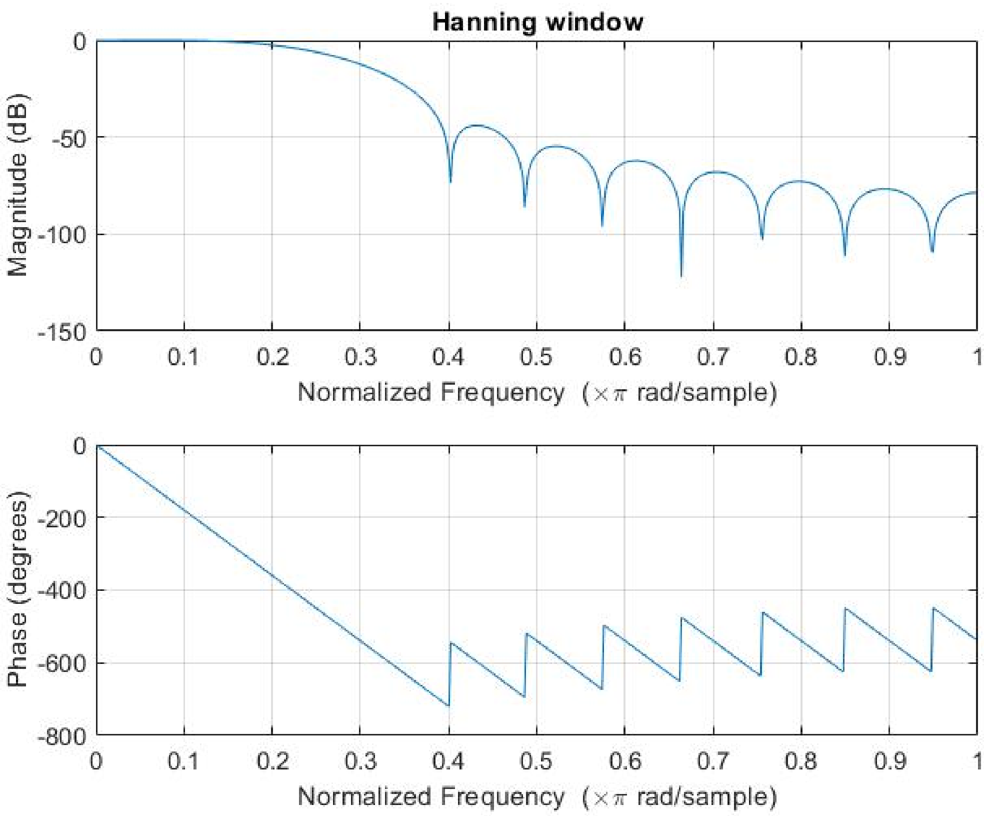
- In the zoomed version of the frequency spectrum, it can be seen that taking more number of points for any window will give lesser width of the different lobes but the heights of corresponding lobes are same.
- It can be seen that second lobes of all three have same normalized absolute value of DFT. Similarly, for third, fourth and subsequent lobes.
- In filter terms, the transition region becomes better with increase in number of samples but the attenuation in stop band doesn't change.

Q3)

Graphs –




Rectangular window
Magnitude (dB)
0
-20
-40
-60
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Normalized Frequency (×π rad/sample)
Phase (degrees)
0
-200
-400
-600
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Normalized Frequency (×π rad/sample)

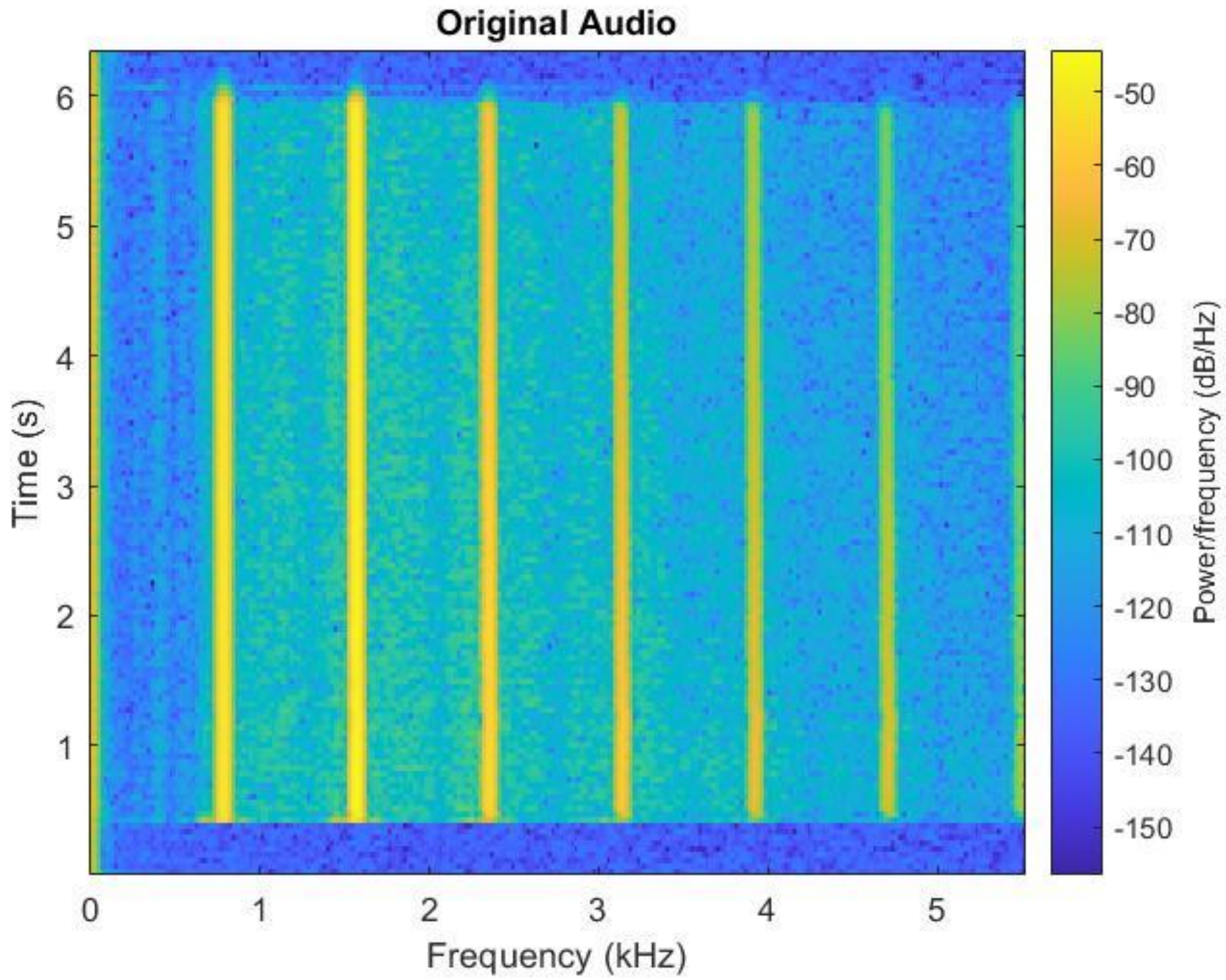

Hanning window
Magnitude (dB)
0
-50
-100
-150
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Normalized Frequency (×π rad/sample)
Phase (degrees)
0
-200
-400
-600
-800
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Normalized Frequency (×π rad/sample)

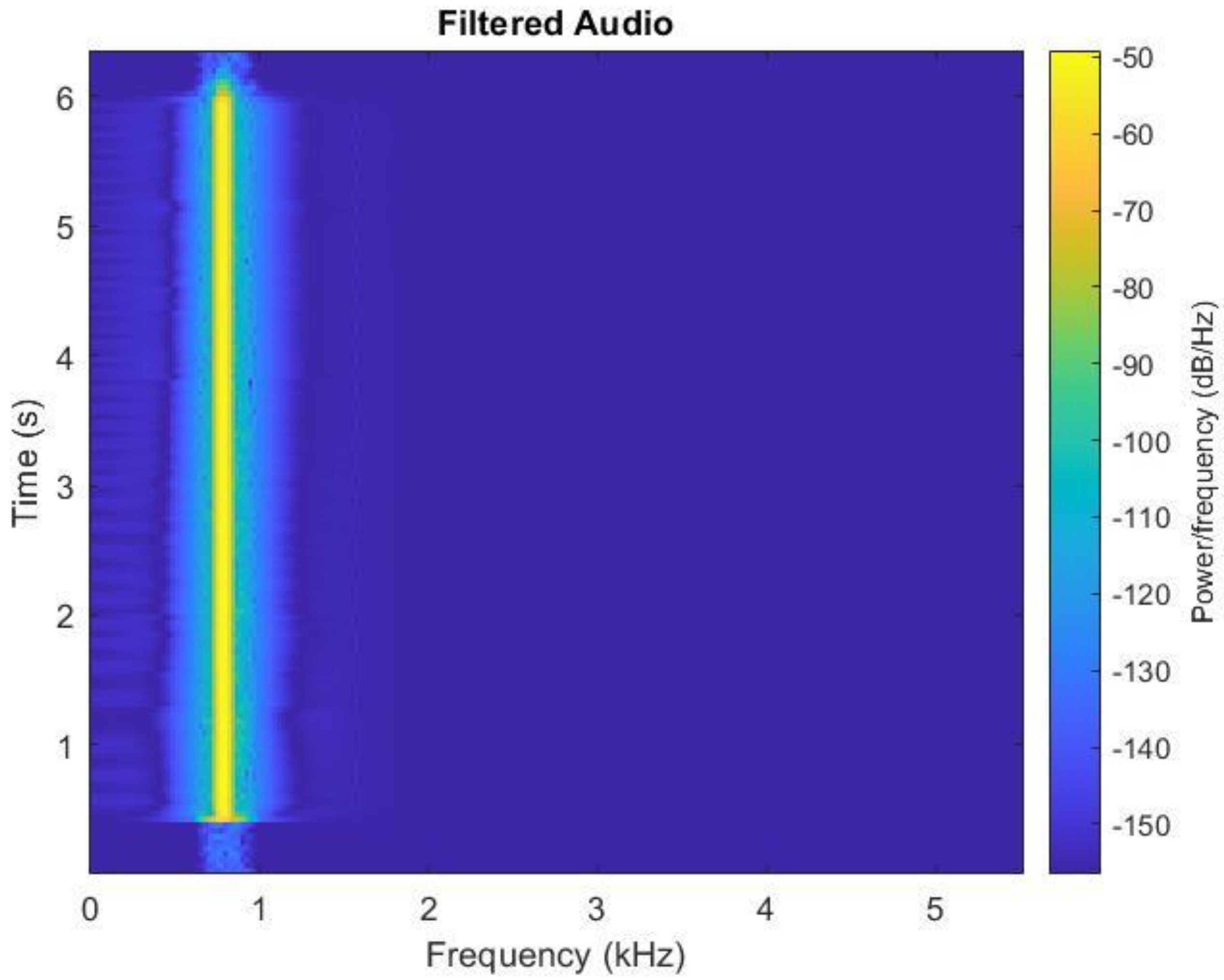
Observations –

- From the impulse response plot, it can be seen that the hanning window has a better impulse response than rectangular window as it dies out faster than rectangular window.
- From the bode plots, it can be seen that hanning window based FIR filter has better attenuation than the one based on rectangular window but the transition region increases.
- It can also be observed that phase plot is linear as expected from a FIR filter.

Q4)

Graphs –





Observations –

- From the spectrogram of the processed audio, it can be seen that only the fundamental is present.
- The fundamental frequency is in the range: 695 Hz – 900 Hz. Rest of the frequencies are filtered.
- The filtered audio is soft to hear.

Q5)

Time – Domain Windowing	Window based FIR filter
• It is used to minimize spectral leakage. • Here, the signal is not delayed.	• It is used to reduce the number of samples stored. • Here, the ideal filter is delayed and a window is multiplied to the delayed impulse function.

Conclusions –

- The different windows were explored in matlab.
- The frequency spectrum of hanning window for different number of samples were plotted and compared.
- The digital low-pass FIR filter was designed and its impulse response and Bode was plotted.
- A band-pass FIR filter was designed to extract only the fundamental component from an audio file.
- The differences between time domain windowing and window based FIR filters were noted.