Bangladesh University of Engineering & Technology

Department of Electrical and Electronics Engineering

Lab Report

Experiment Name:

5. FIR Filter Design

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Labwork 1:

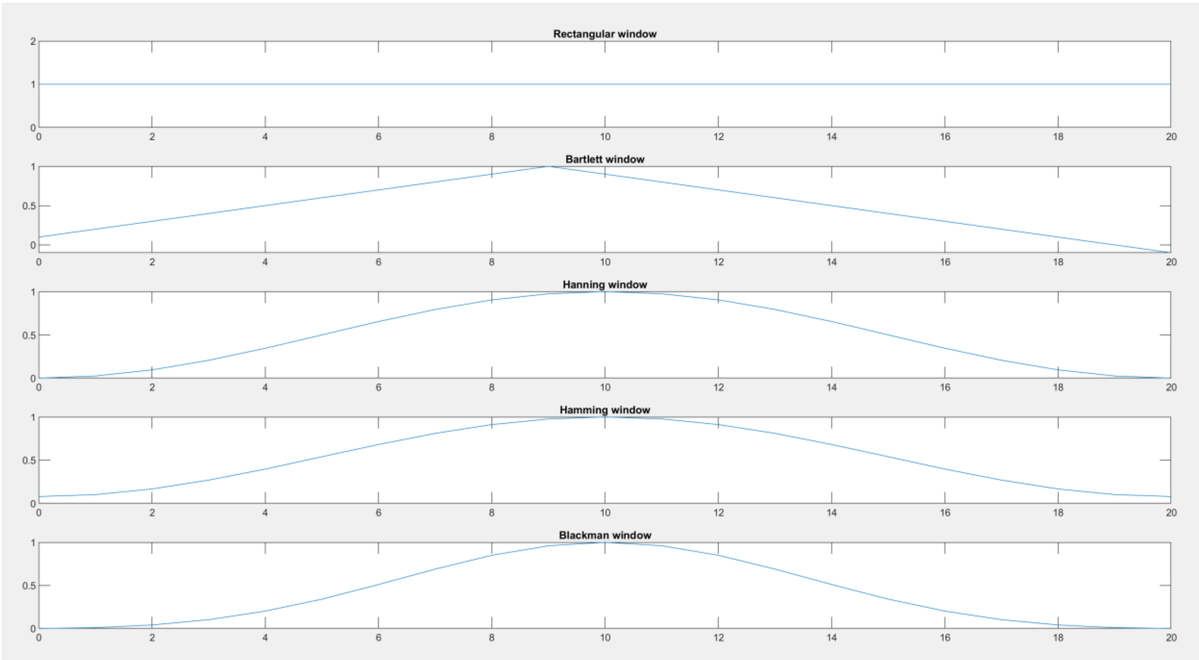
Code:

```
clc;
clearvars;

M = 21;
% rectangular
n = 0:(M-1);
w_rect = ones(1, M);
%barlett
w_bartlett = zeros(1, M);
for i = 1:length(w_bartlett)
    if i >= 0 && i <= (M-1)/2
        w_bartlett(i) = 2*i/(M-1);
    else
        w_bartlett(i) = 2 - (2*i/(M-1));
    end
end
%hanning
w_hann = 0.5*(1-cos(2*pi*n/(M-1)));
%hamming
w_hamm = 0.54 - 0.46*cos(2*pi*n/(M-1));
%blackman
w_black = 0.42 - 0.5*cos(2*pi*n/(M-1)) +
0.08*cos(4*pi*n/(M-1));

%plotting in time domain
subplot(511), plot(n, w_rect), title("Rectangular
window");
subplot(512), plot(n, w_bartlett), title("Bartlett
window");
subplot(513), plot(n, w_hann), title("Hanning window");
subplot(514), plot(n, w_hamm), title("Hamming window");
subplot(515), plot(n, w_black), title("Blackman
window");

figure
N = 512;
```

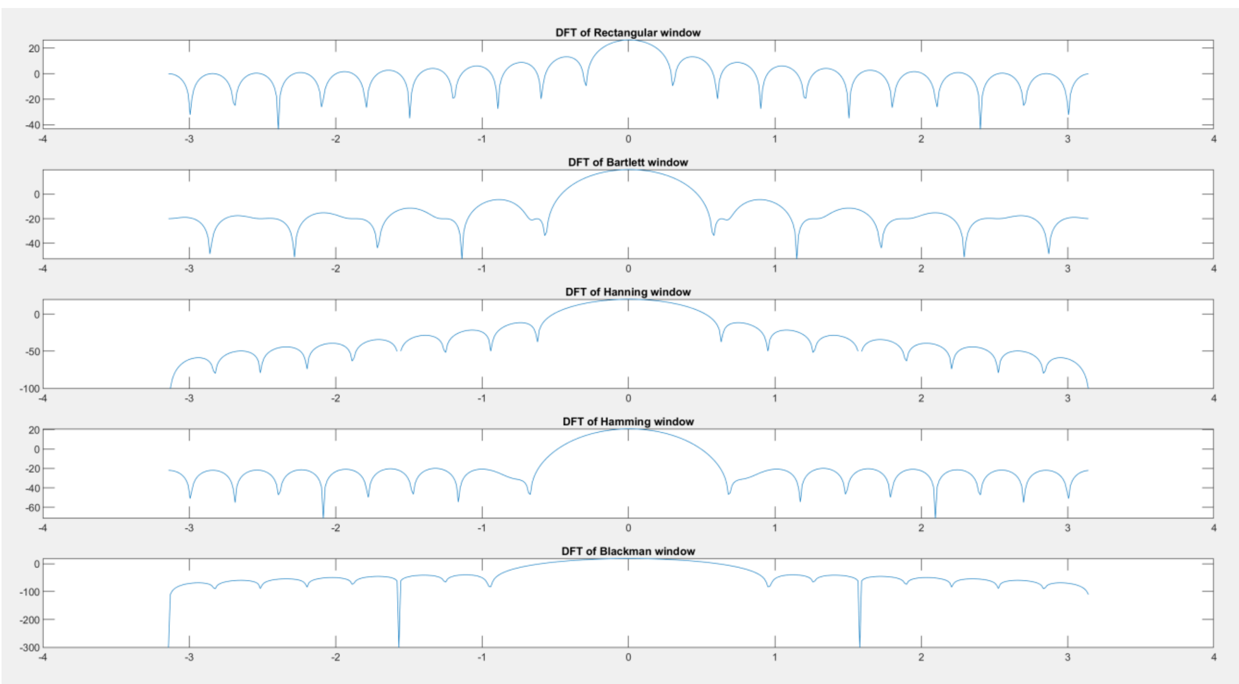
```
w = linspace(-pi, pi, N);
subplot(511), plot(w, 20*log10(abs(fftshift(fft(w_rect,
N))))), title("DFT of Rectangular window");
subplot(512), plot(w,
20*log10(abs(fftshift(fft(w_bartlett, N))))),
title("DFT of Bartlett window");
subplot(513), plot(w, 20*log10(abs(fftshift(fft(w_hann,
N))))), title("DFT of Hanning window");
subplot(514), plot(w, 20*log10(abs(fftshift(fft(w_hamm,
N))))), title("DFT of Hamming window");
subplot(515), plot(w,
20*log10(abs(fftshift(fft(w_black, N))))), title("DFT
of Blackman window");
```

Output:

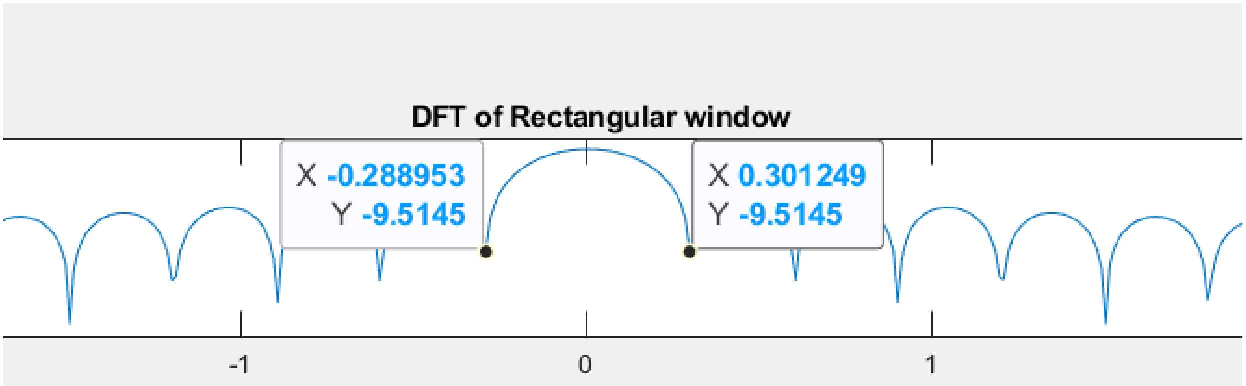
Plot of Window Function:



Plot of Magnitude in dB scale:



Main Lobe Width:



Main Lobe to Side Lobe Amplitude:

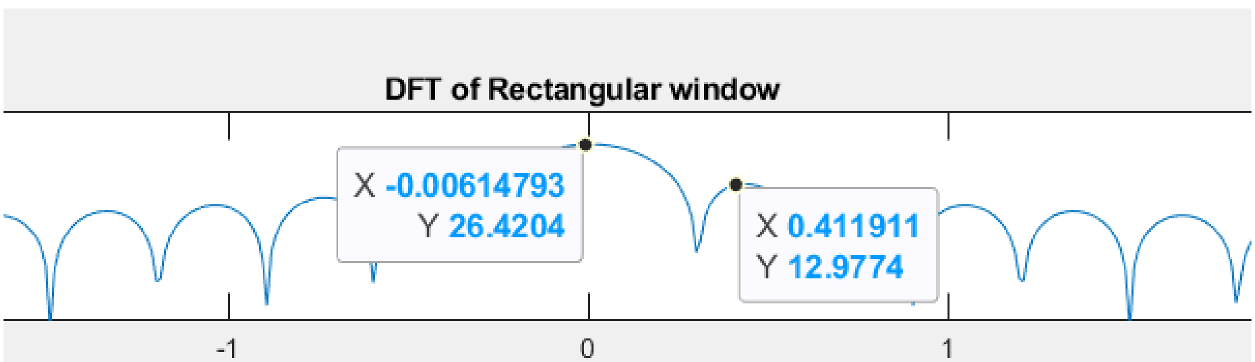


Table: Experimental and Theoretical Data of the Main Lobe Width and peak to side lobe amplitude(dB):

Window Name	Main Lobe Width (Theoretical) M = 21	Main Lobe Width (Experimental)	Peak to side lobe amplitude (dB) (Theoretical)	Peak to side lobe amplitude (dB) (Experimental)
Rectangular	4 π /(M -1)	0.5889	-13 dB	-13.23 dB
Bartlett	8 π /(M -1)	1.155	-27 dB	-24.47 dB
Hanning	8 π /(M – 1)	1.124	-32 dB	-31.64 dB
Hamming	8 π /(M -1)	1.3525	-43 dB	-41.6 dB
Blackman	12π/(M -1)	1.89	-58dB	-58.316 dB

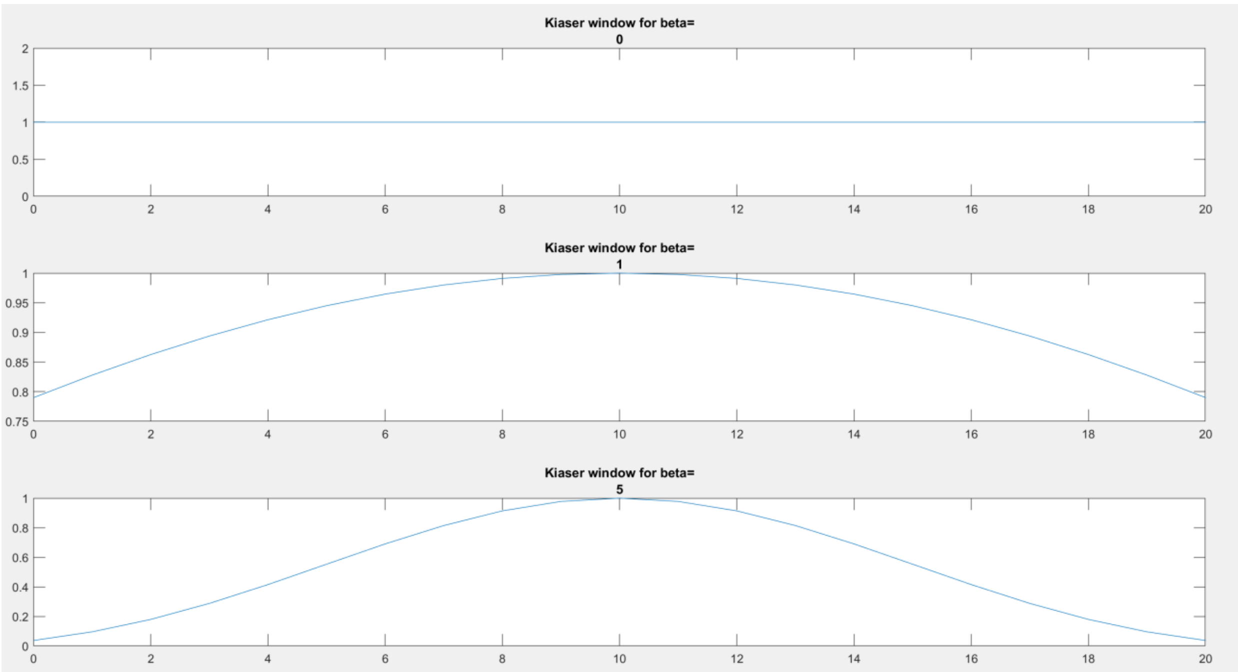
Labwork 2:

Code:

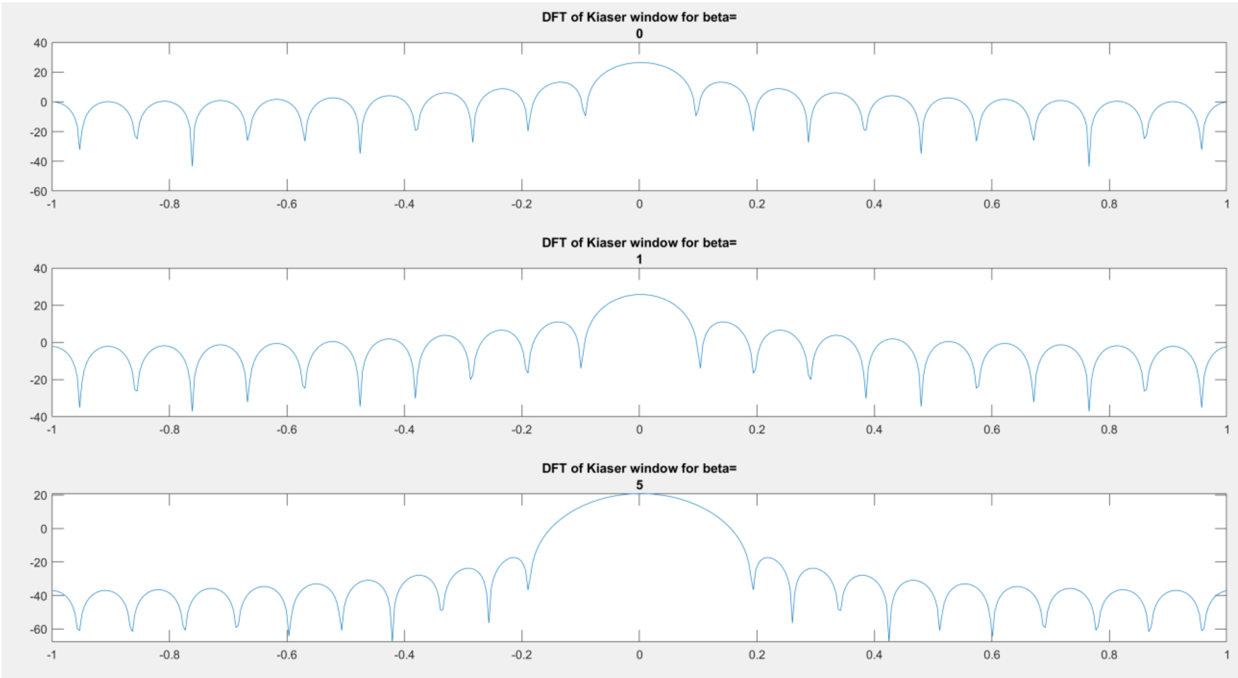
```
clc;
clearvars;

M = 21;
n = 0:M-1;
beta = [0, 1, 5];
w_kaiser = zeros(size(beta, 2), M);
N = 512;
w = linspace(-1, 1, N);
for i = 1:size(beta, 2)
    w_kaiser(i, :) = besseli(0, beta(i)*sqrt(1-(1-
2*n/(M-1)).^2))/ besseli(0, beta(i));
    subplot(size(beta, 2), 1, i), plot(n, w_kaiser(i,
:));
    title(["Kiaser window for beta=",
num2str(beta(i))]);
end

figure

for i = 1:size(beta, 2)
    subplot(size(beta, 2), 1, i), plot(w,
20*log10(abs(fftshift(fft(w_kaiser(i, :), N)))));
    title(["DFT of Kiaser window for beta=",
num2str(beta(i))]);
end
```

Output:

Plot of Kaiser window with beta = 0, 1, 5



Plot of Kaiser Window DFT in magnitude with Beta = 0, 1, 5



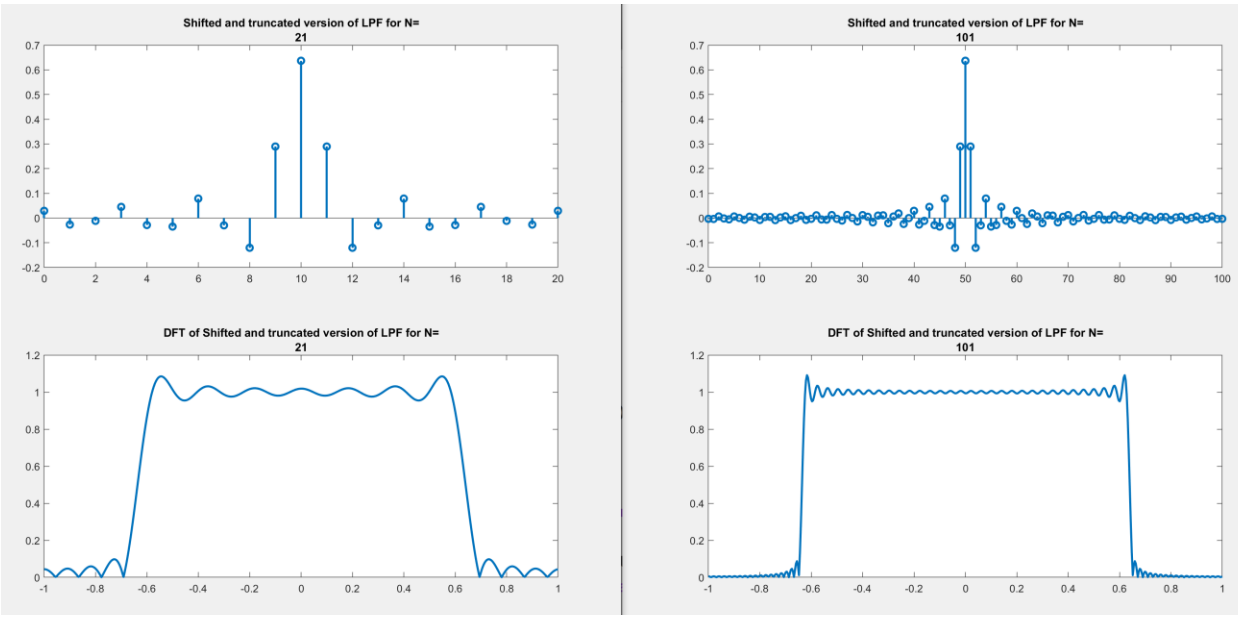
Labwork 3:

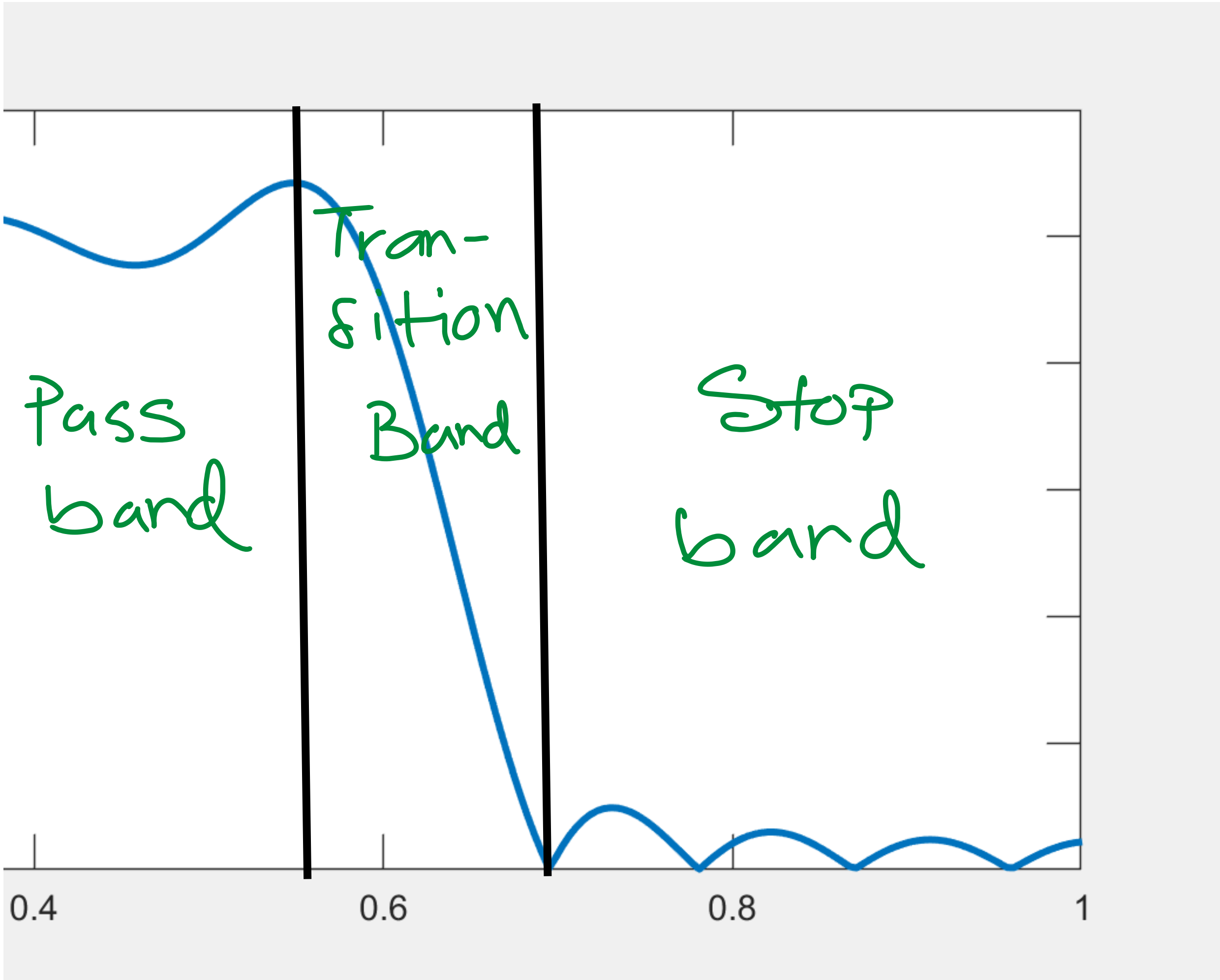
Code:

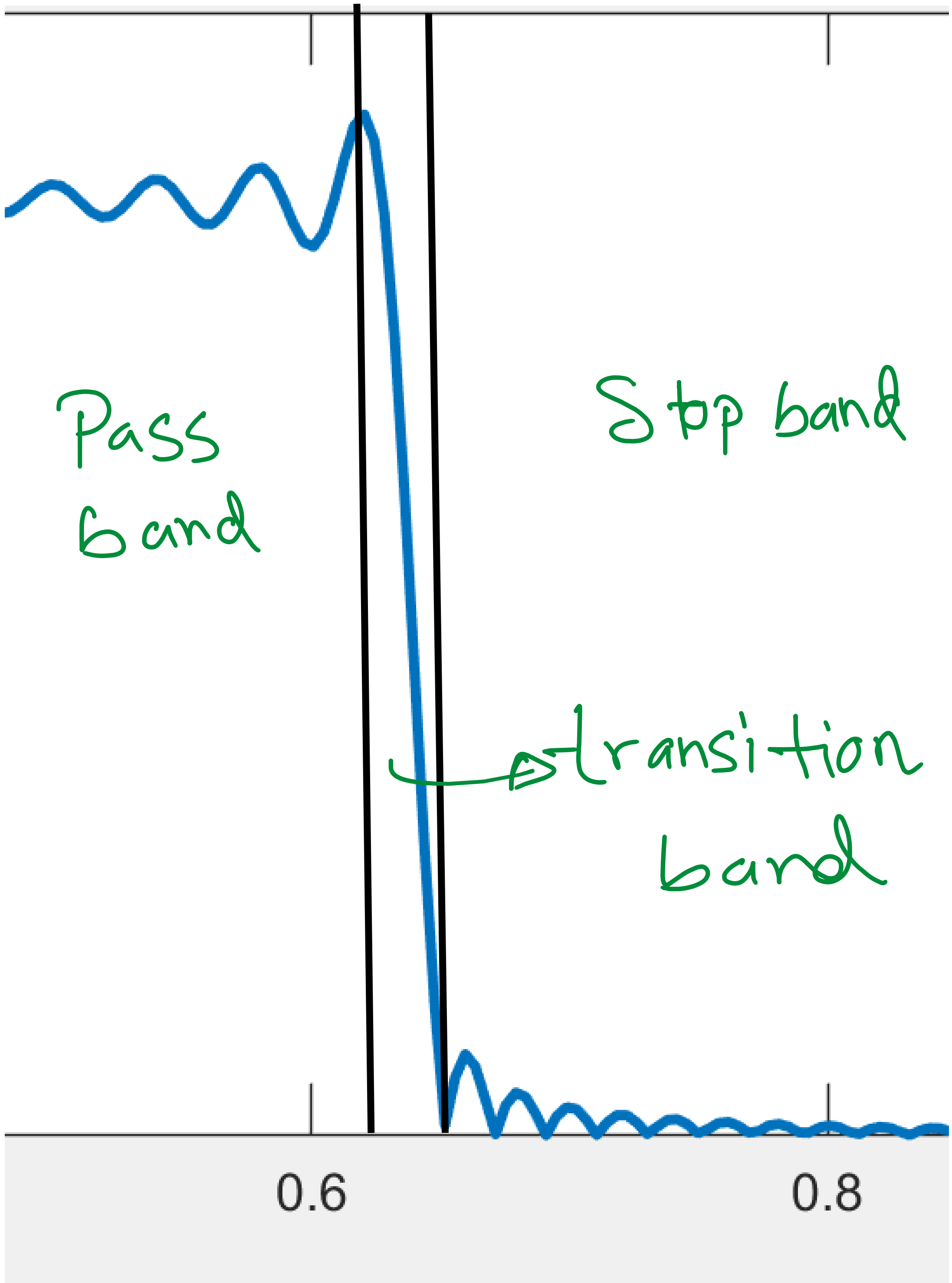
```
clc;
clearvars;
close all;


wc = 2;
N = [21, 101];
h = zeros(1, size(N, 2));

for i = 1:size(N, 2)
    n = 0:N(i)-1;
    h = zeros(1, size(N(i), 2));
    h = wc * sinc(wc*(n - (N(i)-1)/2)/pi)/pi;
    figure()
    subplot(2, 1, 1)
    stem(n, h, "LineWidth", 2);
    title(["Shifted and truncated version of LPF for 
N=", num2str(N(i))]);
    subplot(2, 1, 2)
    plot(linspace(-1,1, 512), abs(fftshift(fft(h, 
512))), "LineWidth", 2);
    title(["DFT of Shifted and truncated version of LPF 
for N=", num2str(N(i))]);
end
```

Output:

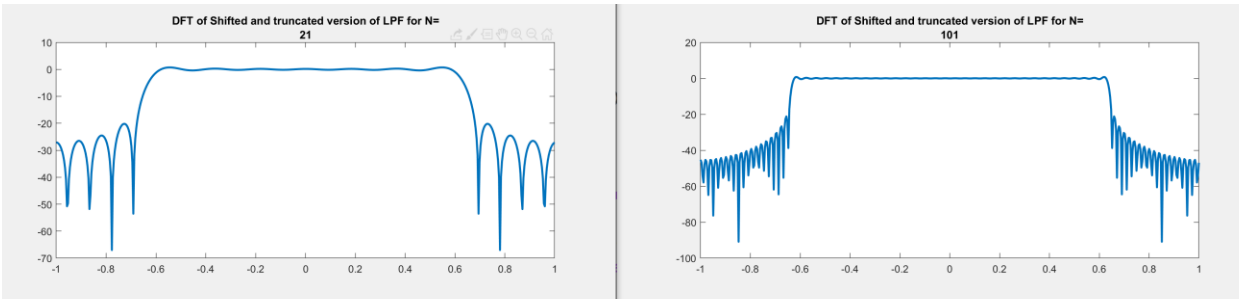
Truncated and Shifted Impulse response and Magnitude Response for two filter where N = 21 and N = 101




Pass band
Tran-
sition
Band
Stop band
0.4
0.6
0.8
1


Pass band
Stop band
transition band
0.6
0.8

Magnitude Response in dB:



For size N=21

Wp=1.73 rad/samples

Ws=2.146 rad/samples

Wc=1.938 rad/samples

For N=101

Wp= 1.95 rad/samples

Ws= 2.05 rad/samples

Wc= 2 rad.samples

Increasing the filter length shows two observable effects on stopband ripple. Firstly, it deceases the lobe width of the stopband ripples region, and secondly, the lobe peaks have also a faster decreasing rate with respect to the frequency.

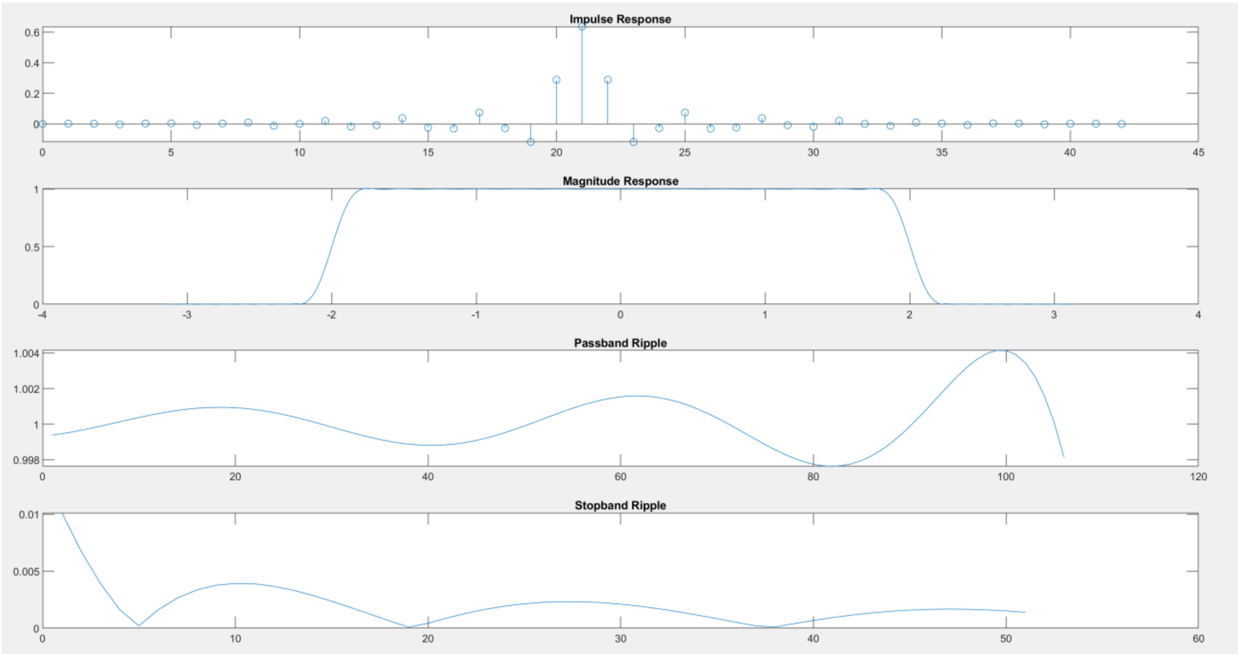
To create an ideal low pass filter, we need the truncating window to have a delta impulse in its frequency response, and such delta nature is more prominent when we increase the order (Length in time domain) of the truncating window, because, stretching in time domain means squeezing in frequency domain. Thus, low pass filter response becomes closer to the ideal as we increase the window length.

Labwork 4:

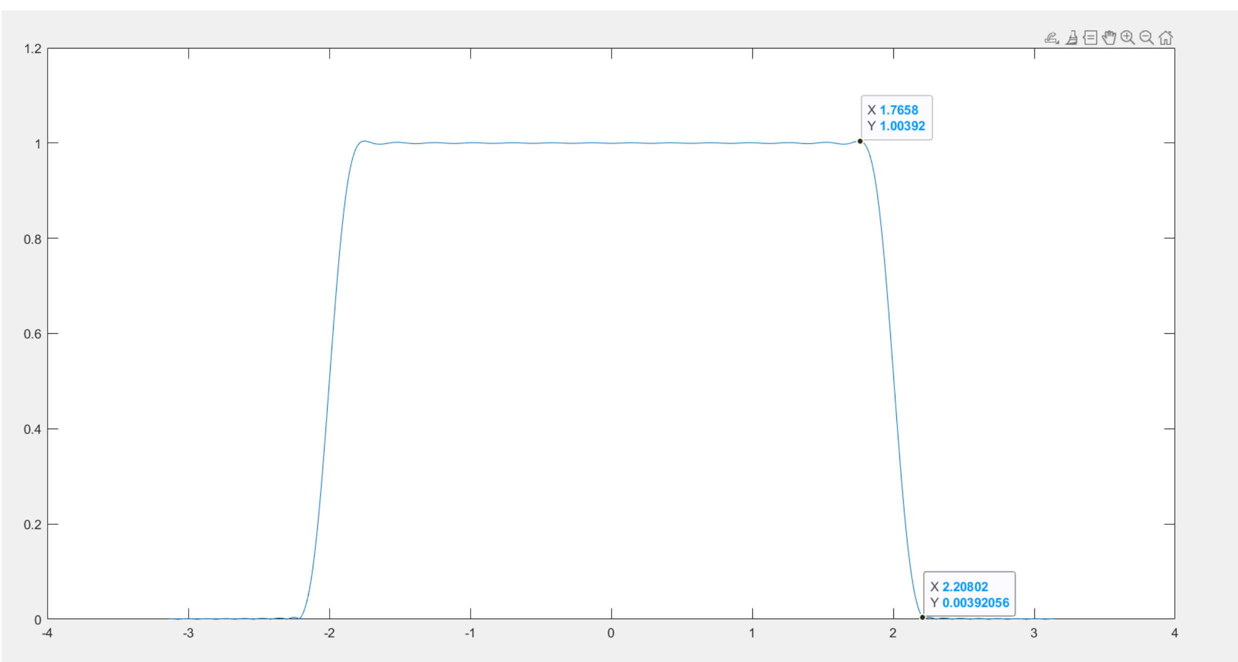
Code:

```
clc;
clearvars;
close all;

del1 = 0.05;
del2 = 0.005;
del = min(del1, del2);
A = -20*log10(del);
ws = 2.2;
wp = 1.8;
wc = 2;
M = ceil(1 + (A - 8)/(2.285*(ws - wp)));
if A > 50
    beta = 0.1102*(A-8.7);
elseif A >= 21 && A <= 50
    beta = 0.5842*(A - 21)^0.4 + 0.07886*(A - 21);
else
    beta = 0;
end

w = (kaiser(M, beta))';
n = 0:M - 1;
alpha = (M - 1)/2;
hd = sinc(wc*(n - alpha)/pi)*wc/pi;
h = hd .* w;
subplot(411), stem(n, h); title("Impulse Response")
Nfft = 1024;
y = abs(fftshift(fft(h, Nfft)));
subplot(412),
plot(linspace(-pi, pi, Nfft), y); title("Magnitude
Response")
subplot(413)
plot(y(700:805)); title("Passband Ripple")
subplot(414)
plot(y(870:920)); title("Stopband Ripple")
```

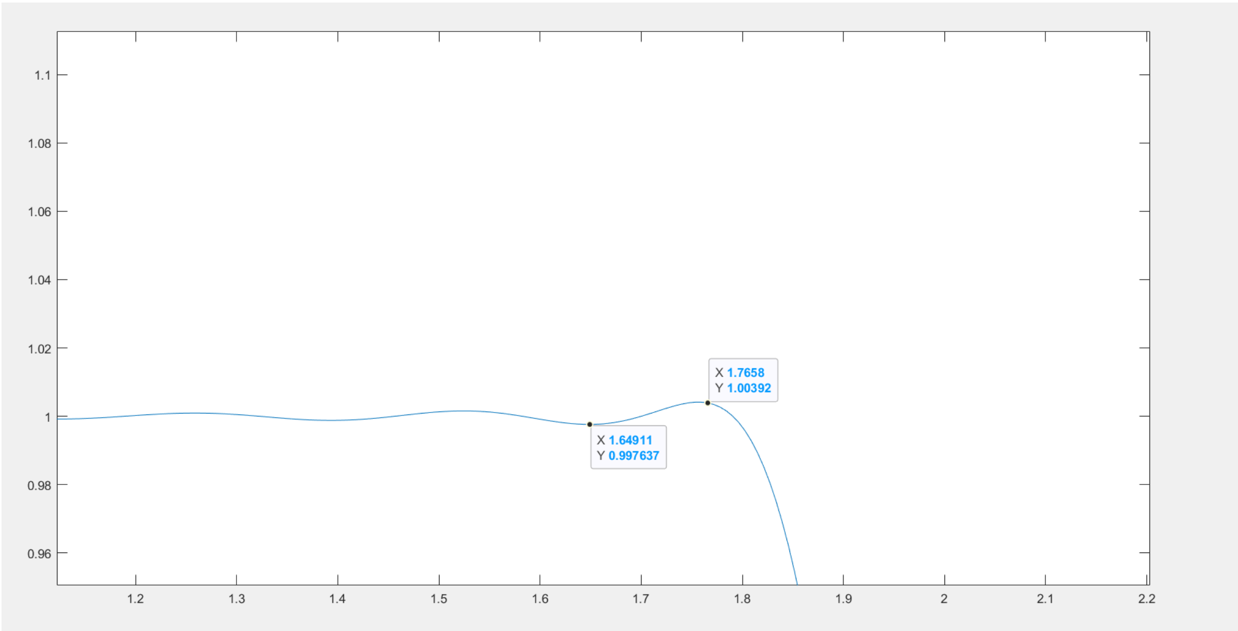
Output:



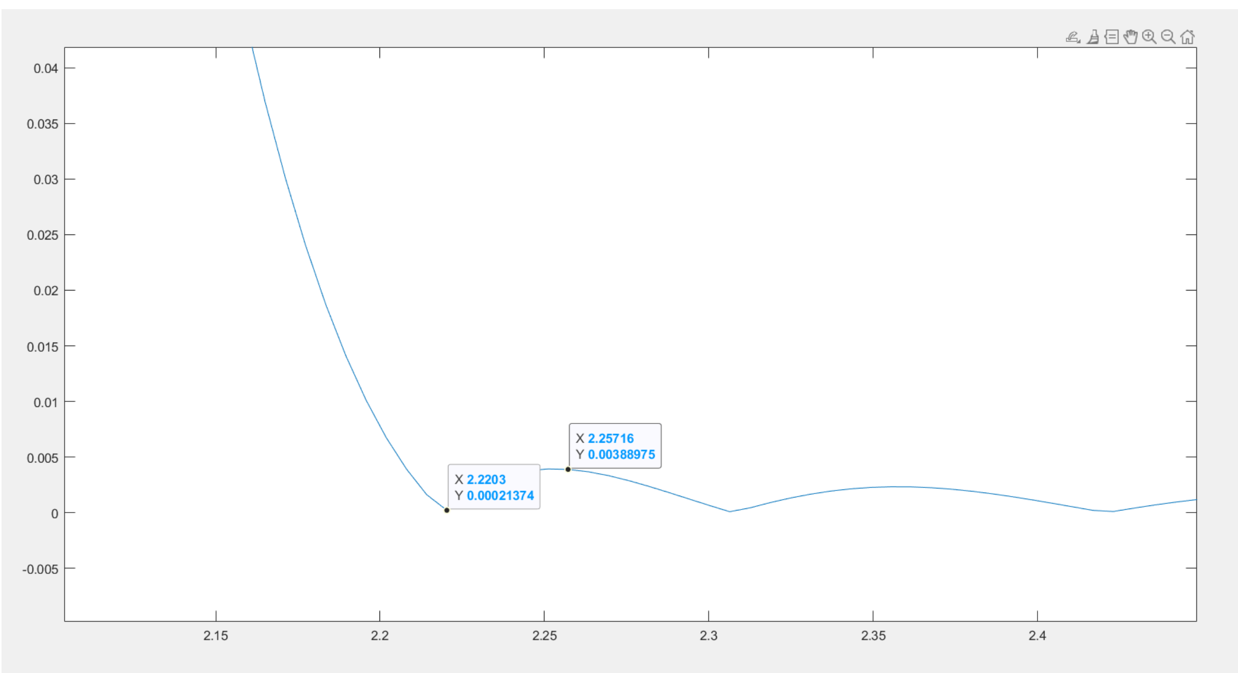
Marked Plot of Ws and Wp:



Marked Plot of delp:



Marked Plot of dels:



Observations:

Values of M = 43 and Beta = 4.0909

Table: Comparison Table of Given and Obtained Data

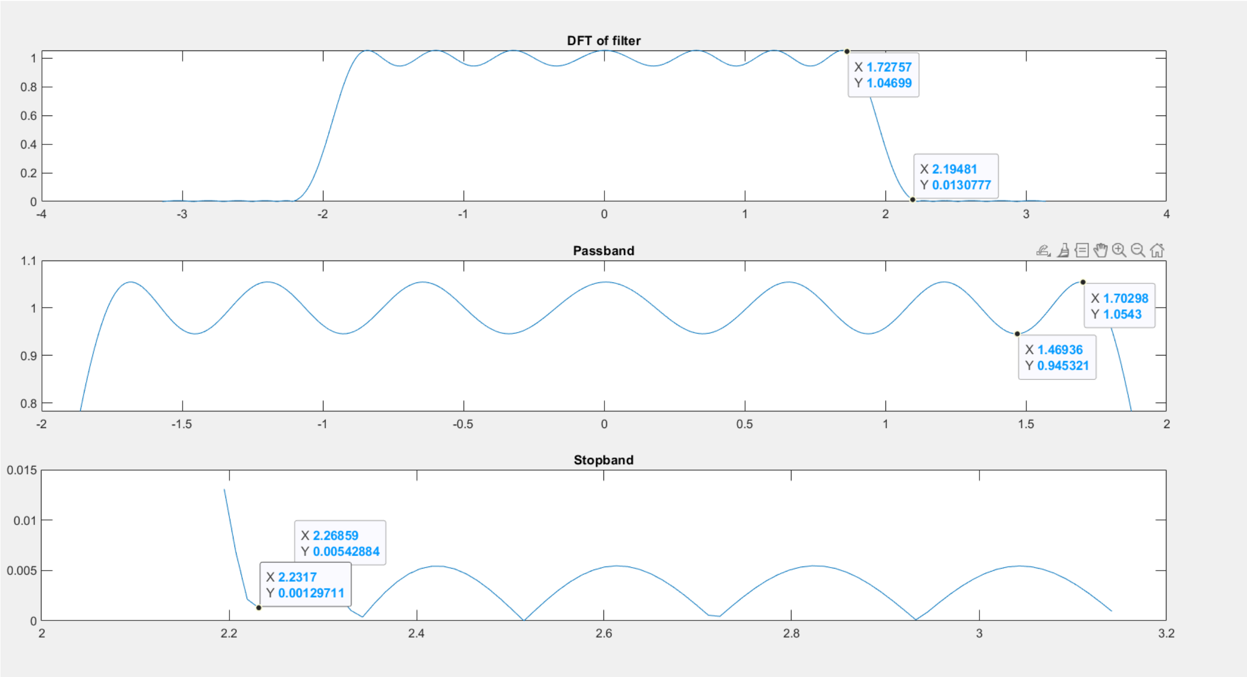
Quantities	Given Data	Obtained Data from Matlab
wp	1.8	1.75
ws	2.2	2.20
delp	0.05	0.0041
dels	0.005	0.0039

All the parameters except the passband ripple value is very close to the design values used for the filter. This is mainly because in the filter design, the minimum of the two ripple values were used. As a result, we get the stopband experimental ripple value close to the design parameter, but the passband ripple is very low.

Labwork 5:

Code:

Output:



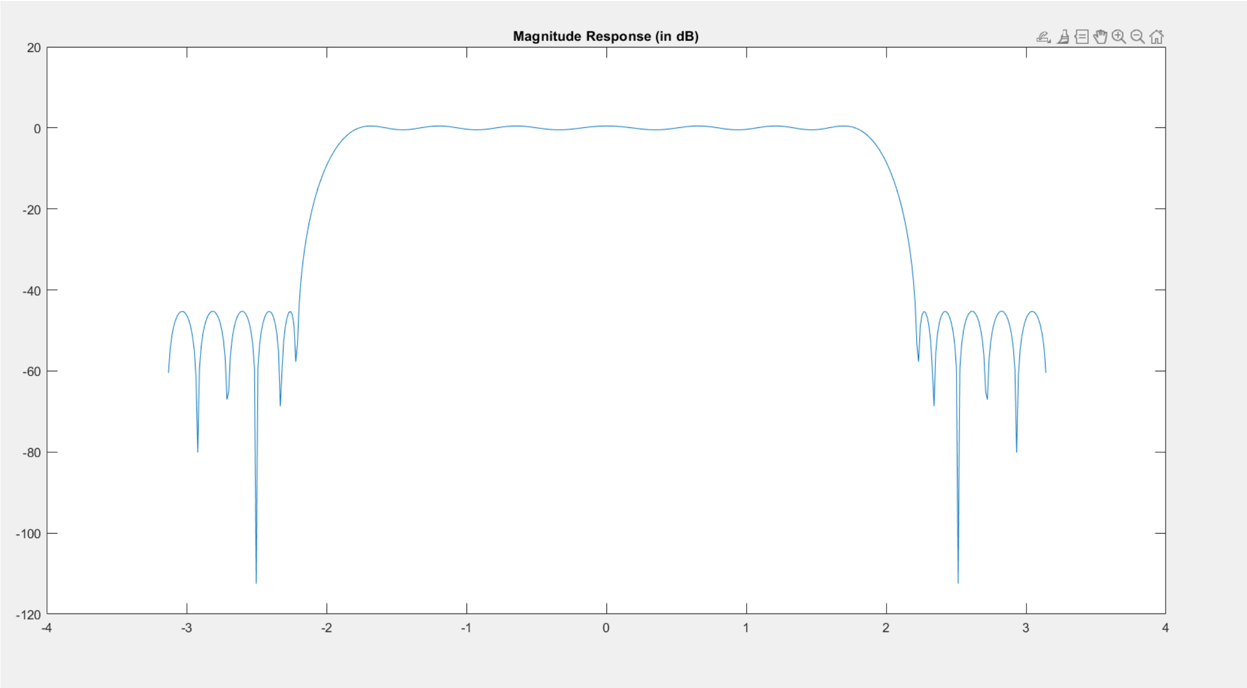


Table: Comparison between the results of Parks and McClellan window and Kaiser window

	Design Value	**Parks and McClellan**	**Kaiser**
M		25	43
wp	1.8	1.727	1.75
ws	2.2	2.195	2.20
wc	2	1.961	1.975
delp	0.05	0.0544	0.0041
dels	0.005	0.00413	0.0039

Observation:

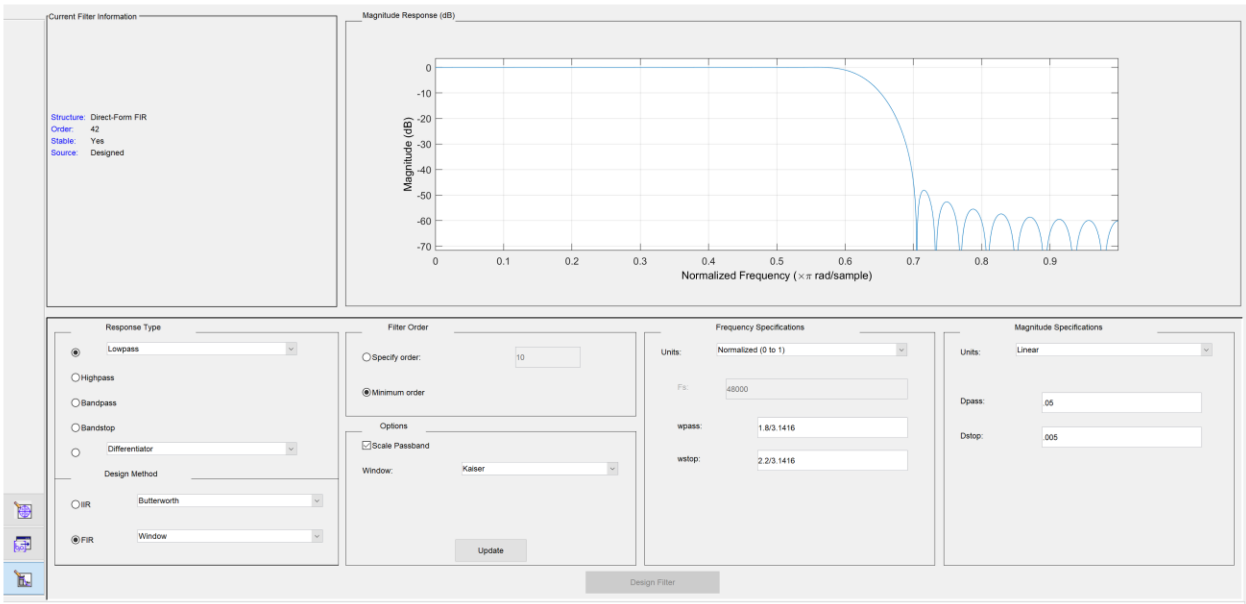
Parks and McClellan algorithm produces a window which satisfactorily maintained the low pass filter's design parameters such as passband, stopband, passband ripple, and stopband ripple. Moreover, significant reduction in the window length was achieved.

However, the cutoff frequency was severely underestimated. This means that the Parks and McClellan can work more efficiently than Kaiser window for the same design parameters, but not for the cut-off frequency. The passband and stopband shapes of the Kaiser window and McClellan window filters have an essential difference.

In McClellan, the passband shape almost represents a sinusoidal, with the ripples almost not decaying, that is why this kind of filters are known as equiripple filters. But in the Kaiser window, ripple value only overshoots near the edge of the passband region and decreases after the stopband frequency region.

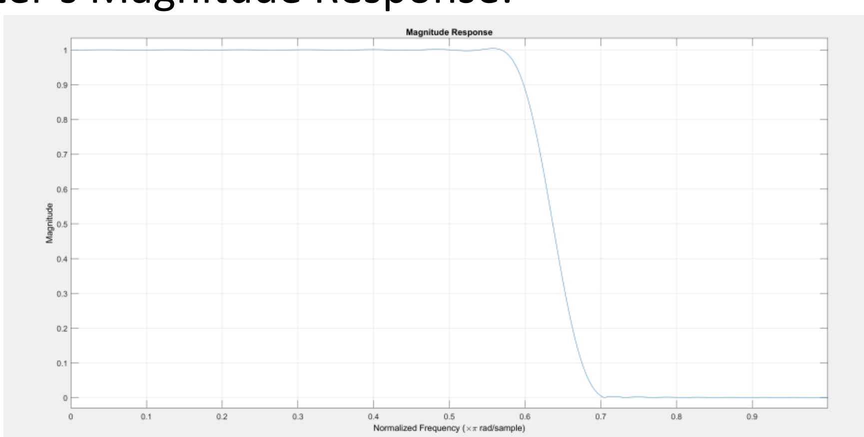
Labwork 4 Using Sptool:

Input Window:



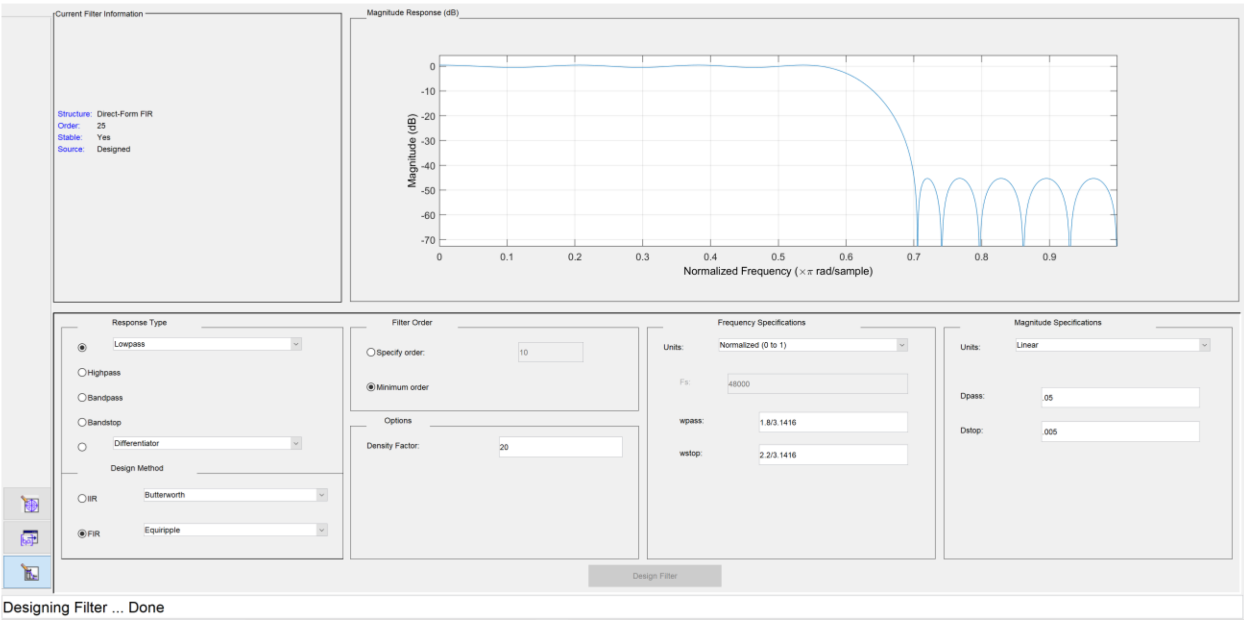
Output:

Plot of filter's Magnitude Response:



Labwork 5 Using Sptool

Input Window:



Output:

Plot of Filter’s Magnitude Response: