Worksheet-6

Design of Finite Impulse Response Filters

Aim: To design FIR filters for the given specifications for all the different windowing techniques using MATLAB.

Questions

1. Design a Low pass filter with passband edge frequency 0.4π, stopband frequency 0.6π and order N=20 using Rectangular Window and plot the frequency response of the filter. Repeat the filter design with same specifications using following window functions and compare the frequency responses.

a) Hamming Window

b) Blackman Window

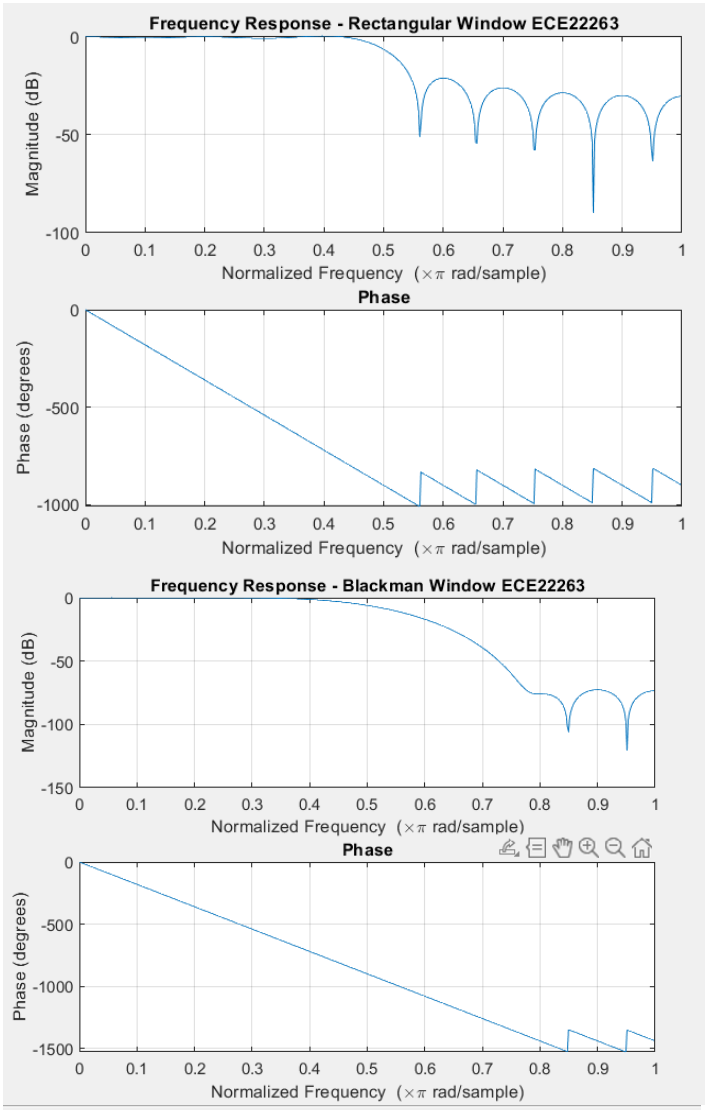
c) Hanning Window

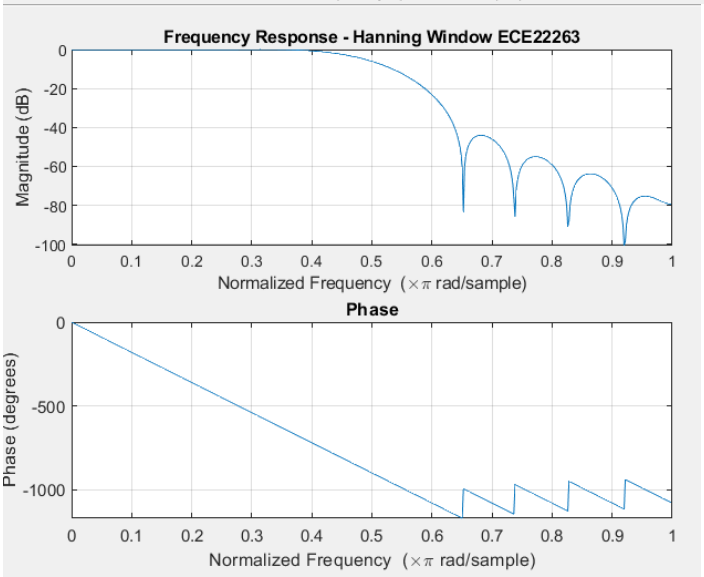
d) Bartlett Window

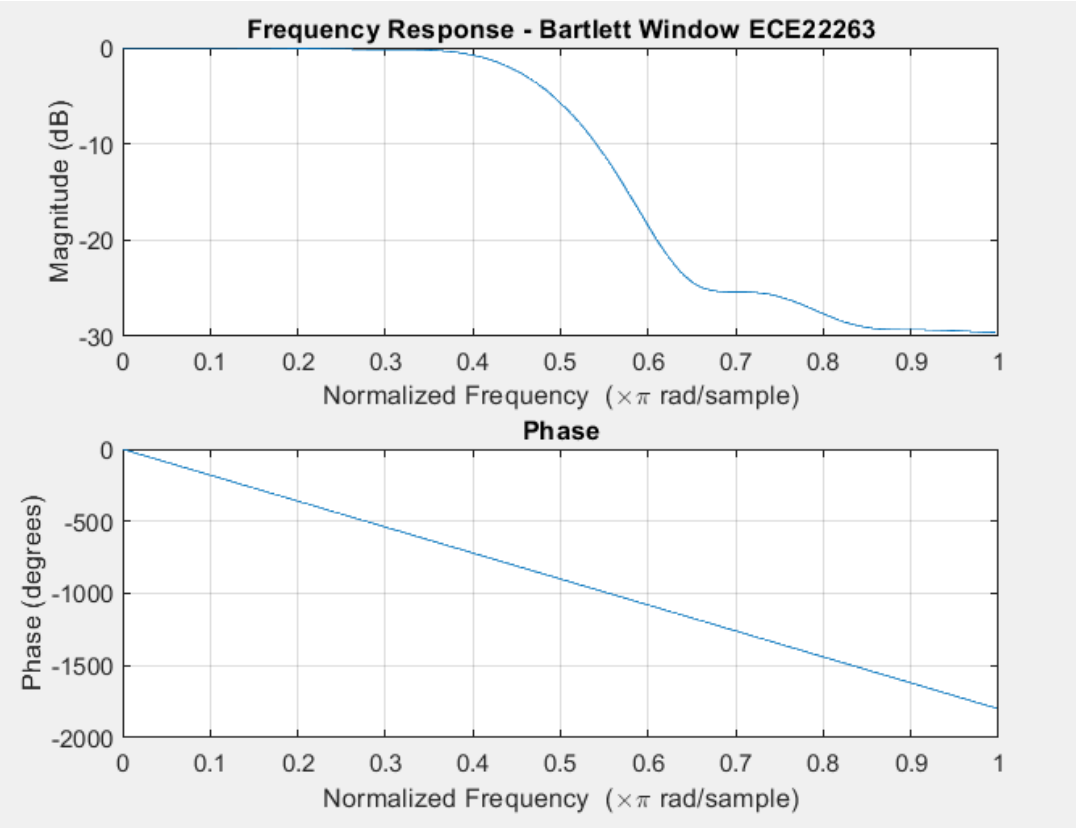
Code

```
wp = 0.4 * pi;
ws = 0.6 * pi;
wc = (ws+wp)/2;
N = 20;
w1= rectwin(N+1);
h1= fir1(N, wc/pi, 'low' , w1 );
freqz(h1, 1, 512)
title('Frequency Response - Rectangular Window ECE22263');
figure;
w2= blackman(N+1);
h1= fir1(N, wc/pi, 'low' , w2 );
freqz(h1, 1, 512)
title('Frequency Response - Blackman Window ECE22263');
figure;
w3 = hanning(N+1);
h1= fir1(N, wc/pi, 'low' , w3 );
freqz(h1, 1, 512)
title('Frequency Response - Hanning Window ECE22263');
figure;
w4 = bartlett(N+1);
h1= fir1(N, wc/pi, 'low' , w4 );
freqz(h1, 1, 512)
title('Frequency Response - Bartlett Window ECE22263');
```

OUTPUT:


Frequency Response - Rectangular Window ECE22263
Magnitude (dB)
Normalized Frequency (×π rad/sample)
Phase
Phase (degrees)
Normalized Frequency (×π rad/sample)
Frequency Response - Blackman Window ECE22263
Magnitude (dB)
Normalized Frequency (×π rad/sample)
Phase
Phase (degrees)
Normalized Frequency (×π rad/sample)


Frequency Response - Hanning Window ECE22263
Magnitude (dB)
Normalized Frequency (×π rad/sample)
Phase
Phase (degrees)
Normalized Frequency (×π rad/sample)


Frequency Response - Bartlett Window ECE22263
Magnitude (dB)
0
-10
-20
-30
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
Phase (degrees)
0
-500
-1000
-1500
-2000
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)

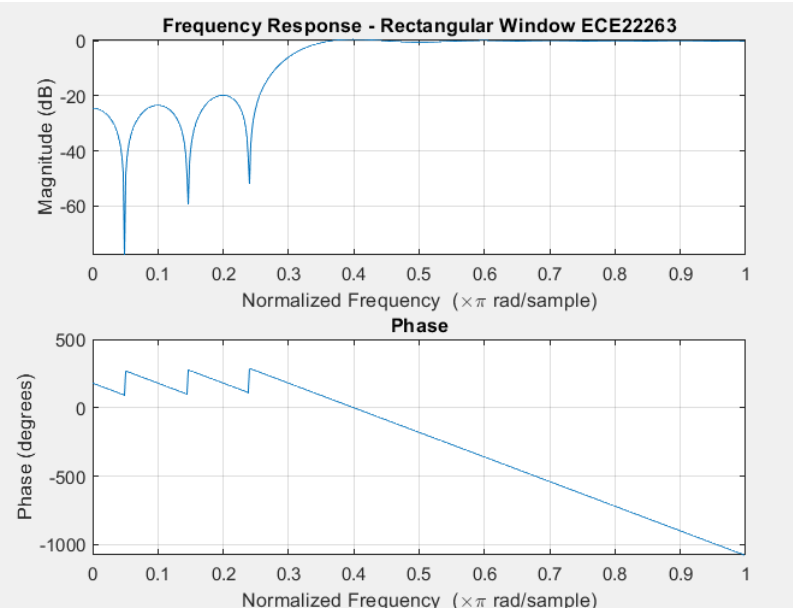
2. Design a FIR high pass filter with passband edge frequency 0.4π, stopband edge frequency 0.2π, order N=20 using Rectangular Window and plot the frequency response of the filter. Repeat the filter design with same specifications using following window functions and compare the frequency responses.

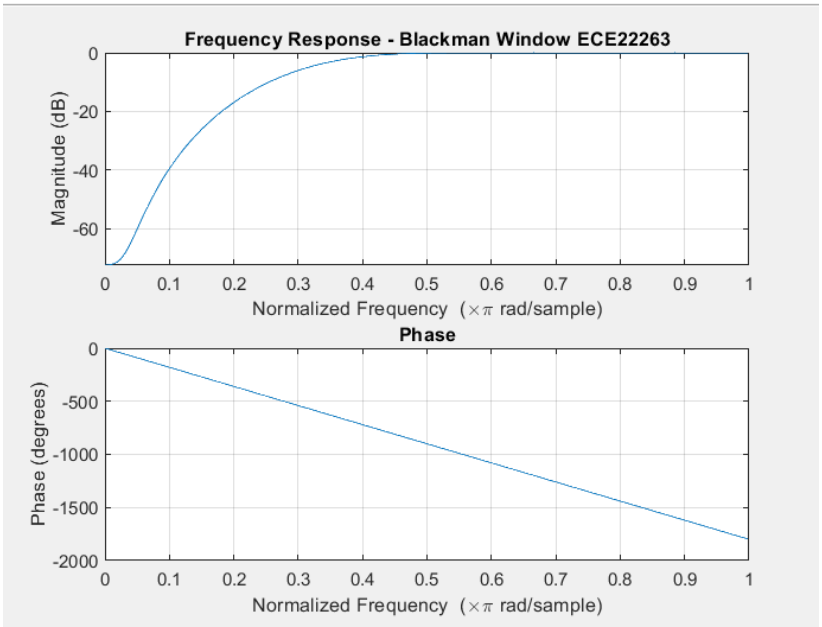
a) Hamming Window
b) Blackman Window
c) Hanning Window
d) Bartlett Window

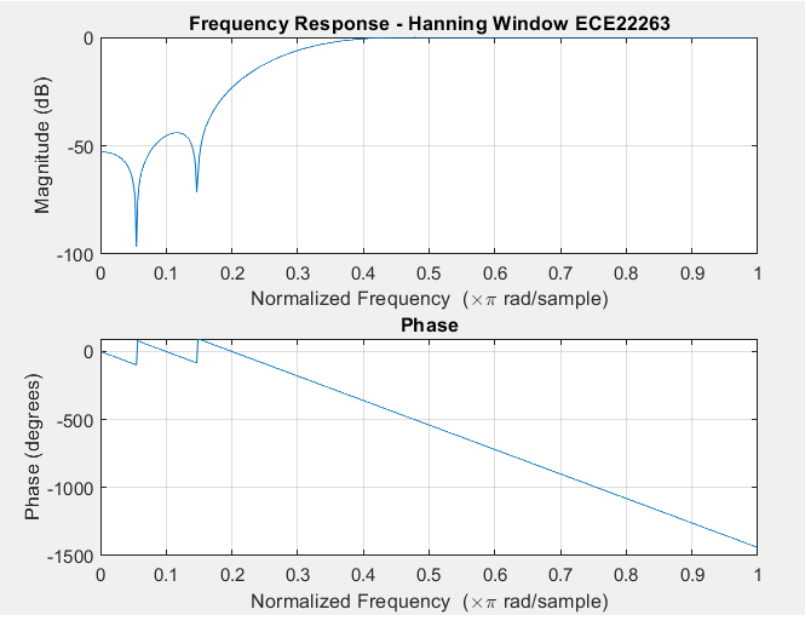
Code

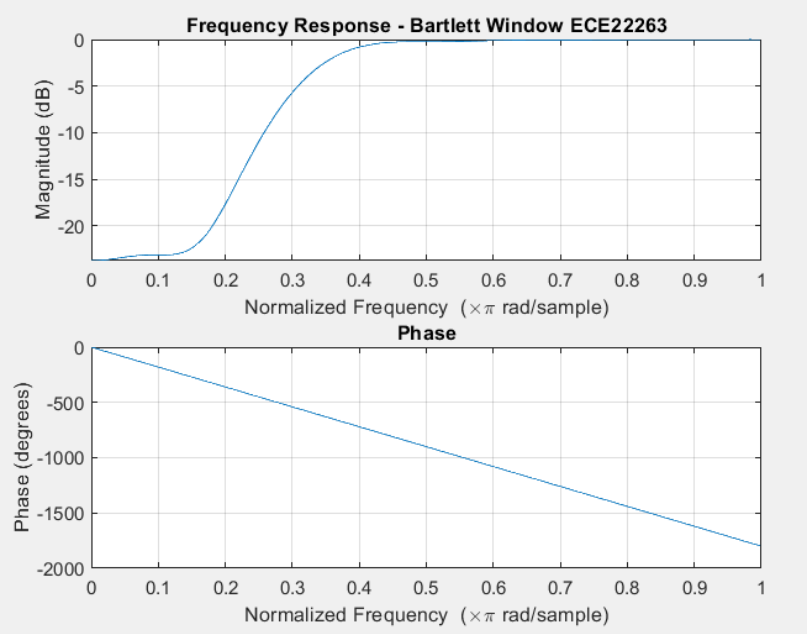
```
wp = 0.4 * pi;
ws = 0.2 * pi;
wc = (ws+wp)/2;
N = 20;
w1= rectwin(N+1);
h1= fir1(N, wc/pi, 'high' , w1 );
freqz(h1, 1, 512)
title('Frequency Response - Rectangular Window ECE22263');
figure;
w2= blackman(N+1);
h1= fir1(N, wc/pi, 'high' , w2 );
freqz(h1, 1, 512)
title('Frequency Response - Blackman Window ECE22263');
figure;
w3 = hanning(N+1);
h1= fir1(N, wc/pi, 'high' , w3 );
freqz(h1, 1, 512)
title('Frequency Response - Hanning Window ECE22263');
figure;
w4 = bartlett(N+1);
h1= fir1(N, wc/pi, 'high' , w4 );
freqz(h1, 1, 512)
title('Frequency Response - Bartlett Window ECE22263');
```

OUTPUT:




Frequency Response - Blackman Window ECE22263
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
Phase (degrees)
0
-500
-1000
-1500
-2000
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)


Frequency Response - Hanning Window ECE22263
Magnitude (dB)
0
-50
-100
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
Phase (degrees)
0
-500
-1000
-1500
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)


Frequency Response - Bartlett Window ECE22263
Magnitude (dB)
0
-5
-10
-15
-20
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
Phase (degrees)
0
-500
-1000
-1500
-2000
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)

3. Design a FIR Band pass filter with $\omega s1 = 0.2\pi$, $\omega p1 = 0.4\pi$, $\omega p2 = 0.7\pi$, $\omega s2 = 0.9\pi$, order N=20 using Rectangular Window and plot the frequency response of the filter. Repeat the filter design with same specifications using following window functions and compare the frequency responses.

a) Hamming Window

b) Blackman Window

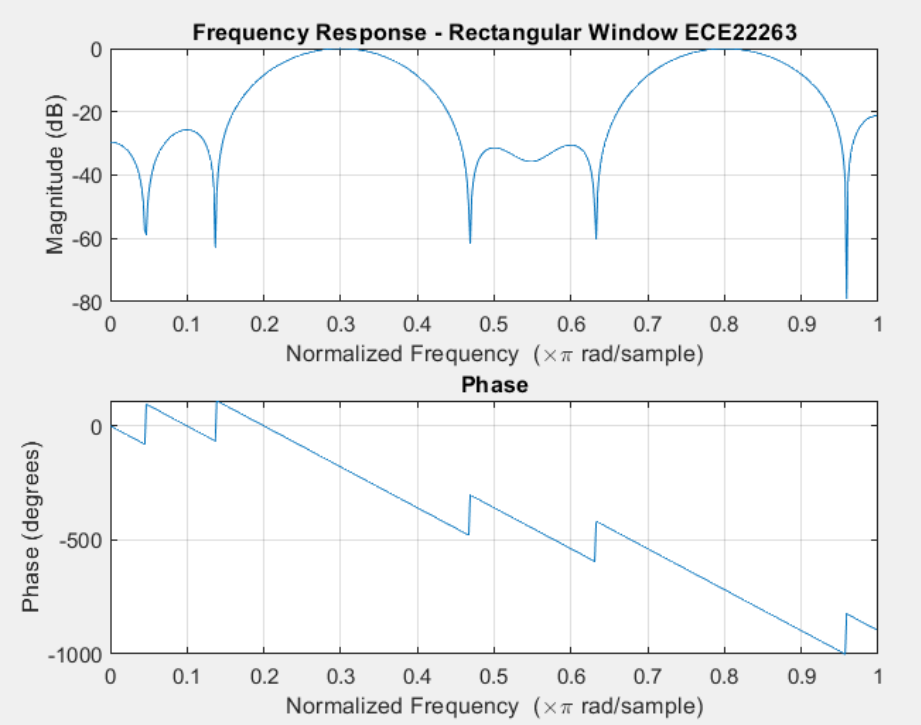
c) Hanning Window

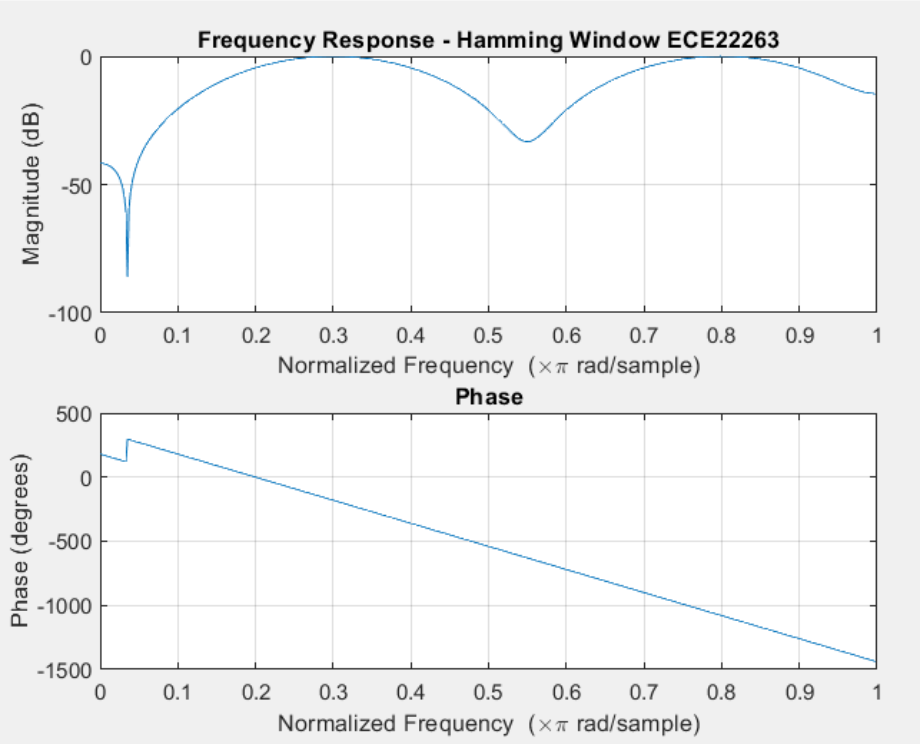
d) Bartlett Window

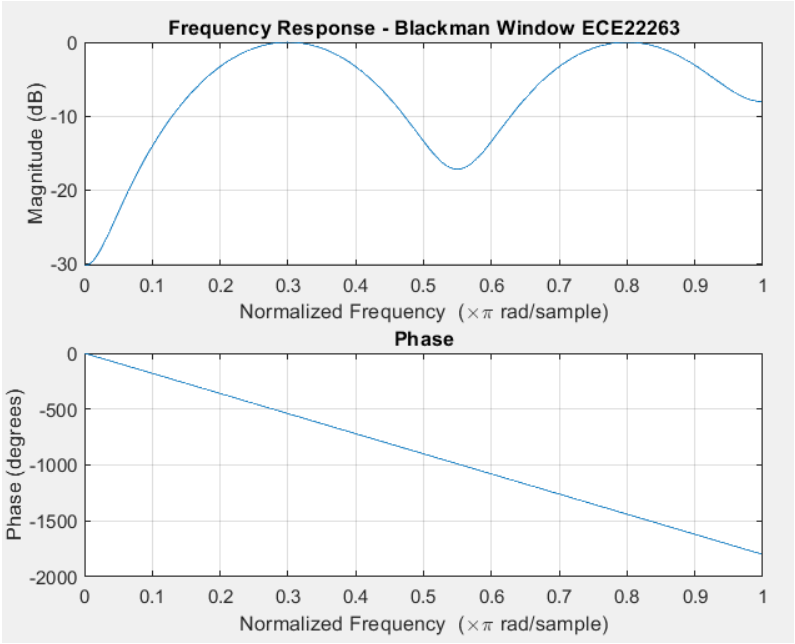
Code

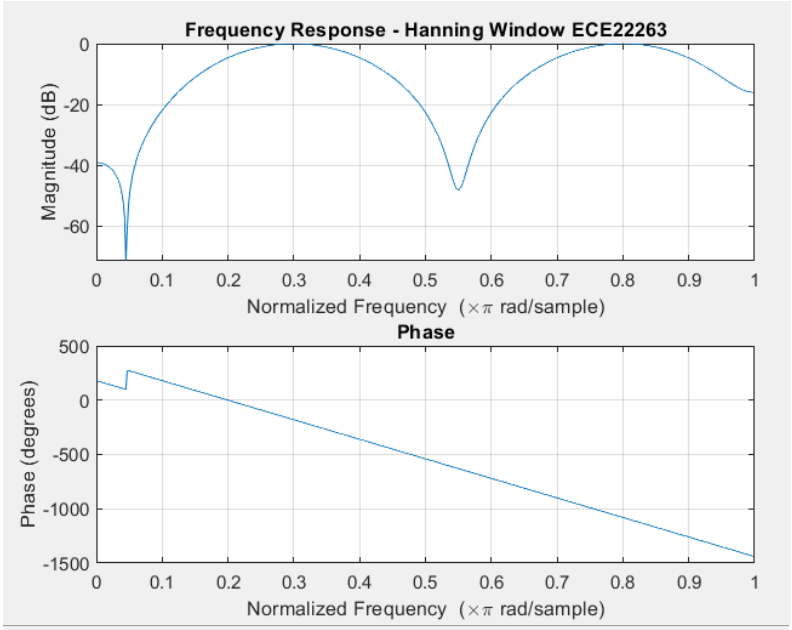
```
wp1 = 0.4 * pi;
ws1 = 0.2 * pi;
wp2 = 0.7 * pi;
ws2 = 0.9 * pi;
wc1 = (wp1 + wp2) / 2;
N = 20;
w_rect = rectwin(N+1);
h_rect = fir1(N, [ws1/pi, wp1/pi, wp2/pi, ws2/pi], 'bandpass', w_rect);
freqz(h_rect, 1, 512);
title('Frequency Response - Rectangular Window ECE22263');
w_hamming = hamming(N+1);
h_hamming = fir1(N, [ws1/pi, wp1/pi, wp2/pi, ws2/pi], 'bandpass', w_hamming);
figure;
freqz(h_hamming, 1, 512);
title('Frequency Response - Hamming Window ECE22263');
w_blackman = blackman(N+1);
h_blackman = fir1(N, [ws1/pi, wp1/pi, wp2/pi, ws2/pi], 'bandpass', w_blackman);
figure;
freqz(h_blackman, 1, 512);
title('Frequency Response - Blackman Window ECE22263');
w_hanning = hanning(N+1);
h_hanning = fir1(N, [ws1/pi, wp1/pi, wp2/pi, ws2/pi], 'bandpass', w_hanning);
figure;
freqz(h_hanning, 1, 512);
title('Frequency Response - Hanning Window ECE22263');
w_bartlett = bartlett(N+1);
h_bartlett = fir1(N, [ws1/pi, wp1/pi, wp2/pi, ws2/pi], 'bandpass', w_bartlett);
figure;
freqz(h_bartlett, 1, 512);
title('Frequency Response - Bartlett Window ECE22263');
```

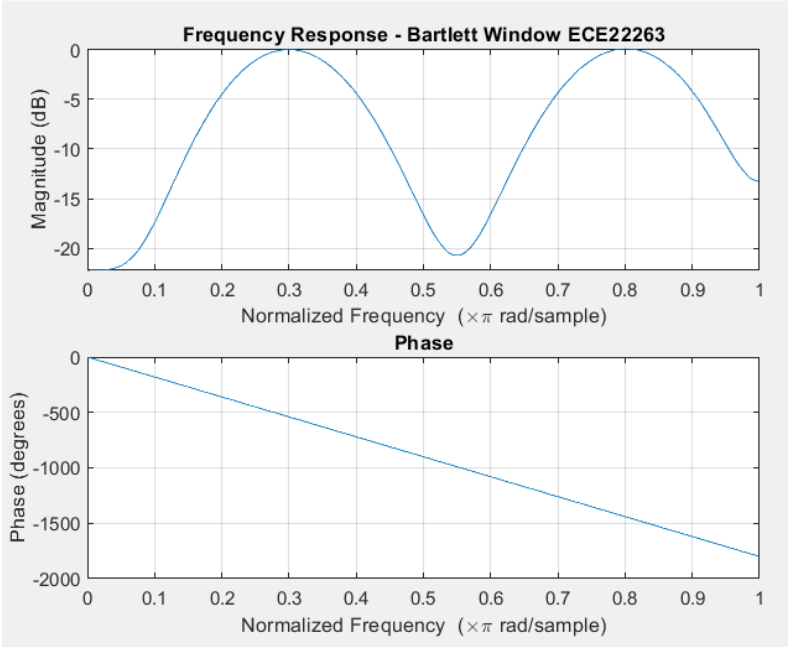
OUTPUT:


Frequency Response - Rectangular Window ECE22263
Magnitude (dB)
0
-20
-40
-60
-80
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
Phase (degrees)
0
-500
-1000
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)


Frequency Response - Hamming Window ECE22263
Magnitude (dB)
0
-50
-100
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
Phase (degrees)
500
0
-500
-1000
-1500
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)


Frequency Response - Blackman Window ECE22263
Magnitude (dB)
0
-10
-20
-30
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
Phase (degrees)
0
-500
-1000
-1500
-2000
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)


Frequency Response - Hanning Window ECE22263
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
Phase (degrees)
500
0
-500
-1000
-1500
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)


Frequency Response - Bartlett Window ECE22263
Magnitude (dB)
0
-5
-10
-15
-20
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
Phase (degrees)
0
-500
-1000
-1500
-2000
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)

4. Design a FIR Band stop filter with $\omega s1 = 0.5\pi$, $\omega p1 = 0.3\pi$, $\omega s2$ 0.6π, $\omega p2 = 0.8\pi$, order N=20 using Rectangular Window and plot the frequency response of the filter. Repeat the filter design with same specifications using following window functions and compare the frequency responses.

a) Hamming Window

b) Blackman Window

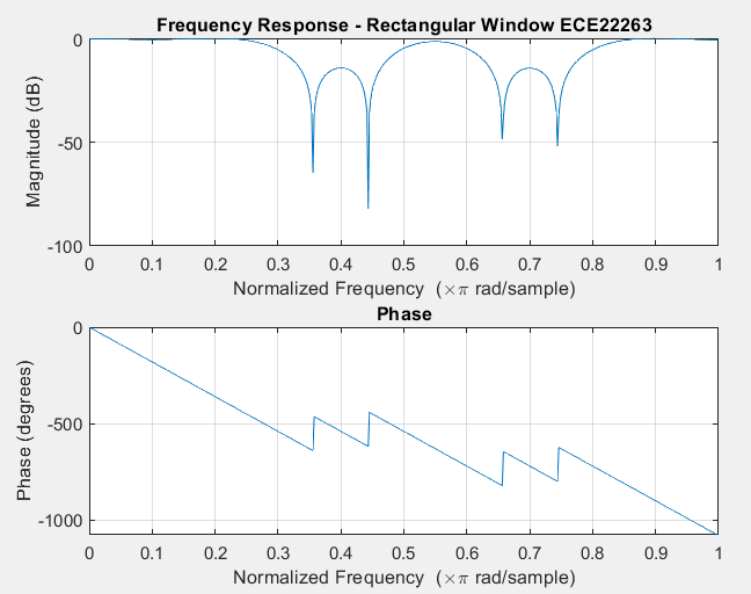
c) Hanning Window

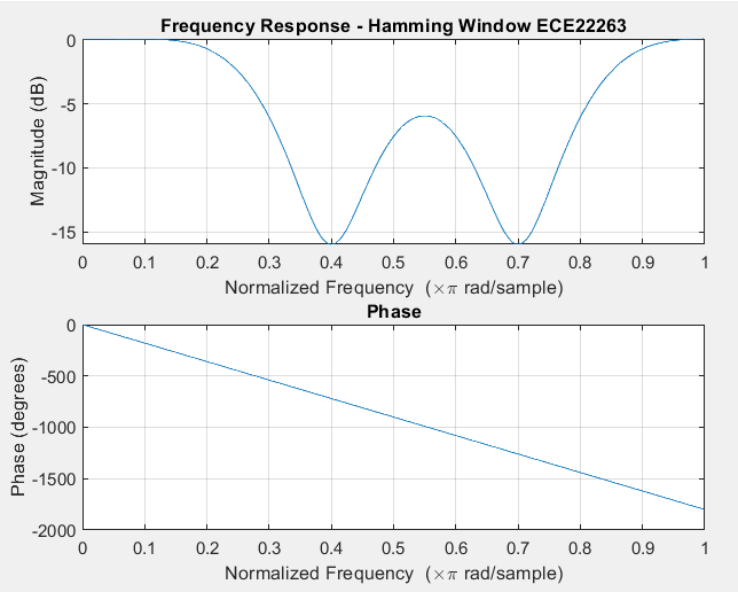
d) Bartlett Window

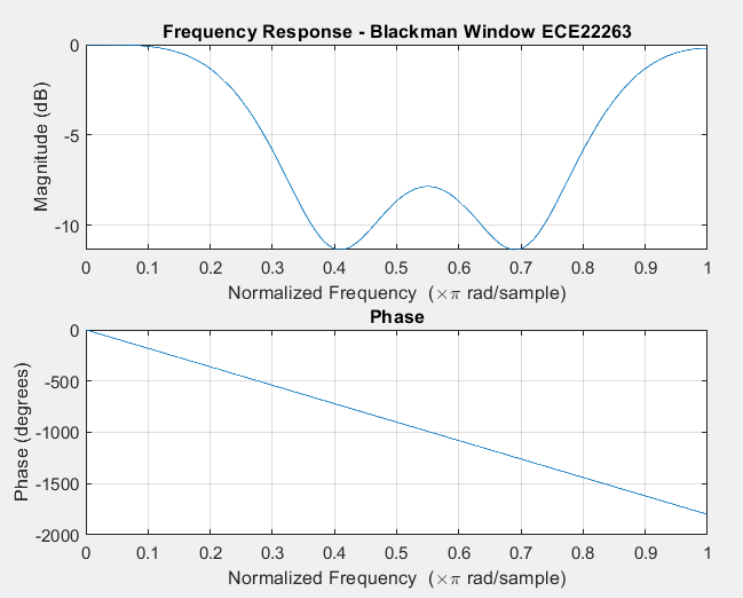
Code

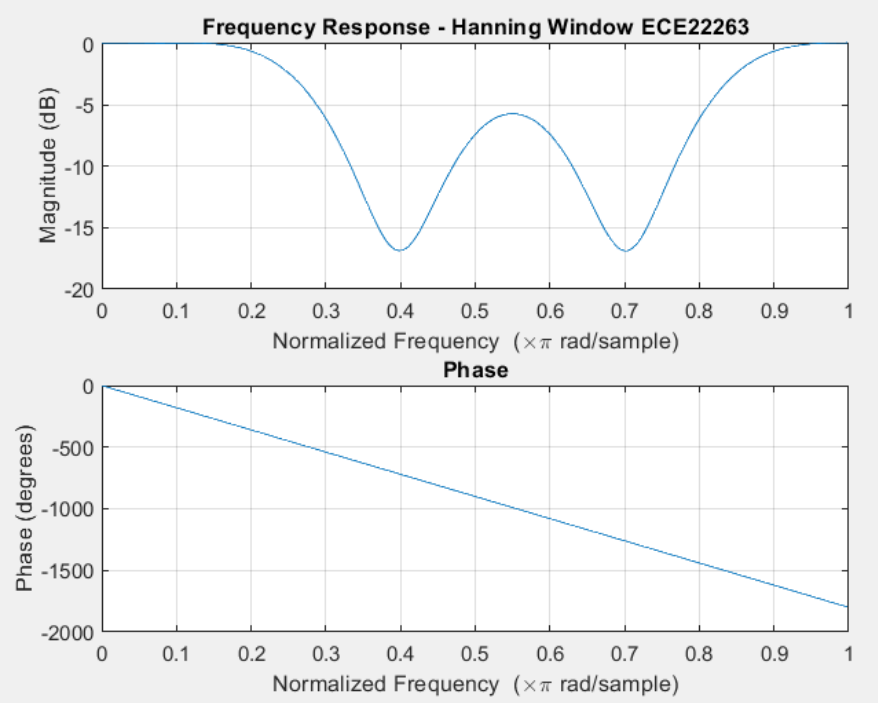
```
ws1 = 0.5 * pi;
wp1 = 0.3 * pi;
ws2 = 0.6 * pi;
wp2 = 0.8 * pi;
wc1 = (ws1 + ws2) / 2;
N = 20;
w_rect = rectwin(N+1);
h_rect = fir1(N, [wp1/pi, ws1/pi, ws2/pi, wp2/pi], 'stop', w_rect);
freqz(h_rect, 1, 512);
title('Frequency Response - Rectangular Window ECE22263');
w_hamming = hamming(N+1);
h_hamming = fir1(N, [wp1/pi, ws1/pi, ws2/pi, wp2/pi], 'stop', w_hamming);
figure;
freqz(h_hamming, 1, 512);
title('Frequency Response - Hamming Window ECE22263');
w_blackman = blackman(N+1);
h_blackman = fir1(N, [wp1/pi, ws1/pi, ws2/pi, wp2/pi], 'stop', w_blackman);
figure;
freqz(h_blackman, 1, 512);
title('Frequency Response - Blackman Window ECE22263');
w_hanning = hanning(N+1);
h_hanning = fir1(N, [wp1/pi, ws1/pi, ws2/pi, wp2/pi], 'stop', w_hanning);
figure;
freqz(h_hanning, 1, 512);
title('Frequency Response - Hanning Window ECE22263');
w_bartlett = bartlett(N+1);
h_bartlett = fir1(N, [wp1/pi, ws1/pi, ws2/pi, wp2/pi], 'stop', w_bartlett);
figure;
freqz(h_bartlett, 1, 512);
title('Frequency Response - Bartlett Window ECE22263');
```

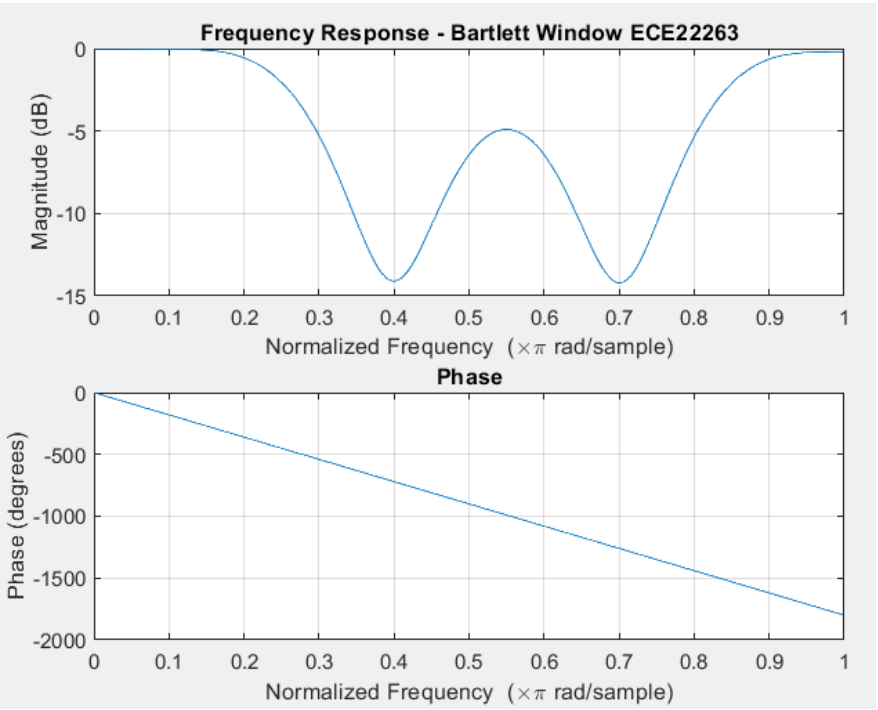
Output


Frequency Response - Rectangular Window ECE22263
Magnitude (dB)
0
-50
-100
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
Phase (degrees)
0
-500
-1000
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)


Frequency Response - Hamming Window ECE22263
Magnitude (dB)
0
-5
-10
-15
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
Phase (degrees)
0
-500
-1000
-1500
-2000
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)


Frequency Response - Blackman Window ECE22263
Magnitude (dB)
0
-5
-10
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
Phase (degrees)
0
-500
-1000
-1500
-2000
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)


Frequency Response - Hanning Window ECE22263
Magnitude (dB)
0
-5
-10
-15
-20
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
Phase (degrees)
0
-500
-1000
-1500
-2000
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)


Frequency Response - Bartlett Window ECE22263
Magnitude (dB)
0
-5
-10
-15
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
Phase (degrees)
0
-500
-1000
-1500
-2000
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)