Chittagong University of Engineering & Technology

EEE-496

Digital Signal Processing Sessional

Design Low Pass, High Pass, Band Pass and Band stop FIR filter using different types of window.

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June 13, 2023

Contents

1 Objectives

The objectives of the experiment are:

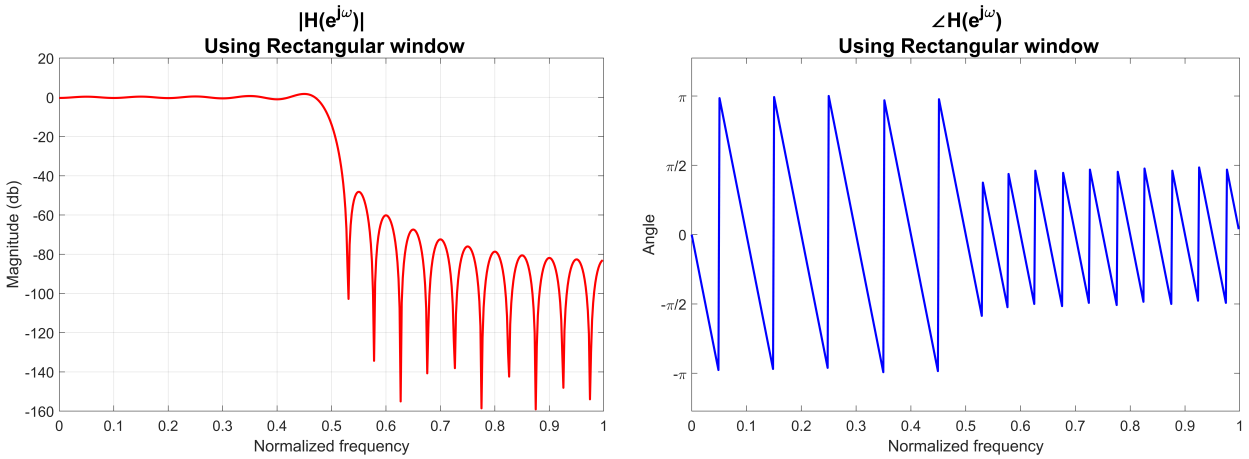
1. To design a low pass filter using Hamming, Hanning, Blackman and Berlett window with MATLAB.
2. To design a high pass filter using Hamming, Hanning, Blackman and Berlett window with MATLAB.
3. To design a band pass and band stop filter using Hamming, Hanning, Blackman and Berlett window with MATLAB.

2 Low pass filter

```
clc;
clear;
close all;
M=40; %filter order
wp=0.4*pi;
ws=0.6*pi;
wc=(wp+ws)/2;
n=0:1:M;
rectangle=1;
barlet=1-2*abs(n-M/2)/M;
hamming=0.54-0.46*cos(2*pi*n/M);
hanning=0.5-0.5*cos(2*pi*n/M);
blackman=0.42-0.5*cos(2*pi*n/M)+0.08*cos(4*pi*n/M);
h_d=(wc/pi)*sinc(wc*(n-M/2)/pi);
window.rect=rectangle;
window.trian=barlet;
window.hamm=hamming;
window.hann=hanning;
window.black=blackman;
fields = fieldnames(window)
L=length(fields);
title_tex=["Rectangular" "Barlet" "Hamming" "Hanning
  " "Blackman"];
```

```
E_lpf=zeros(1,L);
for i=1:L
    h_n=h_d.*getfield(window, fields{i});
    [h, w]=freqz(h_n);
    mag=abs(h);
    E_wp=sum(abs(1-mag(w≤wp)));
    E_ws=sum(abs(0-mag(w≥ws)));
    E_lpf(i)=E_wp+E_ws;
    figure
    plot(w/pi, 20*log(mag), "color", "r", "linewidth
      ", 2)
    grid on;
    xlabel("Normalized frequency");
    ylabel("Magnitude (db)");
    title(["|H(e^{j\omega})|" " Using "+title_tex(i)
       + " window"], "FontSize", 14)
    figure
    plot(w/pi, angle(h), "color", "b", "linewidth",
      2)
    xlabel("Normalized frequency");
    yticks([-pi -pi/2 0 pi/2 pi])
    yticklabels({'-\pi','-\pi/2','0','\pi/2','\pi'})
    ylabel("Angle");
    title(["\angle{H(e^{j\omega})}" " Using "+
      title_tex(i) + " window"], "FontSize", 14)
end
figure
scatter([1 10 20 30 40],E_lpf,60,"r","filled")
xticks([1 10 20 30 40])
xticklabels(title_tex)
title("Total Absolute Error for LPF", "FontSize",
  14)
```

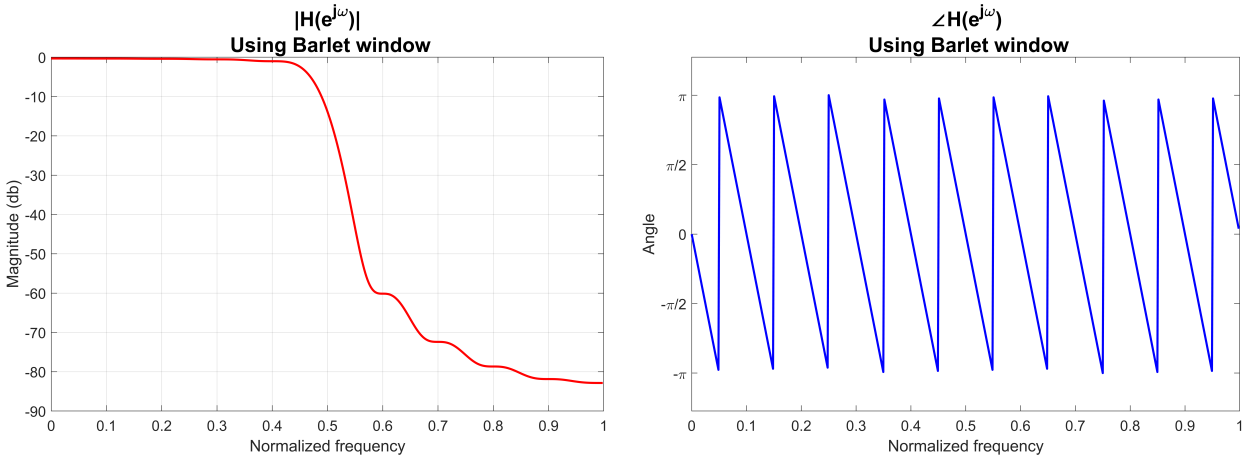
2.1 Frequency response of LPF using rectangular window



(a) (b)

Figure 1: (a) Magnitude response of LPF using rectangular window. (b) Phase response of LPF using rectangular window.

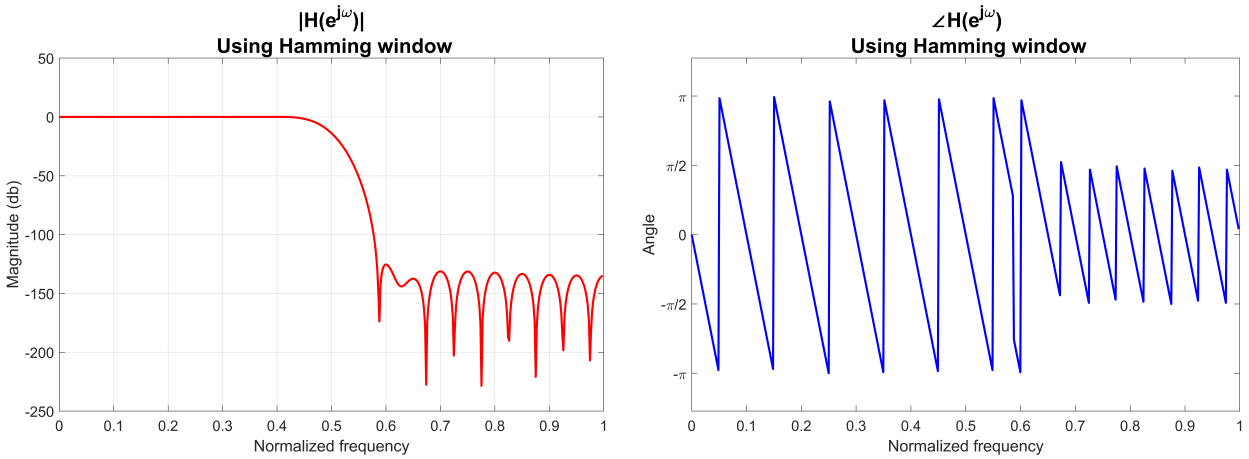
2.2 Frequency response of LPF using Barlet window



(a) (b)

Figure 2: (a) Magnitude response of LPF using Barlet window. (b) Phase response of LPF using Barlet window.

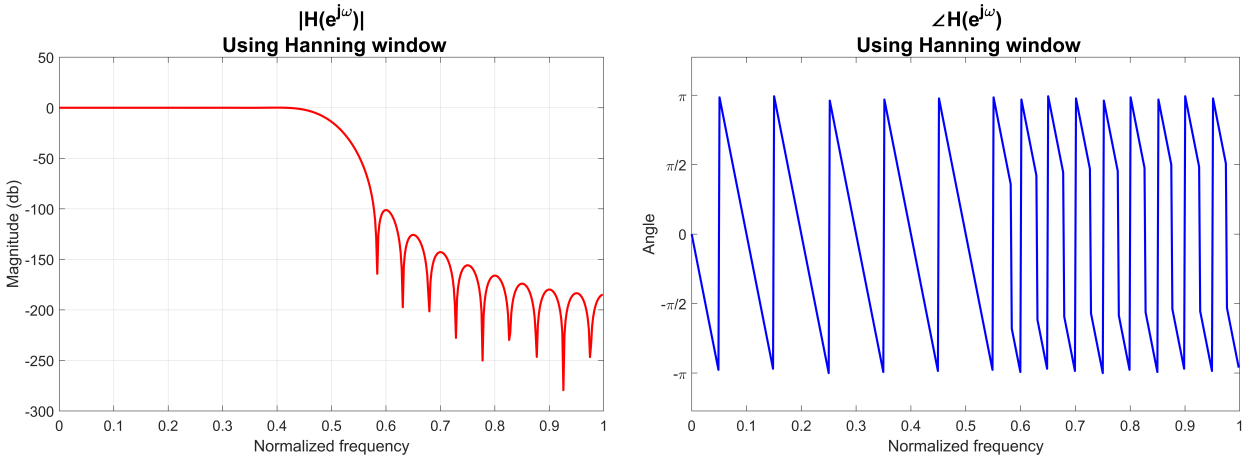
2.3 Frequency response of LPF using Hamming window



(a) (b)

Figure 3: (a) Magnitude response of LPF using hamming window. (b) Phase response of LPF using hamming window.

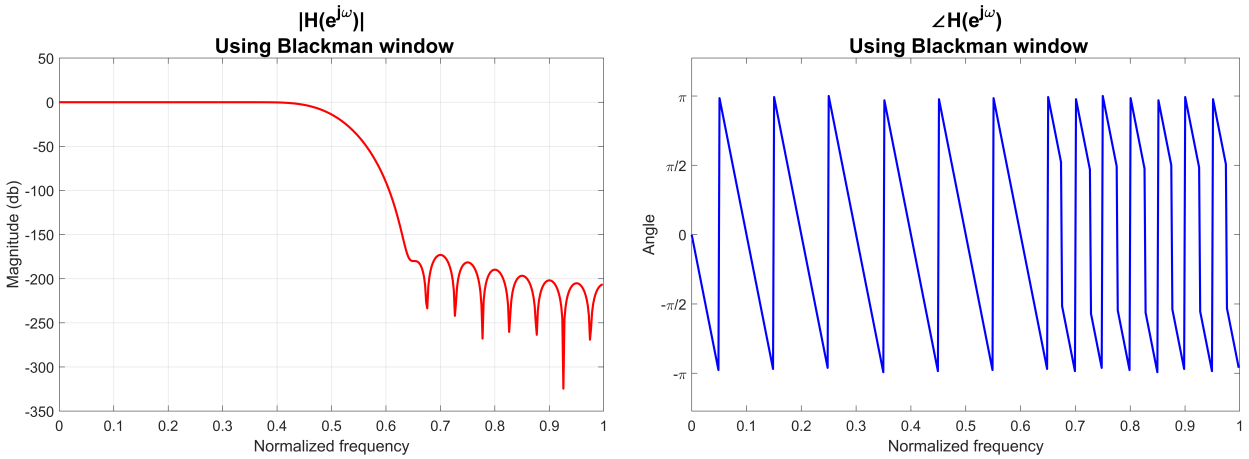
2.4 Frequency response of LPF using Hanning window



(a) (b)

Figure 4: (a) Magnitude response of LPF using hanning window. (b) Phase response of LPF using hanning window.

2.5 Frequency response of LPF using blackman window



(a) (b)

Figure 5: (a) Magnitude response of LPF using blackman window. (b) Phase response of LPF using blackman window.

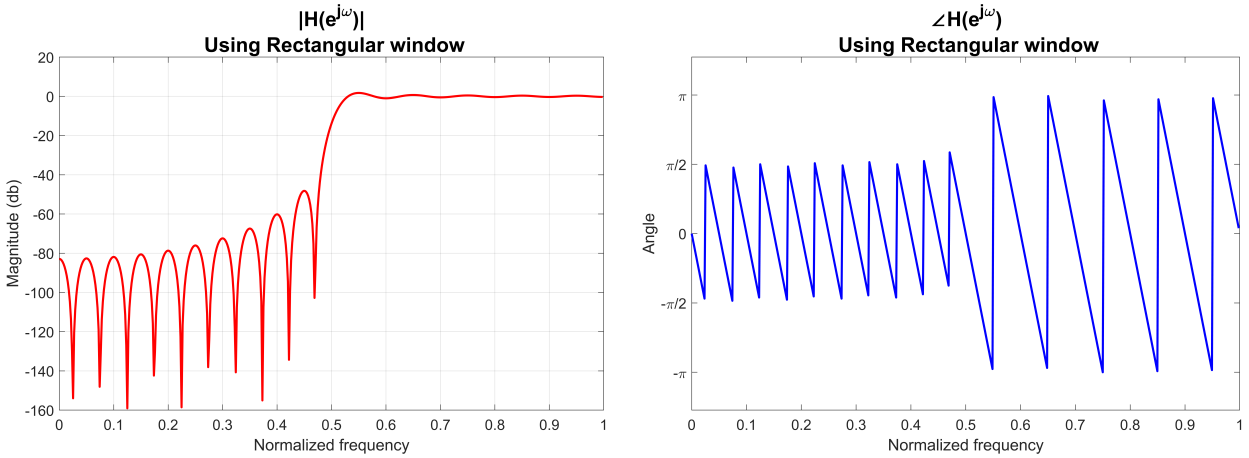
3 High pass filter

```
clc;
clear;
close all;
M=40; %filter order
ws=0.4*pi;
wp=0.6*pi;
wc=(ws+wp)/2;
n=0:1:M;
rectangle=1;
barlet=1-2*abs(n-M/2)/M;
hamming=0.54-0.46*cos(2*pi*n/M);
hanning=0.5-0.5*cos(2*pi*n/M);
blackman=0.42-0.5*cos(2*pi*n/M)+0.08*cos(4*pi*n/M);
h_d=sinc(n-M/2)-(wc/pi)*sinc(wc*(n-M/2)/pi);
window.rect=rectangle;
window.trian=barlet;
```

```
window.hamm=hamming;
window.hann=hanning;
window.black=blackman;
fields = fieldnames(window)
L=length(fields);
title_tex=["Rectangular" "Barlet" "Hamming" "Hanning
  " "Blackman"];
E_hpf=zeros(1,L);
for i=1:L
    h_n=h_d.*getfield(window, fields{i});
    [h, w]=freqz(h_n);
    mag=abs(h);
    E_ws=sum(abs(0-mag(w≤ws)));
    E_wp=sum(abs(1-mag(w≥wp)));
    E_hpf(i)=E_wp+E_ws;
    figure
    plot(w/pi, 20*log(mag), "color", "r", "linewidth
      ", 2)
    grid on;
    xlabel("Normalized frequency");
    ylabel("Magnitude (db)");
    title(["|H(e^{j\omega})|" " Using "+title_tex(i)
       + " window"], "FontSize", 14)
    figure
    plot(w/pi, angle(h), "color", "b", "linewidth",
      2)
    xlabel("Normalized frequency");
    yticks([-pi -pi/2 0 pi/2 pi])
    yticklabels({'-\pi','-\pi/2','0','\pi/2','\pi'})
    ylabel("Angle");
    title(["\angle{H(e^{j\omega})}" " Using "+
      title_tex(i) + " window"], "FontSize", 14)
end
figure
scatter([1 10 20 30 40],E_hpf,60,"r","filled")
xticks([1 10 20 30 40])
```

```
xticklabels(title_tex)
title("Total Absolute Error for HPF", "FontSize",
   14)
```

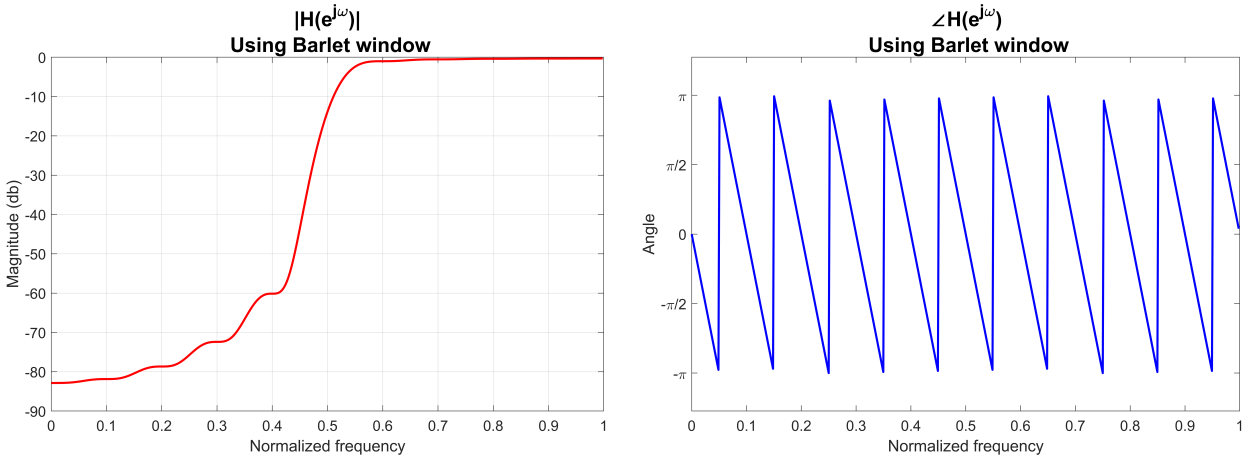
3.1 Frequency response of HPF using rectangular window



(a) (b)

Figure 6: (a) Magnitude response of HPF using rectangular window. (b) Phase response of HPF using rectangular window.

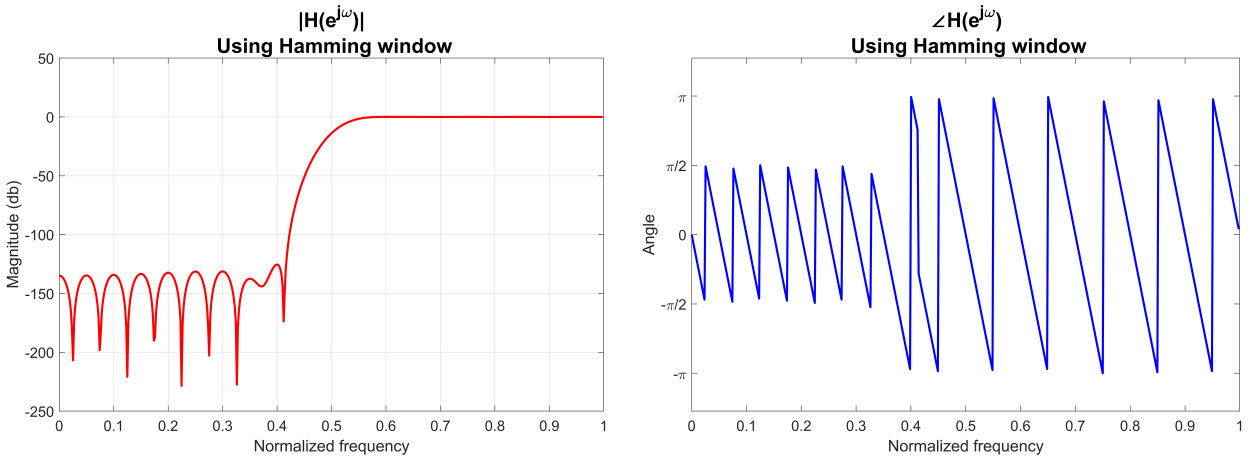
3.2 Frequency response of HPF using Barlet window



(a) (b)

Figure 7: (a) Magnitude response of HPF using Barlet window. (b) Phase response of HPF using Barlet window.

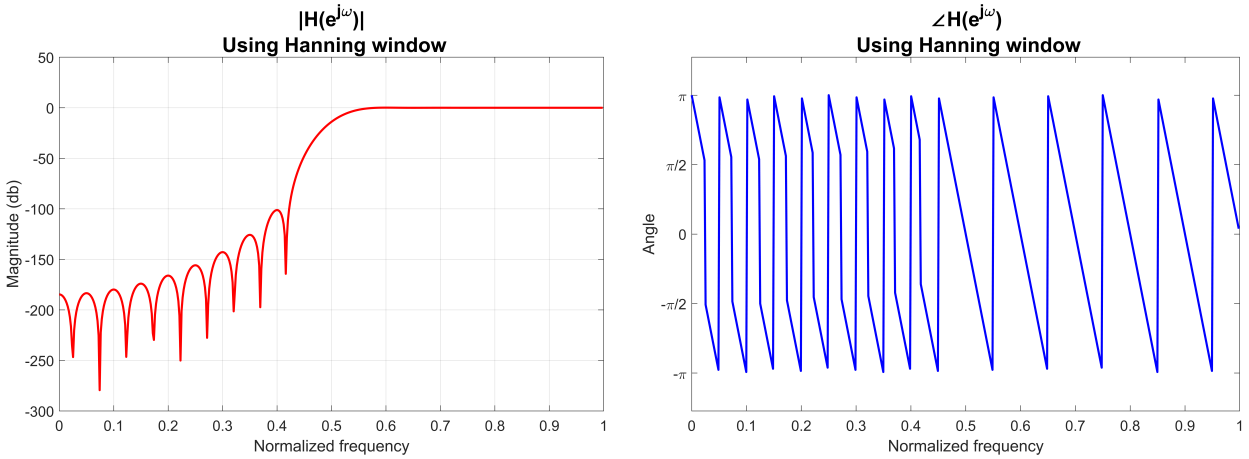
3.3 Frequency response of HPF using Hamming window



(a) (b)

Figure 8: (a) Magnitude response of HPF using hamming window. (b) Phase response of HPF using hamming window.

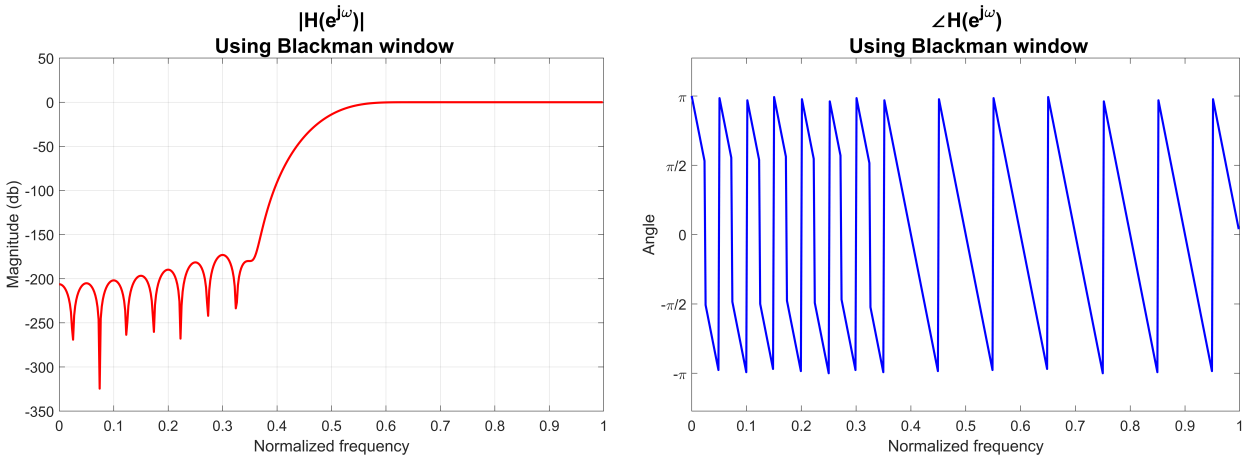
3.4 Frequency response of HPF using Hanning window



(a) (b)

Figure 9: (a) Magnitude response of HPF using hanning window. (b) Phase response of HPF using hanning window.

3.5 Frequency response of HPF using blackman window



(a) (b)

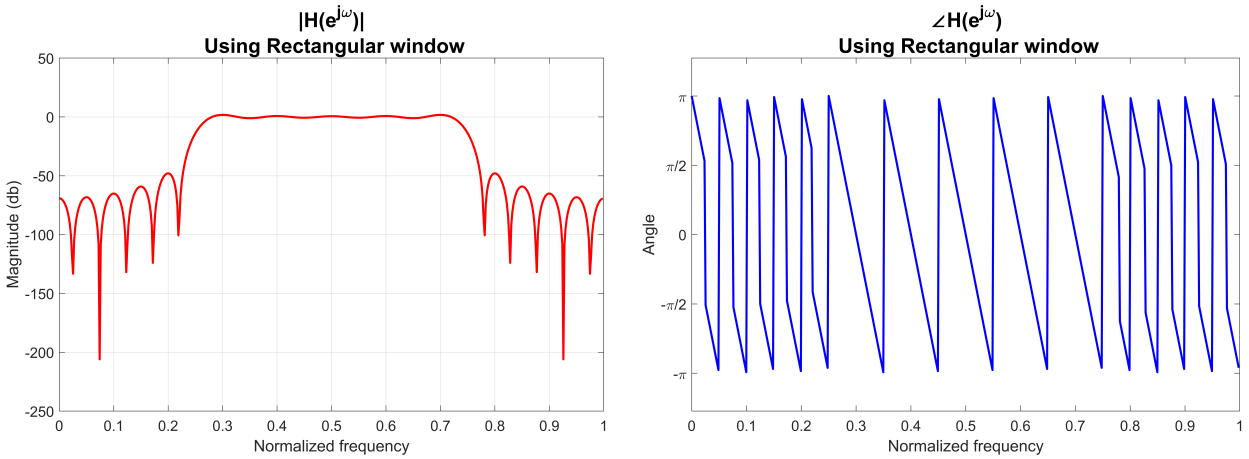
Figure 10: (a) Magnitude response of HPF using blackman window. (b) Phase response of HPF using blackman window.

4 Band pass filter

```
clc;
clear;
close all;
M=40; %filter order
w_cl=pi/4;
w_cu=3*pi/4;
n=0:1:M;
rectangle=1;
barlet=1-2*abs(n-M/2)/M;
hamming=0.54-0.46*cos(2*pi*n/M);
hanning=0.5-0.5*cos(2*pi*n/M);
blackman=0.42-0.5*cos(2*pi*n/M)+0.08*cos(4*pi*n/M);
h_d=(w_cu/pi)*sinc(w_cu*(n-M/2)/pi)-(w_cl/pi)*sinc(
   w_cl*(n-M/2)/pi);
window.rect=rectangle;
window.trian=barlet;
```

```
window.hamm=hamming;
window.hann=hanning;
window.black=blackman;
fields = fieldnames(window)
for i=1:length(fields)
    h_n=h_d.*getfield(window, fields{i});
    [h, w]=freqz(h_n);
    figure
    plot(w/pi, 20*log(abs(h)), "color", "r", "
      linewidth", 2)
    grid on;
    xlabel("Normalized frequency");
    ylabel("Magnitude (db)");
    title_tex=["Rectangular" "Barlet" "Hamming" "
      Hanning" "Blackman"];
    title(["|H(e^{j\omega})|" " Using "+title_tex(i)
       + " window"], "FontSize", 14)
    figure
    plot(w/pi, angle(h), "color", "b", "linewidth",
      2)
    xlabel("Normalized frequency");
    yticks([-pi -pi/2 0 pi/2 pi])
    yticklabels({'-\pi','-\pi/2','0','\pi/2','\pi'})
    ylabel("Angle");
    title_tex=["Rectangular" "Barlet" "Hamming" "
      Hanning" "Blackman"];
    title(["\angle{H(e^{j\omega})}" " Using "+
      title_tex(i) + " window"], "FontSize", 14)
end
```

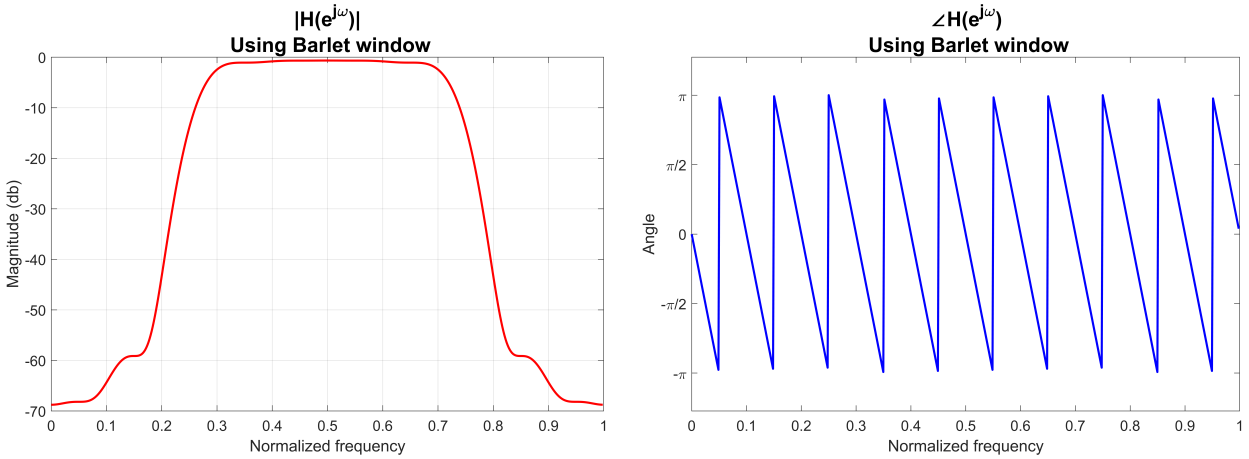
4.1 Frequency response of BPF using rectangular window



(a) (b)

Figure 11: (a) Magnitude response of BPF using rectangular window. (b) Phase response of BPF using rectangular window.

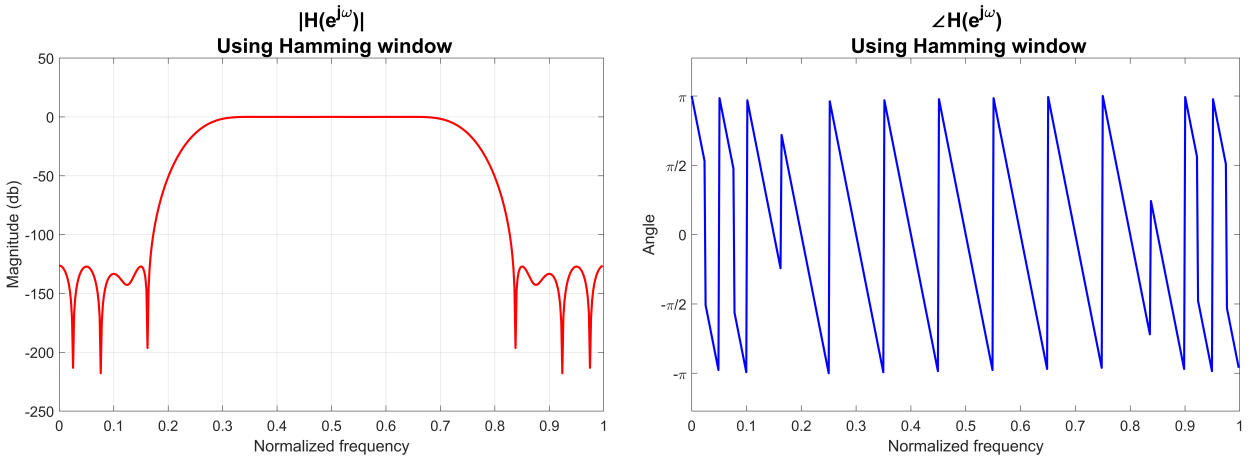
4.2 Frequency response of BPF using Barlet window



(a) (b)

Figure 12: (a) Magnitude response of BPF using Barlet window. (b) Phase response of BPF using Barlet window.

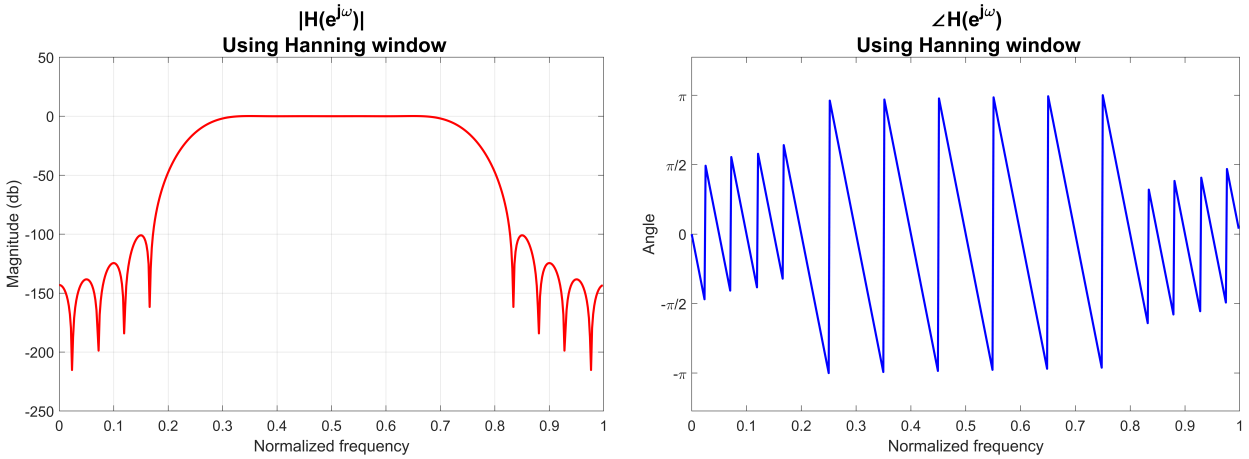
4.3 Frequency response of BPF using Hamming window



(a) (b)

Figure 13: (a) Magnitude response of BPF using hamming window. (b) Phase response of BPF using hamming window.

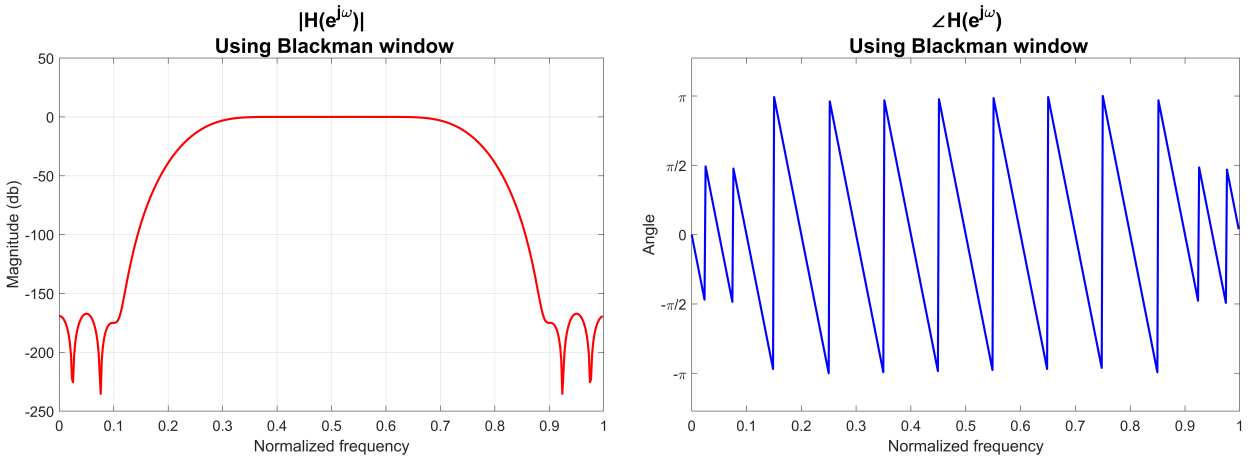
4.4 Frequency response of BPF using Hanning window



(a) (b)

Figure 14: (a) Magnitude response of BPF using hanning window. (b) Phase response of BPF using hanning window.

4.5 Frequency response of BPF using blackman window



(a) (b)

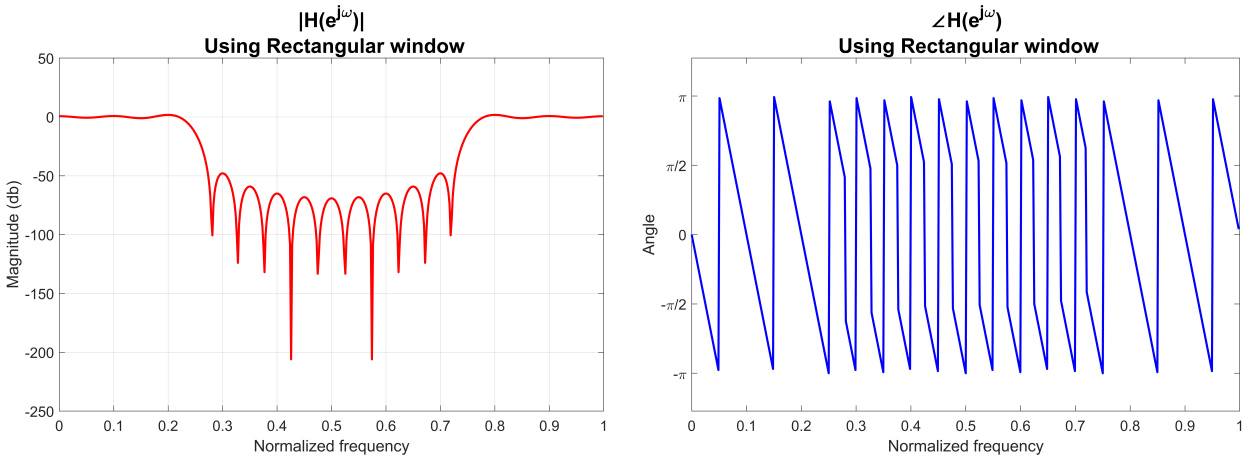
Figure 15: (a) Magnitude response of BPF using blackman window. (b) Phase response of BPF using blackman window.

5 Band stop filter

```
clc;
clear;
close all;
M=40; %filter order
w_c1=pi/4;
w_c2=3*pi/4;
n=0:1:M;
rectangle=1;
barlet=1-2*abs(n-M/2)/M;
hamming=0.54-0.46*cos(2*pi*n/M);
hanning=0.5-0.5*cos(2*pi*n/M);
blackman=0.42-0.5*cos(2*pi*n/M)+0.08*cos(4*pi*n/M);
h_d=sinc(n-M/2)+(w_c1/pi)*sinc(w_c1*(n-M/2)/pi)-(
   w_c2/pi)*sinc(w_c2*(n-M/2)/pi);
window.rect=rectangle;
window.trian=barlet;
```

```
window.hamm=hamming;
window.hann=hanning;
window.black=blackman;
fields = fieldnames(window)
for i=1:length(fields)
    h_n=h_d.*getfield(window, fields{i});
    [h, w]=freqz(h_n);
    figure
    plot(w/pi, 20*log(abs(h)), "color", "r", "
      linewidth", 2)
    grid on;
    xlabel("Normalized frequency");
    ylabel("Magnitude (db)");
    title_tex=["Rectangular" "Barlet" "Hamming" "
      Hanning" "Blackman"];
    title(["|H(e^{j\omega})|" " Using "+title_tex(i)
       + " window"], "FontSize", 14)
    figure
    plot(w/pi, angle(h), "color", "b", "linewidth",
      2)
    xlabel("Normalized frequency");
    yticks([-pi -pi/2 0 pi/2 pi])
    yticklabels({'-\pi','-\pi/2','0','\pi/2','\pi'})
    ylabel("Angle");
    title_tex=["Rectangular" "Barlet" "Hamming" "
      Hanning" "Blackman"];
    title(["\angle{H(e^{j\omega})}" " Using "+
      title_tex(i) + " window"], "FontSize", 14)
end
```

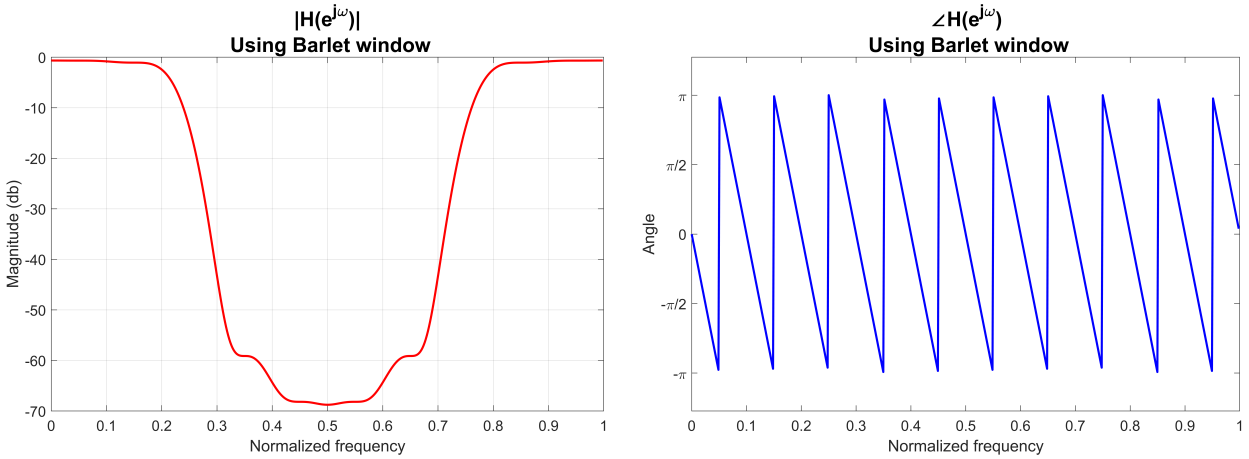
5.1 Frequency response of BSF using rectangular window



(a) (b)

Figure 16: (a) Magnitude response of BSF using rectangular window. (b) Phase response of BSF using rectangular window.

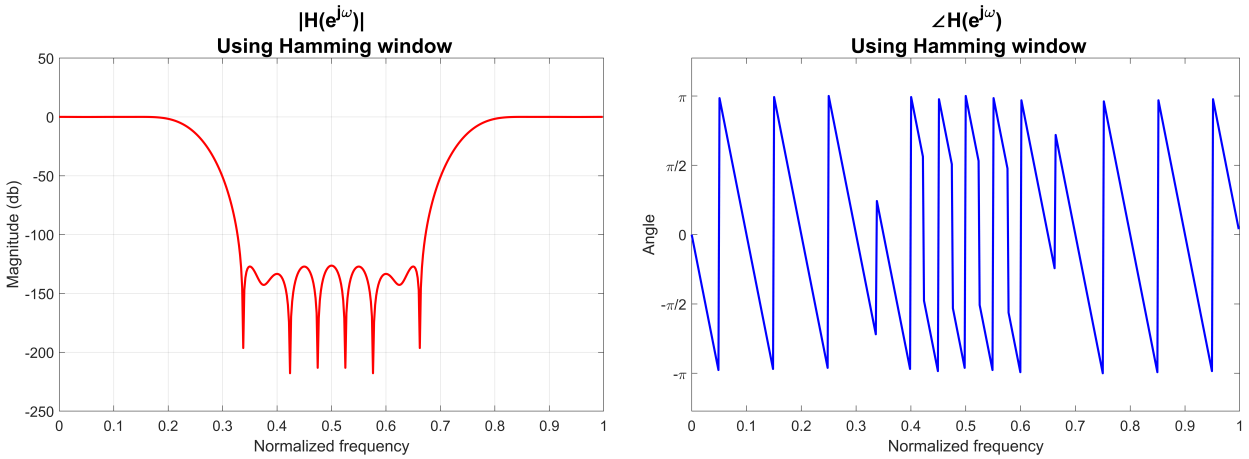
5.2 Frequency response of BSF using Barlet window



(a) (b)

Figure 17: (a) Magnitude response of BSF using Barlet window. (b) Phase response of BSF using Barlet window.

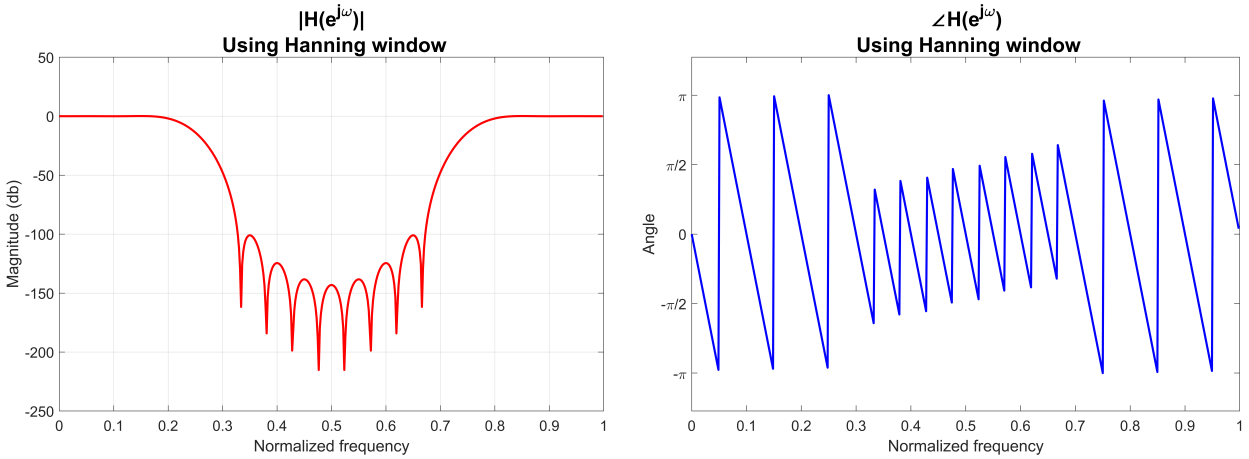
5.3 Frequency response of BSF using Hamming window



(a) (b)

Figure 18: (a) Magnitude response of BSF using hamming window. (b) Phase response of BSF using hamming window.

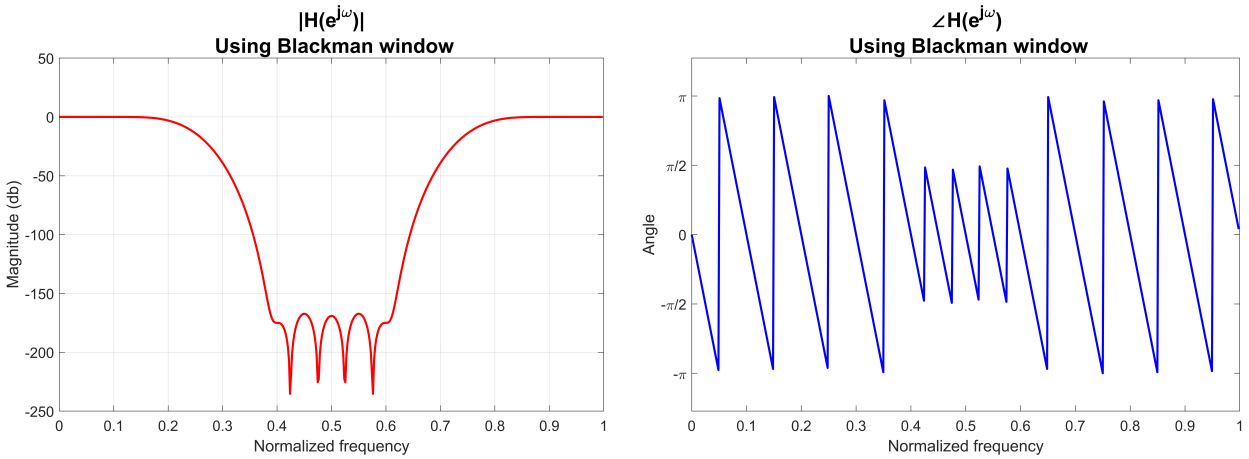
5.4 Frequency response of BSF using Hanning window



(a) (b)

Figure 19: (a) Magnitude response of BSF using hanning window. (b) Phase response of BSF using hanning window.

5.5 Frequency response of BSF using blackman window



(a) (b)

Figure 20: (a) Magnitude response of BSF using blackman window. (b) Phase response of BSF using blackman window.

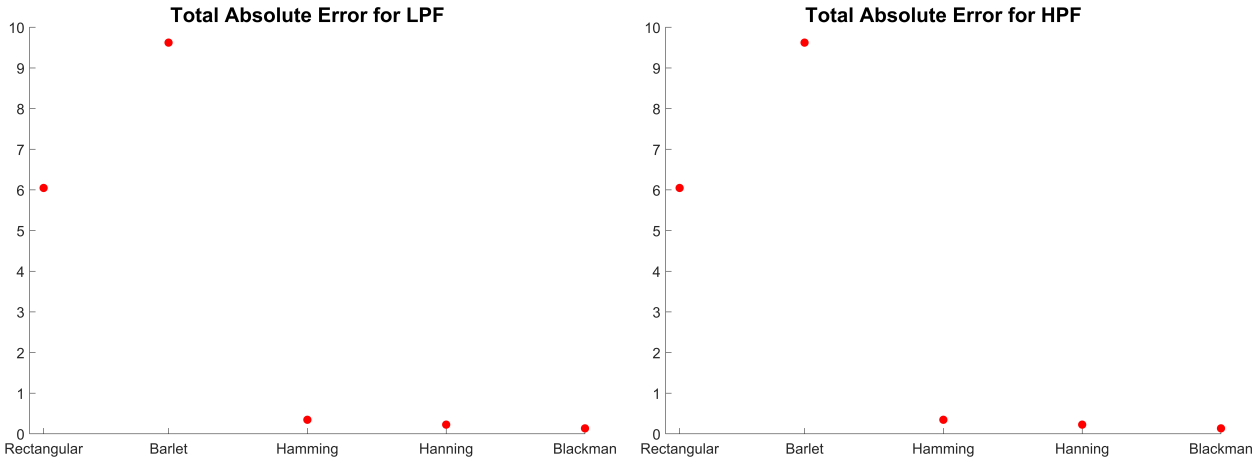
5.6 Error analysis for LPF and HPF

The error function for low pass filter is defined as:

$$E_{low} = \begin{cases} 1 - A_e(e^{j\omega}) & 0 \leq \omega \leq \omega_p \\ 0 - A_e(e^{j\omega}) & \omega_s \leq \omega \leq \pi \end{cases} \tag{1}$$

The error function for high pass filter is defined as:

$$E_{high} = \begin{cases} 0 - A_e(e^{j\omega}) & 0 \leq \omega \leq \omega_s \\ 1 - A_e(e^{j\omega}) & \omega_p \leq \omega \leq \pi \end{cases} \tag{2}$$



(a) (b)

Figure 21: (a) The sum of absolute errors in the low pass filter for each window.Here the barlet window has the maximum error, whereas the Blackman window has the minimum error for a fixed filter order. (b) The sum of absolute errors in the high pass filter for each window.Here the barlet window has the maximum error, whereas the Blackman window has the minimum error for a fixed filter order.

6 Discussion