HW5 Program Assignment

By: 105060012 張育菘

P5

A lowpass FIR filter is given by the specifications: ω_P = 0.3π, ω_S = 0.5π, and A_S = 50 dB.

Use the fir2 function to obtain a minimum length linearphase filter. Use the appropriate window function in the fir2 function. Provide a plot similar to Figure 10.12.

Ans.

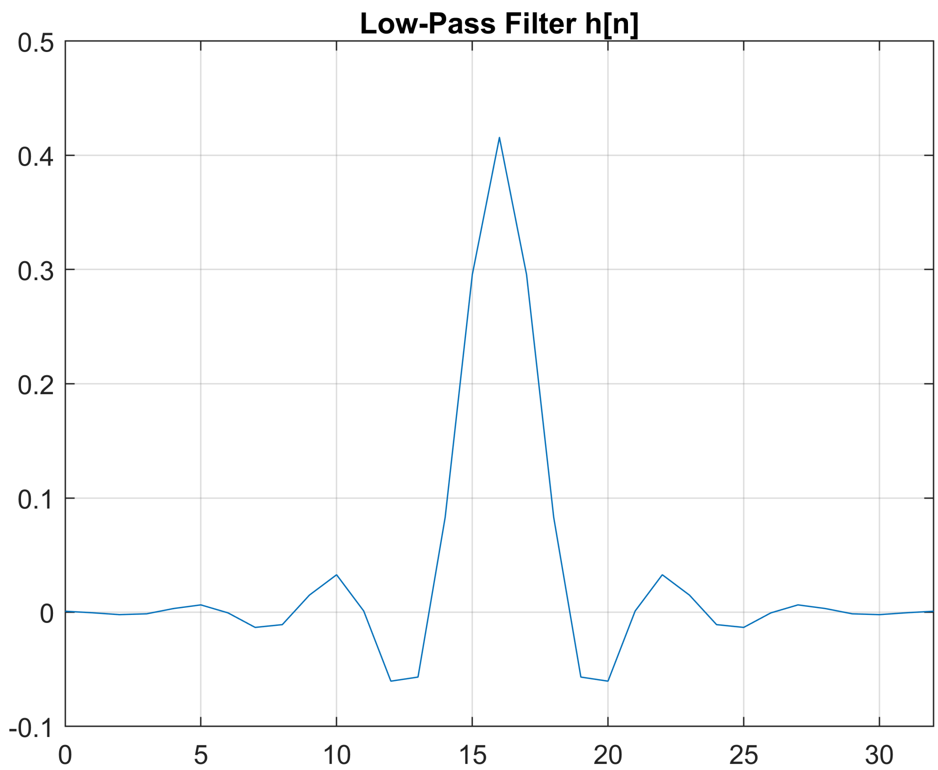
A_S = 50 dB # choose Hamming window

$$\Delta\omega = \omega_S - \omega_P = 0.2\pi \geq 6.6\frac{\pi}{L} \longrightarrow \text{choose } L = 33, M = 32$$

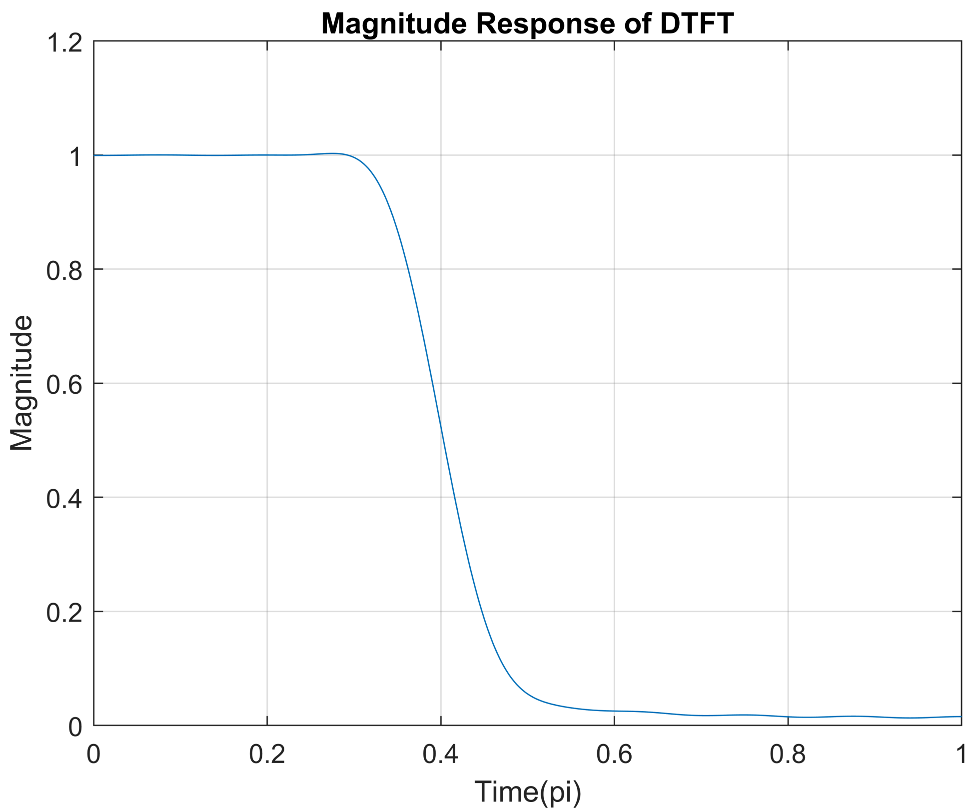
```
close all; clear;
fprintf('1\n');
```

```
1
```

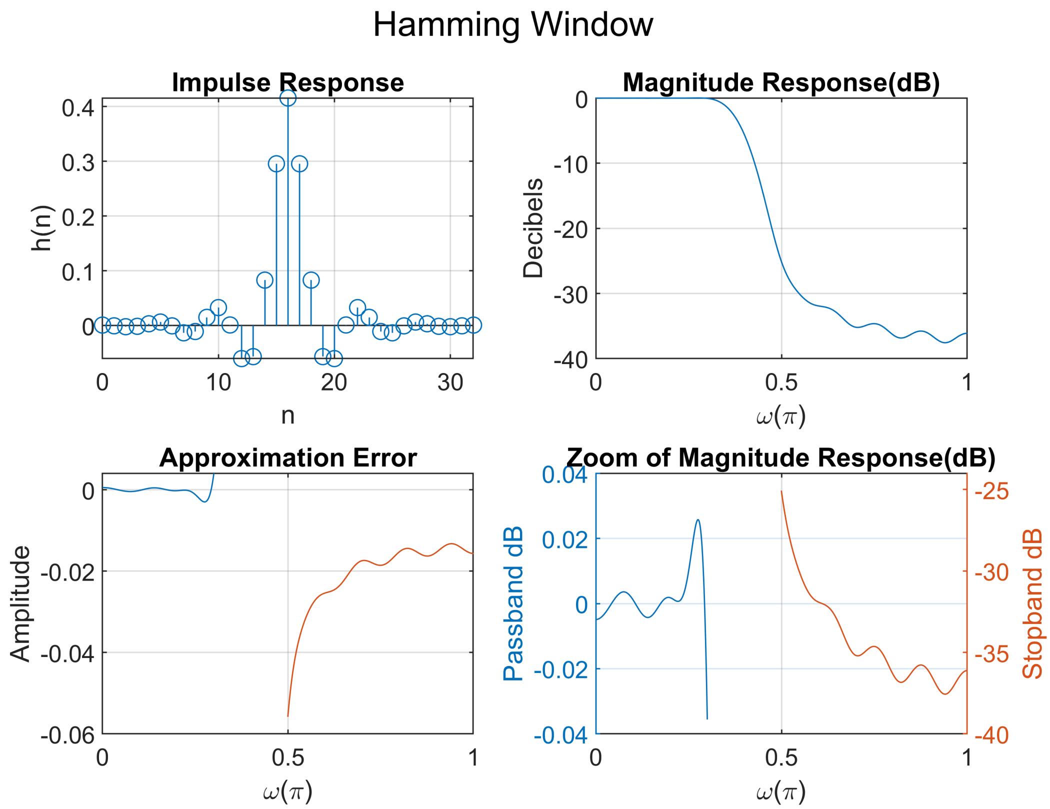
```
wp = 0.3*pi; ws = 0.5*pi; As = 50; M = 32;
deltas = 10^(-As/20);
wc = (wp + ws)/2;

om = linspace(0, pi, 1024);
n = 0:M;

h_lp = ideallp(wc,M);
[hlp_dtft, wlp_dtft] = freqz(h_lp, 1, om);
h = fir2(M, wlp_dtft/pi, abs(hlp_dtft), hamming(M+1));

[h_dtft, w_dtft] = freqz(h, 1, om);
len = length(h_dtft);
loc_ws = ceil((ws/pi)*length(h_dtft));
loc_wp = ceil((wp/pi)*length(h_dtft));

figure; plot(n, h); grid on;
title('Low-Pass Filter h[n]'); xlim([0 M]);
```




```
figure; plot(om/pi, abs(h_dtft)); grid on;
title('Magnitude Response of DTFT');
ylabel('Magnitude');
xlabel('Time(pi)');
```




```
figure; sgtitle('Hamming Window');

subplot(2,2,1); stem(n, h); grid on;
title('Impulse Response');
xlabel('n'); ylabel('h(n)'); xlim([0 M]);

subplot(2,2,2); plot(w_dtft/pi,db(abs(h_dtft))); grid on
title('Magnitude Response(dB)');
xlabel('\omega(\pi)'); ylabel('Decibels');

subplot(2,2,3);
plot(w_dtft(1:loc_wp)/pi,1-abs(h_dtft(1:loc_wp)));
hold on; grid on;
plot(w_dtft(loc_ws:len)/pi,0-abs(h_dtft(loc_ws:len)));
hold on; grid on;
title('Approximation Error');
xlabel('\omega(\pi)'); ylabel('Amplitude'); xlim([0 1]);

subplot(2,2,4);
yyaxis left; plot(w_dtft(1:loc_wp)/pi,db(abs(h_dtft(1:loc_wp))));
hold on; grid on;
title('Zoom of Magnitude Response(dB)');
xlabel('\omega(\pi)'); ylabel('Passband dB');
yyaxis right; plot(w_dtft(loc_ws:len)/pi,db(abs(h_dtft(loc_ws:len))));
hold on; grid on;
ylabel('Stopband dB'); xlim([0 1]);
```



P6

Design a highpass FIR filter to satisfy the specifications: ω_S = 0.3π, ω_P = 0.5π, and A_S = 50 dB.

(a) Use Kaiser window to obtain a minimum length linear-phase filter. Provide a plot similar to Figure 10.12.

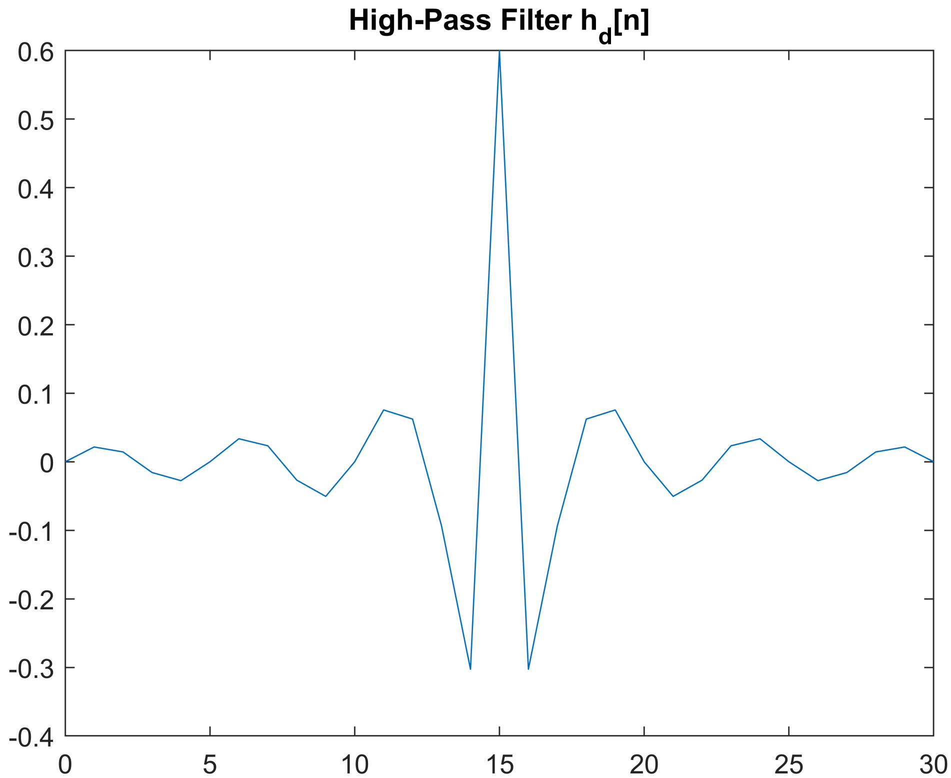
(???) Ideal high-pass filter (???)

```
close all; clear;
fprintf('6(a)\n');
```

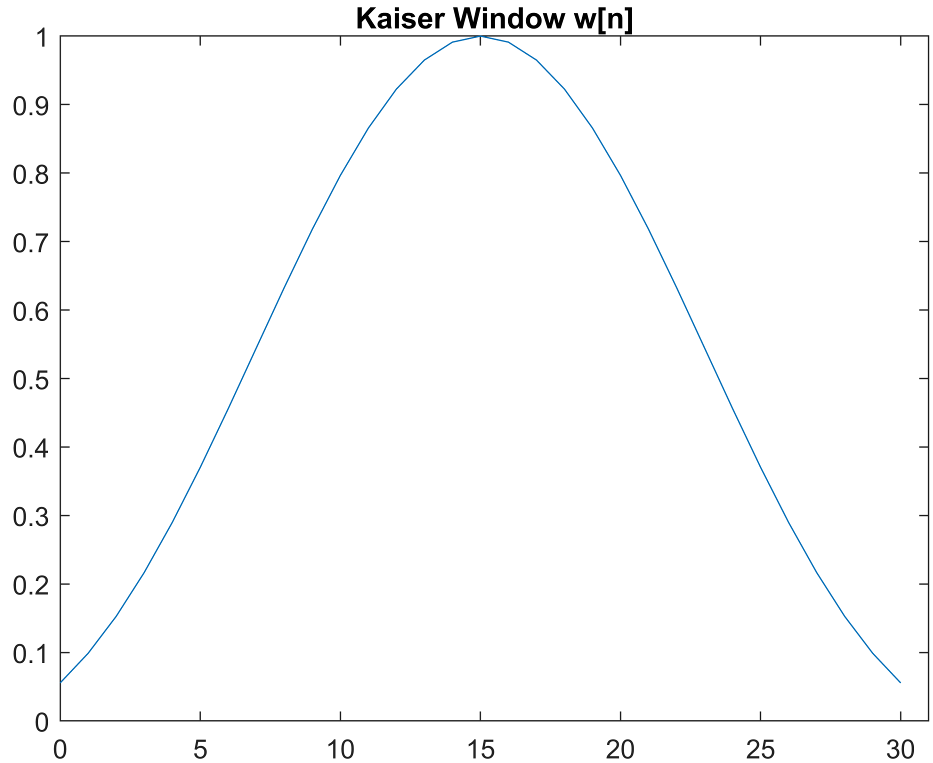
```
6(a)
```

```
wp = 0.5*pi; ws = 0.3*pi; As = 50; A = As;
deltas = 10^(-As/20);

Ap = -20*log10(1-deltas);

wc = (wp + ws)/2;
delta_om = abs(wp - ws);

if (A<21)
    beta = 0;
```

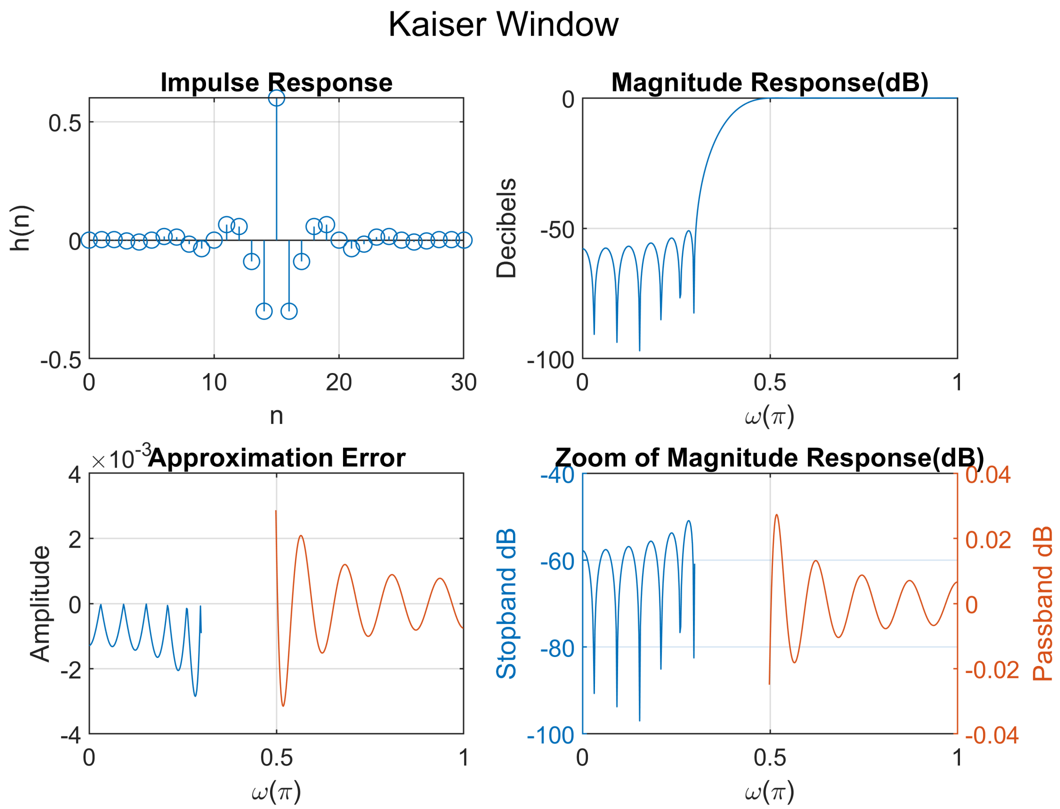
```
elseif (A>=21) && (A<=50)
    beta = 0.5842*(A-21)^(0.4)+0.07886*(A-21);
else
    beta = 0.1102*(A-8.7);
end

M = ceil((A-8)/(2.285*delta_om));
if mod(M, 2) == 1
    M = M + 1;
else
    M = M;
end
L = M + 1;

n = 0:1:M; n_1 = (0:M)-M/2;
hd = sinc(n_1) - (wc*sinc(wc*(n_1)./pi)./pi);
% hd = sinc(pi.*n_1) - ideallp(wc, M)';
% hd = sinc(pi.*n_1) - ((wc/pi).*sinc(wc*n_1));
wn = kaiser(L,beta)';
h = hd.*wn;

[h_dtft,w_dtft] = freqz(h, 1);
len = length(h_dtft);
loc_ws = ceil((ws/pi)*length(h_dtft));
loc_wp = ceil((wp/pi)*length(h_dtft));

figure; plot(n, hd);
title('High-Pass Filter h_d[n]'); xlim([0 M]);
```




```
figure; plot(n, wn);
title('Kaiser Window w[n]'); xlim([0 L]);
```




```
figure; sgtitle('Kaiser Window');

subplot(2,2,1); stem(n, h); grid on;
title('Impulse Response');
xlabel('n'); ylabel('h(n)'); xlim([0 M]);

subplot(2,2,2); plot(w_dtft/pi,db(abs(h_dtft))); grid on;
title('Magnitude Response(dB)');
xlabel('\omega(\pi)'); ylabel('Decibels');

subplot(2,2,3);
plot(w_dtft(1:loc_ws)/pi,0-abs(h_dtft(1:loc_ws)));
hold on; grid on;
plot(w_dtft(loc_wp:len)/pi,1-abs(h_dtft(loc_wp:len)));
hold on; grid on;
title('Approximation Error');
xlabel('\omega(\pi)'); ylabel('Amplitude'); xlim([0 1]);

subplot(2,2,4);
yyaxis left; plot(w_dtft(1:loc_ws)/pi,db(abs(h_dtft(1:loc_ws))));
hold on; grid on;
title('Zoom of Magnitude Response(dB)');
xlabel('\omega(\pi)'); ylabel('Stopband dB');
yyaxis right; plot(w_dtft(loc_wp:len)/pi,db(abs(h_dtft(loc_wp:len))));
hold on; grid on;
ylabel('Passband dB'); xlim([0 1]);
```



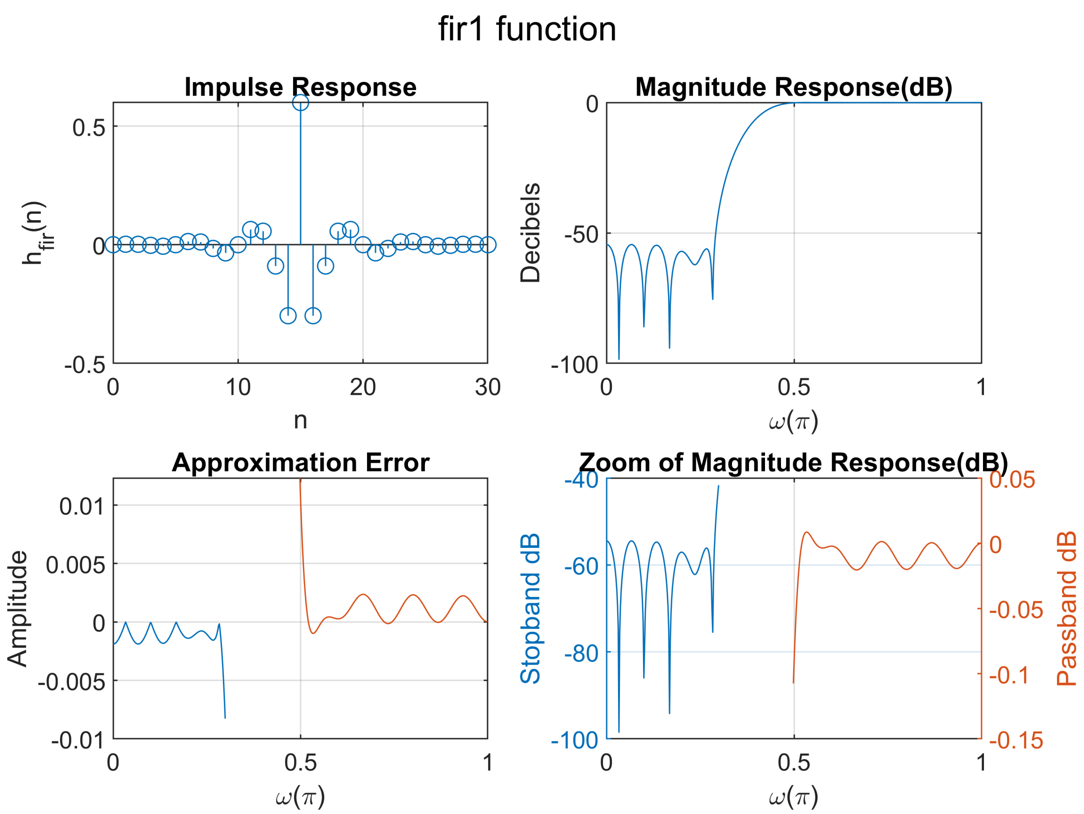
(b) Repeat (a) using the fir1 function.

```
fprintf('6(b)\n');
```

```
6(b)
```

```
n = 0:1:M;
h_fir = fir1(M,wc/pi,'high');
[fir_dtft,wf_dtft] = freqz(h_fir);
lenf = length(fir_dtft);

figure; sgtitle('fir1 function');

subplot(2,2,1); stem(n, h_fir); grid on;
title('Impulse Response');
xlabel('n'); ylabel('h_f_i_r(n)'); xlim([0 M]);

subplot(2,2,2); plot(wf_dtft/pi,db(abs(fir_dtft))); grid on;
title('Magnitude Response(dB)');
xlabel('\omega(\pi)'); ylabel('Decibels');

subplot(2,2,3);
plot(wf_dtft(1:loc_ws)/pi,0-abs(fir_dtft(1:loc_ws)));
hold on; grid on;
plot(wf_dtft(loc_wp:lenf)/pi,1-abs(fir_dtft(loc_wp:lenf)));
```

```
hold on; grid on;
title('Approximation Error');
xlabel('\omega(\pi)'); ylabel('Amplitude'); xlim([0 1]);

subplot(2,2,4);
yyaxis left; plot(wf_dtft(1:loc_ws)/pi,db(abs(fir_dtft(1:loc_ws))));
hold on; grid on;
title('Zoom of Magnitude Response(dB)');
xlabel('\omega(\pi)'); ylabel('Stopband dB');
yyaxis right; plot(wf_dtft(loc_wp:lenf)/pi,db(abs(fir_dtft(loc_wp:lenf))));
hold on; grid on;
ylabel('Passband dB'); xlim([0 1]);
```



P7

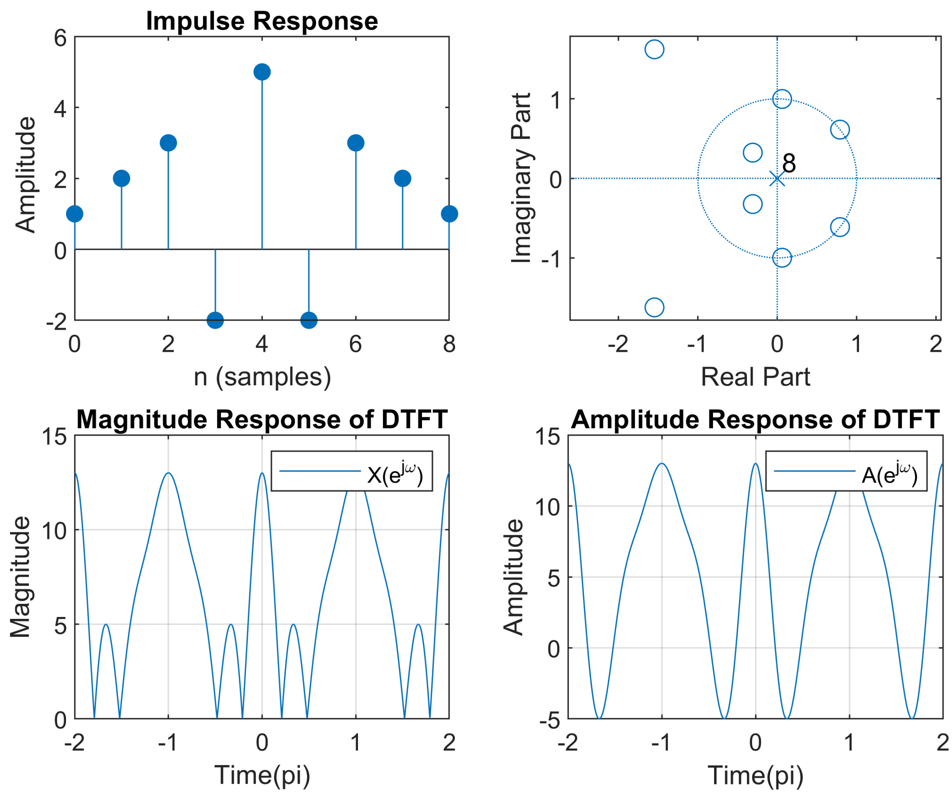
In this problem we reproduce Figures 10.4 and 10.5. For each of the following linear-phase FIR filters described by h[n], obtain impulse response, amplitude response, magnitude response, and pole-zero plots in one figure window. For frequency response plots use the interval $-2\pi \le \omega \le 2\pi$.

(a) Type-I filter: $h[n] = \{1, 2, 3, -2, 5, -2, 3, 2, 1\}$.

```
close all; clear;
fprintf('7(a): Type I\n');
```

```
7(a): Type I
```

```
h1 = [1 2 3 -2 5 -2 3 2 1];
M = length(h1)-1;
om = linspace(-2*pi, 2*pi, 2048);

h1_amp = h1((length(h1)+1)/2);
j = 1;
for i = ((length(h1)-1)/2):-1:1
    h1_amp = h1_amp + (2*h1(i)*cos(om.*j));
    j = j + 1;
end

h1_dtft = dtft12(h1, 0, om);

figure;

subplot(2,2,1); impz(h1, 1);

subplot(2,2,2); zplane(h1, 1);

subplot(2,2,3); plot(om/pi, abs(h1_dtft)); grid on;
title('Magnitude Response of DTFT');
legend('X(e^j^\omega)')
ylabel('Magnitude');
xlabel('Time(pi)');

subplot(2,2,4); plot(om/pi, h1_amp); grid on;
title('Amplitude Response of DTFT');
legend('A(e^j^\omega)')
ylabel('Amplitude');
xlabel('Time(pi)');
```



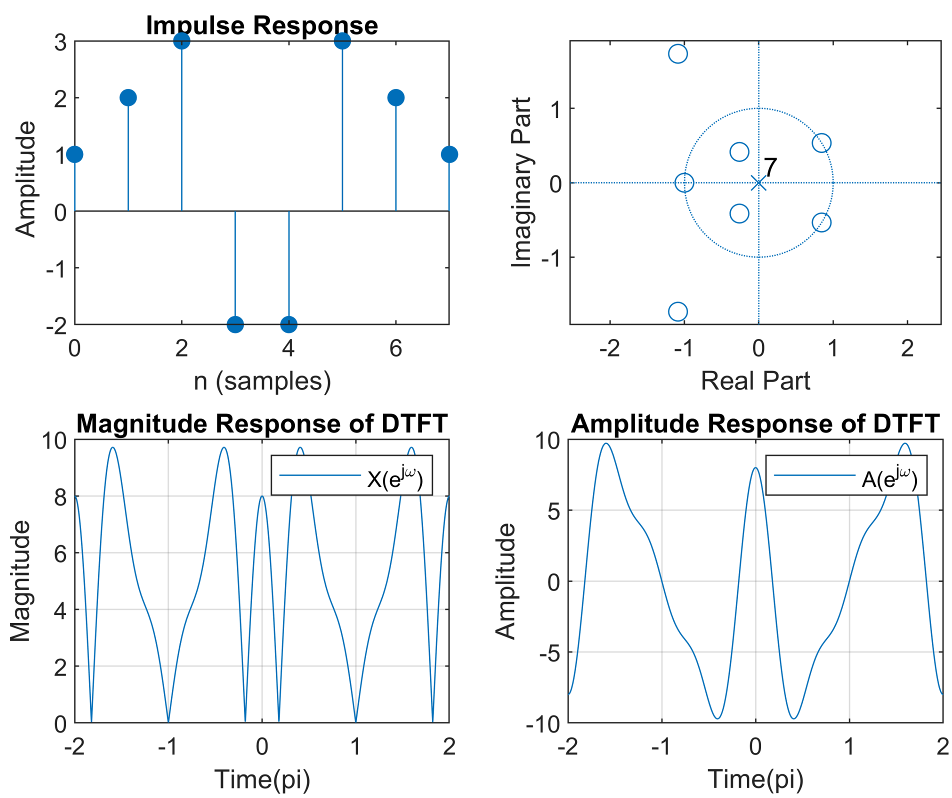
(b) Type-II filter: h[n] = {1, 2, 3, −2, −2, 3, 2, 1}.

```
close all; clear;
fprintf('7(b): Type II\n');
```

```
7(b): Type II
```

```

h2 = [1 2 3 -2 -2 3 2 1];
M = length(h2)-1;
om = linspace(-2*pi, 2*pi, 2048);

h2_amp = 0;
j = 0;
for i = (length(h2)/2):-1:1
    h2_amp = h2_amp + (2*h2(i)*cos((om.*0.5)+(j.*om)));
    j = j + 1;
end

h2_dtft = dtft12(h2, 0, om);

figure;

subplot(2,2,1); impz(h2, 1);

subplot(2,2,2); zplane(h2, 1);
```

```
subplot(2,2,3); plot(om/pi, abs(h2_dtft)); grid on;
title('Magnitude Response of DTFT');
legend('X(e^j^\omega)')
ylabel('Magnitude');
xlabel('Time(pi)');

subplot(2,2,4); plot(om/pi, h2_amp); grid on;
title('Amplitude Response of DTFT');
legend('A(e^j^\omega)')
ylabel('Amplitude');
xlabel('Time(pi)');
```



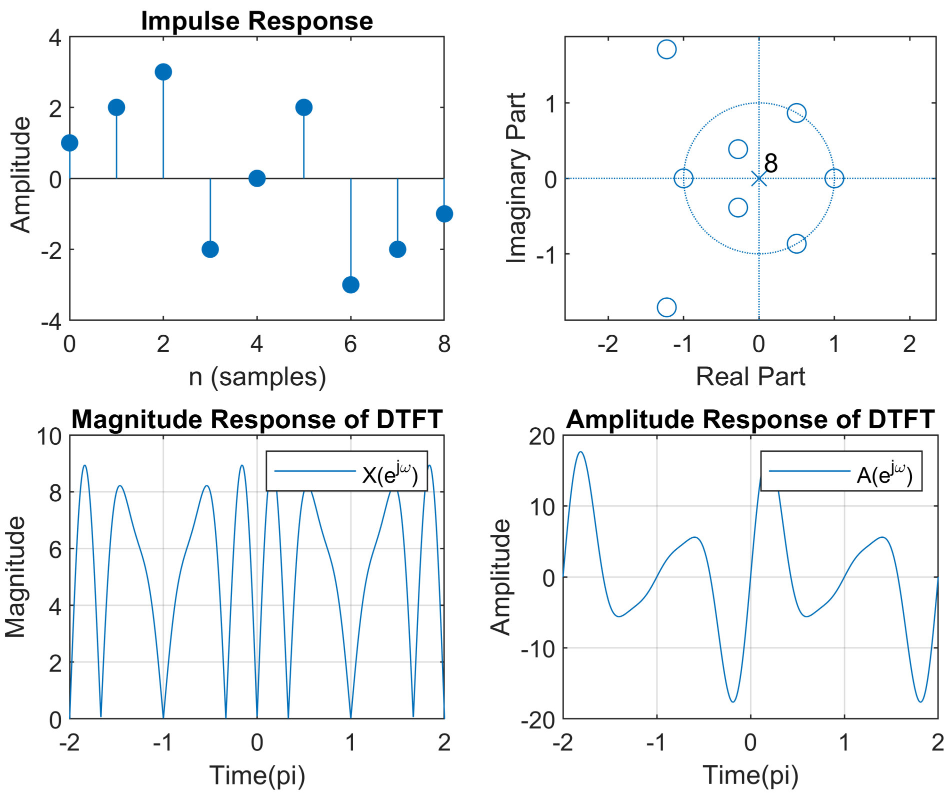
(c) Type-III filter: h[n] = {1, 2, 3, −2, 0, 2, −3, −2, −1}.

```
close all; clear;
fprintf('7(c): Type III\n');
```

```
7(c): Type III
```

```
h3 = [1 2 3 -2 0 2 -3 -2 -1];
M = length(h3)-1;
om = linspace(-2*pi, 2*pi, 2048);

c = zeros(1, M/2);
```

```
for i = 1:1:M/2
    c(i) = 2*h3((M/2)+1-i);
end

c_1 = zeros(1, (M/2));
c_1(M/2) = 2*c(M/2);
for i = ((M/2)-1):-1:2
    c_1(i) = 2*c(i) + c_1(i+1);
end
c_1(1) = 0.5*c_1(2) + c(1);

h3_amp = 0;
for i = 0:1:((M/2)-1)
    h3_amp = h3_amp + (c_1(i+1)*cos(om.*i));
end
h3_amp = h3_amp .* sin(om);

h3_dtft = dtft12(h3, 0, om);

figure;

subplot(2,2,1); impz(h3, 1);

subplot(2,2,2); zplane(h3, 1);

subplot(2,2,3); plot(om/pi, abs(h3_dtft)); grid on;
title('Magnitude Response of DTFT');
legend('X(e^j^\omega)')
ylabel('Magnitude');
xlabel('Time(pi)');

subplot(2,2,4); plot(om/pi, h3_amp); grid on;
title('Amplitude Response of DTFT');
legend('A(e^j^\omega)')
ylabel('Amplitude');
xlabel('Time(pi)');
```



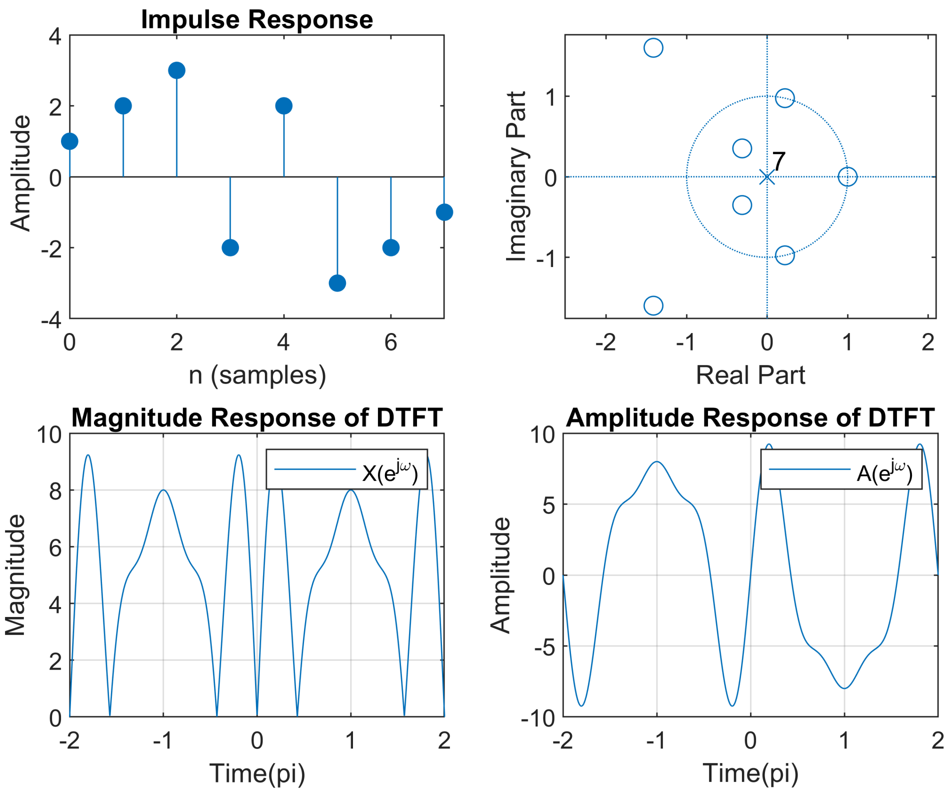
(d) Type-IV filter: h[n] = {1, 2, 3, −2, 2, −3, −2, −1 }.

```
close all; clear;
fprintf('7(d): Type IV\n');
```

```
7(d): Type IV
```

```

h4 = [1 2 3 -2 2 -3 -2 -1];
M = length(h4)-1;
om = linspace(-2*pi, 2*pi, 2048);

d = zeros(1, (M+1)/2);
for i = 1:1:(M+1)/2
    d(i) = 2*h4(((M+1)/2)+1-i);
end

d_1 = zeros(1, (M+1)/2);
d_1((M+1)/2) = 2*d((M+1)/2);
for i = ((M-1)/2):-1:2
    d_1(i) = 2*d(i) + d_1(i+1);
end
d_1(1) = 0.5*d_1(2) + d(1);

h4_amp = 0;
for i = 0:1:(M-1)/2
```

```
    h4_amp = h4_amp + (d_1(i+1)*cos(om.*i));
end
h4_amp = h4_amp .* sin(om./2);

h4_dtft = dtft12(h4, 0, om);

figure;

subplot(2,2,1); impz(h4, 1);

subplot(2,2,2); zplane(h4, 1);

subplot(2,2,3); plot(om/pi, abs(h4_dtft)); grid on;
title('Magnitude Response of DTFT');
legend('X(e^j^\omega)')
ylabel('Magnitude');
xlabel('Time(pi)');

subplot(2,2,4); plot(om/pi, h4_amp); grid on;
title('Amplitude Response of DTFT');
legend('A(e^j^\omega)')
ylabel('Amplitude');
xlabel('Time(pi)');
```



P8

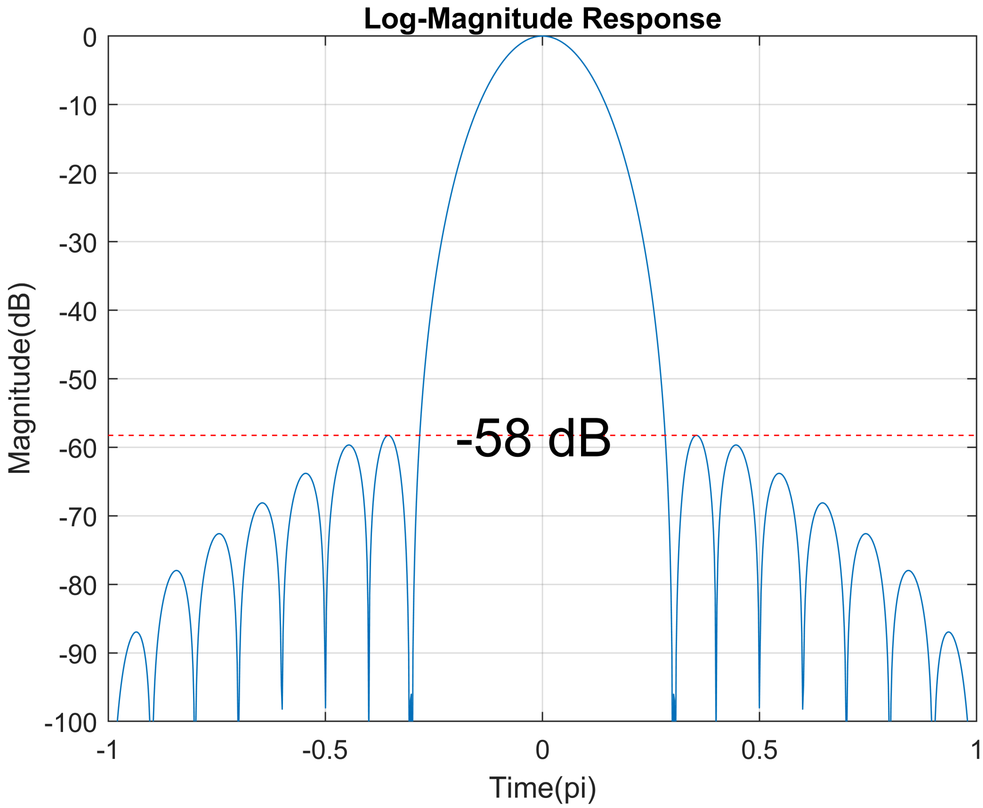
Consider a Blackman window of length L = 21.

(a) Compute and plot the log-magnitude response in dB over $-\pi \le \omega \le \pi$. In the plot measure and show the value of the peak of the first sidelobes.

```
close all; clear;
fprintf('8(a)\n');
```

```
8(a)
```

```

om = linspace(-pi, pi, 1024);
om_len = length(om);
L = 21; M = L - 1;
% blackm = 0.42 - 0.5*cos(2*pi*n/M) + 0.08*cos(4*pi*n/M);
blackm = blackman(L);
blackm_dtft = freqz(blackm, 1, om);
blackm_dtft = blackm_dtft./max(abs(blackm_dtft)); % nomorlize

[pks,locs] = findpeaks(20*log10(abs(blackm_dtft)),om);
sort_dtft = sort(pks,"descend");
sidelobe = sort_dtft(2);
text_8a = [int2str(sidelobe), ' dB'];

figure; plot(om/pi, 20*log10(abs(blackm_dtft))); grid on;
title('Log-Magnitude Response'); ylim([-100 0]);
line([om(1)/pi,om(om_len)/pi],[sidelobe,sidelobe],'linestyle','--', 'color', 'r');
text(-0.2,sidelobe,text_8a, 'Fontsize', 20);
ylabel('Magnitude(dB)');
xlabel('Time(pi)');
```




```
fprintf("Peak of the first sidelobes is %f dB (in Magnitude Response)", sidelobe);
```

```
Peak of the first sidelobes is -58.256904 dB (in Magnitude Response)
```

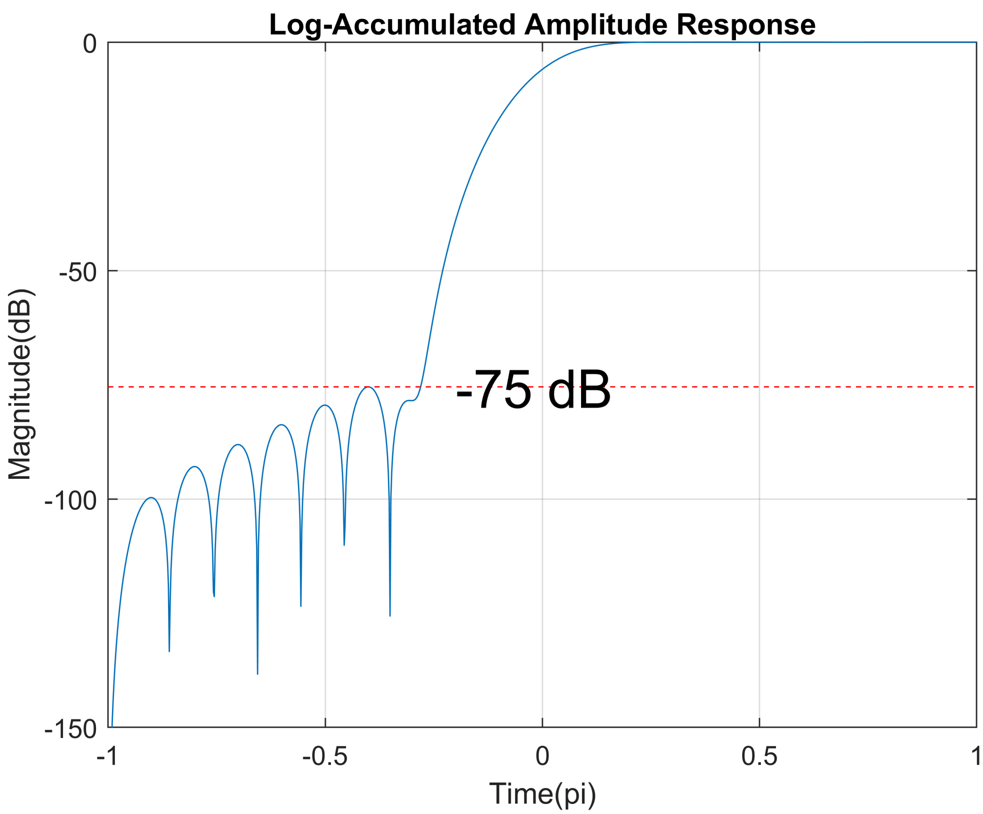
(b) Compute and plot the accumulated amplitude response in dB using the cumsum function. In the plot measure and show the value of the peak of the first sidelobe.

```
fprintf('8(b)\n');
```

```
8(b)
```

```
% Use Type I linear phase filter find amplitude response
blackm_amp = blackm((length(blackm)+1)/2);
j = 1;
for i = ((length(blackm)-1)/2):-1:1
    blackm_amp = blackm_amp + (2*blackm(i)*cos(om.*j));
    j = j + 1;
end

blackm_cum = cumsum(blackm_amp);
blackm_cum = blackm_cum ./ max(blackm_cum); % nomorlize

[pks,locs] = findpeaks(20*log10(abs(blackm_cum)),om);
```

```
sort_cum = sort(pks,"descend");
sidelobe_cum = sort_cum(5);
text_8b = [int2str(sidelobe_cum), ' dB'];

figure; plot(om/pi, 20*log10(abs(blackm_cum))); grid on;
title('Log-Accumulated Amplitude Response'); ylim([-150 0]);
line([om(1)/pi,om(om_len)/pi],[sidelobe_cum,sidelobe_cum],'linestyle','--', 'color', 'r');
text(-0.2,sidelobe_cum,text_8b, 'Fontsize', 20);
ylabel('Magnitude(dB)');
xlabel('Time(pi)');
```




```
fprintf("Peak of the first sidelobes is %f dB (in Amplitude Response)\n", sidelobe_cum);
```

```
Peak of the first sidelobes is -75.457425 dB (in Amplitude Response)
```

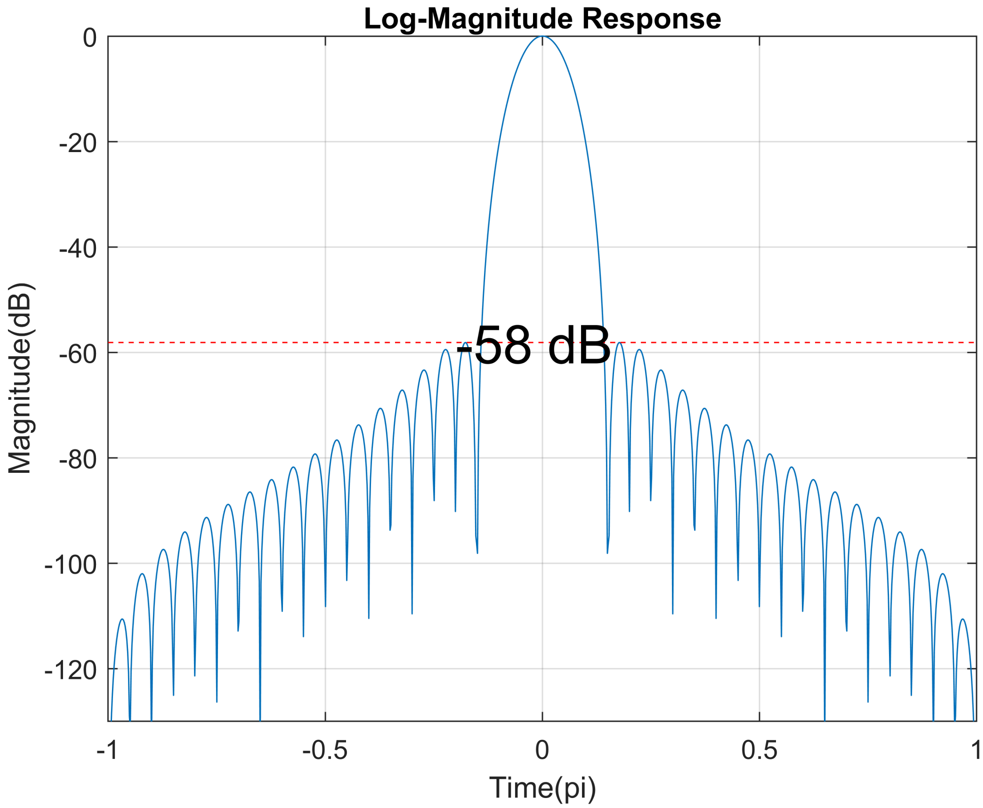
(c) Repeat (a) and (b) for L = 41.

```
close all; clear;
fprintf('8(c): L = 41\n');
```

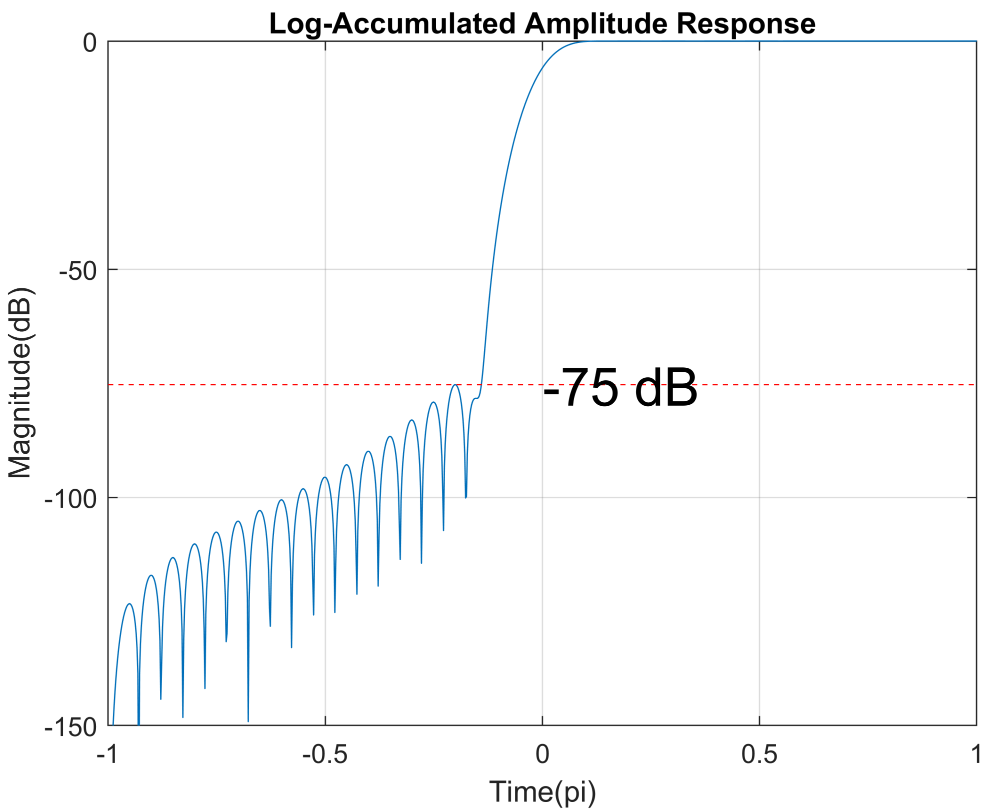
```
8(c): L = 41
```

```
om = linspace(-pi, pi, 1024);
om_len = length(om);
```

```
L = 41;
blackm = blackman(L);
blackm_dtft = freqz(blackm, 1, om);
blackm_dtft = blackm_dtft./max(abs(blackm_dtft)); % nomorlize

% Use Type I linear phase filter find amplitude response
blackm_amp = blackm((length(blackm)+1)/2);
j = 1;
for i = ((length(blackm)-1)/2):-1:1
    blackm_amp = blackm_amp + (2*blackm(i)*cos(om.*j));
    j = j + 1;
end

% Find the accumulated amplitude response
blackm_cum = cumsum(blackm_amp);
blackm_cum = blackm_cum ./ max(blackm_cum); % nomorlize

[pks,locs] = findpeaks(20*log10(abs(blackm_dtft)),om);
sort_dtft = sort(pks,"descend");
sidelobe = sort_dtft(2);
text_dtft = [int2str(sidelobe), ' dB'];

[pks,locs] = findpeaks(20*log10(abs(blackm_cum)),om);
sort_cum = sort(pks,"descend");
sidelobe_cum = sort_cum(10);
text_cum = [int2str(sidelobe_cum), ' dB'];

figure; plot(om/pi, 20*log10(abs(blackm_dtft))); grid on;
title('Log-Magnitude Response'); ylim([-130 0]);
line([om(1)/pi,om(om_len)/pi],[sidelobe,sidelobe],'linestyle','--', 'color', 'r');
text(-0.2,sidelobe,text_dtft, 'Fontsize', 20);
ylabel('Magnitude(dB)');
xlabel('Time(pi)');
```




```
figure; plot(om/pi, 20*log10(abs(blackm_cum))); grid on;
title('Log-Accumulated Amplitude Response'); ylim([-150 0]);
line([om(1)/pi,om(om_len)/pi],[sidelobe_cum,sidelobe_cum],'linestyle','--', 'color', 'r');
text(0,sidelobe_cum,text_cum, 'Fontsize', 20);
ylabel('Magnitude(dB)');
xlabel('Time(pi)');
```




```
fprintf("Peak of the first sidelobes is %f dB (in Magnitude Response)\n", sidelobe);
```

```
Peak of the first sidelobes is -58.119680 dB (in Magnitude Response)
```

```
fprintf("Peak of the first sidelobes is %f dB (in Amplitude Response)\n", sidelobe_cum);
```

```
Peak of the first sidelobes is -75.299049 dB (in Amplitude Response)
```

P9

An ideal lowpass filter has a cutoff frequency of ω_c = 0.4π. We want to obtain a length L = 40 linear-phase FIR filter using the frequency-sampling method.

(a) Let the sample at ω_c be equal to 0.5. Obtain the resulting impulse response h[n]. Plot the log-magnitude response in dB and determine the minimum stopband attenuation.

Ans:

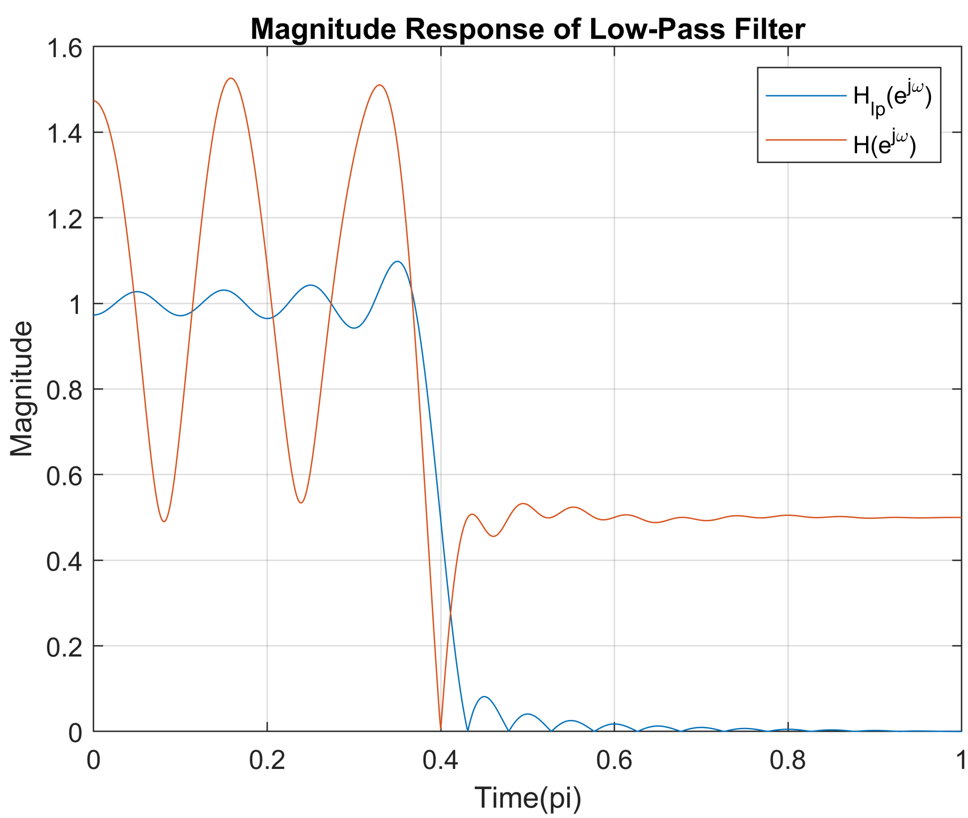
Stopband attenuation (dB): $A_S = -20\log_{10}(\delta_S)$

$$H_d[k] = H_d\left(e^{j\omega_c}\right) = H_d\left(e^{j2\pi\frac{k}{L}}\right) = H_d\left[L\frac{\omega_c}{2\pi}\right]$$

```
close all; clear;
fprintf('9(a)\n');
```

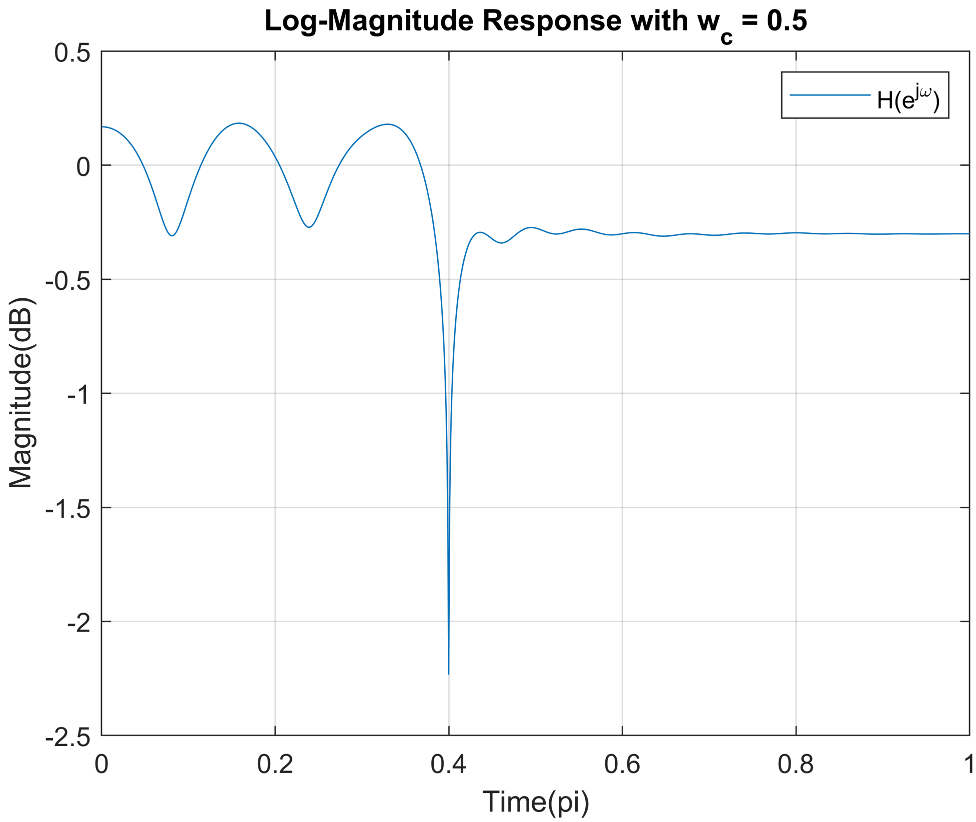
```
9(a)
```

```
om = linspace(0, pi, 1024);

L = 40; M = L-1; wc = 0.4*pi;
h_lp = ideallp(wc,L-1);
[hlp_dtft, wlp_dtft] = freqz(h_lp, 1, om);

h = h_lp;
% the sample at wc be equal to 0.5
h(L*wc/(2*pi)) = 0.5;
[h_dtft, w_dtft] = freqz(h, 1, om);

figure;
plot(wlp_dtft/pi, abs(hlp_dtft)); hold on; grid on;
plot(w_dtft/pi, abs(h_dtft)); hold off; grid on;
title('Magnitude Response of Low-Pass Filter');
legend('H_l_p(e^j^\omega)', 'H(e^j^\omega)');
ylabel('Magnitude');
xlabel('Time(pi)');
```




```
figure; plot(w_dtft/pi, log10(abs(h_dtft))); grid on;
```

```
title('Log-Magnitude Response with w_c = 0.5');
legend('H(e^j^\omega)');
ylabel('Magnitude(dB)');
xlabel('Time(pi)');
```




```
[pks,locs] = findpeaks(log10(abs(h_dtft)),w_dtft);
index_min = 0;
for i = 1:1:length(pks)
    if pks(i) <= 0
        index_min = i;
        break;
    end
end

fprintf("The minimum stopband attenuation is %f dB", -20*pks(index_min));
```

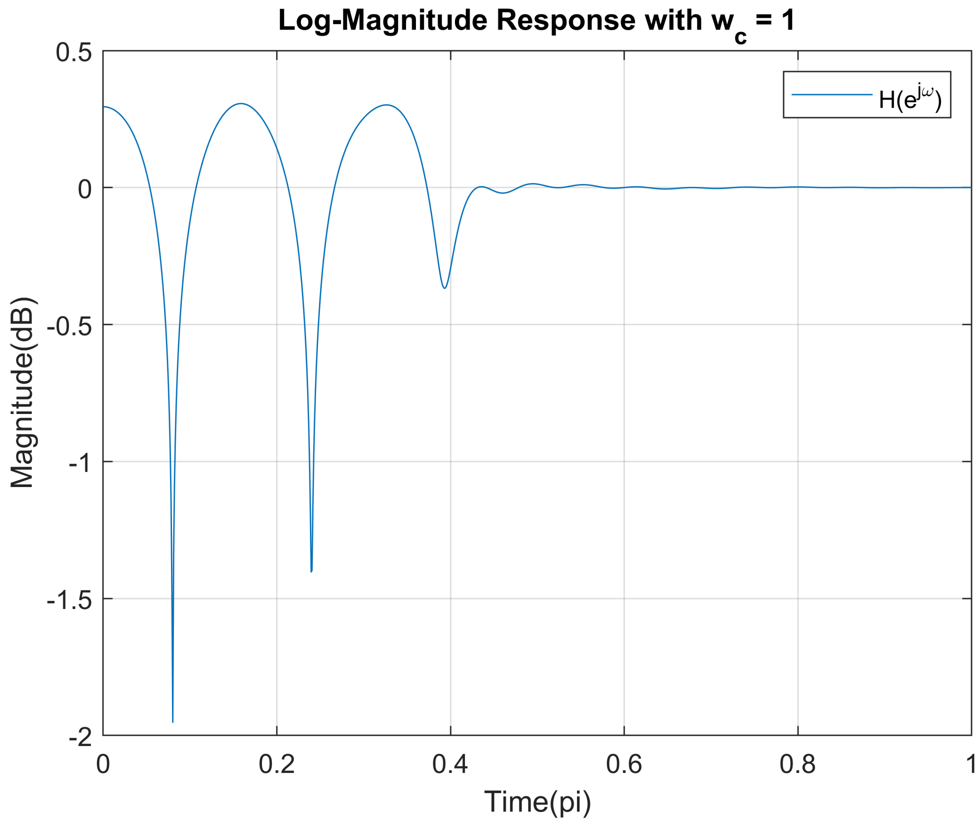
```
The minimum stopband attenuation is 5.890004 dB
```

(b) Now vary the value of the sample at ω_c and find the largest minimum stopband attenuation. Obtain the resulting impulse response h[n] and plot the log-magnitude response in dB in the plot window of (a).

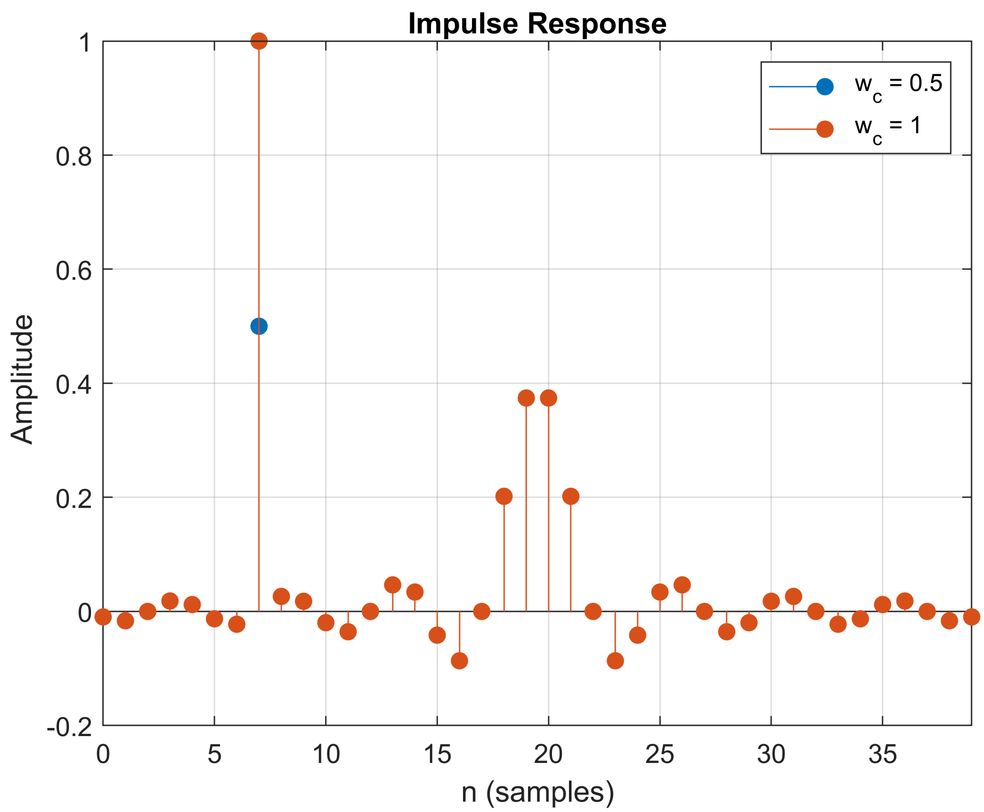
```
fprintf('9(b)\n');
```

```
9(b)
```

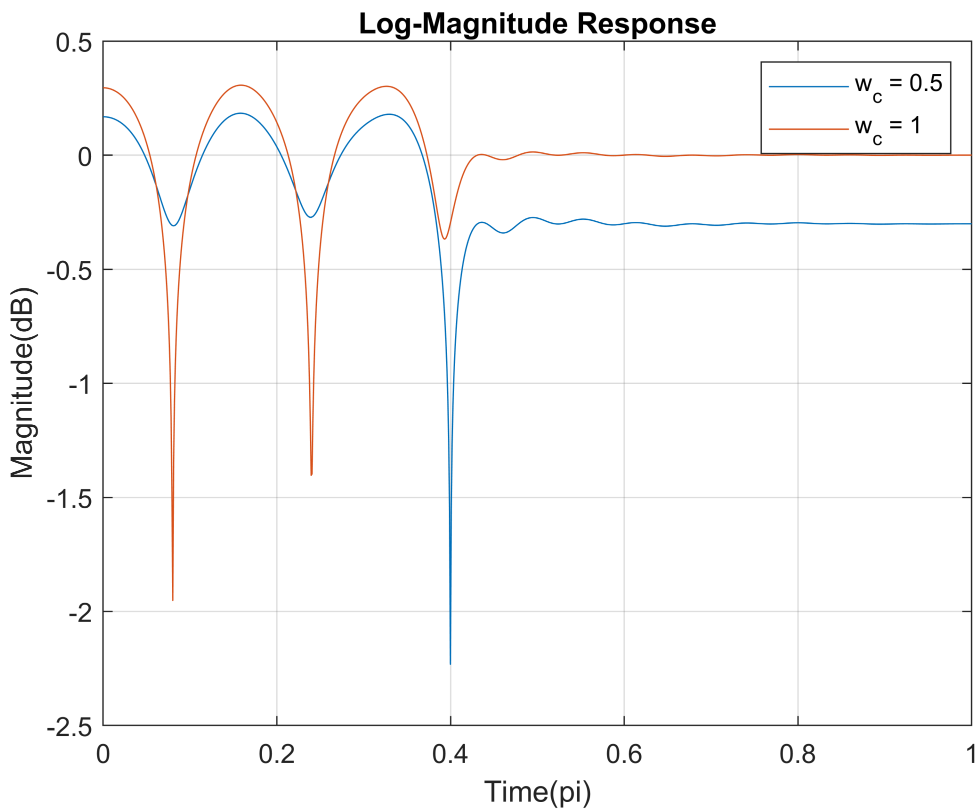
```
om = linspace(0, pi, 1024);

L = 40; wc = 0.4*pi;
h_lp = ideallp(wc,L-1);
[hlp_dtft, wlp_dtft] = freqz(h_lp, 1, om);

select_s = zeros(1, 3); % pk_value, wc_s, index
select_s(1) = -100;

for wc_s = 0: 0.05: 1
    hs = h_lp;
    % the sample at wc be equal to wc_s
    hs(L*wc/(2*pi)) = wc_s;
    [hs_dtft, ws_dtft] = freqz(hs, 1, om);
    [pkss,locss] = findpeaks(log10(abs(hs_dtft)),ws_dtft);
    indexs_min = 1;
    for i = 1:1:length(pkss)
        if pkss(i) <= 0.01
            indexs_min = i;
            break;
        end
    end
    if select_s(1) < pkss(indexs_min)
        select_s(1) = pkss(indexs_min);
        select_s(2) = wc_s;
        select_s(3) = indexs_min;
    end
end

hs = h_lp;
% the sample at wc be equal to wc_s
hs(L*wc/(2*pi)) = select_s(2);
[hs_dtft, ws_dtft] = freqz(hs, 1, om);

figure; plot(ws_dtft/pi, log10(abs(hs_dtft))); grid on;
title(['Log-Magnitude Response with w_c = ', num2str(select_s(2))]);
legend('H(e^j^\omega)');
ylabel('Magnitude(dB)');
xlabel('Time(pi)');
```




```
figure;
impz(h, 1); hold on; grid on;
impz(hs, 1); hold off; grid on;
title('Impulse Response');
legend(['w_c = 0.5'], ['w_c = ', num2str(select_s(2))]);
```




```
figure;
plot(w_dtft/pi, log10(abs(h_dtft))); hold on; grid on;
plot(ws_dtft/pi, log10(abs(hs_dtft))); hold off; grid on;
title('Log-Magnitude Response');
legend(['w_c = 0.5'], ['w_c = ', num2str(select_s(2))]);
ylabel('Magnitude(dB)');
xlabel('Time(pi)');
```




```
fprintf("The largest minimum stopband attenuation is %f dB", -20*select_s(1));
```

```
The largest minimum stopband attenuation is -0.059322 dB
```

(c) Compare your results with those obtained using the fir2 function (choose hamming window).

```
fprintf('9(c)\n');
```

```
9(c)
```

```
M1 = M + 1; % for M is even
h_fir = fir2(M1, w_dtft/pi, abs(h_dtft), hamming(M1+1));
hs_fir = fir2(M1, ws_dtft/pi, abs(hs_dtft), hamming(M1+1));

[h_fir_dtft, w_fir_dtft] = freqz(h_fir, 1, om);
[hs_fir_dtft, ws_fir_dtft] = freqz(hs_fir, 1, om);

[pks_fir,locs_fir] = findpeaks(log10(abs(h_fir_dtft)),w_fir_dtft);
index_min_fir = 0;
for i = 1:1:length(pks_fir)
    if pks_fir(i) <= 0
        index_min_fir = i;
        break;
```

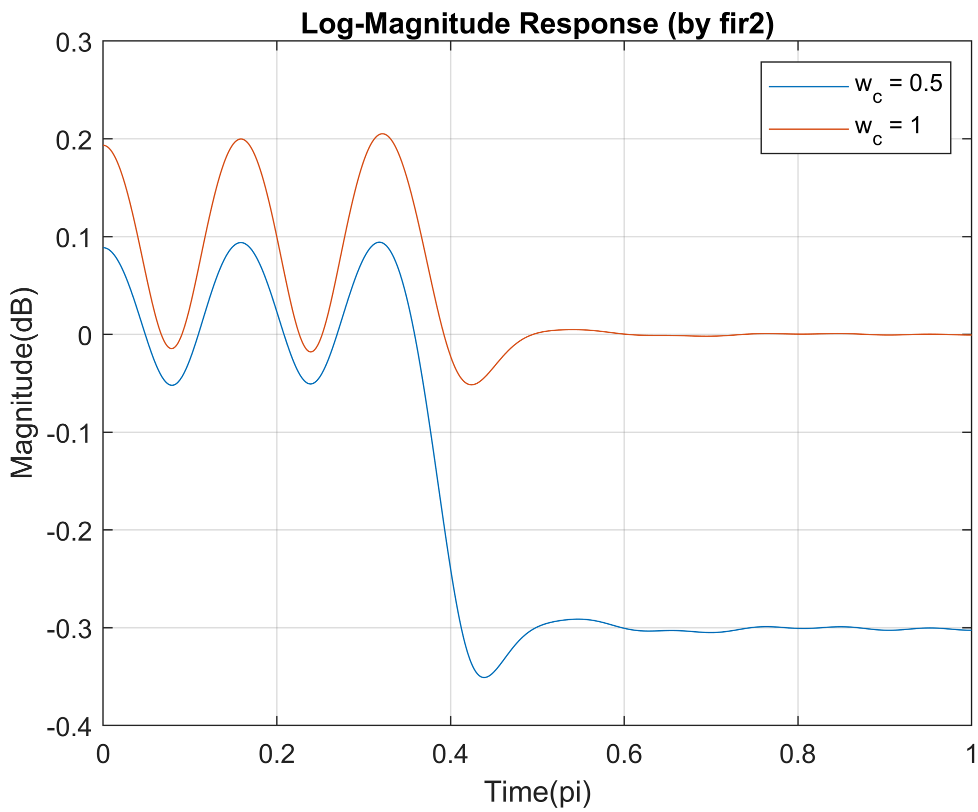
```
    end
end

[pkss_fir,locss_fir] = findpeaks(log10(abs(hs_fir_dtft)),ws_fir_dtft);
indexs_min_fir = 1;
for i = 1:1:length(pkss_fir)
    if pkss_fir(i) <= 0.01
        indexs_min_fir = i;
        break;
    end
end

fprintf("By fir2, A_s (with w_c = 0.5) is %f dB", -20*pks_fir(index_min_fir));
```

```
By fir2, A_s (with w_c = 0.5) is 5.824315 dB
```

```
fprintf("By fir2, the largest A_s (with w_c = %.1f) is %f dB", select_s(2), -20*pkss_fir(indexs
```

```
By fir2, the largest A_s (with w_c = 1.0) is -0.097305 dB
```

```


figure;
plot(w_fir_dtft/pi, log10(abs(h_fir_dtft))); hold on; grid on;
plot(ws_fir_dtft/pi, log10(abs(hs_fir_dtft))); hold off; grid on;
title('Log-Magnitude Response (by fir2)');
legend(['w_c = 0.5'], ['w_c = ', num2str(select_s(2))]);
ylabel('Magnitude(dB)');
xlabel('Time(pi)');
```



We can find that the signals of Log-magnitude Response after processing by function fir2 are smoother than the original version, and the values of minimum stopband attenuation are quite similar to the results before using fir2.