Contents

Bandpass Filter Design: Lab P-14: 4 Lab Exercise

```
clc
clear
close all
```

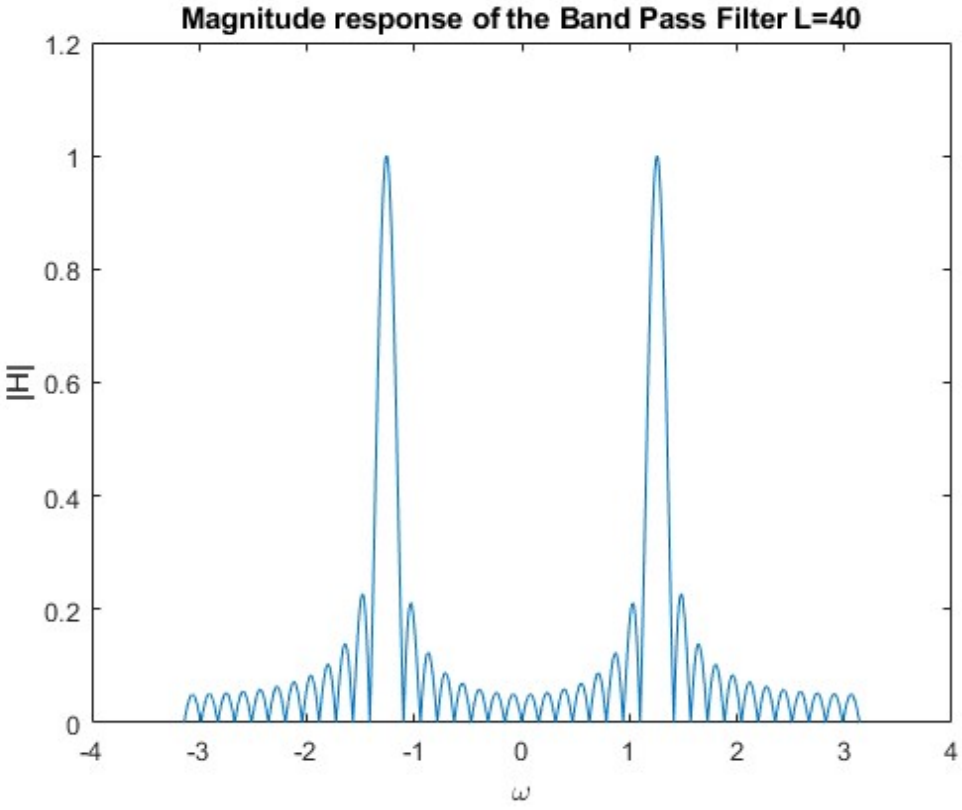
4.1

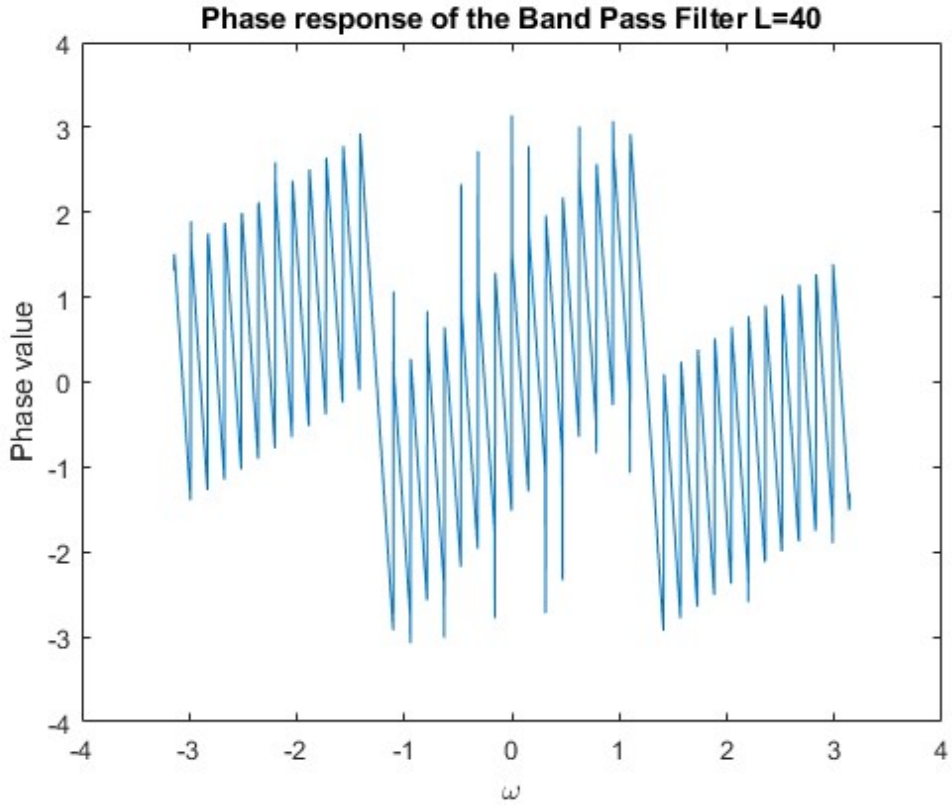
```
W = 0.4*pi;                 % Center frequency definition
WW = -pi:(pi/1000):pi;      % frequency range
```

4.1a)

```
L = 40;                     % Window length setup

h_40 = BPF(L, W);           % Band Pass filter with the length of 40
HH_40 = freqz(h_40, 1 ,WW);

figure
plot(WW, abs(HH_40));
title('Magnitude response of the Band Pass Filter L=40')
xlabel('\omega')
ylabel('|H|')
```

```
figure
plot(WW, angle(HH_40));
title('Phase response of the Band Pass Filter L=40')
xlabel('\omega')
ylabel('Phase value')
```


Magnitude response of the Band Pass Filter L=40
|H|
ω
1.2
1
0.8
0.6
0.4
0.2
0
-4
-3
-2
-1
0
1
2
3
4


Phase response of the Band Pass Filter L=40
Phase value
ω
4
3
2
1
0
-1
-2
-3
-4
-4
-3
-2
-1
0
1
2
3
4

4.1b)

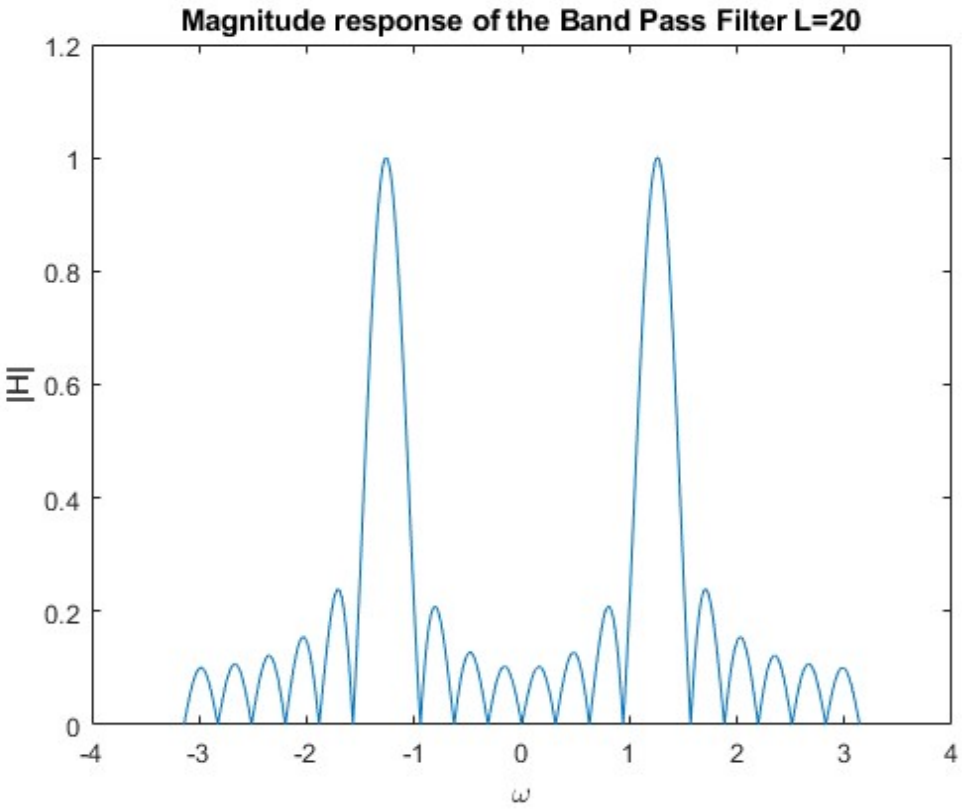
```
PB_40 = zeros(size(HH_40));
for i=1:length(HH_40)
    if abs(HH_40(i)) >= 0.5
        PB_40(i) = abs(HH_40(i));
    else
        PB_40(i) = 0;
    end
end

NUmnz_40 = nnz(PB_40)/2;    % non zero element of PB vector for L = 40
fprintf("Bandpass Width (L=%d) is %d\n", L, NUmnz_40);
```

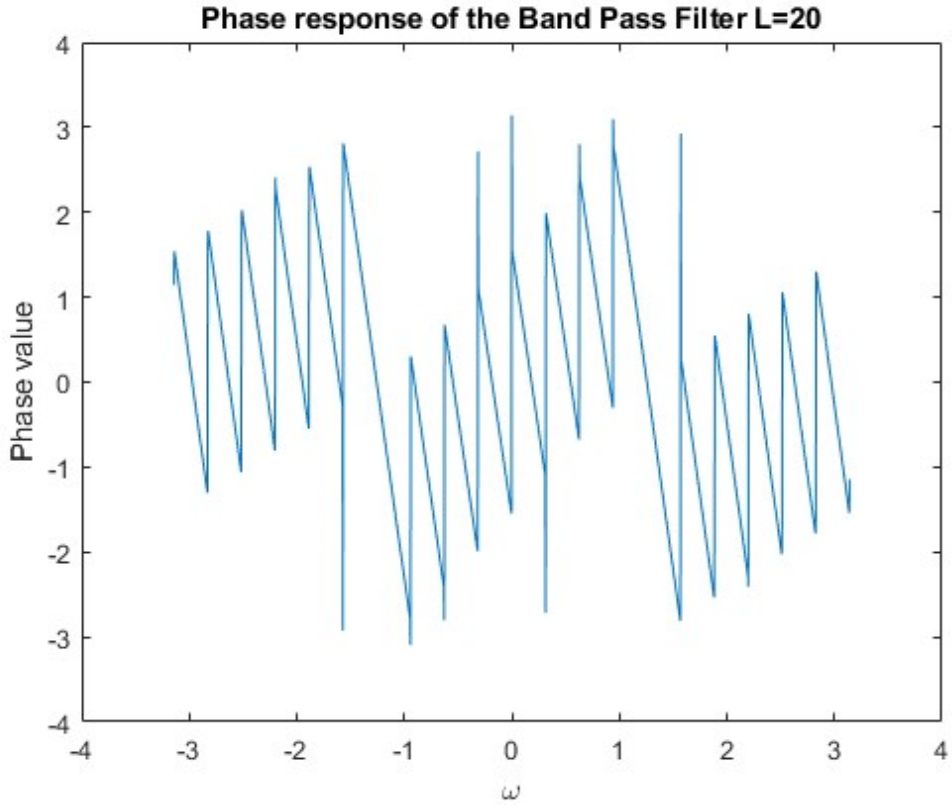
```
Bandpass Width (L=40) is 60
```

4.1c.1) L = 20

```
L = 20;                     % Window length setup

h_20 = BPF(L, W);           % Band Pass filter with the length of 20
HH_20 = freqz(h_20, 1, WW);

figure
plot(WW, abs(HH_20));
title('Magnitude response of the Band Pass Filter L=20')
xlabel('\omega')
ylabel('|H|')

figure
plot(WW, angle(HH_20));
title('Phase response of the Band Pass Filter L=20')
xlabel('\omega')
ylabel('Phase value')

PB_20 = zeros(size(HH_20));
for i=1:length(HH_20)
    if abs(HH_20(i)) >= 0.5
        PB_20(i) = abs(HH_20(i));
    else
        PB_20(i) = 0;
    end
end

NUmnz_20 = nnz(PB_20)/2;    % non zero element of PB vector for L = 20
fprintf("Bandpass Width (L=%d) is %d\n", L, NUmnz_20);
```

```
Bandpass Width (L=20) is 121
```

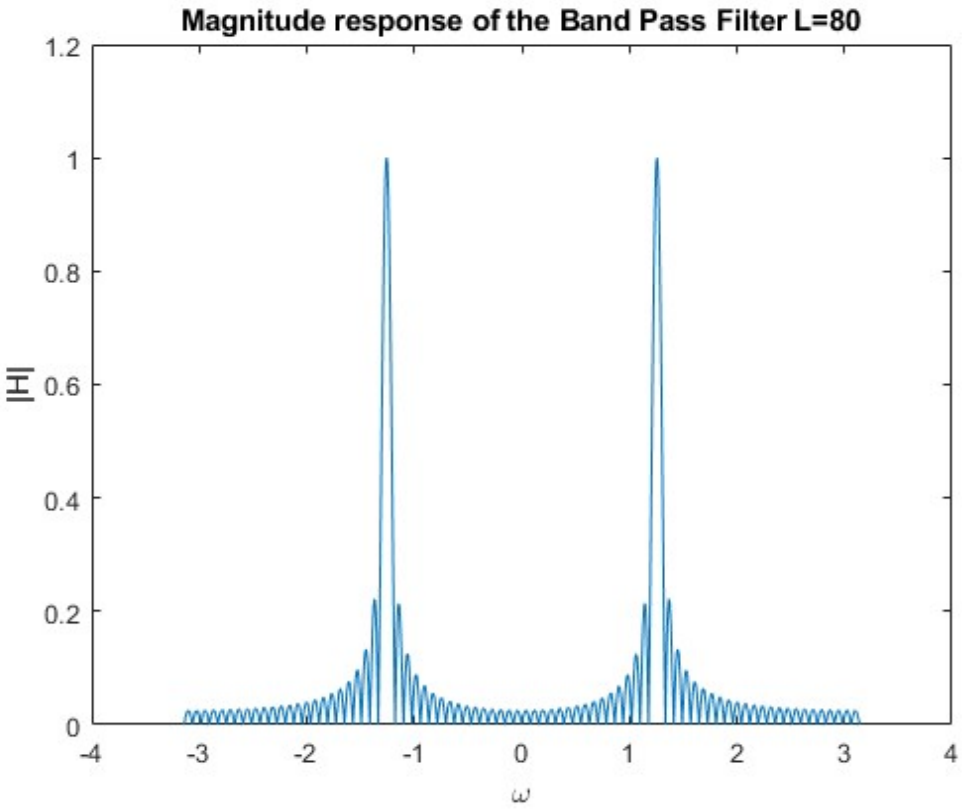

Magnitude response of the Band Pass Filter L=20
|H|
ω
1.2
1
0.8
0.6
0.4
0.2
0
-4
-3
-2
-1
0
1
2
3
4

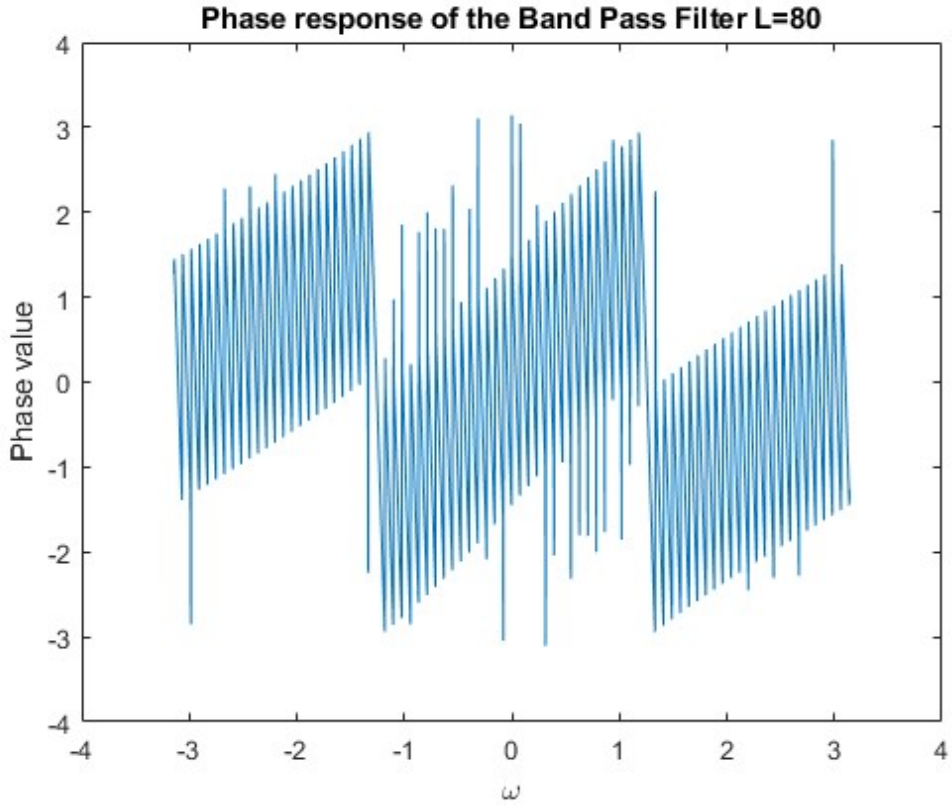

Phase response of the Band Pass Filter L=20
Phase value
ω
4
3
2
1
0
-1
-2
-3
-4
-4
-3
-2
-1
0
1
2
3
4

4.1c.2) L = 80

```
L = 80;                     % Window length setup

h_80 = BPF(L, W);           % Band Pass filter with the length of 80
HH_80 = freqz(h_80, 1, WW);

figure
plot(WW, abs(HH_80));
title('Magnitude response of the Band Pass Filter L=80')
xlabel('\omega')
ylabel('|H|')

figure
plot(WW, angle(HH_80));
title('Phase response of the Band Pass Filter L=80')
xlabel('\omega')
ylabel('Phase value')

PB_80 = zeros(size(HH_80));
for i=1:length(HH_80)
    if abs(HH_80(i)) >= 0.5
        PB_80(i) = abs(HH_80(i));
    else
        PB_80(i) = 0;
    end
end

NUmnz_80 = nnz(PB_80)/2;     % non zero element of PB vector for L = 80
fprintf("Bandpass Width (L=%d) is %d\n", L, NUmnz_80);
```

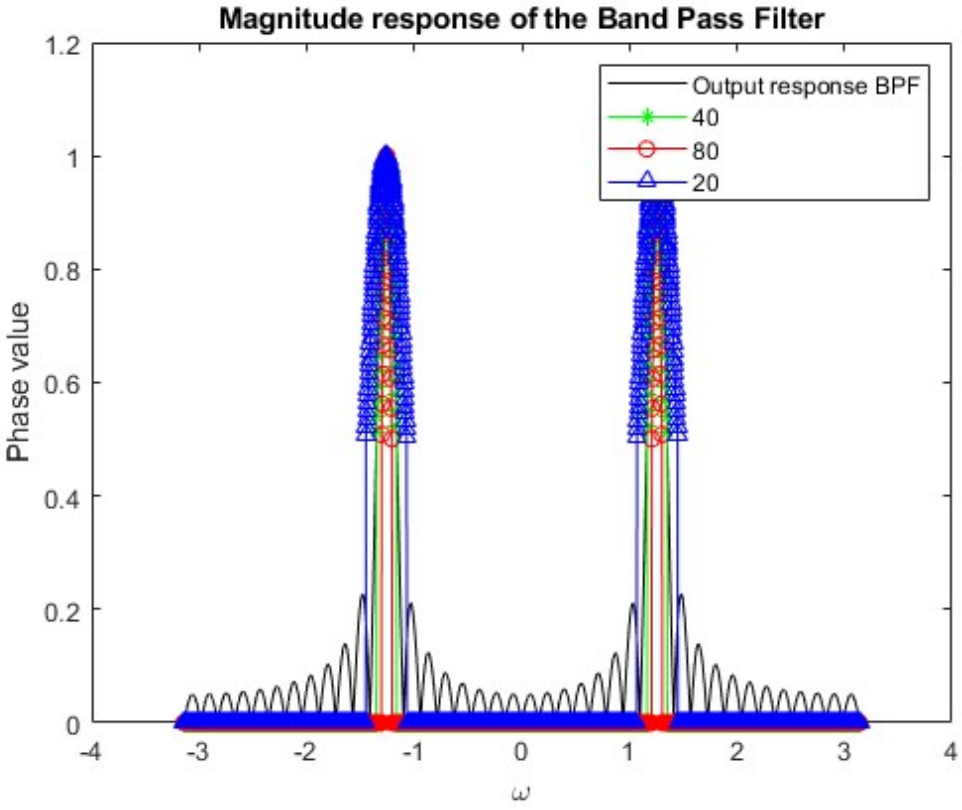
```
Bandpass Width (L=80) is 31
```

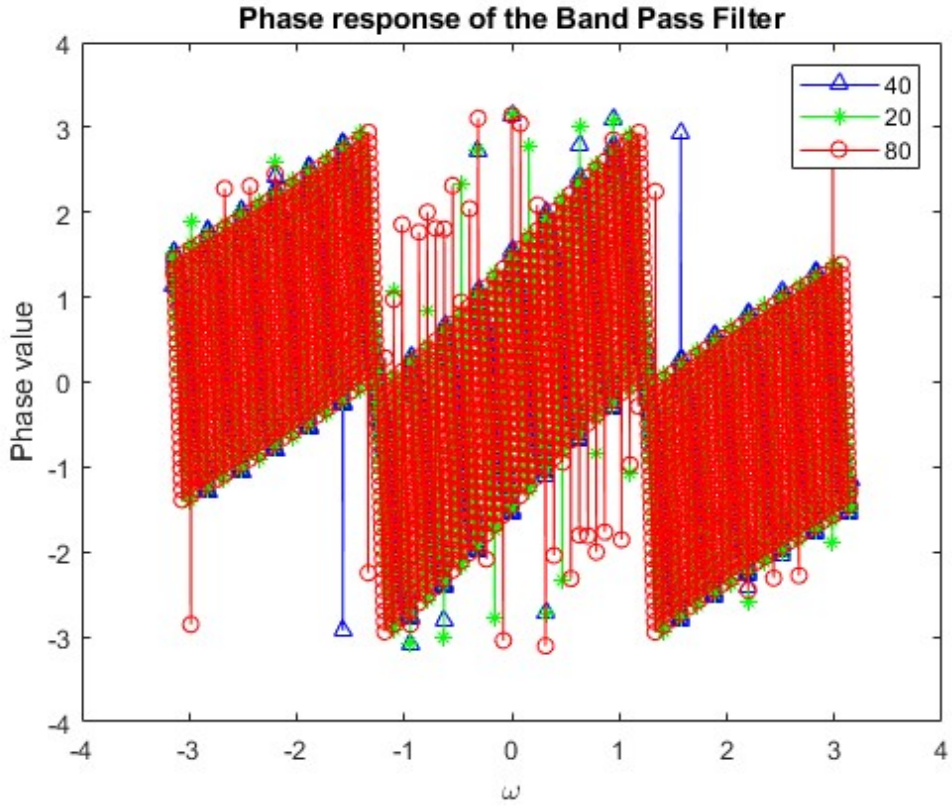

Magnitude response of the Band Pass Filter L=80
|H|
ω
1.2
1
0.8
0.6
0.4
0.2
0
-4
-3
-2
-1
0
1
2
3
4


Phase response of the Band Pass Filter L=80
Phase value
ω
4
3
2
1
0
-1
-2
-3
-4
-4
-3
-2
-1
0
1
2
3
4

4.1c.3) Comparison of 20, 40, 80

```
figure;
plot(WW,abs(HH_40),'k')
hold on
plot(WW, PB_40, 'g-*', WW, PB_80, 'r-o', WW, PB_20, 'b-^')
title('Magnitude response of the Band Pass Filter')
xlabel('\omega'); ylabel('Phase value')
legend('Output response BPF','40','80','20')


figure;
plot(WW, angle(HH_20), 'b-^', ...
     WW, angle(HH_40), 'g-*', ...
     WW, angle(HH_80), 'r-o')
title('Phase response of the Band Pass Filter')
xlabel('\omega'); ylabel('Phase value')
legend('40','20','80');
```


Magnitude response of the Band Pass Filter
Output response BPF
40
80
20
Phase value
ω


Phase response of the Band Pass Filter
40
20
80
Phase value
ω

4.1c.4) What happens when L is doubled or halved?

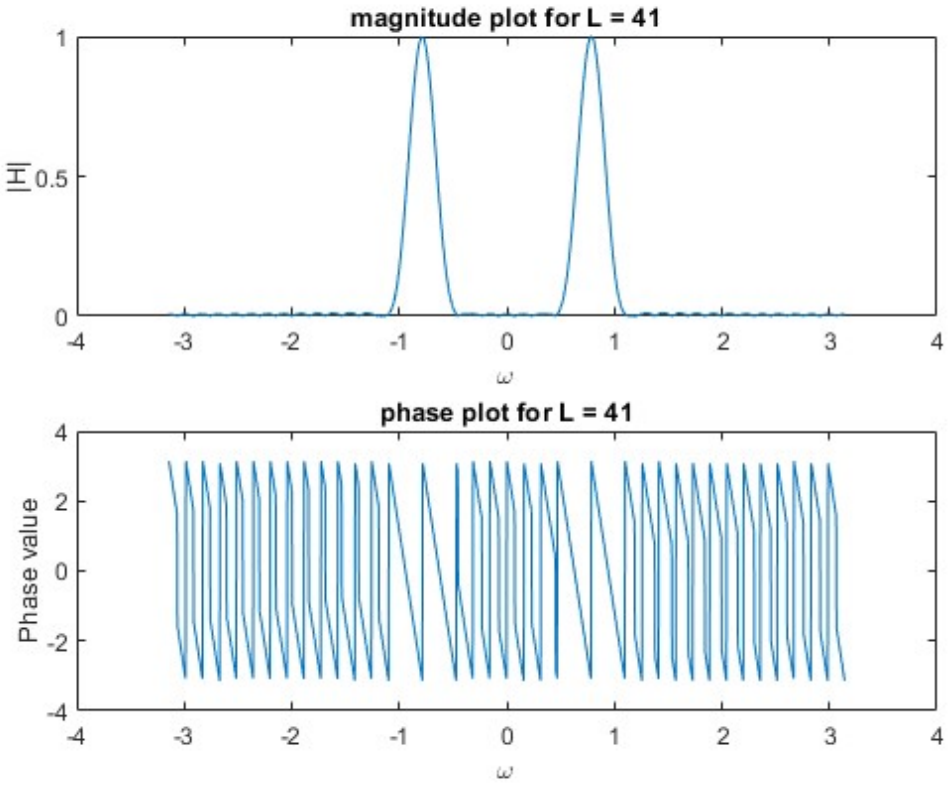
When L is doubled the pass band width is halved. When L is halved the pass band width is doubled.

4.2

```
w_hat = 0.25*pi;
```

4.2a

```
L=41;
pause(1)
HH = p4sub(L, w_hat);
```



4.2b.1 L=41

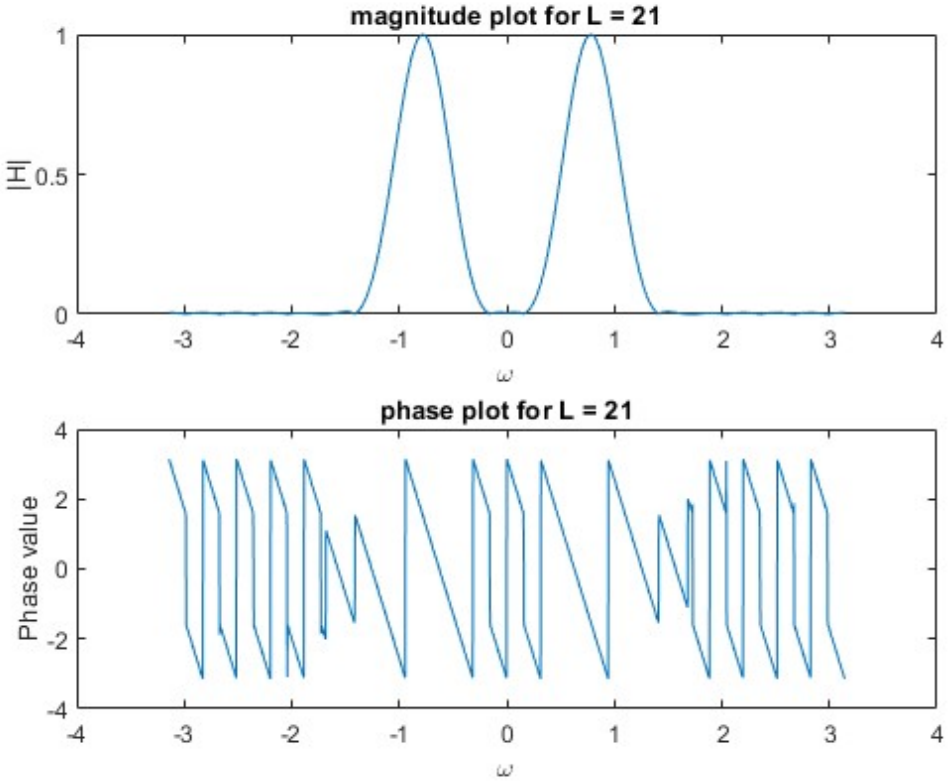
```
determinePassBand(L, HH);
```

```
Pass band width=0.279602 radians for L = 41
```

4.2b.2 L=21

```
L=21;
HH = p4sub(L, w_hat);
determinePassBand(L, HH);
```

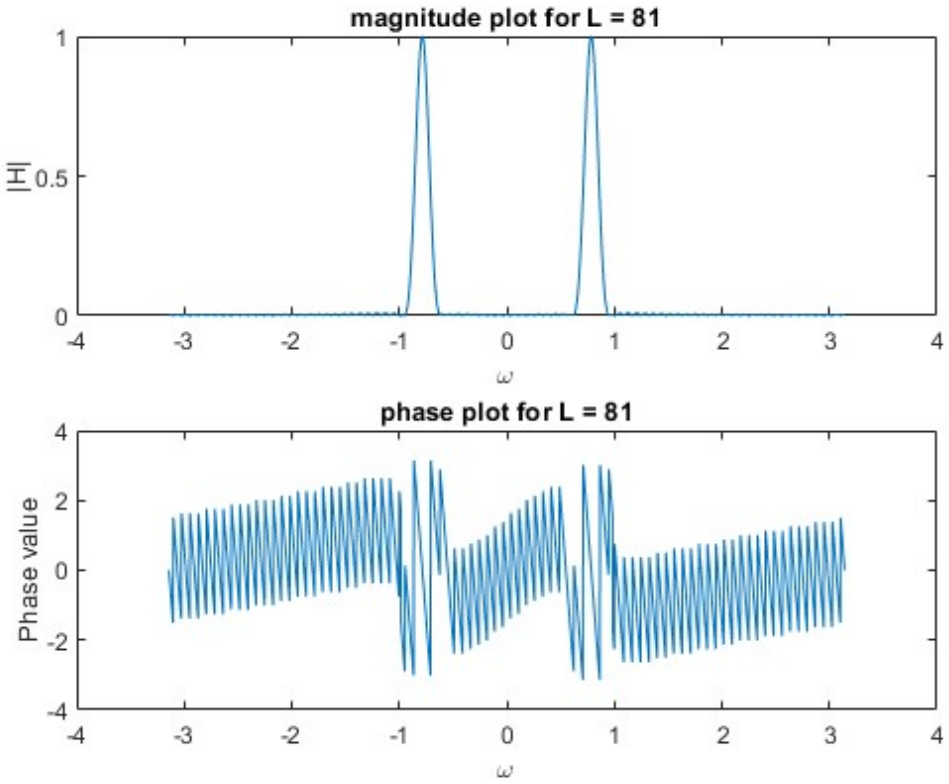
```
Mag & Phase Response of Frequencies of Interests (L=21)
   w    |   mag    |   phase
0.000pi | 0.005499 | -3.110177
0.100pi | 0.104399 | -3.110177
0.250pi | 1.000601 | -1.539380
0.400pi | 0.121711 | 0.031416
0.500pi | 0.005508 | 0.031416
0.750pi | 0.000164 | 1.602212
Pass band width=0.568628 radians for L = 21
```



4.2b.3 L=81

```
L=81;
HH = p4sub(L, w_hat);
determinePassBand(L, HH);
```

```
Mag & Phase Response of Frequencies of Interests (L=81)
   w    |   mag    |   phase
0.000pi | 0.003661 | 0.125664
0.100pi | 0.004098 | 0.125664
0.250pi | 0.999627 | 0.125664
0.400pi | 0.002718 | 0.125664
0.500pi | 0.003043 | 0.125664
0.750pi | 0.003437 | 0.125664
Pass band width=0.141372 radians for L = 81
```



4.2c

```
fprintf("x[n] = %f + %fcos(0.1pi*n + %f) + %fcos(0.25pi*n + %f)\n", ...
    2 * 0.007350, 2 * 0.007290, pi/3-3.078761, 1.001234, -pi/3 - 3.078761);

% the magnitude of the first two terms is almost zero because they are in
% the stop band
% the magnitude of the last term is almost one because it is in the pass
% band
```

```
x[n] = 0.014700 + 0.014580cos(0.1pi*n + -2.031563) + 1.001234cos(0.25pi*n + -4.125959)
```

4.2d

The magnitude response of the filter is approximately 1 at 0.25pi This means that the magnitude of the response will be scaled by approximately 1 at the frequency on the other hand, the magnitude is approximately 0 away from 0.25 pi This means that the magnitude of the response will be approximately 0 for frequencies away from 0.25pi

4.2 Functions

```
function HH = p4sub(L, w_hat)
    w = -pi:(pi/1000):pi;

    h = gen_hamming(w_hat, L);
    HH = freqz(h, 1, w);

    figure
    subplot(2,1,1);
    plot(w, abs(HH));
    xlabel('\omega'); ylabel('|H|');
    title(sprintf("magnitude plot for L = %d", L))

    subplot(2,1,2);
    plot(w, angle(HH));
    xlabel('\omega'); ylabel('Phase value')
    title(sprintf("phase plot for L = %d", L))

    foi = [0, 100, 250, 400, 500, 750];     % Frequencies of Interest

    fprintf("Mag & Phase Response of Frequencies of Interests (L=%d)\n", L);
    fprintf("   w    |   mag    |   phase\n");
    for i = foi
         fprintf("0.%03dpi | %.6f | %.6f \n", i, abs(HH(1000+i)), angle(HH(1000+i)));
    end
end


function width = determinePassBand(L, HH)
    width = nnz(abs(HH) > 0.5) / 2;
    fprintf("Pass band width=%f radians for L = %d\n\n", width * pi/1000, L);
end
```

```
Mag & Phase Response of Frequencies of Interests (L=41)
   w    |   mag    |   phase
0.000pi | 0.007350 | -3.078761
0.100pi | 0.007290 | -3.078761
0.250pi | 1.001234 | -3.078761
0.400pi | 0.006967 | -3.078761
0.500pi | 0.006841 | -3.078761
0.750pi | 0.007136 | -3.078761
```

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