7. FIR Filter Design

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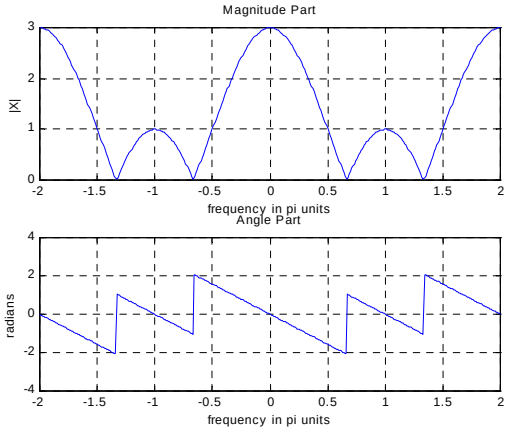
Magnitude Response & Amplitude Response

例： **h[n]=[1 1 1] n=[0 1 2];**

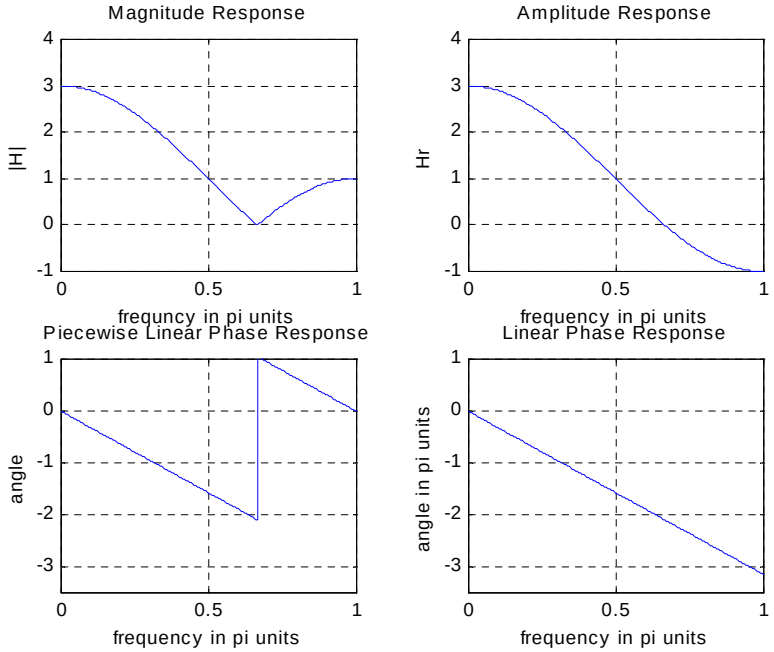
＊ **Plot DTFT:**

Matlab1: n=[0 1 2]; h=[1 1 1]; [X]=plot_dtft(h,n);



＊ **Magnitude Response & Amplitude Response**

```
w = 0:0.001:pi;
magh1=1+2*cos(w);
H1=abs(magh1);
w1=[0:0.001:2*pi/3]; w2=[2*pi/3:0.001:pi];
phaha=-w1; phahb=pi-w2;
wc=[w1,w2];
w3=[-pi:0.001:pi];
pha=[phaha,phahb];
subplot(2,2,1),plot(w/pi,H1);grid;axis([0,1,-1,4]);
xlabel('frequncy in pi units'); ylabel('|H|')
title('Magnitude Response')
subplot(2,2,2),plot(w/pi,magh1);grid;axis([0,1,-1,4]);
xlabel('frequency in pi units'); ylabel('Hr');
title('Amplitude Response')
subplot(2,2,3),plot(wc/pi,pha);grid; axis([0,1,-3.5,1]);
xlabel('frequency in pi units'); ylabel('angle');
title('Piecewise Linear Phase Response')
subplot(2,2,4),plot(w/pi,-w);grid;axis([0,1,-3.5,1]);
xlabel('frequency in pi units'); ylabel('angle ');
title('Linear Phase Response')
```


Magnitude Response
|H|
frequncy in pi units
Amplitude Response
Hr
frequency in pi units
Piecewise Linear Phase Response
angle
frequency in pi units
Linear Phase Response
angle in pi units
frequency in pi units

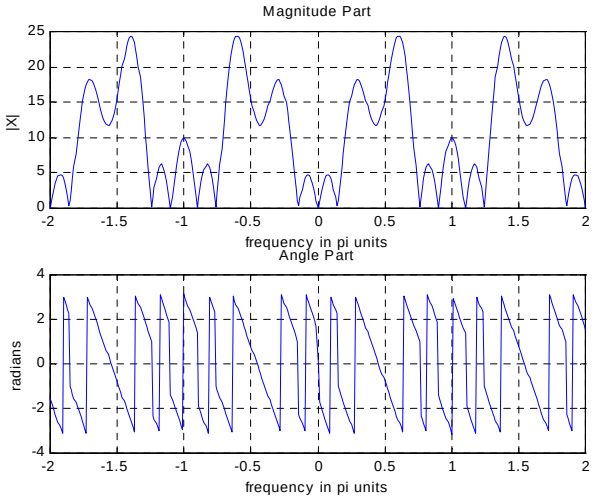
＊ 計算四種 LP FIR Filter Amplitude Response

```
function [Hr,w,a,L] = Hr_Type124(h)
% Compute Amplitude response Hr(w) of a Type-1 to Type-4 LP FIR filter
M = length(h);    w = [0:1:500]'*pi/500;
if ((mod(M,2)==1)&(h(1)==h(M)))
  L = (M-1)/2;
  a = [h(L+1) 2*h(L:-1:1)]; % 1x(L+1) row vector
  n = [0:1:L];                          % (L+1)x1 column vector
  Hr = cos(w*n)*a';
   elseif ((mod(M,2)==0)&(h(1)==h(M)))
   L = M/2;
   a = 2*[h(L:-1:1)];
   n = [1:1:L]; n=n-0.5;
   Hr = cos(w*n)*a';
      elseif ((mod(M,2)==1)&(h(1)== (-h(M))))
        L = (M-1)/2;
        a = [2*h(L+1:-1:1)];
          n = [0:1:L];
      Hr = sin(w*n)*a';
         elseif ((mod(M,2)==0)&(h(1)== (-h(M))))
           L = M/2;
           a = 2*[h(L:-1:1)];
           n = [1:1:L]; n=n-0.5;
         Hr = sin(w*n)*a';
end
```

例： h[n]=[-4,1,-1,-2,5,6,-6,-5,2,1,-1,4]; n=0:1:11;

＊ **Plot DTFT:**

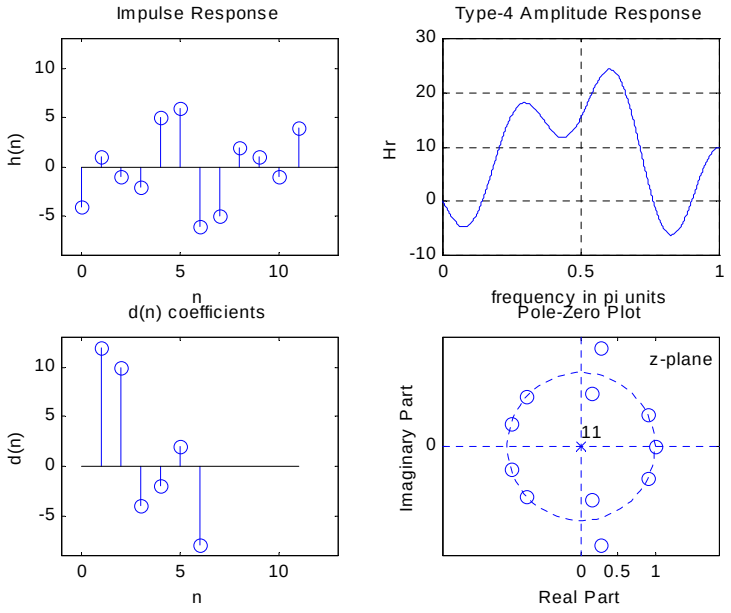
Matlab1: n=0:1:11; h=[-4,1,-1,-2,5,6,-6,-5,2,1,-1,4]; [X]=plot_dtft(h,n);



＊ 決定「振幅」響應 **Hr(w)**和 **H(z)**的零點位置

Matlab: h = [-4,1,-1,-2,5,6,-6,-5,2,1,-1,4];

```
M = length(h); n=0:M-1;
[Hr,w,d,L] = Hr_Type124(h);
d,L
dmax=max(d)+1; dmin=min(d)-1;
k=0:20;
xa=0.*k; xb=0.*n;
subplot(2,2,1); stem(n,h); axis([-1 2*L+1 dmin dmax])
xlabel('n'); ylabel('h(n)'); title('Impulse Response')
hold on
plot(k,xa,'k');
hold off
subplot(2,2,3); stem(1:L,d); axis([-1 2*L+1 dmin dmax])
xlabel('n'); ylabel('d(n)'); title('d(n) coefficients')
hold on
plot(n,xb,'k');
hold off
subplot(2,2,2); plot(w/pi,Hr); grid;
xlabel('frequency in pi units'); ylabel('Hr');
title('Type-4 Amplitude Response')
subplot(2,2,4); zplane(h,1)
set(gca,'XTickMode','manual','XTick',[0,0.5,1]);
set(gca,'YTickMode','manual','YTick',[-20:10:30]);
title('Pole-Zero Plot');
gtext('z-plane');
```



FIR Filter Design Example

＊ 使用函式

function hd = ideal_lp(wc,M); % 可計算出理想低通濾波器之脈衝響應 (可給定點數)

```
% Ideal LowPass filter computation
alpha=(M-1)/2;
n=[0:1:(M-1)];
m=n-alpha+eps;                    % add smallest number to avoid divide by zero
hd=sin(wc*m) ./ (pi*m);
```

function [db,mag,pha,grd,w] = freqz_m(b,a);

```
% Modified version of freqz subroutine
% ----------------------------------
% [db,mag,pha,grd,w] = freqz_m(b,a)
%    db = Relative magnitude in dB computed over 0 to pi radians
% mag = absolute magnitude computed over 0 to pi radians
% pha = Phase response in radinas over 0 to pi radians
% grd = Group delay over 0 to pi radians
%      w = 501 frequnecy samples between 0 to pi radians
%      b = numerator polynomial of H(z)    (for FIR: b=h)
%      a = denominator polynomial of H(z)    (for FIR: a=[1])
[H,w] = freqz(b,a,1000,'whole');    % 0~2*pi 分 1001 點，或說 0~pi 分 501 點
H = (H(1:1:501))'; w = (w(1:1:501))';
mag = abs(H);
db = 20*log10((mag+eps)/max(mag));    % 取 Magnitude Response in dB
pha = angle(H);
grd = grpdelay(b,a,w);    % 計算 Group Delay Response
```

例： 設計一具以下規格之 **FIR LP Filter**

wp=0.2π Rp=0.25dB ws=0.3π As=50dB

Matlab:

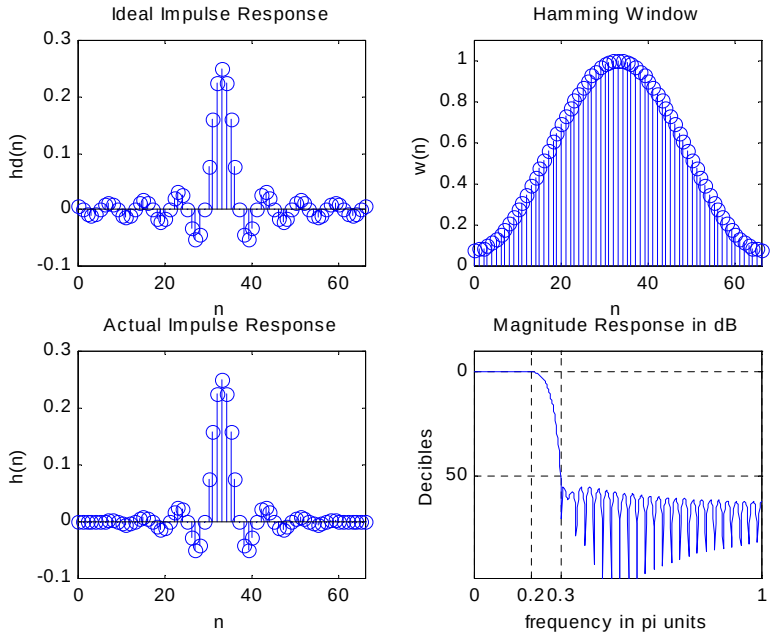
```
wp = 0.2*pi; ws = 0.3*pi;
tr_width = ws - wp;
M = ceil(6.6*pi/tr_width) + 1
n=[0:1:M-1];
wc = (ws+wp)/2;    % Ideal LPF cutoff frequency
hd = ideal_lp(wc,M);
w_ham = (hamming(M))';          % 選擇 Hamming Window
h = hd .* w_ham;
[db,mag,pha,grd,w] = freqz_m(h,[1]);
delta_w = 2*pi/1000;      % w 取的間格，需參考 freqz_m.m
Rp = -(min(db(1:1:wp/delta_w+1)))      % Actual Passband Ripple
As = -round(max(db(ws/delta_w+1:1:501)))    % Min Stopband attenuation
% Plots
subplot(1,1,1)
subplot(2,2,1); stem(n,hd); title('Ideal Impulse Response')
axis([0 M-1 -0.1 0.3]); xlabel('n'); ylabel('hd(n)')
xa=0.*n;
hold on
plot(n,xa,'k');
hold off
subplot(2,2,2); stem(n,w_ham); title('Hamming Window')
axis([0 M-1 0 1.1]); xlabel('n'); ylabel('w(n)')
subplot(2,2,3); stem(n,h); title('Actual Impulse Response')
axis([0 M-1 -0.1 0.3]); xlabel('n'); ylabel('h(n)')
hold on
plot(n,xa,'k');
hold off
subplot(2,2,4); plot(w/pi,db); title('Magnitude Response in dB');grid
axis([0 1 -100 10]); xlabel('frequency in pi units'); ylabel('Decibles')
set(gca,'XTickMode','manual','XTick',[0,0.2,0.3,1]);
```

M = 67

Rp = 0.0394

As = 52

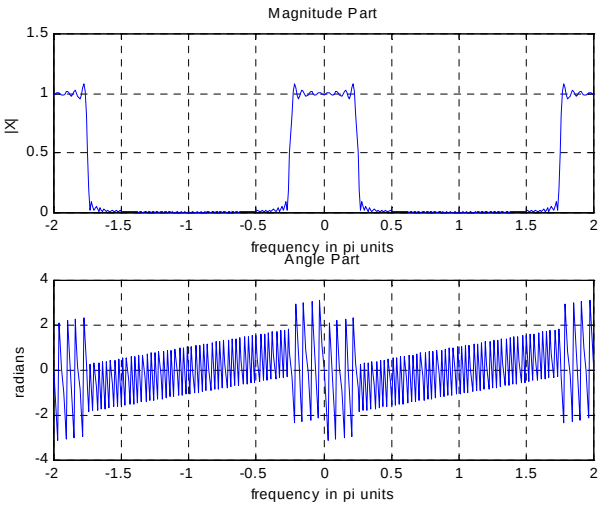
set(gca,'YTickMode','manual','YTick',[-50,0]);
set(gca,'YTickLabelMode','manual','**YTickLabel**',['50';' 0'])



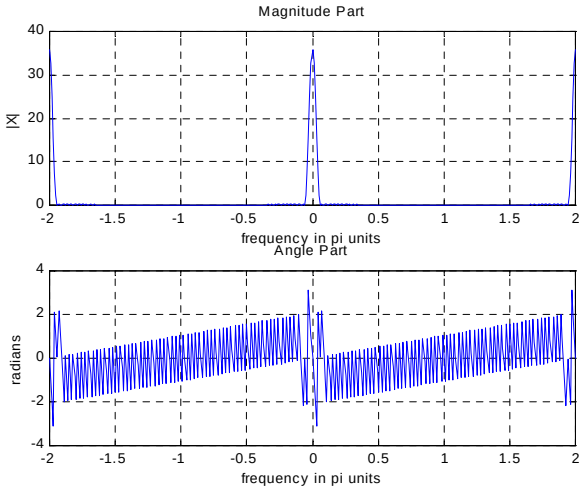
註： hd(n)與 w(n)之 DTFT

Matlab: n=0:1:66; [X]=plot_dtft(hd,n); [X]=plot_dtft(w_ham,n);

Hd(e^{jw})



W_ham(e^{jw})

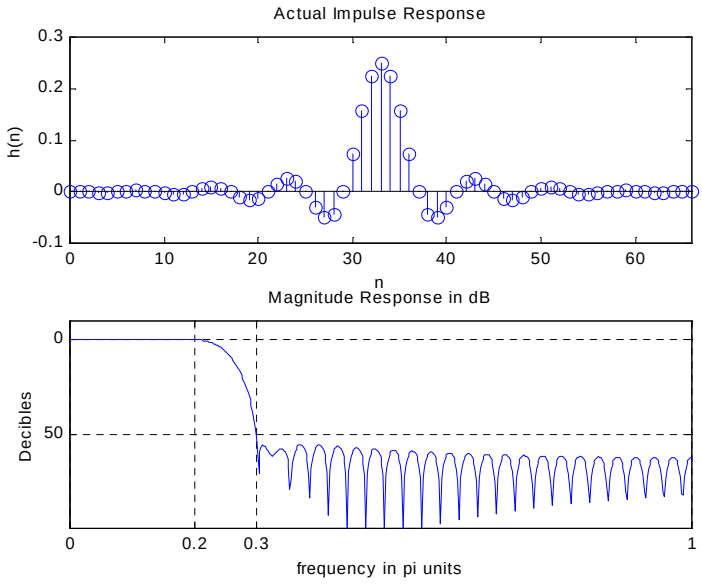


利用 直接 **fir1.m** 設計 **FIR Filter**

例： 設計一具以下規格之 **FIR LP Filter**

wp=0.2π　Rp=0.25dB　ws=0.3π　As=50dB

Matlab:
```
M = 67; wp=0.2; ws=0.3; n=[0:1:M-1];
w=(wp+ws)/2;
w_kind = (hamming(M))';
b=fir1(M-1,w,w_kind);    % w_kind 若沒輸入，則預設爲 Hamming Window
[db,mag,pha,grd,w] = freqz_m(b,[1]);
delta_w = 2*pi/1000;      % w 取的間格，需參考 freqz_m.m
Rp = -(min(db(1:1:wp/delta_w+1)))      % Actual Passband Ripple
As = -round(max(db(ws/delta_w+1:1:501)))    % Min Stopband attenuation
% Plots
xa=0.*n;
subplot(2,1,1); stem(n,b); title('Actual Impulse Response')
axis([0 M-1 -0.1 0.3]); xlabel('n'); ylabel('h(n)')
hold on
plot(n,xa,'k');
hold off
subplot(2,1,2); plot(w/pi,db); title('Magnitude Response in dB');grid
axis([0 1 -100 10]); xlabel('frequency in pi units'); ylabel('Decibles')
set(gca,'XTickMode','manual','XTick',[0,0.2,0.3,1]);
set(gca,'YTickMode','manual','YTick',[-50,0]);
set(gca,'YTickLabelMode','manual','YTickLabel',['50';' 0'])
```



註：

B = FIR1(N,Wn,'**high**') designs a highpass filter.

B = FIR1(N,Wn,'**stop**') is a bandstop filter if Wn = [W1 W2].

若沒註明 則表示爲 **“低通”**

注意哦！ wp=0.2; ws=0.3; 可別寫成 wp=0.2*pi; ws=0.3*pi; 哦！