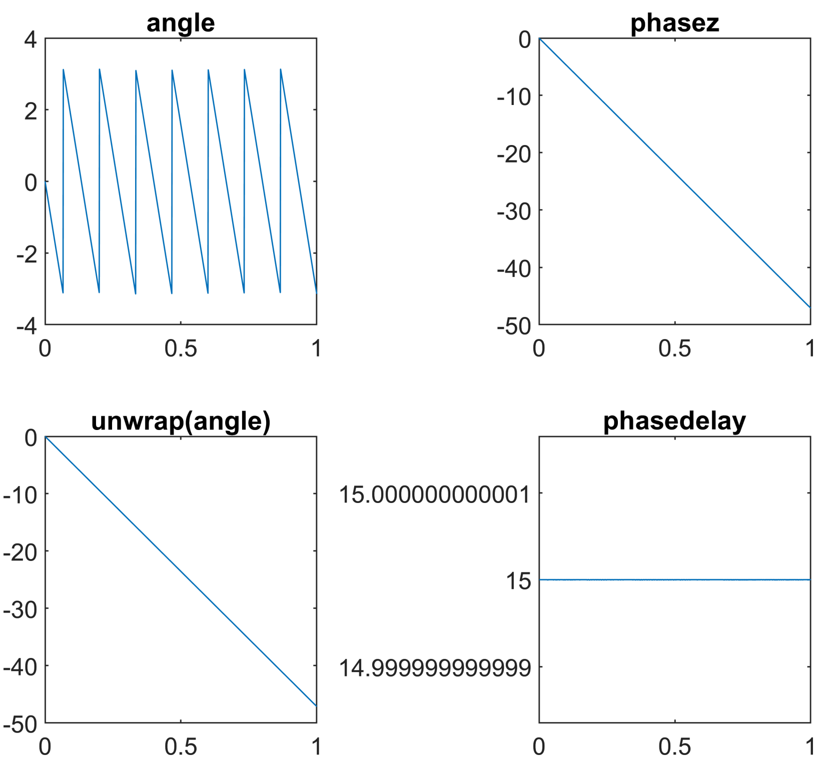
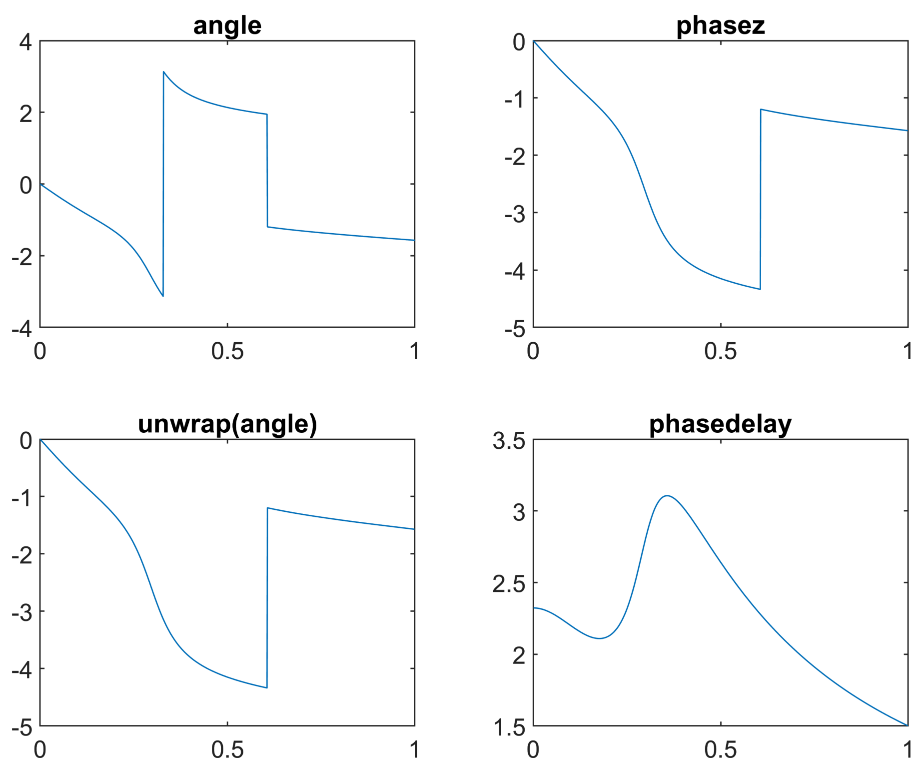
```
close all;
clear all;
clc;
```

Problem 8

```
% (a)
b = zeros(1,16);
b(end) = 1;
a = 1;

w = linspace(0,1,1000)*pi;
H = freqz(b,a,w);
H_phase = angle(H);
H_phase2 = phasez(b,a,w);
H_phase_unwrap = unwrap(H_phase2);
Pd = phasedelay(b,a,w);

figure();
subplot 221
plot(w/pi,H_phase);title("angle");
subplot 222
plot(w/pi,H_phase2);title("phasez");
subplot 223
plot(w/pi,H_phase_unwrap);title("unwrap(angle)");
subplot 224
plot(w/pi,Pd);title("phasedelay");
```



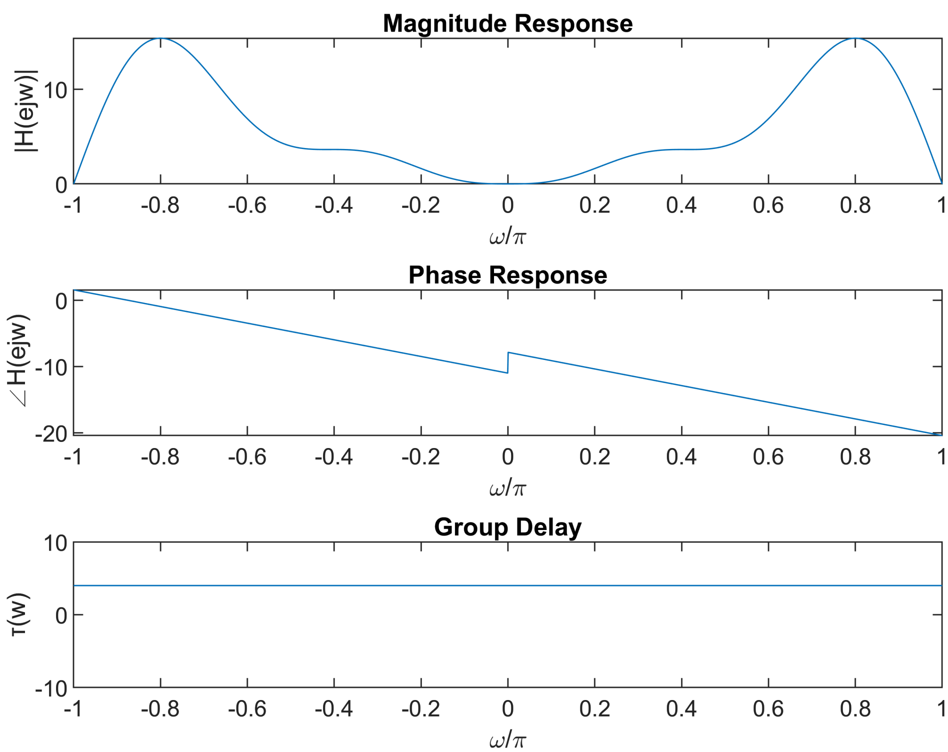
```
% (b)
b = [1 1.655 1.655 1];
a = [1 -1.57 1.264 -0.4];

w = linspace(0,1,1000)*pi;
H = freqz(b,a,w);
H_phase = angle(H);
H_phase2 = phasez(b,a,w);
H_phase_unwrap = unwrap(H_phase2);
Pd = phasedelay(b,a,w);

figure();
subplot 221
plot(w/pi,H_phase);title("angle");
subplot 222
plot(w/pi,H_phase2);title("phasez");
subplot 223
plot(w/pi,H_phase_unwrap);title("unwrap(angle)");
subplot 224
plot(w/pi,Pd);title("phasedelay");
```



Problem 9

```
% (a)
b = [1 -2 3 -4 0 4 -3 2 -1];
a = [1];

w = linspace(-1,1,2000)*pi;
```

```
H = freqz(b, a, w);
gd = grpdelay(b,a,w);
figure();
subplot 311
plot(w/pi, abs(H));title('Magnitude Response');
xlabel("\omega/\pi");ylabel("|H(ejw)|");
subplot 312
plot(w/pi, unwrap(angle(H)));title("Phase Response");
xlabel("\omega/\pi");ylabel("∠H(ejw)");
subplot 313
plot(w/pi,gd);title("Group Delay");axis([-inf,inf,-10,10]);
xlabel("\omega/\pi");ylabel("τ(w)");
```

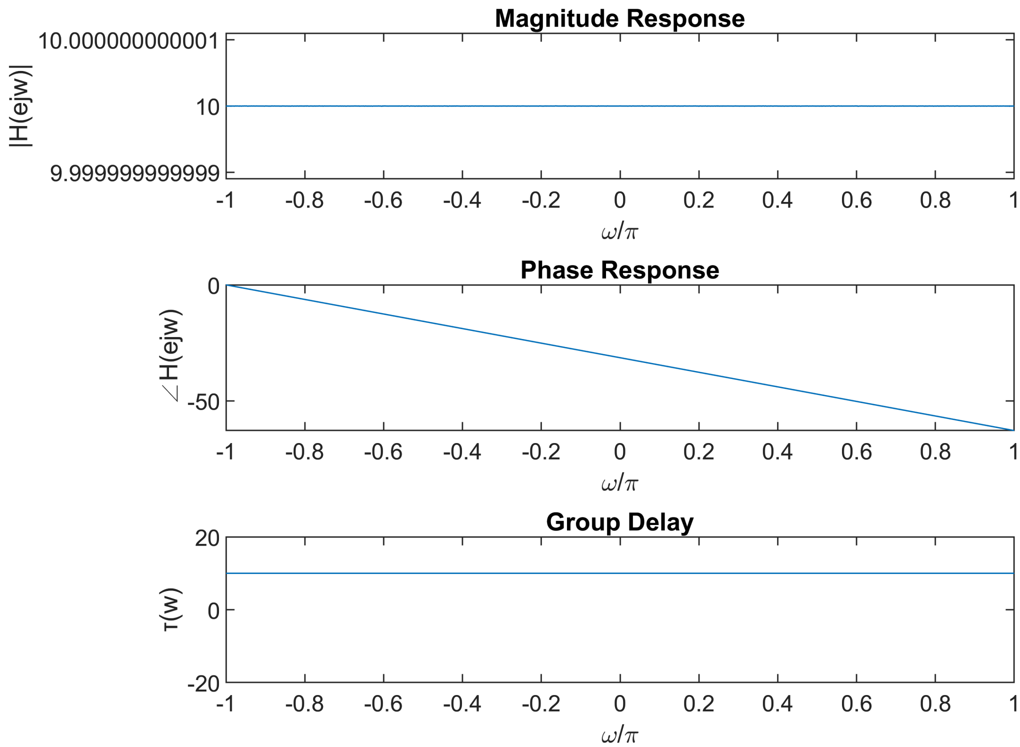


Note

matlab group delay畫不出phase在w=0時有無限大的group delay，所以不能單看group delay的圖決定是否有phase distortion，依phase response可以看出該系統不是linear phase，故有phase distortion。

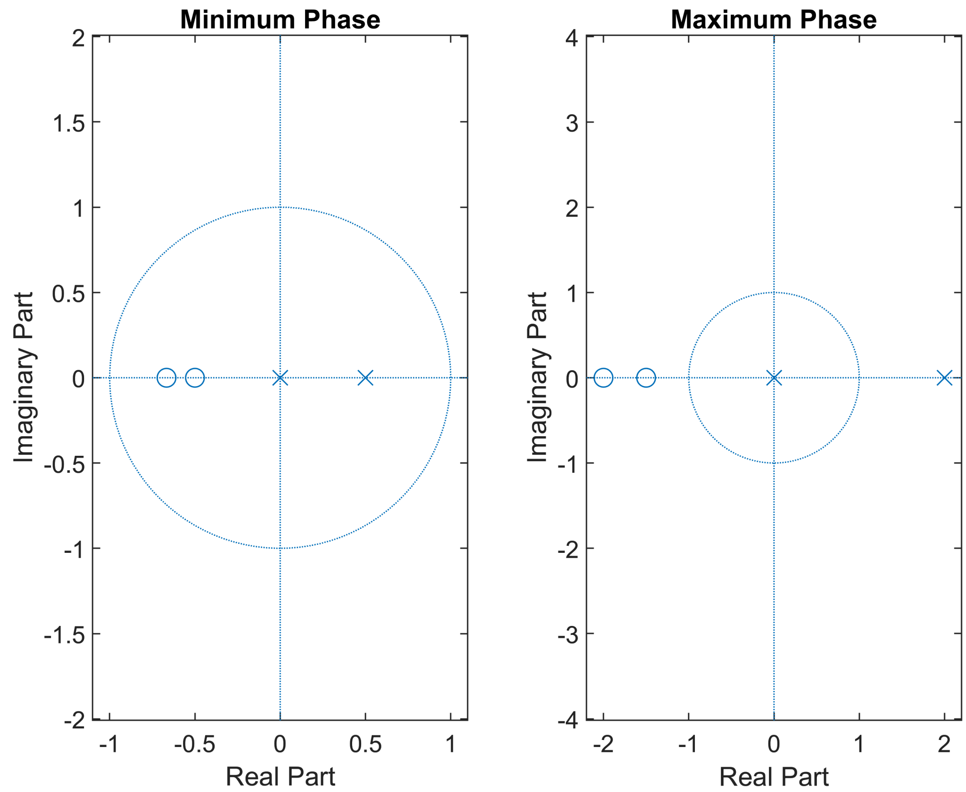
```
% (b)
b = [0 0 0 0 0 0 0 0 0 0 0 10];
a = [1];

w = linspace(-1,1,2000)*pi;
H = freqz(b, a, w);
gd = grpdelay(b,a,w);
figure();
subplot 311
plot(w/pi, abs(H));title("Magnitude Response");
```

```
xlabel("\omega/\pi");ylabel("|H(ejw)|");
subplot 312
plot(w/pi, unwrap(angle(H)));title("Phase Response");
xlabel("\omega/\pi");ylabel("∠H(ejw)");
subplot 313
plot(w/pi,gd);title("Group Delay");axis([-inf,inf,-20,20]);
xlabel("\omega/\pi");ylabel("τ(w)");
```

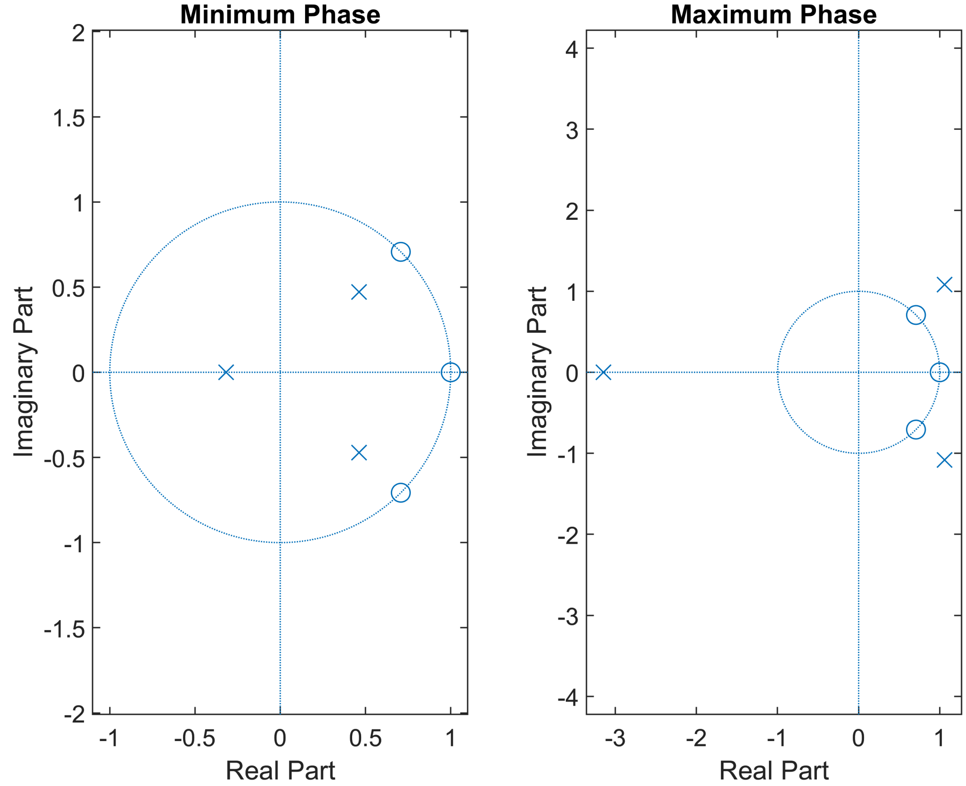


Problem 10

```
% (a)
 b = [1 2 0.75];
 a = [1 -0.5];
 bmin = polystab(b)*norm(b)/norm(polystab(b));
 bmax = fliplr(bmin);
 amin = polystab(a)*norm(a)/norm(polystab(a));
 amax = fliplr(amin);

 figure();
 subplot 121
 zplane(bmin,amin);title("Minimum Phase");
 subplot 122
 zplane(bmax,amax);title("Maximum Phase");
```




```
% (b)
b = [1 -2.4142 2.4142 -1];
a = [1 -1.8 1.62 0.729];
bmin = polystab(b)*norm(b)/norm(polystab(b));
bmax = fliplr(bmin);
amin = polystab(a)*norm(a)/norm(polystab(a));
amax = fliplr(amin);

figure();
subplot 121
zplane(bmin,amin);title("Minimum Phase");
subplot 122
zplane(bmax,amax);title("Maximum Phase");
```



Problem 11

$$x_c(t) = \frac{5}{2}e^{j\frac{\pi}{6}}e^{j200\pi t} + \frac{5}{2}e^{-j\frac{\pi}{6}}e^{-j200\pi t} + \frac{2}{j}e^{j300\pi t} - \frac{2}{j}e^{-j300\pi t}$$

The spectra of $x_c(t)$ is:

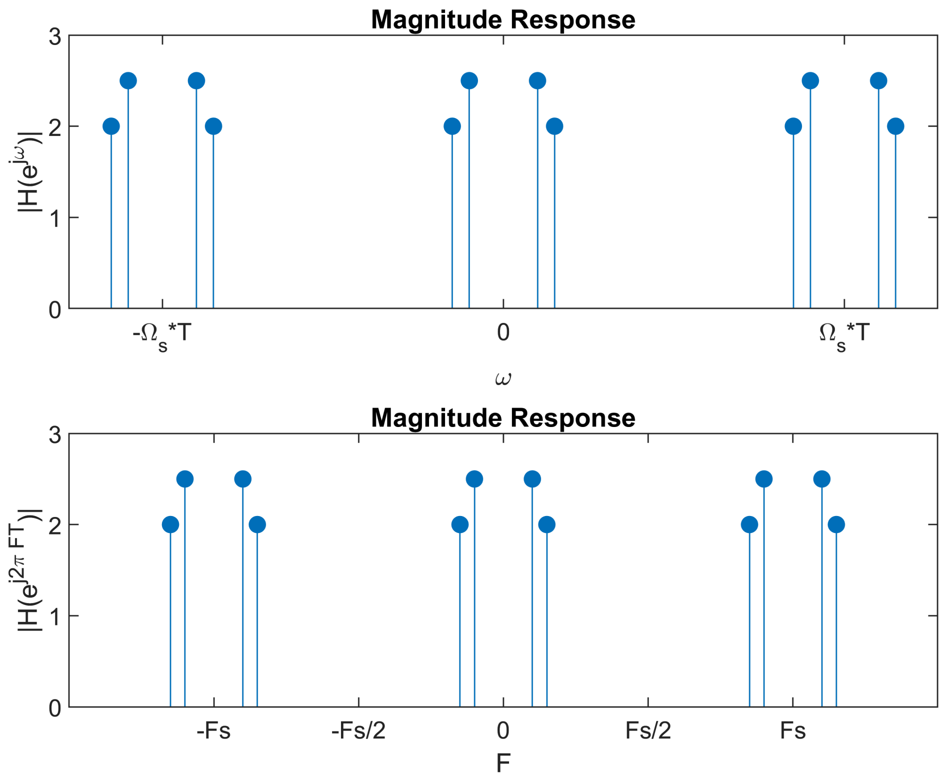
$$Xc(j\Omega) = \begin{cases} \frac{5}{2}e^{j\frac{\pi}{6}}, & \Omega = 200\pi \\ \frac{5}{2}e^{-j\frac{\pi}{6}}, & \Omega = -200\pi \\ \frac{2}{j}, & \Omega = 300\pi \\ -\frac{2}{j}, & \Omega = -300\pi \\ 0, & \text{elsewhere} \end{cases}$$

The spectra $X(e^{j\omega})$ of $x[n]$ is:

$$X(e^{j\omega})\big|_{\omega=\Omega T} = F_s \sum_{k=-\infty}^{\infty} X_c(j\Omega - j2\pi k F_s)$$

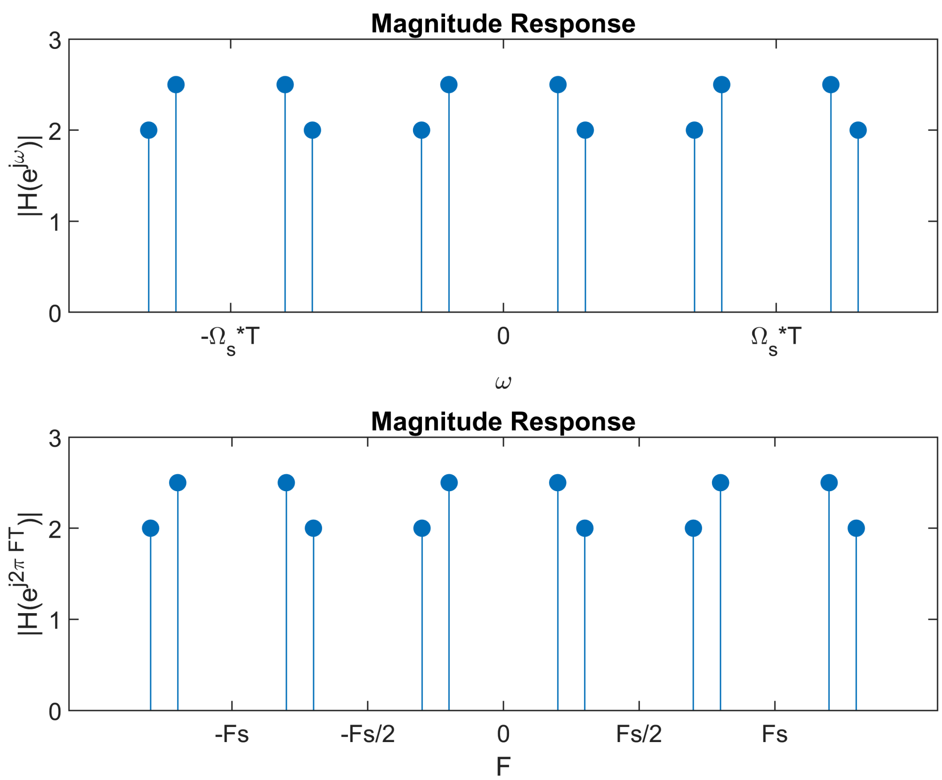
$$X(e^{j\omega})\big|_{\omega=2\pi F T} = F_s \sum_{k=-\infty}^{\infty} X_c[j2\pi(F - kF_s)]$$

```
% (a) The signal can recovered for x[n]
clear all; clc;
Fs = 1e3;
T = 1/Fs;
FH = 150;
FL = FH+Fs;
F = -FL:50:FL;
X = zeros(1,length(F));
for k = -1:1
ind = F == -150+k*Fs; X(ind) = X(ind)-2/1j;
ind = F == -100+k*Fs; X(ind) = X(ind)+5/2*exp(-1j*pi/6);
ind = F == 100+k*Fs; X(ind) = X(ind)+5/2*exp(1j*pi/6);
ind = F == 150+k*Fs; X(ind) = X(ind)+2/1j;
end
ind = X==0;
X(ind) = nan;

figure();
subplot 211
stem(F*2*pi*T,abs(X),"filled");
ylim([0 max(abs(X))+0.5]);
set(gca,"XTick",[-Fs*2*pi*T 0 Fs*2*pi*T])
set(gca,"XTickLabel",["-\Omega_s*T","0","\Omega_s*T"]);
xlabel("\omega")
ylabel("|H(e^{j\omega})|")
title('Magnitude Response');

subplot 212
stem(F,abs(X),"filled")
ylim([0 max(abs(X))+0.5])
set(gca,"XTick",[-Fs -Fs/2 0 Fs/2 Fs])
set(gca,"XTickLabel",["-Fs","-Fs/2","0","Fs/2","Fs"])
xlabel("F")
ylabel("|H(e^{j2\pi FT})|")
title("Magnitude Response")
```



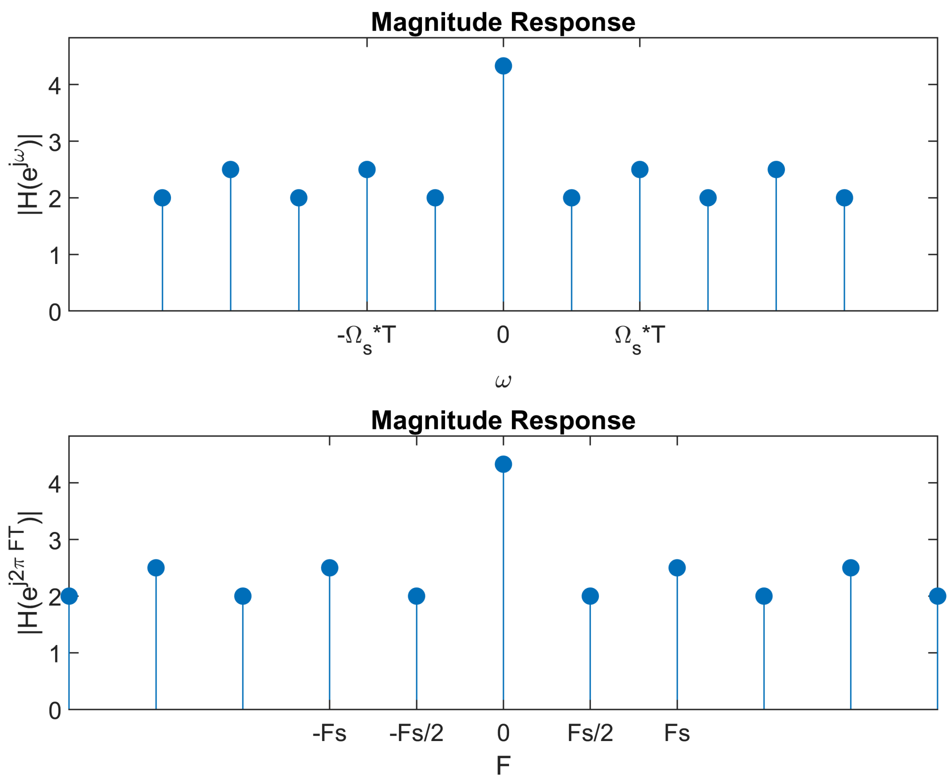

```
% (b) The signal can recovered for x[n]
clear all; clc;
Fs = 500;
T = 1/Fs;
FH = 150;
FL = FH+Fs;
F = -FL:50:FL;
X = zeros(1,length(F));
for k = -1:1
ind = F == -150+k*Fs; X(ind) = X(ind)-2/1j;
ind = F == -100+k*Fs; X(ind) = X(ind)+5/2*exp(-1j*pi/6);
ind = F == 100+k*Fs; X(ind) = X(ind)+5/2*exp(1j*pi/6);
ind = F == 150+k*Fs; X(ind) = X(ind)+2/1j;
end
ind = X==0;
X(ind) = nan;

figure();
subplot 211
stem(F*2*pi*T,abs(X),"filled");
ylim([0 max(abs(X))+0.5]);
set(gca,"XTick",[-Fs*2*pi*T 0 Fs*2*pi*T])
set(gca,"XTickLabel",["-\Omega_s*T","0","\Omega_s*T"]);
xlabel("\omega")
ylabel("|H(e^{j\omega})|")
title('Magnitude Response');

subplot 212
```

```
stem(F,abs(X),"filled")
ylim([0 max(abs(X))+0.5])
set(gca,"XTick",[-Fs -Fs/2 0 Fs/2 Fs])
set(gca,"XTickLabel",["-Fs","-Fs/2","0","Fs/2","Fs"])
xlabel("F")
ylabel("|H(e^{j2\pi FT})|")
title("Magnitude Response")
```




```
% (c) The signal can NOT recovered for x[n]
clear all; clc;
Fs = 100;
T = 1/Fs;
FH = 150;
FL = FH+Fs;
F = -FL:50:FL;
X = zeros(1,length(F));
for k = -1:1
ind = F == -150+k*Fs; X(ind) = X(ind)-2/1j;
ind = F == -100+k*Fs; X(ind) = X(ind)+5/2*exp(-1j*pi/6);
ind = F == 100+k*Fs; X(ind) = X(ind)+5/2*exp(1j*pi/6);
ind = F == 150+k*Fs; X(ind) = X(ind)+2/1j;
end
ind = X==0;
X(ind) = nan;

figure();
subplot 211
```

```
stem(F*2*pi*T,abs(X),"filled");
ylim([0 max(abs(X))+0.5]);
set(gca,"XTick",[-Fs*2*pi*T 0 Fs*2*pi*T])
set(gca,"XTickLabel",["-\Omega_s*T","0","\Omega_s*T"]);
xlabel("\omega")
ylabel("|H(e^{j\omega})|")
title('Magnitude Response');

subplot 212
stem(F,abs(X),"filled")
ylim([0 max(abs(X))+0.5])
set(gca,"XTick",[-Fs -Fs/2 0 Fs/2 Fs])
set(gca,"XTickLabel",["-Fs","-Fs/2","0","Fs/2","Fs"])
xlabel("F")
ylabel("|H(e^{j2\pi FT})|")
title("Magnitude Response")
```




```
% (d)
% Part (a) & (b) satisfies Nyquist-Shannon sampling theorem,
% while part (c) doesn't.
% As a result, part (a) & (b) can be recovered but (c) cannot.
```