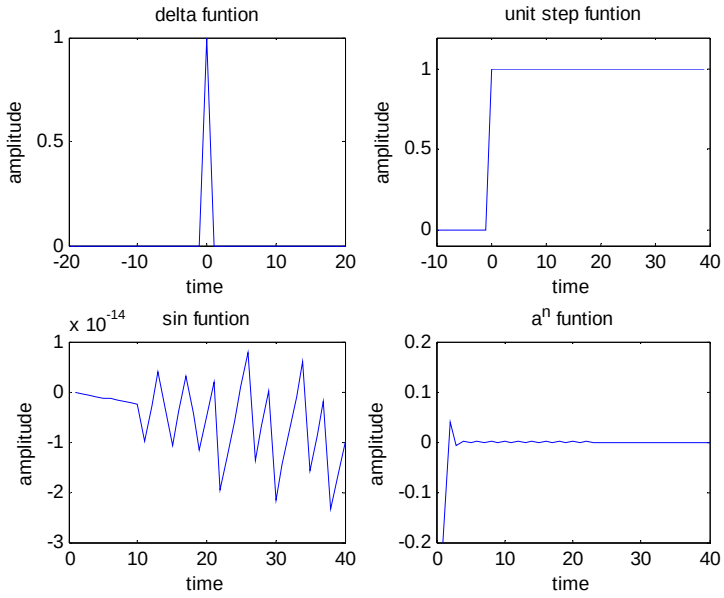
试验一

1． 程序如下：

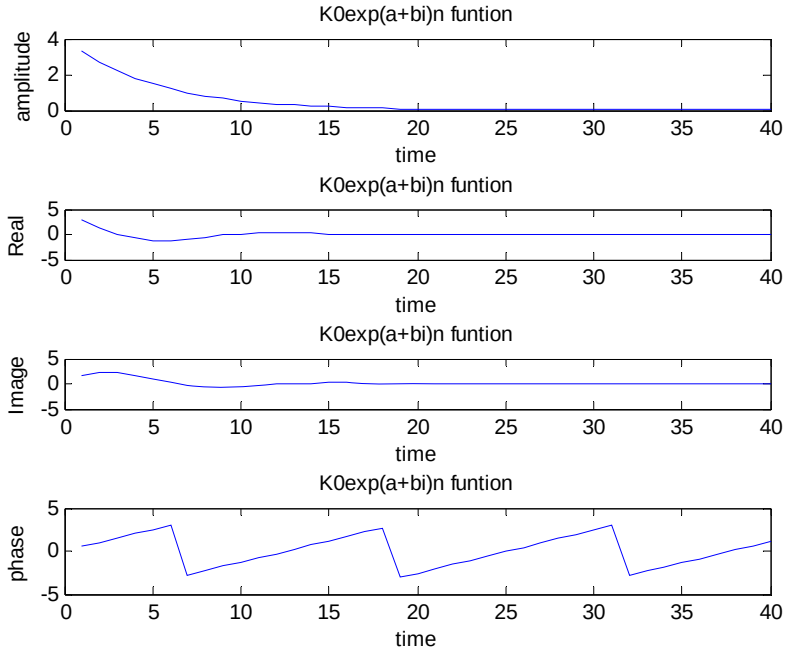
```
clc;clear all;
% parameter setting
N=40;   %sequence length
% generate delta function
delta=zeros(1,N+1);
delta(N/2+1)=1;
figure(1)
subplot(2,2,1)
plot(-N/2:N/2,delta);xlabel('time');ylabel('amplitude');title('delta funtion')
hold on;

% generate unit step funtion
fun1=[zeros(1,N/4) ones(1,N)];
subplot(2,2,2)
plot(-N/4:N-1,fun1);xlabel('time');ylabel('amplitude');
title('unit step funtion');axis([-10 40 -0.1 1.2])

%generate sin funtion
w=2*pi;
n=1:N;
fun2=sin(w.*n);
subplot(2,2,3)
plot(n,fun2);xlabel('time');ylabel('amplitude');title('sin funtion')

%generate a^n funtion
clear;
N=40;
a=-0.2;
n=1:N;
fun3=a.^n;
subplot(2,2,4)
plot(n,fun3);xlabel('time');ylabel('amplitude');title('a^n funtion')
% generate K0exp(a+bi)n
clear;
K0=4;
N=40;
n=1:N;
a=-0.2;b=0.5;
fun4=K0*exp((a+i*b).*n);
figure(2)
subplot(4,1,1)
plot(n,abs(fun4))；xlabel('time');ylabel('amplitude');title('K0exp(a+bi)n funtion')
```

```
subplot(4,1,2)
plot(n,real(fun4))；xlabel('time');ylabel('Real');title('K0exp(a+bi)n funtion')
subplot(4,1,3)
plot(n,imag(fun4))；xlabel('time');ylabel('Image');title('K0exp(a+bi)n funtion')
subplot(4,1,4)
plot(n,angle(fun4))；xlabel('time');ylabel('phase');title('K0exp(a+bi)n funtion')

% generate Asin(2*pi*f*n+w)
clear;
A=1.5;
f=30;
w=pi/4;
n=0:0.01:0.4;
fun=A*sin(2*pi*f.*n+w);
figure(3)
plot(n,fun);xlabel('time');ylabel('phase');title('A*sin(2*pi*f*n+w) funtion')
```

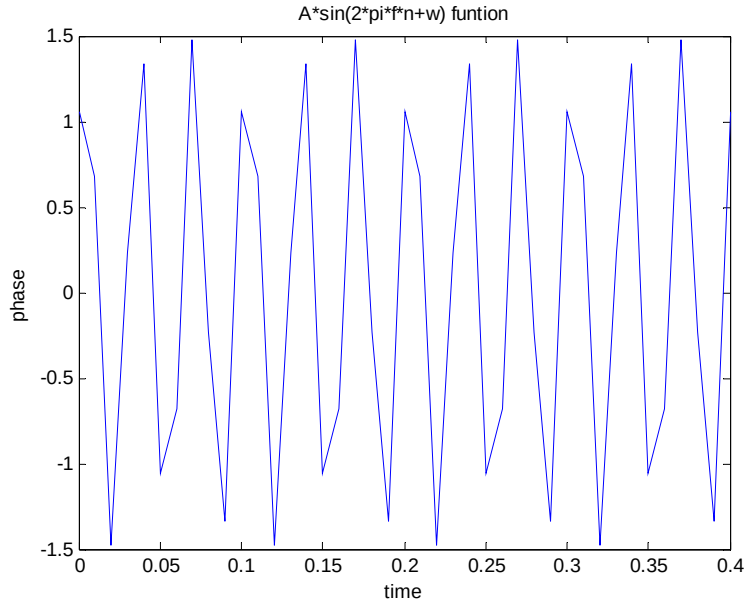
Simulation Results：



Figure(1)



Figure(2)



Figure(3)

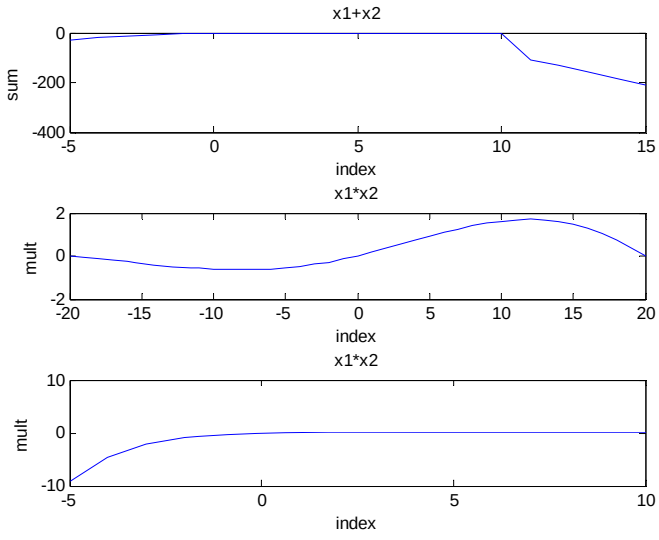
试验二

1. 程序如下：

```
% paramete setting
clc;clear;
n=0:10;
x1=n.^2-n;
k=-5:15;
```

```
x2=-k.^2+k;
xx1=[zeros(1,(min(n)-min(k))) x1 zeros(1,(max(k)-max(n)))];
y=xx1+x2;
subplot(3,1,1)
plot(k,y);xlabel('index');ylabel('sum');title('x1+x2')
% y=x1*x2
clear;
n=-20:20;
w=pi/20;
a=1.05;
x1=sin(w.*n);
x2=a.^n;
y=x1.*x2;
subplot(3,1,2)
plot(n,y);xlabel('index');ylabel('mult');title('x1*x2');
% y=x1*x2
clear
n1=-10:10;
n2=-5:15;
w=pi/20;
a=0.6;
x1=sin(w.*n1);
x2=a.^n2;
q=max([min(n1),min(n2)]);
w=min([max(n1),max(n2)]);
y=x1((end-length(q:w)+1):end).*x2(1:length(q:w));
subplot(3,1,3)
plot(q:w,y);
xlabel('index');ylabel('mult');title('x1*x2')
```

Simulation Results：

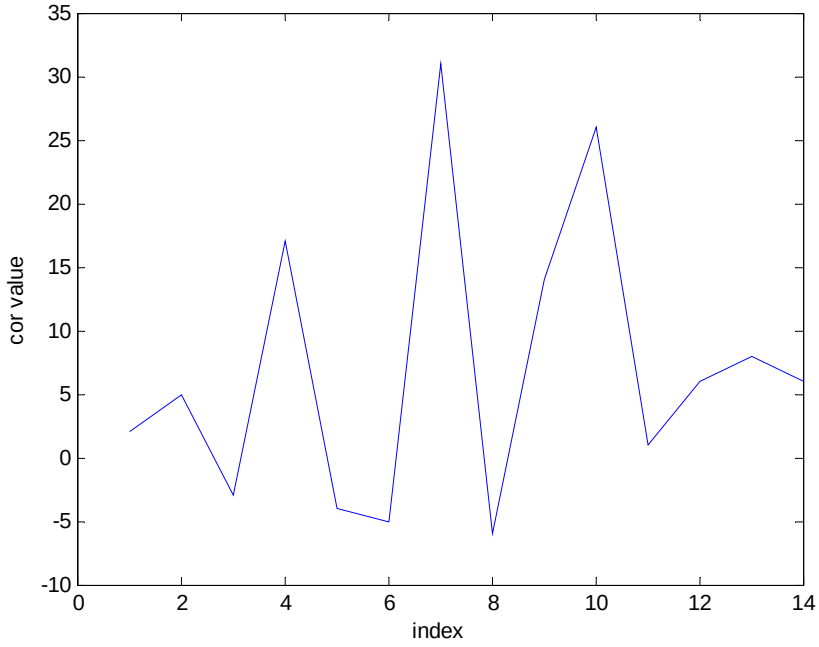


试验三

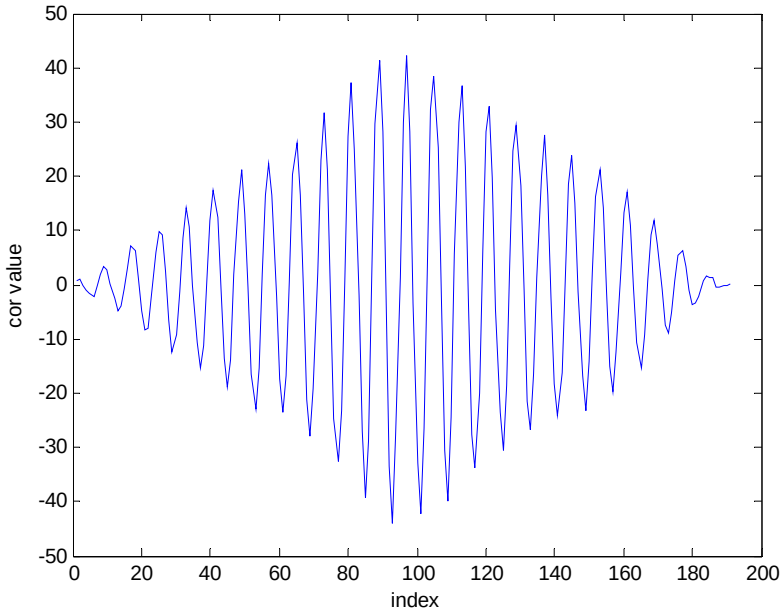
1． 程序如下：

```
%conv()function
x=[1 3 -2 1 2 -1 4 4 2];
y=[2 -1 4 1 -2 3];
cor=conv(x,y);
plot(1:length(cor),cor)
xlabel('index')
ylabel('cor value')
pause;
clf;
%signal +noise
clear;
n=0:95;
sig=cos(0.25*pi.*n)
noise=rand(1,length(n))-0.5;
y=sig+noise;
cor=conv(y,y);
plot(1:length(cor),cor)
xlabel('index')
ylabel('cor value')
```

Simulation Results:



Figure（1）



Figure（2）

试验四

1. 程序如下：

4.1-a:

```
b=1;
a=[1,-1,0.9];
h=[zeros(1,20),1,zeros(1,100)];
y=filter(b,a,h);
n=-20:100;
stem(n,y);
xlabel('n');
ylabel('h(n)')
```

4.1-b:

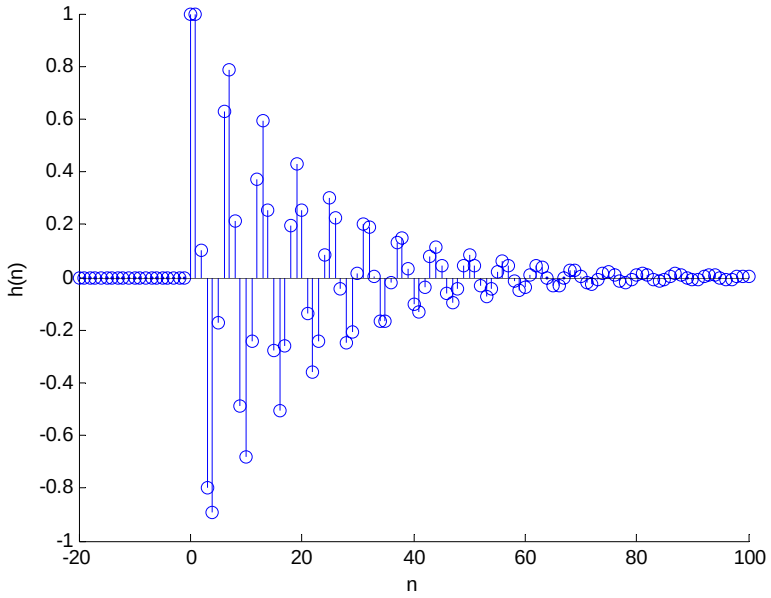
```
b=1;
a=[1,-1,0.9];
u=[zeros(1,20),ones(1,101)];
y=filter(b,a,u);
n=-20:100;
stem(n,y);
xlabel('n');
ylabel('s(n)')
```

4.2

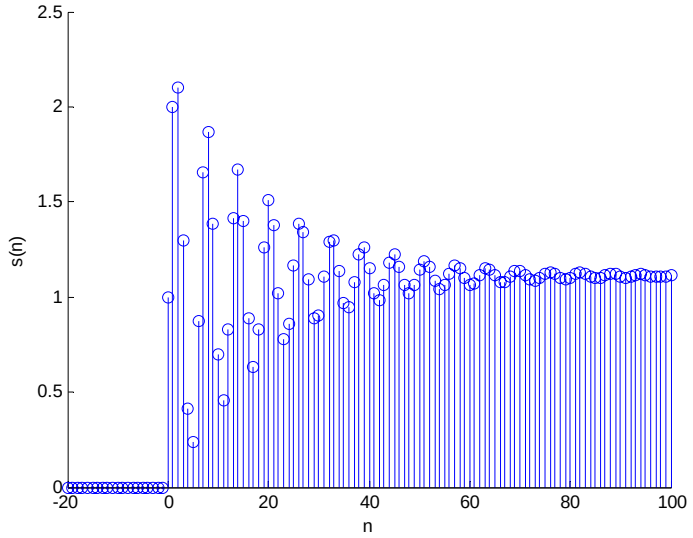
```
b=[1];
a=[1,-3/2,1/2];
```

```
n1=-10:-1;
n2=0:10;
x=[zeros(size(n1)),(1/4).^n2];
y=[zeros(size(n1)-[0,2]),10,4,zeros(size(n2))];
xic=filtic(b,a,y,x);
y=filter(b,a,x,xic);
subplot(2,1,1)
stem([n1,n2],x);
xlabel('n');
ylabel('x(n)');
grid;
subplot(2,1,2);
stem([n1,n2],y);
xlabel('n');
ylabel('y(n)');
grid
```

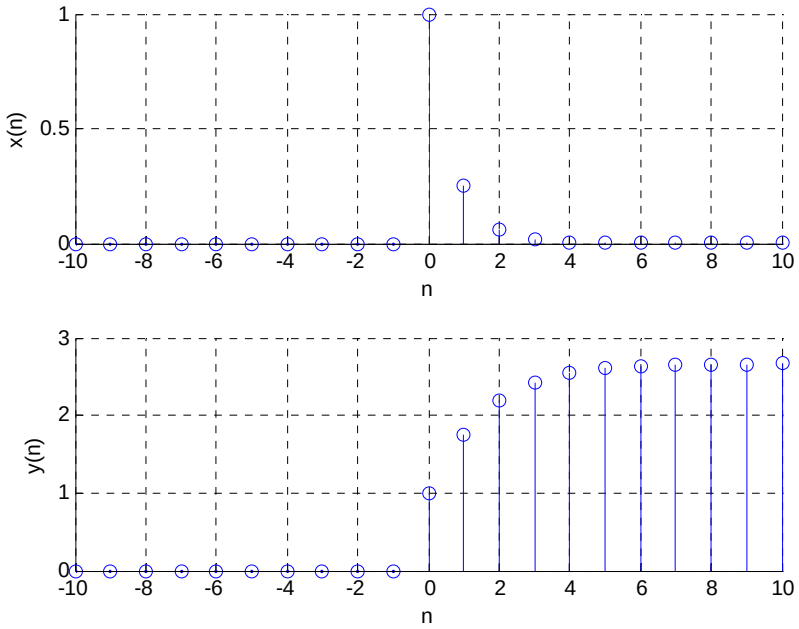
Simulation Results：



Figure(4.1-a)



Figure(4.1-b)



Figure(4.2)

试验五

1. 程序如下：

5.1 :

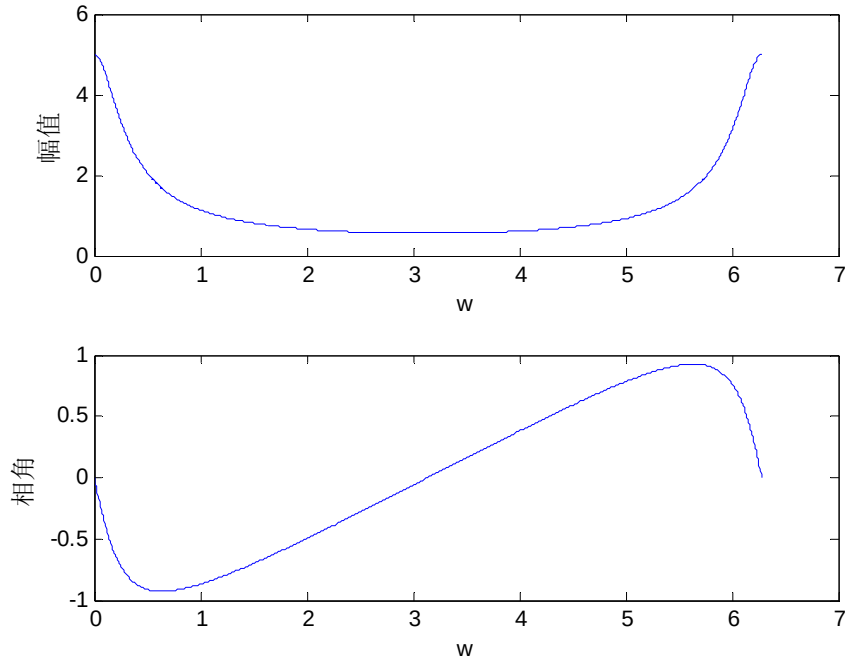
```
w= [0:1:1000]*pi/500;
y=exp(j*w)./(exp(j*w)-0.8*ones(1,1001));
subplot(2,1,1);
plot(w,abs(y));
xlabel('w');
ylabel('幅值');
```

```
subplot(2,1,2);
plot(w,angle(y));
xlabel('w');
ylabel('相角')
```

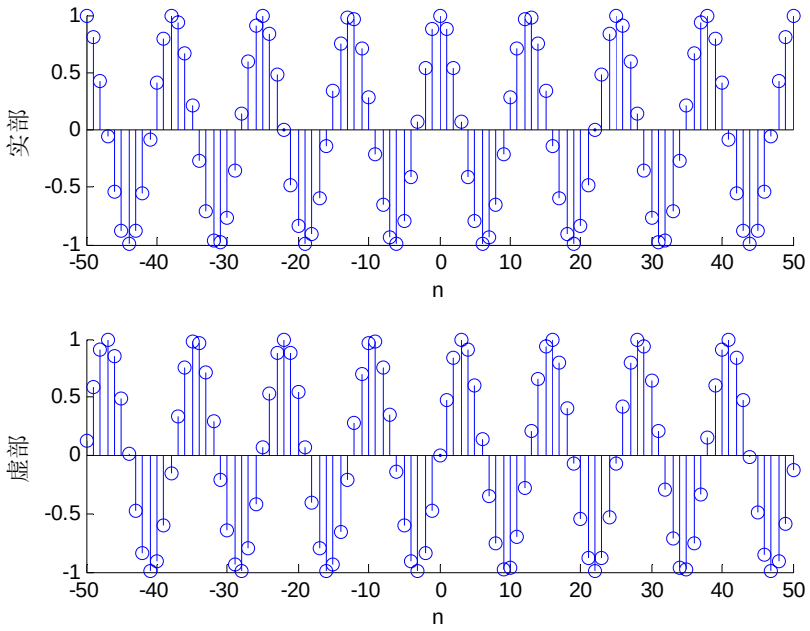
5.2 :

```
n=-50:50;
w=0.5;
x=exp(j*w.*n);
subplot(2,1,1);
stem(n,real(x));
xlabel('n');
ylabel('实部');
subplot(2,1,2);
stem(n,imag(x));
xlabel('n');
ylabel('虚部')
```

Simulation Results：



Figure(5.1)



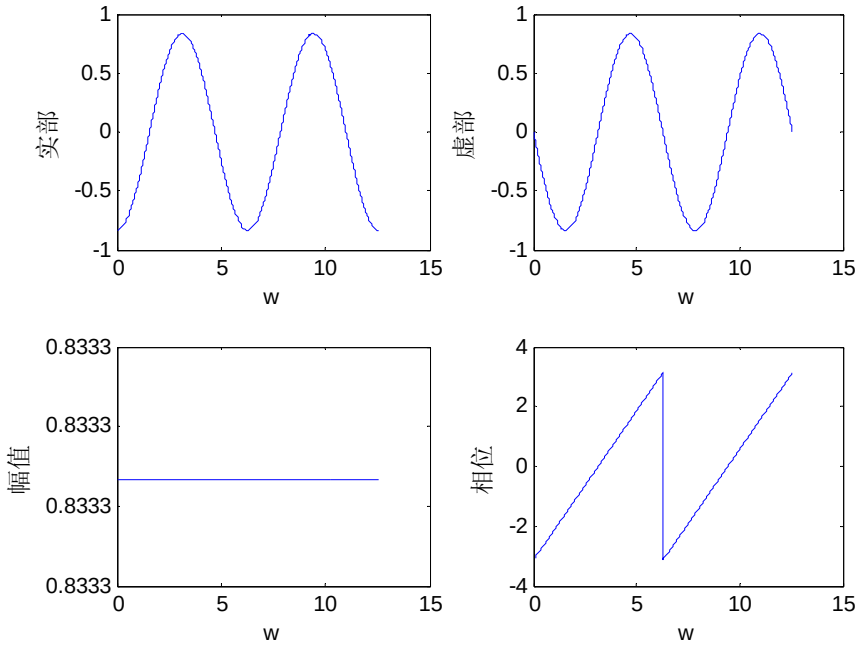
Figure(5.2)

试验六

1. 程序如下：

```
A=input('please input A:');
w=[0:2000]*pi/500;
h=exp(j*w)./(exp(j*pi)-A*ones(size(w)));
subplot(2,2,1);
plot(w,real(h));xlabel('w');ylabel('实部');
subplot(2,2,2);
plot(w,imag(h));xlabel('w');ylabel('虚部');
subplot(2,2,3);
plot(w,abs(h));xlabel('w');ylabel('幅值');
subplot(2,2,4);
plot(w,angle(h));xlabel('w');ylabel('相位')
```

Simulation Results：

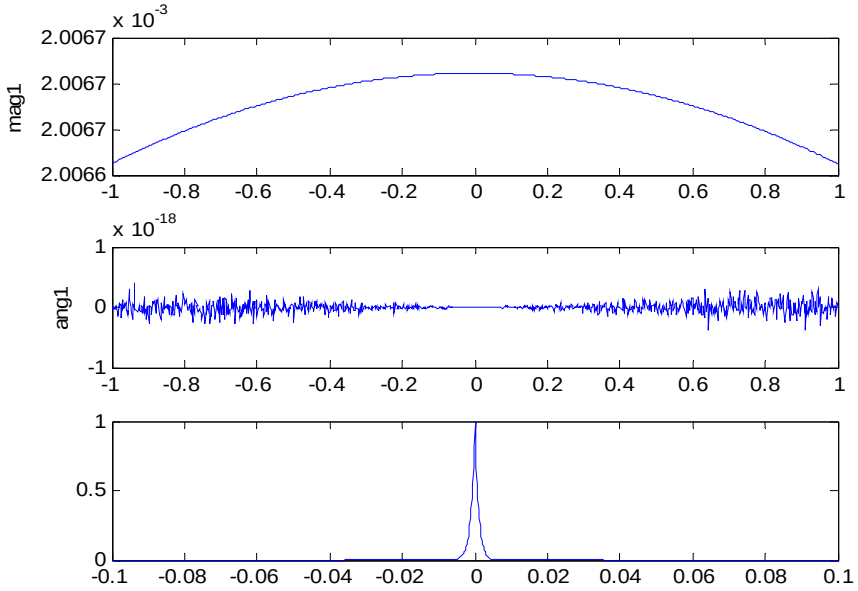


试验七

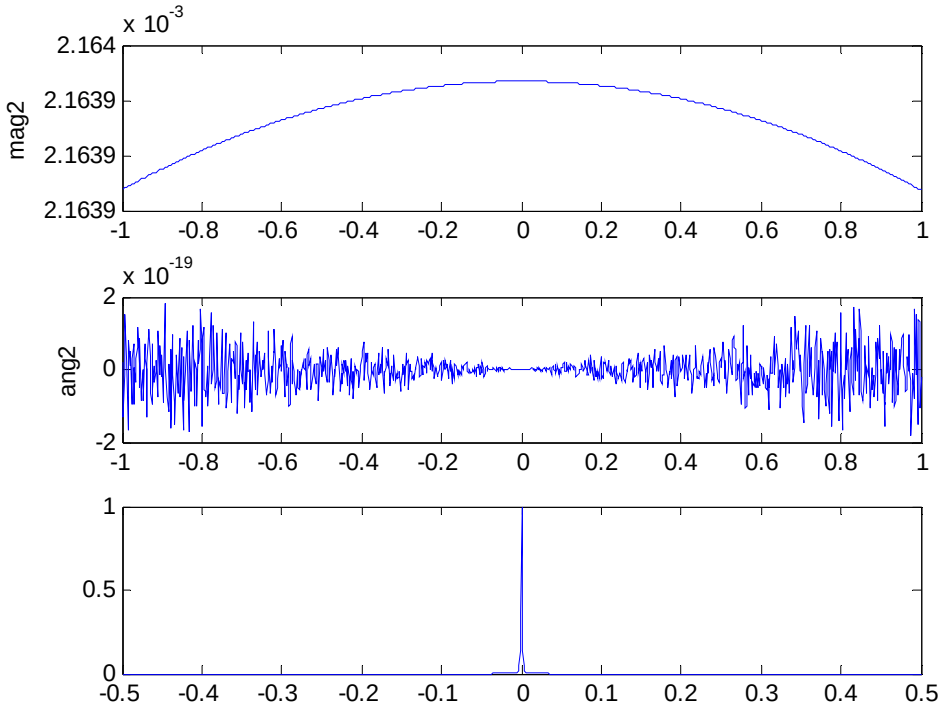
1．程序如下：

```
w=linspace(-pi,pi,1000);
f1=5000;f2=1000;
dt1=1/f1;dt2=1/f2;
n=[-500:500];
n1=n*dt1;
m=[-500:500];
n2=m*dt2;
x1=exp(-1000*abs(n1));
x2=exp(-1000*abs(n2));
y1=(1/f1)*x1*exp(-j*n1'*w);
mag1=abs(y1);
ang1=angle(y1);
figure(1)
subplot(3,1,1); plot(w/pi,mag1); ylabel('mag1');
subplot(3,1,2); plot(w/pi,ang1); ylabel('ang1');
subplot(3,1,3); plot(n1,x1);
figure(2);
y2=(1/f2)*x2*exp(-j*n2'*w);
mag2=abs(y2);
ang2=angle(y2);
subplot(3,1,1); plot(w/pi,mag2); ylabel('mag2');
subplot(3,1,2); plot(w/pi,ang2); ylabel('ang2');
subplot(3,1,3);plot(n2,x2);
```

Simulation Results:



Figure(1)



Figure(2)

试验八

1． 程序如下：

8.1：

```
f=32;
dt=1/f;
```

```
N=32;
n=0:N-1;k=n;
n=n*dt;
x=0.15*sin(2*pi*n)+sin(2*pi*2*n)-0.1*sin(2*pi*3*n);
y=x*exp(-j*2*pi/N).^(n'*k);
subplot(3,1,1);stem(n,x,'filled');ylabel('x');
subplot(3,1,2);stem(k,abs(y),'filled');ylabel('mag X(k)');
subplot(3,1,3);stem(k,angle(y),'filled');ylabel('ang X(k)');
```

8.2：

```
N=16;
n=0:N-1;k=n;
x=sin(pi*n/8)+sin(pi*n/4);
y=x*exp(-j*2*pi/N).^(n'*k);
subplot(3,1,1);stem(n,x,'filled');ylabel('x');
subplot(3,1,2);stem(k,abs(y),'filled');ylabel('mag X(k)');
subplot(3,1,3);stem(k,angle(y),'filled');ylabel('ang X(k)');
```

8.3：

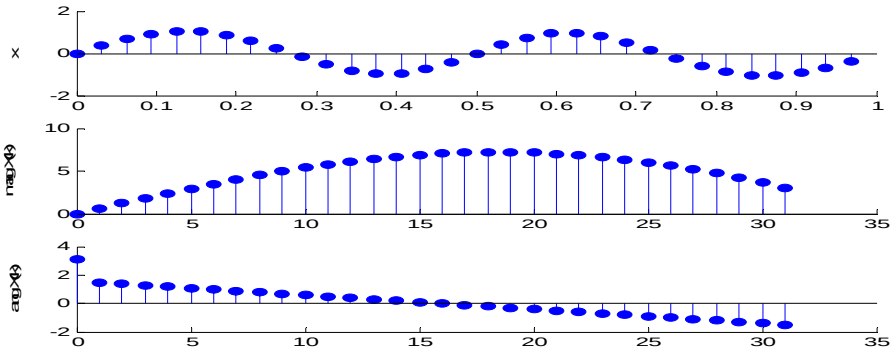
```
for N=8:8:16
n=0:N-1;k=n;
x=[n<=3];
y=x*exp(-j*2*pi/N).^(n'*k);
figure;
subplot(3,1,1);stem(n,x,'filled');ylabel('x（n）');
subplot(3,1,2);stem(k,abs(y),'filled');ylabel('mag X(k)');
subplot(3,1,3);stem(k,angle(y),'filled');ylabel('ang X(k)');
end
```

8.4：

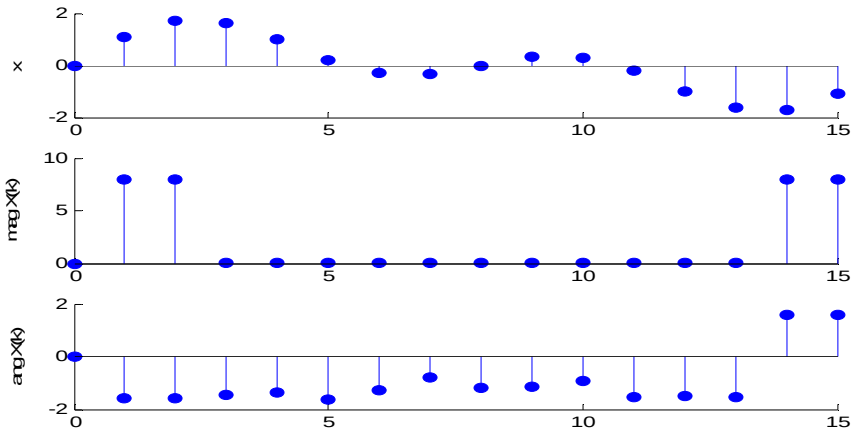
```
for N=5:5:10
n=0:N-1;k=n;
x=[n>=0];
n1=0:6*N-1;k1=n1;
x1=x(mod(n1,N)+1);
y=x*exp(-j*2*pi/N).^(n'*k);
y1=x1*exp(-j*2*pi/N).^(n1'*k1);
w=linspace(-2*pi,2*pi,500);
y2=x*exp(-j*n'*w);
figure;
subplot(4,2,1);stem(n,x,'.');ylabel('x');
subplot(4,2,2);stem(n1,x1,'.');ylabel('x~(n)');
subplot(4,2,3);stem(k,abs(y),'.');ylabel('mag X(k)');
subplot(4,2,4);stem(k,angle(y),'.');ylabel('ang X(k)');
```

```
subplot(4,2,5);stem(k1,abs(y1),'.');ylabel('mag X~(k)');
subplot(4,2,6);stem(k1,angle(y1),'.');ylabel('ang X~(k)');
subplot(4,1,4);plot(w/pi,abs(y2));xlabel('X pi');ylabel('X(w)');
end
```

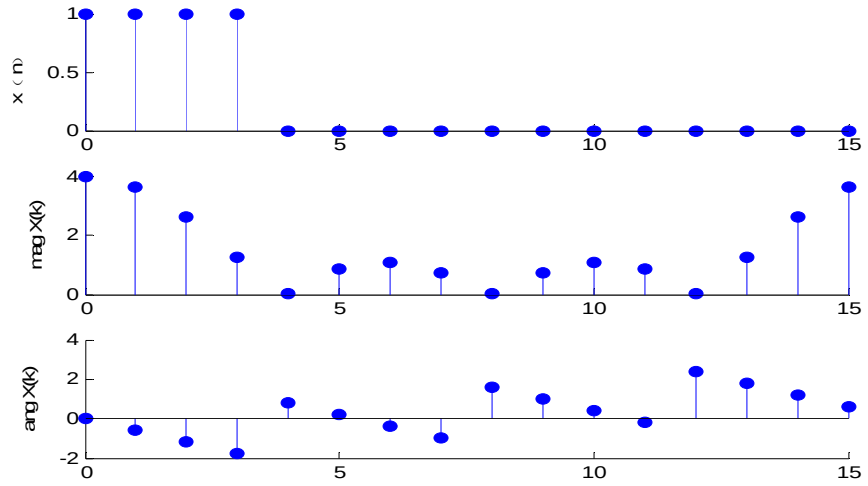
Simulation Results：



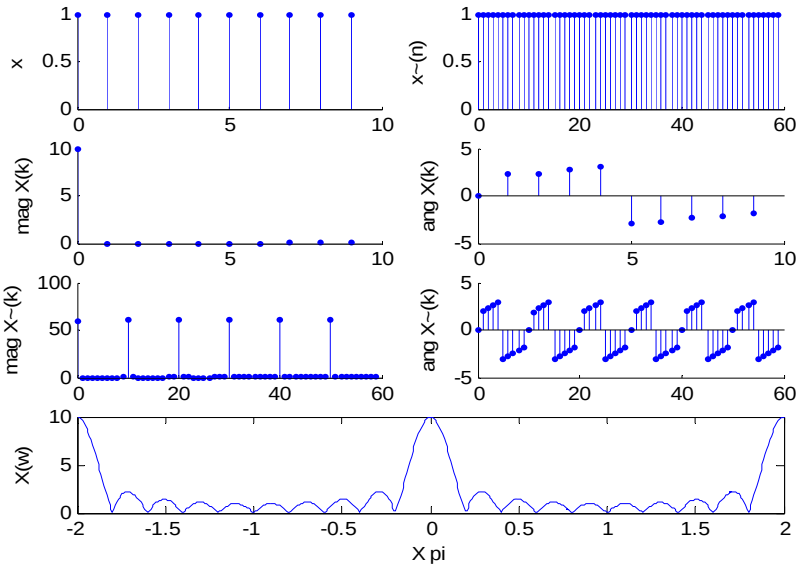
Figure（8.1）



Figure（8.2）



Figure（8.3）



Figure（8.4）

试验九

1． 程序如下：

9.1：

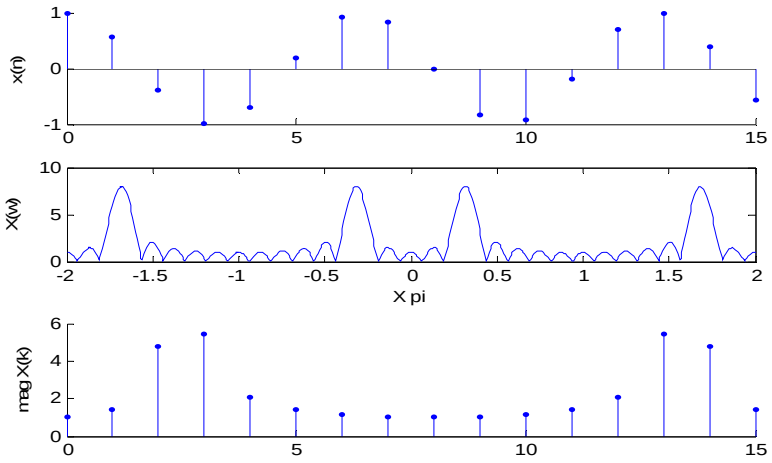
```
for N=16:16:32
n=0:15;
x1=cos(5*n*pi/16);
n=0:N-1;k=n;
x=zeros(1,N);
x(find(n<=15))=x1;
y=x*exp(-j*2*pi/N).^(n'*k);
w=linspace(-2*pi,2*pi,500);
y1=x*exp(-j*n'*w);
figure;
subplot(3,1,1);stem(n,x,'.');ylabel('x(n)');
subplot(3,1,2);plot(w/pi,abs(y1));xlabel('X pi');ylabel('X(w)');
subplot(3,1,3);stem(k,abs(y),'.');ylabel('mag X(k)');
end
```

9.2:

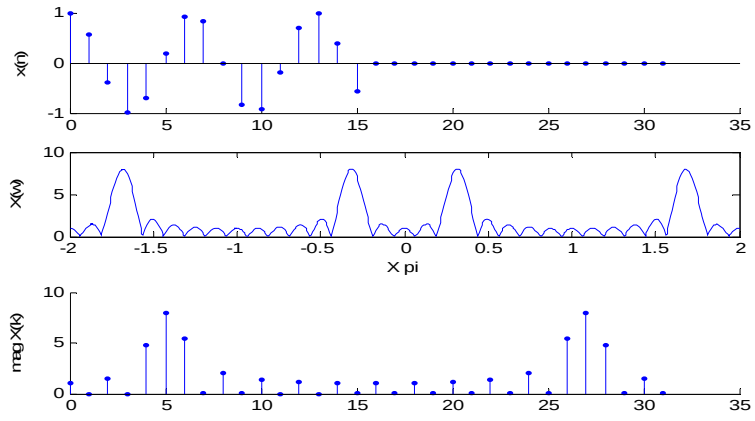
```
n=0:11;
x=[1,2,3,4,5,6,6,5,4,3,2,1];
k=n;
N=length(n);
y=x*exp(-j*2*pi/N).^(n'*k);%DFT
w=linspace(-2*pi,2*pi,500);
y1=x*exp(-j*n'*w);%DTFT
figure;
```

```
subplot(4,1,1);stem(n,x,'.');ylabel('x（n）');
subplot(4,2,3);stem(k,abs(y),'.');ylabel('mag X(k)');
subplot(4,2,4);stem(k,angle(y),'.');ylabel('ang X(k)');
subplot(4,1,3);plot(w/pi,abs(y1));xlabel('X pi');ylabel('X(jw)');
subplot(4,1,4);plot(w/pi,angle(y1));xlabel('X pi');ylabel('arg(jw)');

figure;%mag
stem(2*k/N,abs(y),'filled');
hold on;
plot(w/pi,abs(y1));xlabel('X pi');title('mag');

figure;%arg
stem(2*k/N,angle(y),'filled');
hold on;
plot(w/pi,angle(y1));xlabel('X pi');title('arg');
```

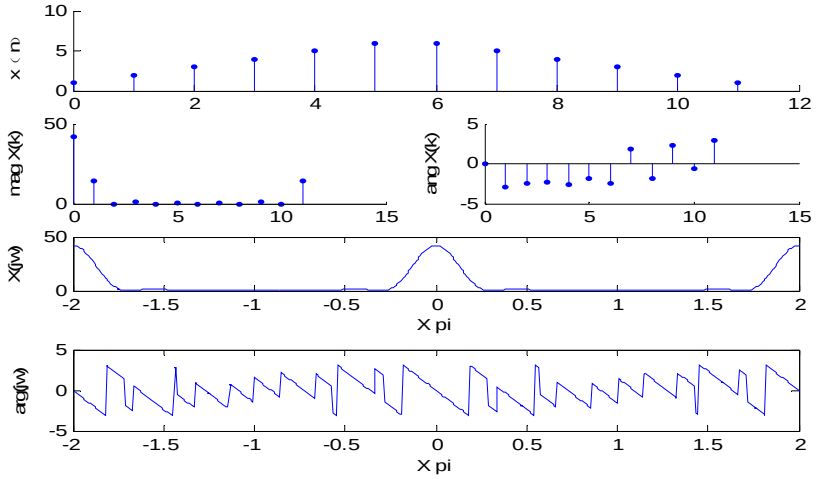
Simulation Results：



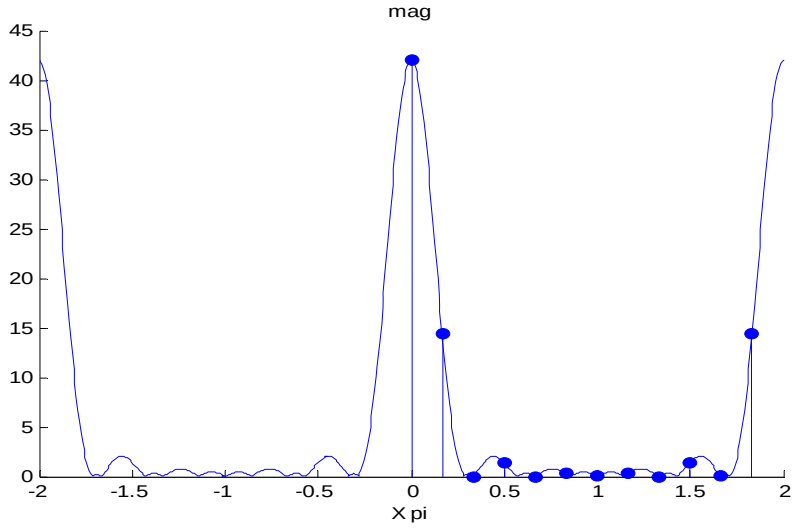
Figure(9.1.1)



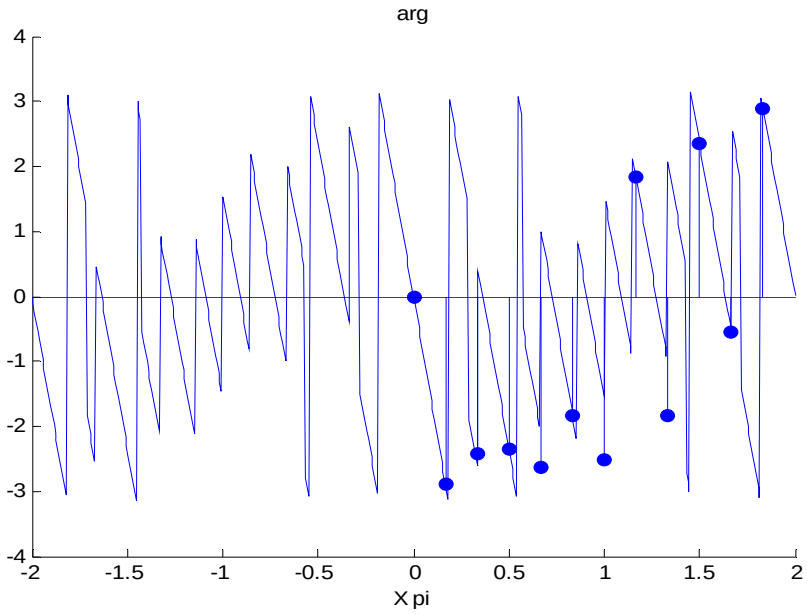
Figure(9.1.2)



Figure(9.2.1)



Figure(9.2.2)



Figure(9.2.3)

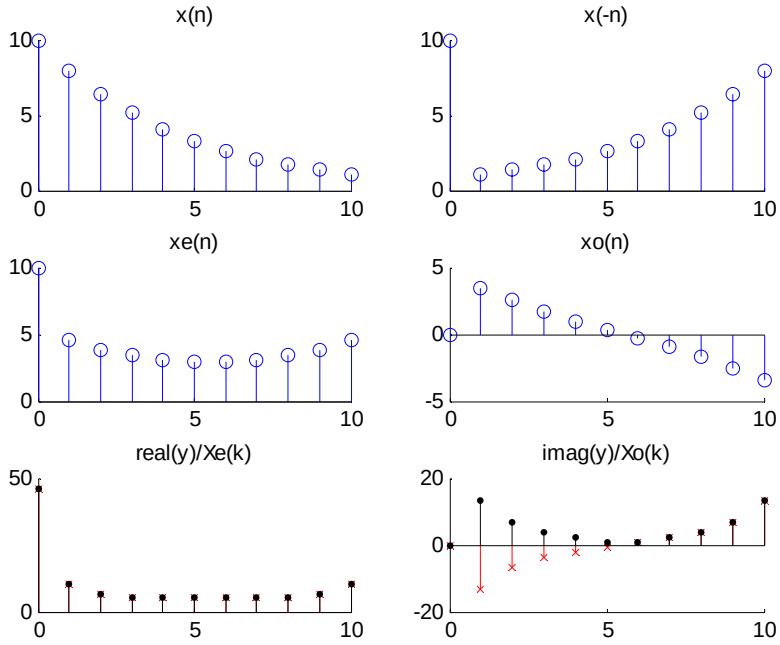
试验十

1． 程序如下：

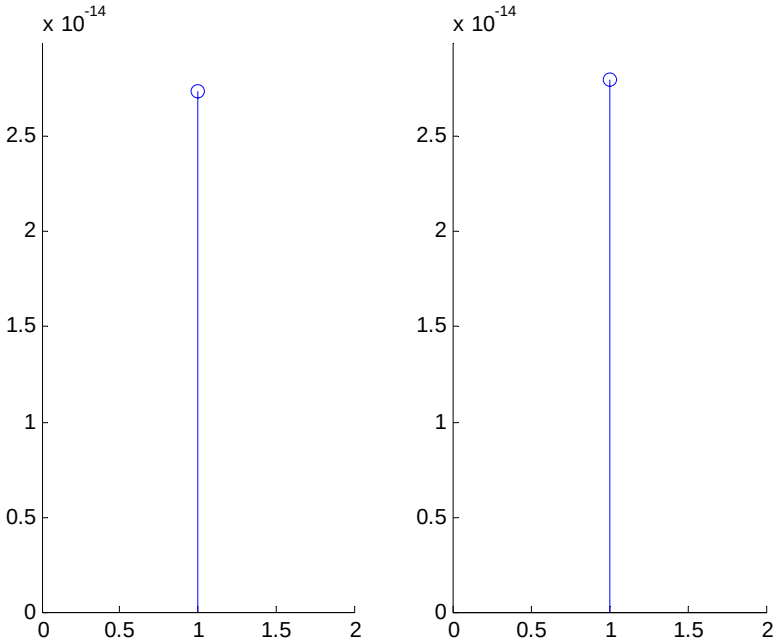
```
n=0:10;
x=10*0.8.^n;
N=length(n);
k=n;
xr=x(mod(-n,N)+1);
xe=0.5*(x+xr);
xo=0.5*(x-xr);
ye=xe*exp(-j*2*pi/N).^(n'*k);
yo=xo*exp(-j*2*pi/N).^(n'*k);
y=x*exp(-j*2*pi/N).^(n'*k);
errore=max(abs(real(y)-ye));
erroro=max(abs(j*imag(y)-yo));
subplot(321),stem(n,x);title('x(n)');
subplot(322),stem(n,xr);title('x(-n)');
subplot(323),stem(n,xe);title('xe(n)');
subplot(324),stem(n,xo);title('xo(n)');
subplot(325),stem(k,real(y),'xr');
hold
subplot(325),stem(k,ye,'.k');title('real(y)/Xe(k)');
subplot(326),stem(k,imag(y),'xr');
hold
subplot(326),stem(k,abs(yo),'.k');title('imag(y)/Xo(k)');
figure;
subplot(121),stem(errore);
```

subplot(122),stem(erroro);

Simulation Results：



Figure（1）



Figure（2）

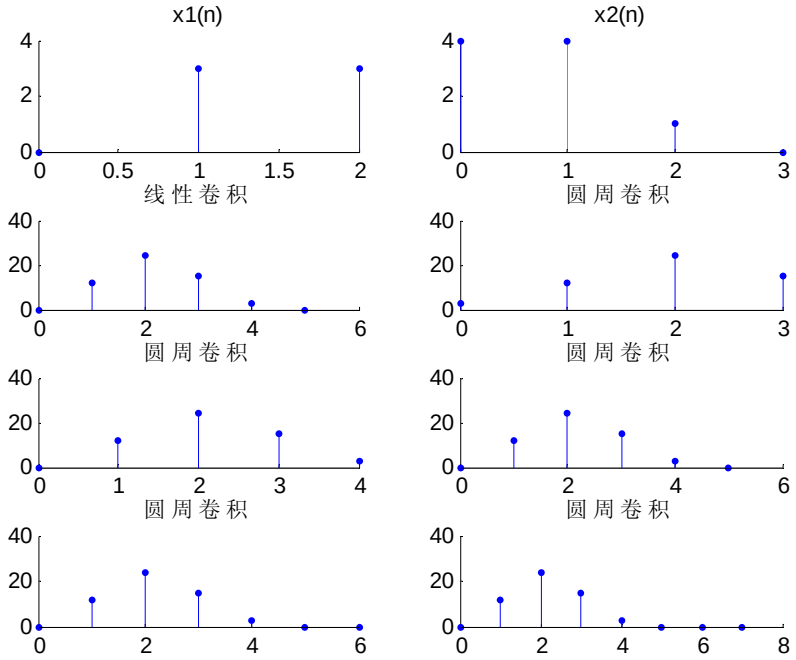
试验十一

1． 程序如下：

```
clc;clear;
N1=3;N2=4;
```

```
n1=0:N1-1;n2=0:N2-1;
x1=zeros(1,N1);
x2=zeros(1,N2);
x1(2)=1+2;
x1(3)=3;
x2(1)=4;
x2(2)=3+1;
x2(3)=1;
y1=conv(x1,x2);
n01=min(n1)+min(n2);
n02=max(n1)+max(n2);
ny=[n01:n02];
subplot(421),stem(n1,x1,'.');title('x1(n)');
subplot(422),stem(n2,x2,'.');title('x2(n)');
subplot(423),stem(ny,y1,'.');title('线性卷积');
for N=4:8
   n=0:N-1;
   x3=zeros(1,N);x4=x3;
   x3(find(n<N1))=x1;
   x4(find(n<N2))=x2;
   k=n;
   xk1=x3*exp(-j*2*pi/N).^(n'*k);
   xk2=x4*exp(-j*2*pi/N).^(n'*k);
   yk2=xk1.*xk2;
   y2=yk2*(exp(j*2*pi/N)).^(n'*k)/N;
   y2=abs(y2);
   subplot(4,2,N),stem(k,y2,'.');
   title('圆周卷积');
end
```

Simulation Results：



试验十二

1． 程序如下：

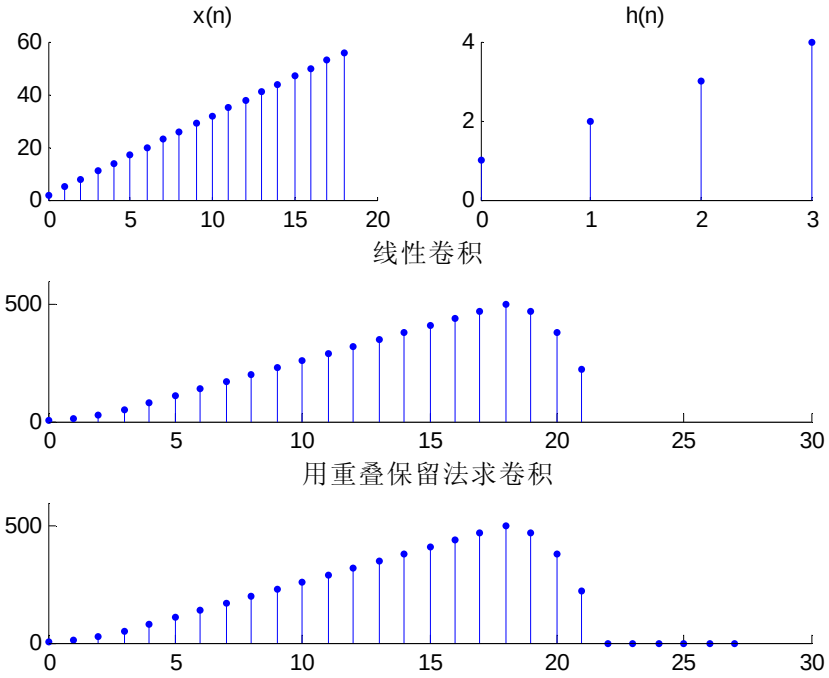
12.1

```
nx=0:18;
x=3*nx+2;
h=[1,2,3,4];
M=length(h);
nh=0:M-1;
y1=conv(x,h);
n01=min(nx)+min(nh);
n02=max(nx)+max(nh);
ny1=[n01:n02];
subplot(321),stem(nx,x,'.');title('x(n)');
subplot(322),stem(nh,h,'.');title('h(n)');
subplot(312),stem(ny1,y1,'.');axis([0,30,0,600]);title('线性卷积');
n=0:27;
x=[x,zeros(1,9)];
N=7;
L=N+M-1;
y=zeros(1,4*N);
for k=0:3
x1=zeros(1,L);
x1(4:10)=x(k*N+1:(k+1)*N);
  if k~=0
        x1(1:3)=x(k*N-2:k*N);
```

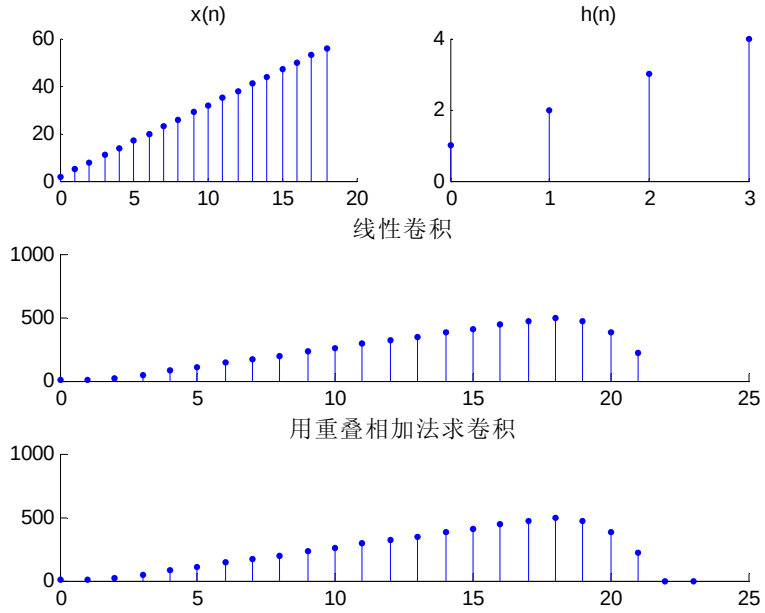
```
  end
  x1k=fft(x1,L);
  hk=fft(h,L);
  yk=x1k.*hk;
  y2=ifft(yk);
y(k*N+1:(k+1)*N)=y2(4:10);
end
subplot(313),stem(n,y,'.');axis([0,30,0,600]);title('用重叠保留法求卷积');

12.2
nx=0:18;
x=3*nx+2;
h=[1,2,3,4];
M=length(h);
nh=0:M-1;
y1=conv(x,h);
n01=min(nx)+min(nh);
n02=max(nx)+max(nh);
ny1=[n01:n02];
subplot(321),stem(nx,x,'.');title('x(n)');
subplot(322),stem(nh,h,'.');title('h(n)');
subplot(312),stem(ny1,y1,'.');title('线性卷积');
N=7;
n=0:3*N-1;
x=[x,0,0];
ny=0:23;
y=zeros(1,length(ny));
for k=0:2
    n1=k*N:(k+1)*N-1;
  x1=x(find((n>=min(n1))&(n<=max(n1))));
  xk=fft(x1,N+3);
  hk=fft(h,N+3);
  yk=xk.*hk;
  y2=ifft(yk);
  y2=abs(y2);
y(find(ny==min(n1)):find(ny==min(n1))+9)...
  =y(find(ny==min(n1)):find(ny==min(n1))+9)+y2;
end
subplot(313),stem(ny,y,'.');title('用重叠相加法求卷积');

12.3
nx=0:18;
x=3*nx+2;
h=[1,2,3,4];
```

```
M=length(h);
nh=0:M-1;
y1=conv(x,h);
n01=min(nx)+min(nh);
n02=max(nx)+max(nh);
ny1=[n01:n02];
subplot(321),stem(nx,x,'.');title('x(n)');
subplot(322),stem(nh,h,'.');title('h(n)');
subplot(312),stem(ny1,y1,'.');title('线性卷积');
N=7;
n=0:3*N-1;
x=[x,0,0];
ny=0:23;
y=zeros(1,length(ny));
for k=0:2
  n1=k*N:(k+1)*N-1;
  x1=x(find((n>=min(n1))&(n<=max(n1))));
  xk=fft(x1,N+3);
  hk=fft(h,N+3);
  yk=xk.*hk;
  y2=ifft(yk);
  y2=abs(y2);
y(find((ny>=min(n1))&(ny<=(max(n1)+3))))...
  =y(find((ny>=min(n1))&(ny<=(max(n1)+3))))+y2;
end
subplot(313),stem(ny,y,'.');title('用重叠相加法求卷积');
```

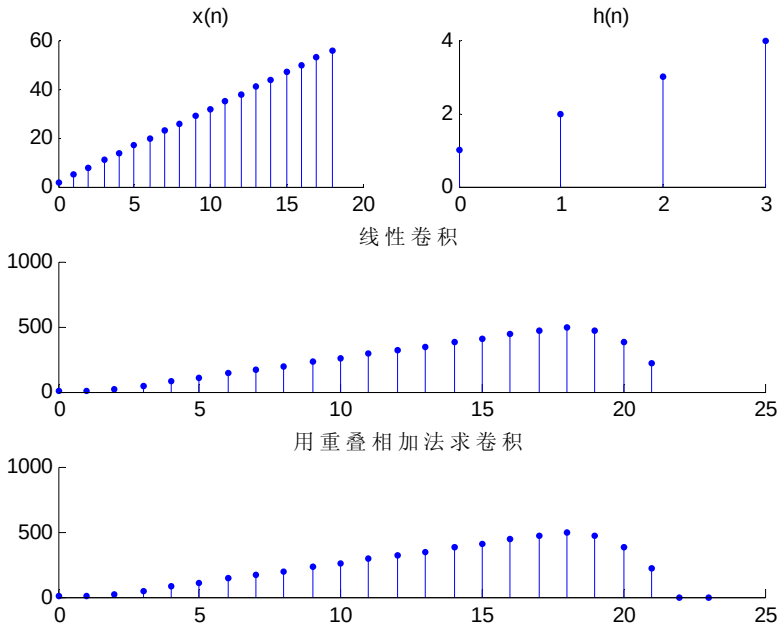
Simulation Results：



Figure（12.1）



Figure（12.20



Figure（12.3）

试验十三

1．程序如下：

```
x=ones(1,8);
n=0:length(x)-1;

t0=clock;
[m1,a1]=dft1(x);
subplot(321),stem(n,m1,'.');
title('用dft1实现 mag');
subplot(322),stem(n,a1,'.');
title('angle');
t1=etime(clock,t0);

t0=clock;
[m2,a2]=dft2(x);
subplot(323),stem(n,m2,'.');
title('用dft2实现 mag');
subplot(324),stem(n,a2,'.');
title('angle');
t2=etime(clock,t0);

t0=clock;
xk=fft(x);
subplot(325),stem(n,abs(xk),'.');
title('用FFT实现 mag');
```

```
subplot(326),stem(n,angle(xk),'.');
title('angle');
t3=etime(clock,t0);

figure;
subplot(311),stem(t1,'.');ylabel('单位：s');title('用dft1实现');
subplot(312),stem(t2,'.');ylabel('单位：s');title('用dft2实现');
subplot(313),stem(t3,'.');ylabel('单位：s');title('用FFT实现');
```

调用的函数：

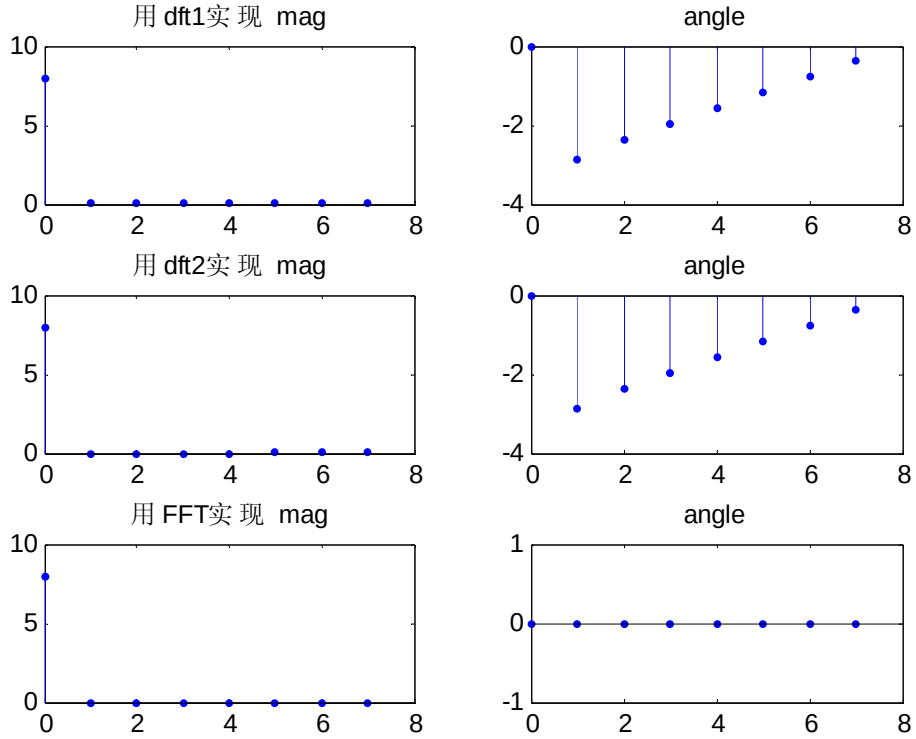
%dft1.m

```
function[Am,pha]=dft1(x)
N=length(x);
w=exp(-j*2*pi/N);
for k=1:N
    sum=0;
    for n=1:N
        sum=sum+x(n)*w^((k-1)*(n-1));
    end
        Am(k)=abs(sum);
        pha(k)=angle(sum);
end
```

%dft2.m

```
function[a,p]=dft2(x)
N=length(x);
n=0:N-1;
k=n;
w=exp(-j*2*pi/N);
nk=n'*k;
wnk=w.^(nk);
xk=x*wnk;
a=abs(xk);
p=angle(xk);
```

结果：



2. 程序如下：

```
p=8;
n=0:15;
figure;
for k=1:3
    q=2^k;
x1=exp(-((n-p).^2)/q);
subplot(3,2,2*k-1),stem(n,x1,'.');
title('q变化 x(n)');
[m,a,w]=dtft(x1);
subplot(3,2,2*k),plot(w/pi,m);
title('q变化 abs[X(w)]');
end

q=8;
figure;
for k=1:3
    p=-2*(k^2)+11*k-1;
    x1=exp(-((n-p).^2)/q);
    subplot(3,2,2*k-1),stem(n,x1,'.');
title('p变化 x(n)');
[m,a,w]=dtft(x1);
subplot(3,2,2*k),plot(w/pi,m);
title('p变化 abs[X(w)]');
```

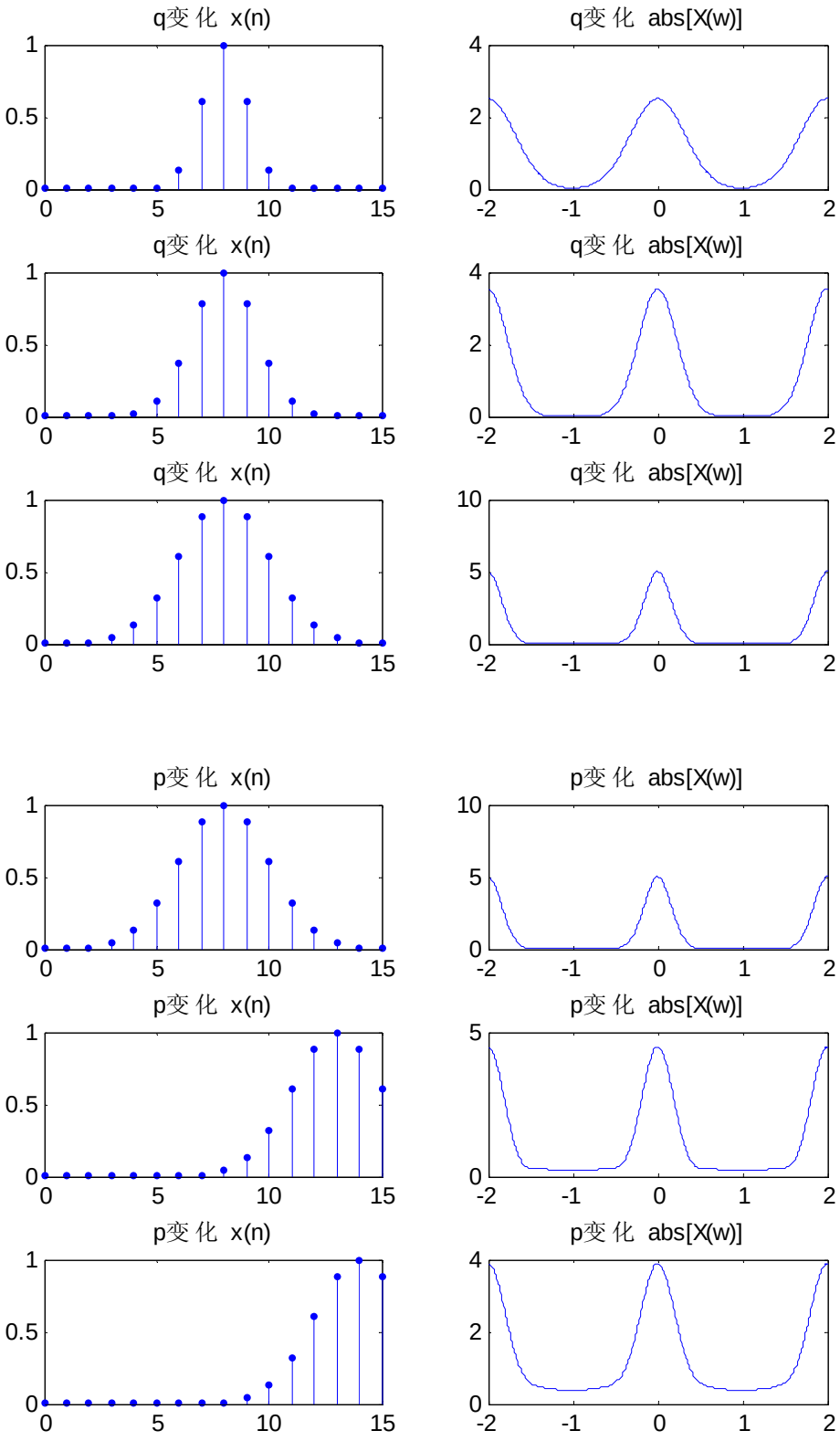
```
end
```

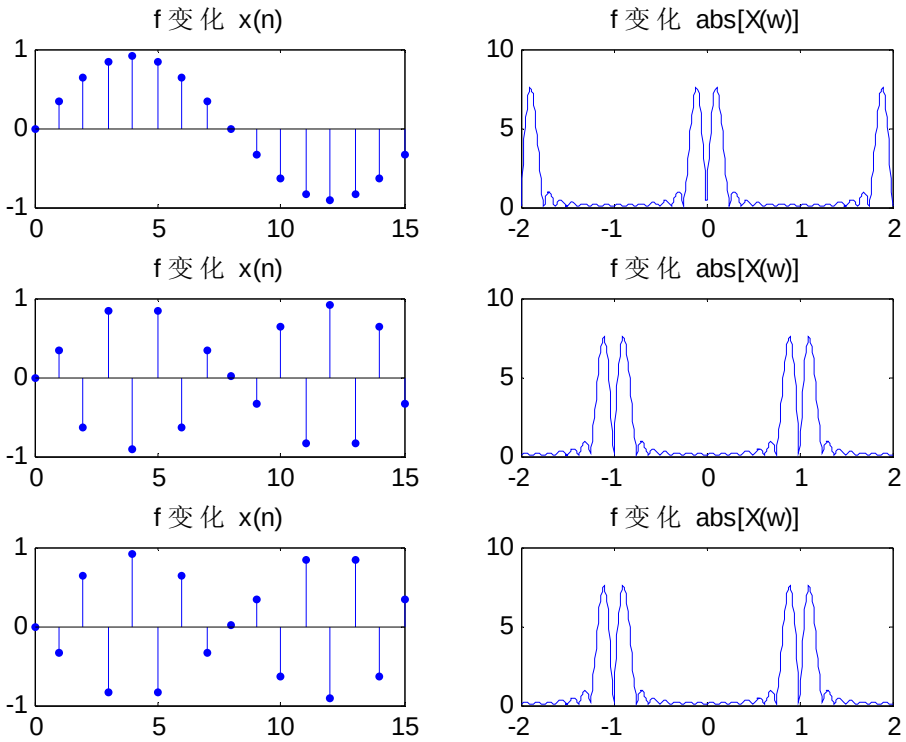
```
figure;
f1=[0.0625,0.4375,0.5625];
for k=1:3
    f=f1(k);
    a=0.1;
x2=exp(-a)*sin(2*pi*f*n);
subplot(3,2,2*k-1),stem(n,x2,'.');
title('f 变化 x(n)');
[m,a,w]=dtft(x2);
subplot(3,2,2*k),plot(w/pi,m);
title('f 变化 abs[X(w)]');
end
```

调用的函数：

```
%dtft.m
function[m,a,w]=dtft(x)
N=length(x);
n=0:N-1;
w=linspace(-2*pi,2*pi,500);
y=x*exp(-j*n'*w);
m=abs(y);
a=angle(y);
```

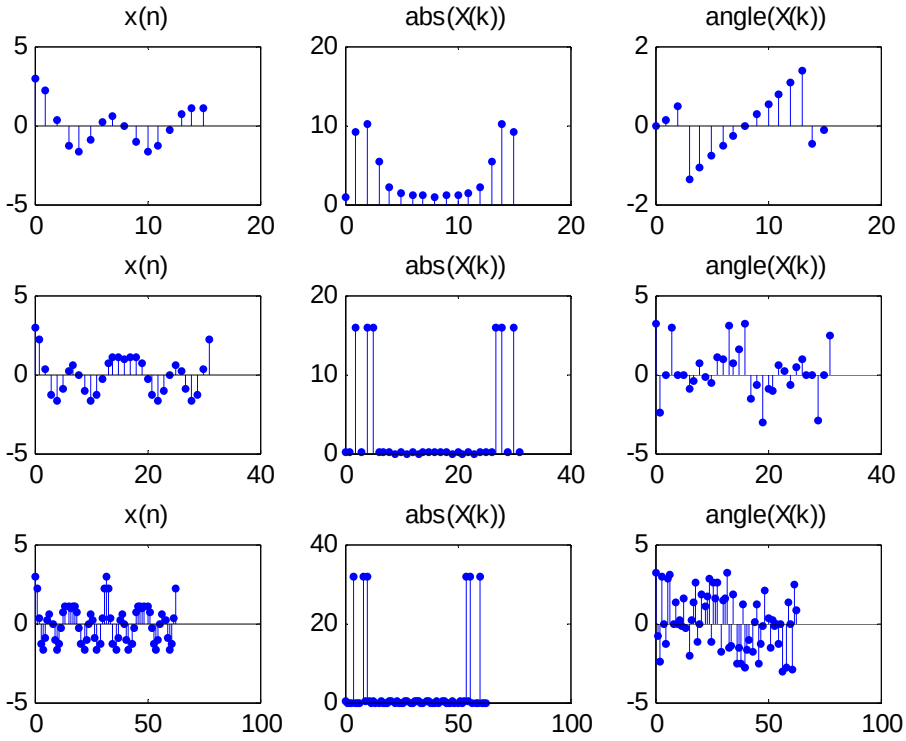
结果：


q变 化 x(n)
q变 化 abs[X(w)]
q变 化 x(n)
q变 化 abs[X(w)]
q变 化 x(n)
q变 化 abs[X(w)]
p变 化 x(n)
p变 化 abs[X(w)]
p变 化 x(n)
p变 化 abs[X(w)]
p变 化 x(n)
p变 化 abs[X(w)]



3.程序：

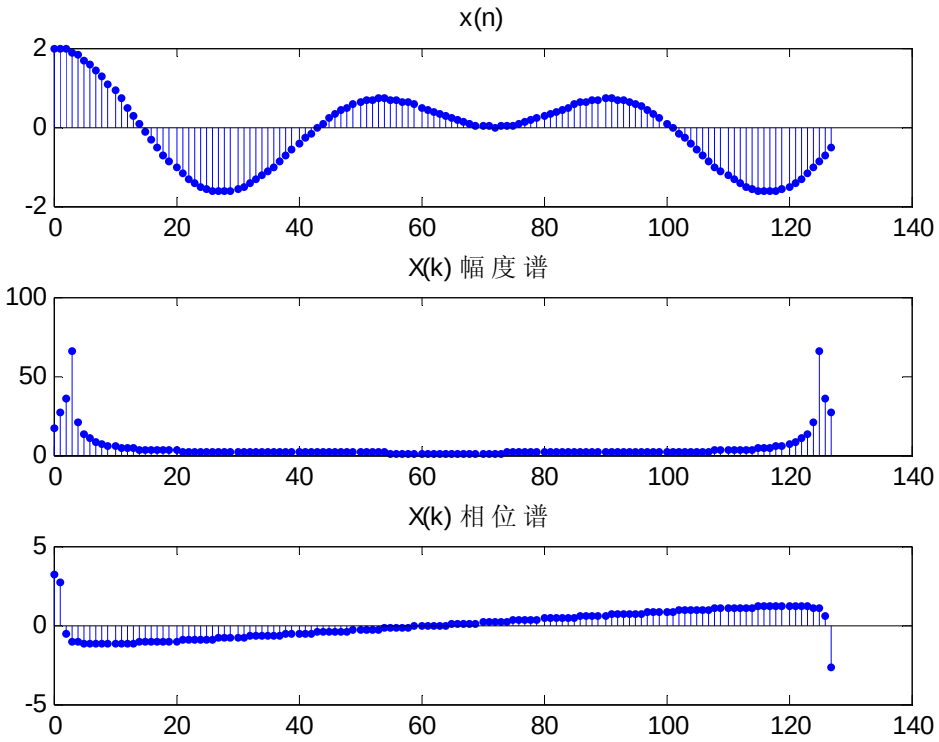
```
f=64;
dt=1/f;
N=[16,32,64];
for k=1:3
    n=0:N(k)-1;
    nt=n*dt;
    x=cos(8*pi*nt)+cos(16*pi*nt)+cos(20*pi*nt);
    y=fft(x);
    subplot(3,3,3*k-2),stem(n,x,'.');
    title('x(n)');
    subplot(3,3,3*k-1),stem(n,abs(y),'.');
    title('abs(X(k))');
    subplot(3,3,3*k),stem(n,angle(y),'.');
    title('angle(X(k))');
end
```

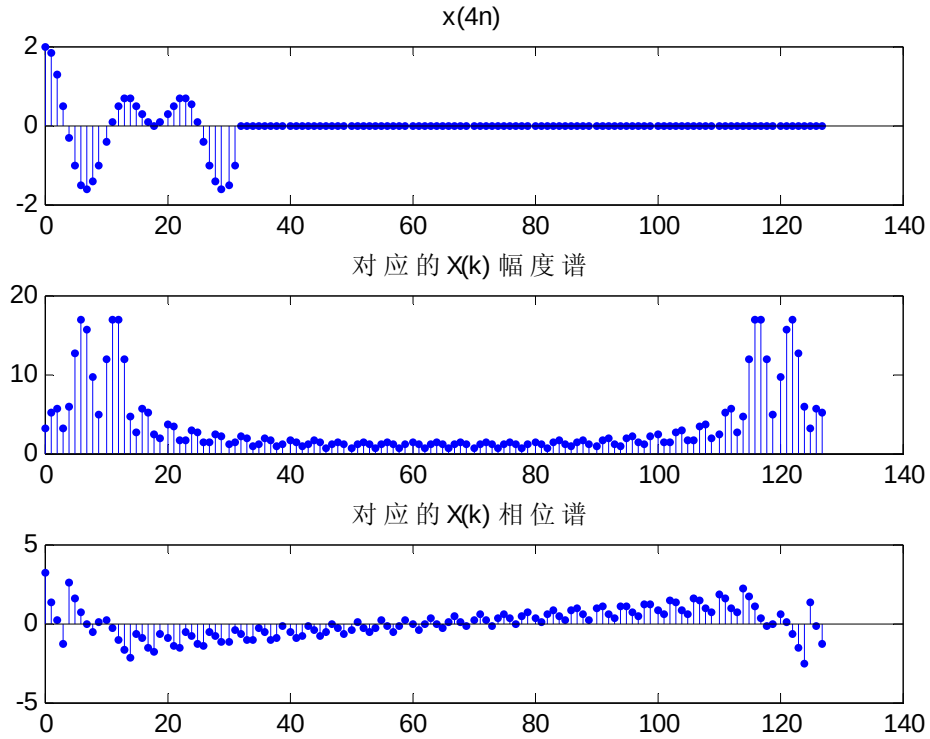


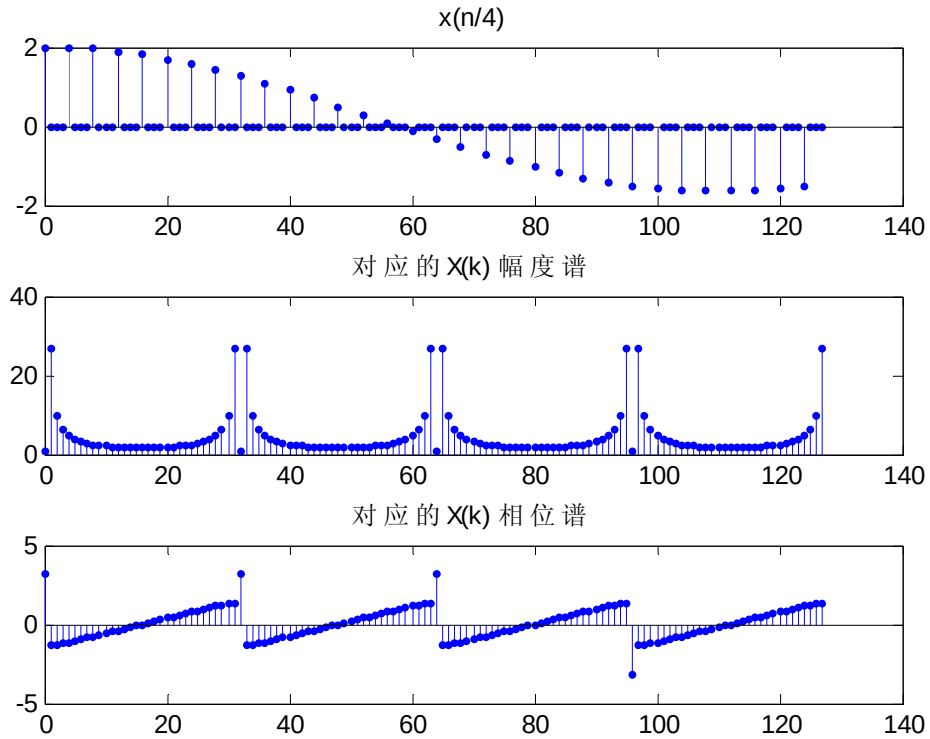
4. 程序如下：

```
n=0:127;
x=cos(n*pi/36)+cos(1.5*n*pi/36);
y=fft(x);
figure;
subplot(311),stem(n,x,'.');
title('x(n)');
subplot(312),stem(n,abs(y),'.');
title('X(k) 幅度谱');
subplot(313),stem(n,angle(y),'.');
title('X(k) 相位谱');

N=length(n);
n1=0:N/4-1;
x1=cos(4*n1*pi/36)+cos(1.5*4*n1*pi/36);
x1=[x1,zeros(1,N*3/4)];
y1=fft(x1,128);
figure;
subplot(311),stem(n,x1,'.');
title('x(4n)');
subplot(312),stem(n,abs(y1),'.');
title('对应的X(k) 幅度谱');
subplot(313),stem(n,angle(y1),'.');
title('对应的X(k) 相位谱');
```

```
n2=0:(N-1)*4;
x2=zeros(1,N*4-3);
for k=0:127
x2(k*4+1)=cos(k*pi/36)+cos(1.5*k*pi/36);
end
x3=zeros(1,N);
x3=x2(1:N);
y2=fft(x3,128);
figure;
subplot(311),stem(n,x3,'.');
title('x(n/4)');
subplot(312),stem(n,abs(y2),'.');
title('对应的X(k) 幅度谱');
subplot(313),stem(n,angle(y2),'.');
title('对应的X(k) 相位谱');
```




x(4n)
2
0
-2
0 20 40 60 80 100 120 140
对 应 的 X(k) 幅 度 谱
20
10
0
0 20 40 60 80 100 120 140
对 应 的 X(k) 相 位 谱
5
0
-5
0 20 40 60 80 100 120 140

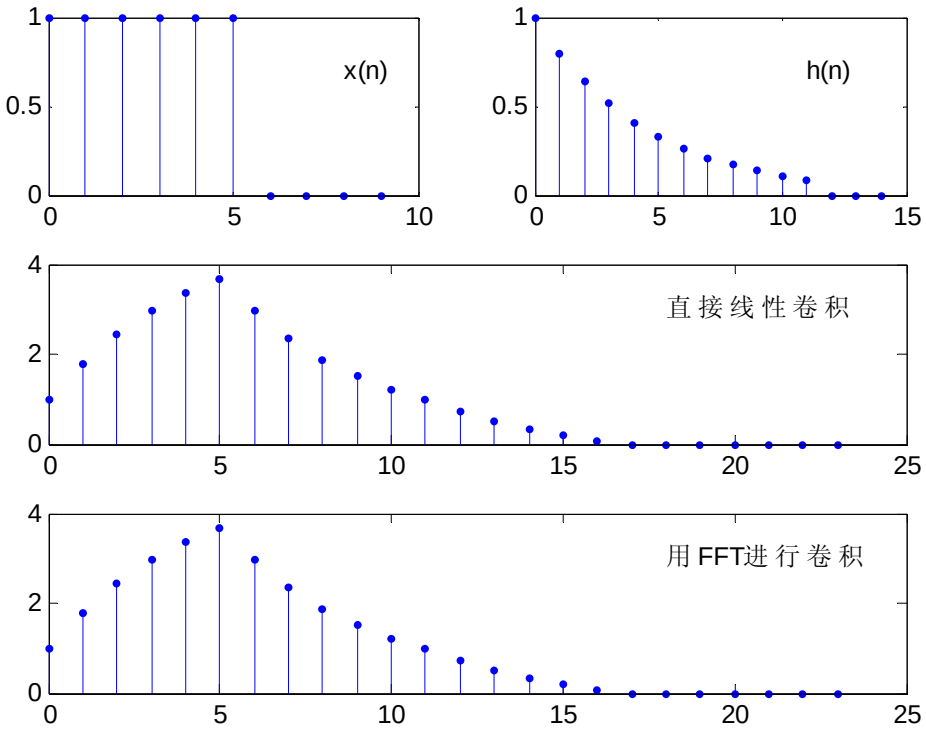

x(n/4)
2
0
-2
0 20 40 60 80 100 120 140
对 应 的 X(k) 幅 度 谱
40
20
0
0 20 40 60 80 100 120 140
对 应 的 X(k) 相 位 谱
5
0
-5
0 20 40 60 80 100 120 140

实验十四

1. 程序如下：

```
N=10;M=15;
nx=0:N-1;
x=[nx<=5];
n1=0:11;
h1=0.8.^n1;
nh=0:M-1;
h=zeros(1,M);
h(find(nh<=11))=h1;
y1=conv(x,h);
n01=min(nx)+min(nh);
n02=max(nx)+max(nh);
ny1=[n01:n02];
subplot(321),stem(nx,x,'.');
text(8,0.7,'x(n)');
subplot(322),stem(nh,h,'.');
text(11,0.7,'h(n)');
subplot(312),stem(ny1,y1,'.');
text(18,3,'直接线性卷积');
n=0:N+M-2;
L=length(n);
xk=fft(x,L);
hk=fft(h,L);
yk=xk.*hk;
y2=ifft(yk);
y2=abs(y2);
subplot(313),stem(n,y2,'.');
text(18,3,'用FFT进行卷积');
```

结果：



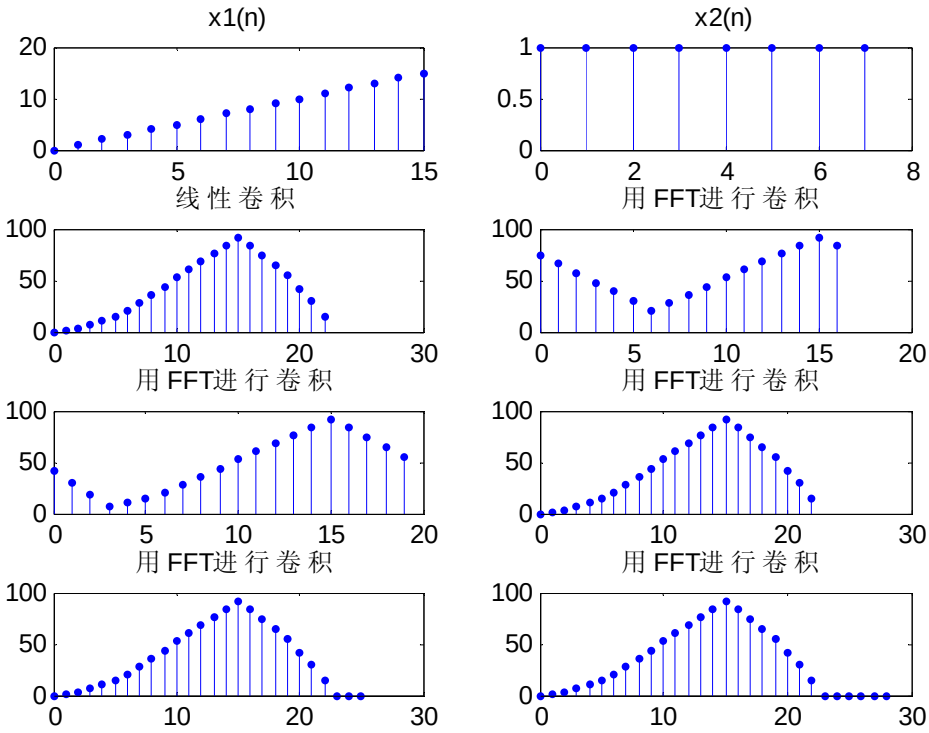
2.

程序如下：

```
n1=0:15;
x1=n1;
n2=0:7;
M=length(n2);
x2=ones(1,M);
y1=conv(x1,x2);
n01=min(n1)+min(n2);
n02=max(n1)+max(n2);
ny1=[n01:n02];
subplot(421),stem(n1,x1,'.');
title('x1(n)');
subplot(422),stem(n2,x2,'.');
title('x2(n)');
subplot(423),stem(ny1,y1,'.');
title('线性卷积');

for L=17:3:29
n=0:L-1;
xk1=fft(x1,L);
xk2=fft(x2,L);
yk=xk1.*xk2;
y2=ifft(yk);
```

```
y2=abs(y2);
subplot(4,2,(L-5)/3),stem(n,y2,'.');
title('用FFT进行卷积');
end
```

结果：



实验十五

程序如下：

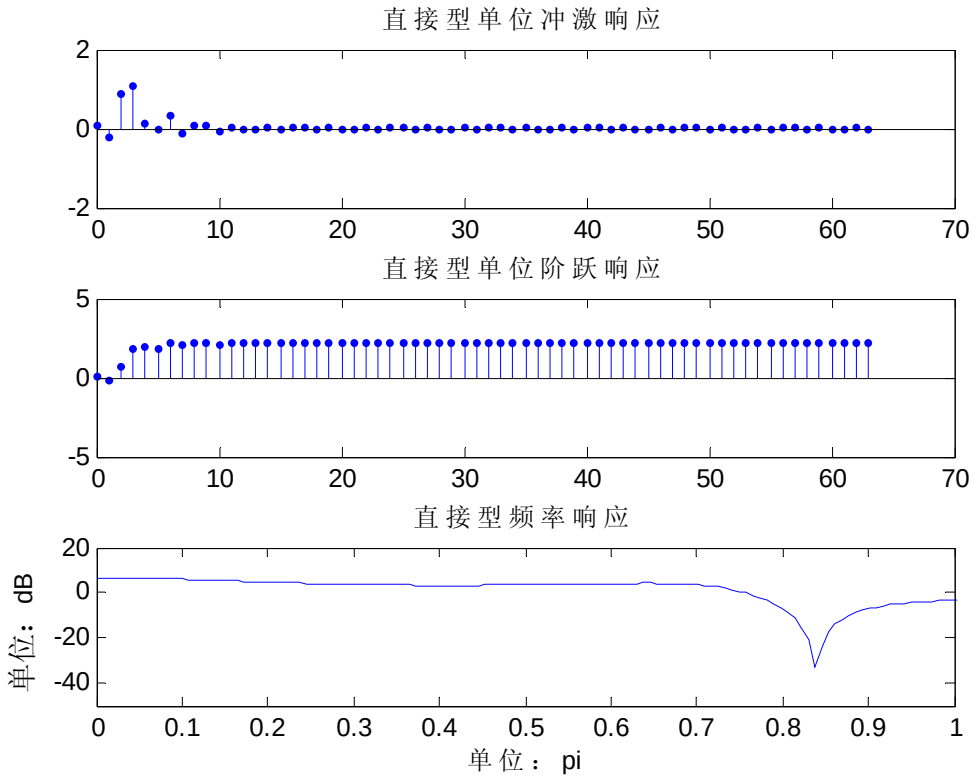
```
b=[1,-3,11,27,18];
a=[16,12,2,-4,-1];
n=0:63;
figure;
h=impz(b,a,n);
u=dstep(b,a,n);
w=linspace(-2*pi,2*pi,500);
H=freqz(b,a,w);
H=20*log10(abs(H));
subplot(3,1,1),stem(n,h,'.');
title('直接型单位冲激响应');
subplot(3,1,2),stem(n,u,'.');
title('直接型单位阶跃响应');
subplot(3,1,3),plot(w/pi,H);
```

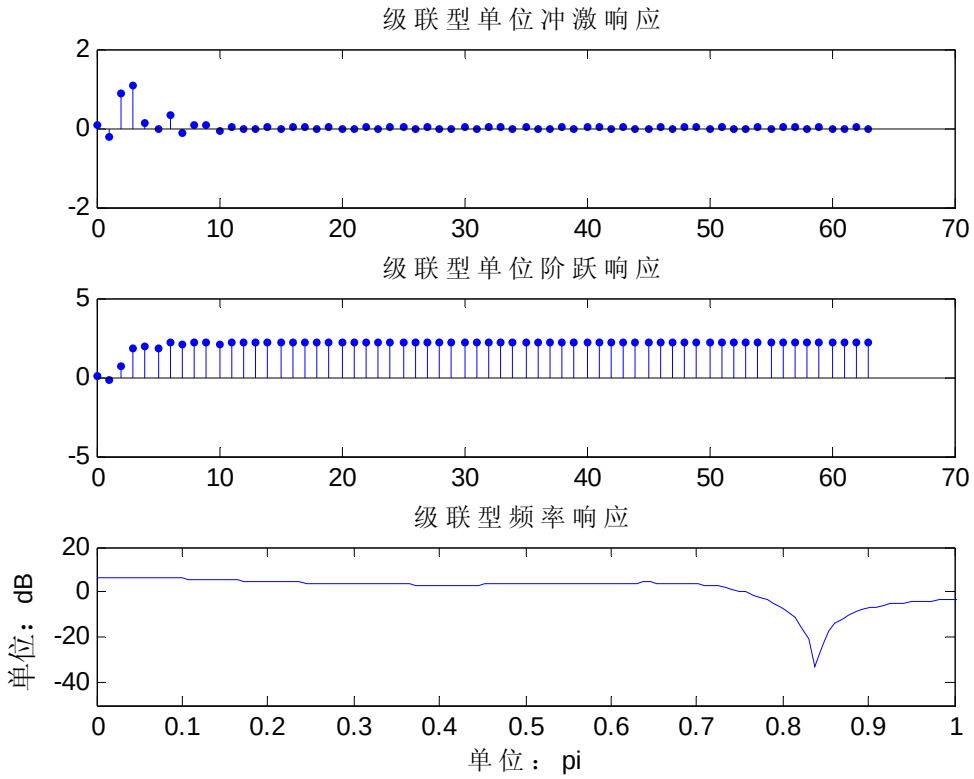
```
title('直接型频率响应');
axis([0,1,-50,20]);
xlabel('单位：pi');
ylabel('单位：dB');

[sos,g]=tf2sos(b,a);
N=size(sos);
N=N(1);
h0=[n==0];
for k=1:N
    b1=sos(k,1:3);
    a1=sos(k,4:6);
    h1=impz(b1,a1,n);
    h0=conv(h0,h1);
end
h0=g*h0;
h0=h0(1:64);
figure;
subplot(3,1,1),stem(n,h0,'.');
title('级联型单位冲激响应');

u0=[n>=0];
for k=1:N
    b1=sos(k,1:3);
    a1=sos(k,4:6);
    h1=impz(b1,a1,n);
    u0=conv(u0,h1);
end
u0=g*u0;
u0=u0(1:64);
subplot(3,1,2),stem(n,u0,'.');
title('级联型单位阶跃响应');
w=linspace(-2*pi,2*pi,500);
H0=ones(1,length(w));
for k=1:N
    b1=sos(k,1:3);
    a1=sos(k,4:6);
H1=freqz(b1,a1,w);
H0=H0.*H1;
end
H0=g*H0;
H0=20*log10(abs(H0));
subplot(3,1,3),plot(w/pi,H0);
title('级联型频率响应');
```

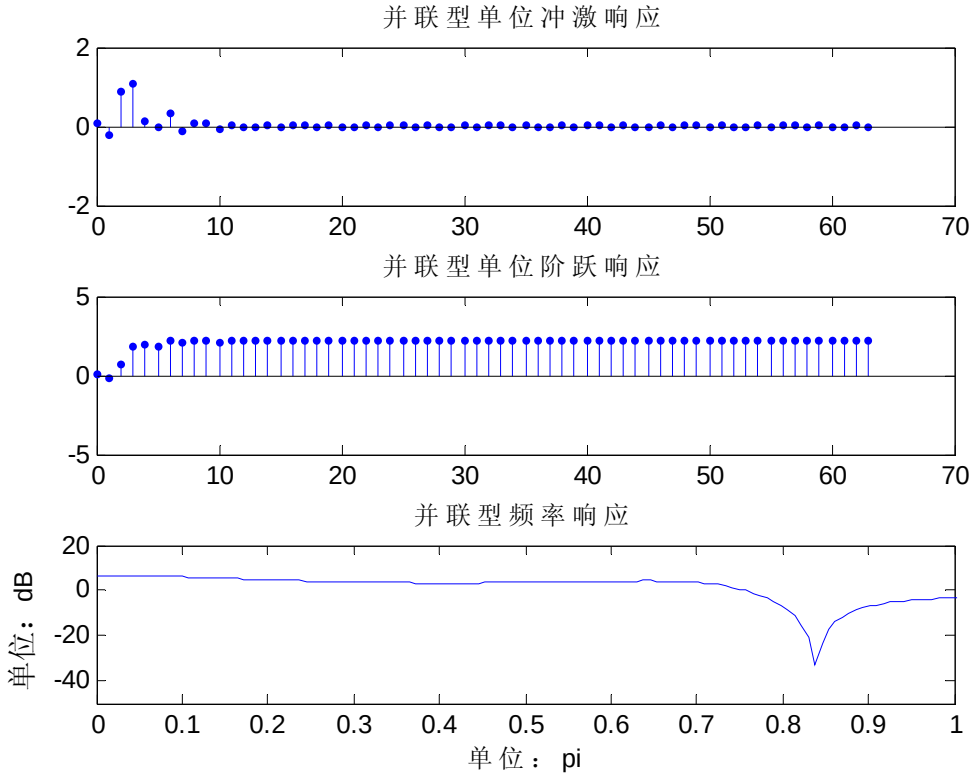
```
axis([0,1,-50,20]);
xlabel('单位：pi');
ylabel('单位：dB');


[r,p,q]=residuez(b,a);
N=size(r);
N=N(1);
h0=zeros(1,64);
for k=1:N
    b1=r(k);
    a1=[1,-1*p(k)];
    s=[n==0];
    h1=filter(b1,a1,s);
    h0=h0+h1;
end
h1=[n==0];
h1=q*h1;
h0=h0+h1;
figure;
subplot(3,1,1),stem(n,h0,'.');
title('并联型单位冲激响应');



u0=zeros(1,64);
for k=1:N
    b1=[r(k),0];
    a1=[1,-1*p(k)];
    s=[n>=0];
    u1=filter(b1,a1,s);
    u0=u0+u1;
end
u1=[n>=0];
u1=q*u1;
u0=u0+u1;
subplot(3,1,2),stem(n,u0,'.');
title('并联型单位阶跃响应');


w=linspace(-2*pi,2*pi,500);
H10=zeros(1,length(w));
for k=1:N
    b1=[r(k),0];
```

```
    a1=[1,-1*p(k)];
H11=freqz(b1,a1,w);
H10=H10+H11;
end
H10=q+H10;
H10=20*log10(abs(H10));
subplot(3,1,3),plot(w/pi,H10);
title('并联型频率响应');
axis([0,1,-50,20]);
xlabel('单位：pi');
ylabel('单位：dB');
```

结果：







试验十八

2． 程序如下：

```
b=[1, 3, 5, 3, 1];
a=[1];
```

```
[b0,B,A]=dir2cas(b,a);
b0,B,A
```

调用的函数：dir2cas.m

```
function[b0,B,A]=dir2cas(b,a)
  b0=b(1);b=b/b0;
  a0=a(1);a=a/a0;
  b0=b0/a0;
  M=length(b);N=length(a);
  if N>M
      b=[b,zeros(1,N-M)];
  elseif M>N
      a=[a,zeros(1,M-N)];N=M;
  end
  K=floor(N/2);B=zeros(K,3);A=zeros(K,3);
  if K*2==N
      b=[b 0];
      a=[a 0];
  end
  broots=cplxpair(roots(b));
  aroots=cplxpair(roots(a));
  for i=1:2:2*K
      Brow=broots(i:1:i+1,:);
      Brow=real(poly(Brow));
      B(fix((i+1)/2),:)=Brow;
      Arow=aroots(i:1:i+1,:);
      Arow=real(poly(Arow));
      A(fix((i+1)/2),:)=Arow;
  end
```

结果：

```
b0 =

     1

B =

    1.0000    2.2435    2.9656
    1.0000    0.7565    0.3372

A =

     1     0     0
     1     0     0
```

3．程序：

```
h=[1,3,5,-3,-1]/9;
[N,Hk,wk]=dir2fs(h)
```

调用的函数：dir2fs.m

```
function[N,Hk,wk]=dir2fs(b);
N=length(b);
Hk=fft(b);
k=0:N-1;
wk=exp(2*pi*i/N).^k;
```

结果：

```
N =

     5

Hk =

  Columns 1 through 4

   0.5556                  -0.0000 - 0.9452i   0.0000 + 0.5841i   0.0000 - 0.5841i

  Column 5

  -0.0000 + 0.9452i

wk =

  Columns 1 through 4

   1.0000                   0.3090 + 0.9511i  -0.8090 + 0.5878i  -0.8090 - 0.5878i

  Column 5

   0.3090 - 0.9511i
```

实验十九

2 与 3 程序如下：

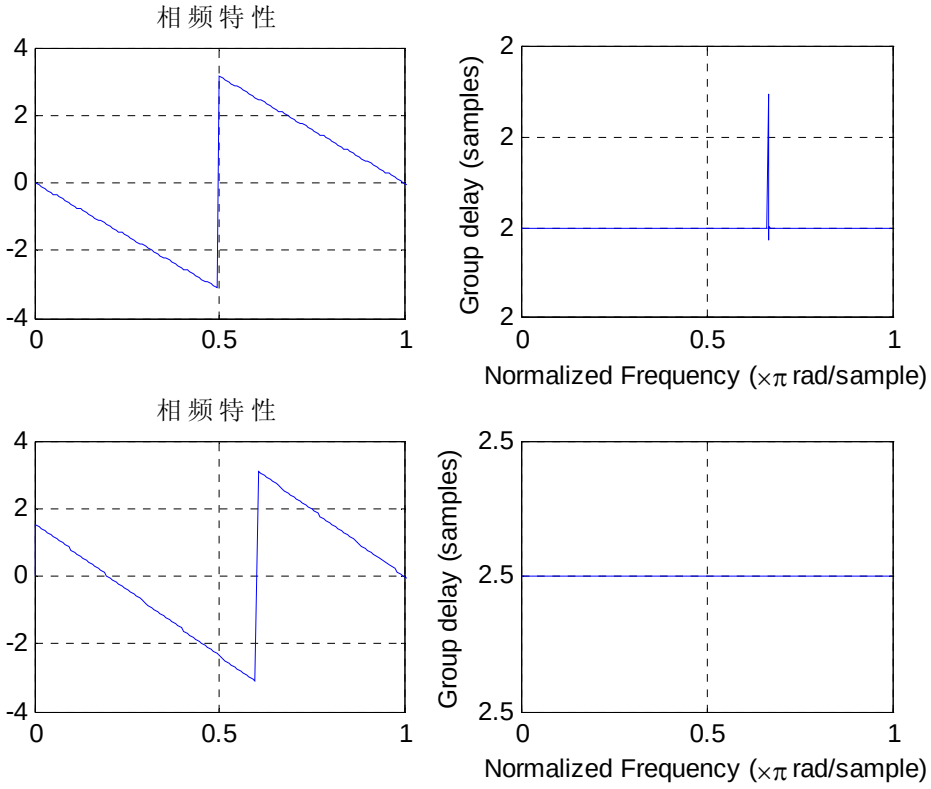
```
h=[1,2,3,2,1];
[H,p,w]=dtft(h);
subplot(221),plot(w/pi,p);grid;
axis([0,1,-4,4]);
title('相频特性');
subplot(222),grpdelay(h,1);

h=[1,2,3,-3,-2,-1];
[H,p,w]=dtft(h);
subplot(223),plot(w/pi,p);grid;
axis([0,1,-4,4]);
title('相频特性');
subplot(224),grpdelay(h,1);
```

调用的函数：dtft.m

```
function[m,a,w]=dtft(x)
```

```
N=length(x);
n=0:N-1;
w=linspace(-2*pi,2*pi,500);
y=x*exp(-j*n'*w);
m=abs(y);
a=angle(y);
```

结果：



4. 程序如下：

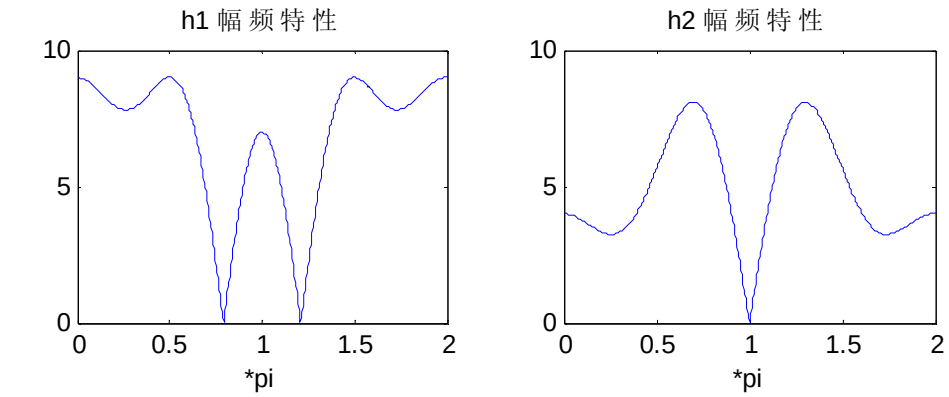
```
h1=[1,-2,3,5,3,-2,1];
h2=[1,-2,3,3,-2,1];
h3=[1,-2,3,5,-3,2,-1];
h4=[1,-2,3,-3,2,-1];
figure;
[a1,w1,type1,tao1]=amp(h1);type1
subplot(221),plot(w1/pi,abs(a1));
xlabel('*pi');
title('h1 幅频特性');

[a2,w2,type2,tao2]=amp(h2);type2
subplot(222),plot(w2/pi,abs(a2));
title('h2 幅频特性');
xlabel('*pi');
[a3,w3,type3,tao3]=amp(h3);type3
subplot(223),plot(w3/pi,abs(a3));
```

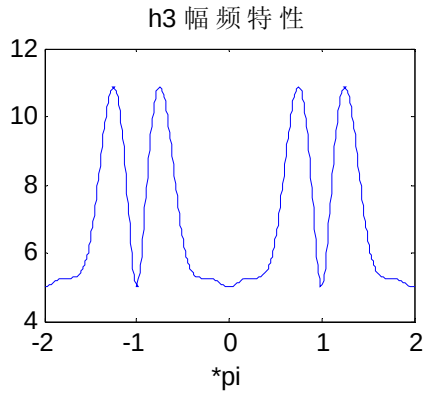
```
title('h3 幅频特性');
xlabel('*pi');
[a4,w4,type4,tao4]=amp(h4);type4
subplot(224),plot(w4/pi,abs(a4));
title('h4 幅频特性');
xlabel('*pi');


figure;
subplot(221),zplane(h1,1);title('h1 零点');
subplot(222),zplane(h2,1);title('h2 零点');
subplot(223),zplane(h3,1);title('h3 零点');
subplot(224),zplane(h4,1);title('h4 零点');
```

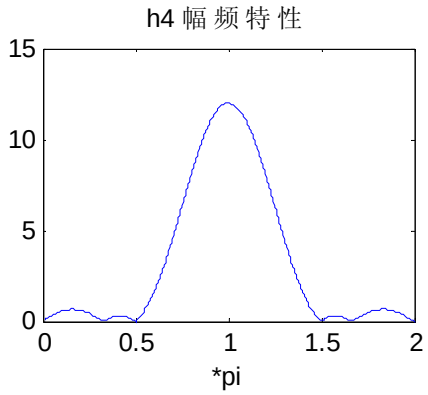
调用的函数：amp.m

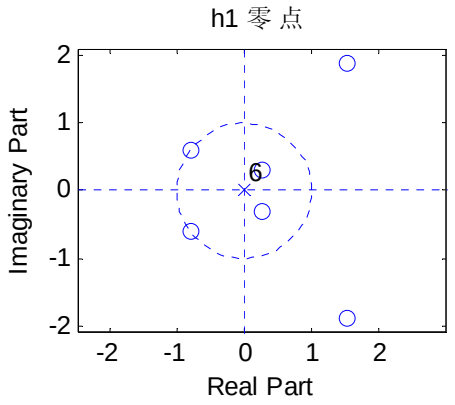
```
function [A,w,type,tao]=amp(h);
N=length(h);
tao=(N-1)/2;
L=floor((N-1)/2);
n=1:L+1;
w=[0:500]*2*pi/500;
if all(abs(h(n)-h(N-n+1))<1e-10)
    A=2*h(n)*cos(((N+1)/2-n)'*w)-mod(N,2)*h(L+1);
    type=2-mod(N,2);
elseif all(abs(h(n)+h(N-n+1))<1e-10)&(h(L+1)*mod(N,2)==0)
    A=2*h(n)*sin(((N+1)/2-n)'*w);
    type=4-mod(N,2);
else disp('错误：这是非线性相位系统！');
    [A,m,w]=dtft(h);
    A=A.*exp(i*m);
    type='?';
    tao='?';

end
```

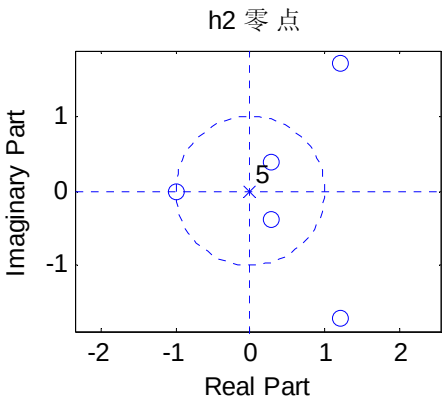
结果：

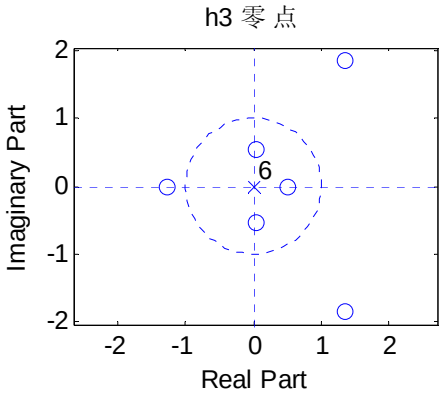


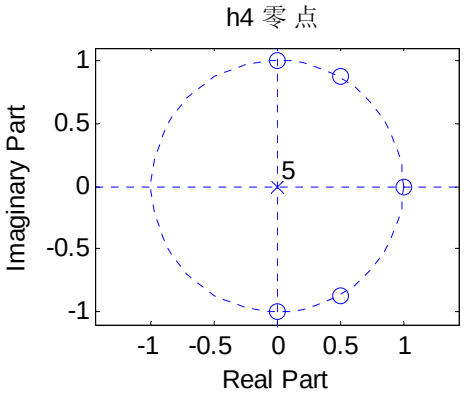












实验二十三

程序：

```
op=0.2*pi;
rp=1;
```

```
os=0.3*pi;
as=16;

figure;
[b,a]=afd_butt(op,os,rp,as);
[H,w]=freqs(b,a);
h=impulse(b,a);
t=0:length(h)-1;
subplot(221),plot(w/(2*pi),abs(H));title('巴特幅频特性');xlabel('Hz');
subplot(222),plot(w/(2*pi),angle(H));title('巴特相频特性');xlabel('Hz');
subplot(223),plot(w/(2*pi),20*log10(abs(H)/max(abs(H))));title('巴特幅度分贝表示
');xlabel('Hz');
subplot(224),plot(t,h);title('巴特单位冲激响应h(t)');xlabel('sec');

figure;
[b,a]=afd_chb1(op,os,rp,as);
[H,w]=freqs(b,a);
h=impulse(b,a);
t=0:length(h)-1;
subplot(221),plot(w/(2*pi),abs(H));title('切比1幅频特性');xlabel('Hz');
subplot(222),plot(w/(2*pi),angle(H));title('切比1相频特性');xlabel('Hz');
subplot(223),plot(w/(2*pi),20*log10(abs(H)/max(abs(H))));title('切比1幅度分贝表示
');xlabel('Hz');
subplot(224),plot(t,h);title('切比1单位冲激响应h(t)');xlabel('sec');


figure;
[b,a]=afd_chb2(op,os,rp,as);
[H,w]=freqs(b,a);
h=impulse(b,a);
t=0:length(h)-1;
subplot(221),plot(w/(2*pi),abs(H));title('切比2幅频特性');xlabel('Hz');
subplot(222),plot(w/(2*pi),angle(H));title('切比2相频特性');xlabel('Hz');
subplot(223),plot(w/(2*pi),20*log10(abs(H)/max(abs(H))));title('切比2幅度分贝表示
');xlabel('Hz');
subplot(224),plot(t,h);title('切比2单位冲激响应h(t)');xlabel('sec');


figure;
[b,a]=afd_elip(op,os,rp,as);
[H,w]=freqs(b,a);
h=impulse(b,a);
t=0:length(h)-1;
subplot(221),plot(w/(2*pi),abs(H));title('椭圆幅频特性');xlabel('Hz');
```

```
subplot(222),plot(w/(2*pi),angle(H));title('椭圆相频特性');xlabel('Hz');
subplot(223),plot(w/(2*pi),20*log10(abs(H)/max(abs(H))));title('椭圆幅度分贝表示
');xlabel('Hz');
subplot(224),plot(t,h);title('椭圆单位冲激响应h(t)');xlabel('sec');
```

调用的函数：

(1)afd_butt.m

```
function [b,a]=afd_butt(Wp,Ws,Rp,As);
%Analog Lowpass Filter Design :Butterworth
%-----------------------------------------
%[b,a]=afd_butt(Wp,Ws,Rp,As);
%b=Numberator coefficients of Ha(s)
%a=Denominator coefficients of Ha(s)
%Wp=Passband edge frequency in rad/sec;Wp>0
%Ws=Stopband edge frequency in rad/sec;Ws>Wp>0
%Rp=Passband ripple in +dB;(Rp>0)
%As=Stopband attenuation in +dB;(As>0)
if Wp<=0
    error('Passband edge must be larger than 0')
end
if Ws<=Wp
    error('Stopband edge must be larger than Passband edge')
end
if (Rp<=0)|(As<0)
    error('PB ripple and/or SB attenuation must be larger than 0')
end
N=ceil(log10((10^(Rp/10)-1)/(10^(As/10)))/(2*log10(Wp/Ws)));
fprintf('\n***Butterworth Filter Order=%2.0f\n',N)
OmegaC=Wp/((10^(Rp/10)-1)^(1/(2*N)));
[b,a]=u_buttap(N,OmegaC);
```

(2) afd_chb1.m

```
% Chebyshev I 型模拟低通滤波器原型设计;
% afd_chb1.m;
function [b a]=afd_chb1(Wp,Ws,Rp,As);
% Anolog Lowpass Filter Design:chebyshev-1
% ^^^^^^^^^^^^^^^^^^^
% [b a]=afd_chb1(Wp,Ws,Rp,As);
%  b=numerator polynomial coefficients of Ha(s);
%  a=denominator polynomial coefficients of Ha(s);
%  Wp=passband edge frequency in rad/sec;Wp>0;
%  Ws=stopband edge frequency in rad/sec;Ws>Wp>0;
%  Rp=passband ripple in +dB;(Rp>0);
%  As=stopband attenuation in + dB;(As>0);
%  ^^^^^^^^^^^^^^^^^^^^
```

```
if Wp<=0
    error('passband edge must be larger than 0')
end
if Ws<=Wp
    error('stopband dege must be larger than passband edge')
end
if(Rp<=0)|(As<0)
    error('PB ripple and/or SB attenuation must be larger than 0')
end
ep=sqrt(10^(Rp/10)-1);
A=10^(As/20);
OmegaC=Wp;
OmegaR=Ws/Wp;
g=sqrt(A*A-1)/ep;
N=ceil(log10(g+sqrt(g*g-1))/log10(OmegaR+sqrt(OmegaR*OmegaR-1)));
fprintf('\n***Chebyshev-1 filter order=%2.0f\n',N)
[b a]=u_chblap(N,Rp,OmegaC);
```

(3) afd_chb2.m

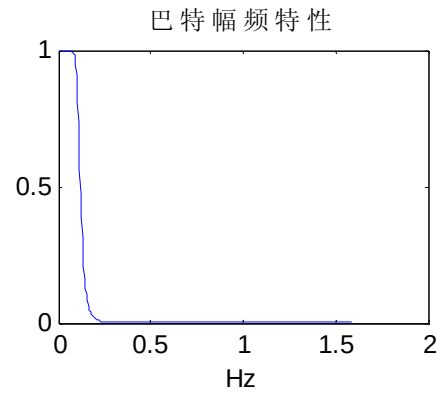
```
% Chebyshev II 型模拟低通滤波器原型设计;
% afd_chb2.m;
function [b a]=afd_chb2(Wp,Ws,Rp,As);
% Anolog Lowpass Filter Design:chebyshev-2
% ^^^^^^^^^^^^^^^^^^^
% [b a]=afd_chb1(Wp,Ws,Rp,As);
%  b=numerator polynomial coefficients of Ha(s);
%  a=denominator polynomial coefficients of Ha(s);
%  Wp=passband edge frequency in rad/sec;Wp>0;
%  Ws=stopband edge frequency in rad/sec;Ws>Wp>0;
%  Rp=passband ripple in +dB;(Rp>0);
%  As=stopband attenuation in + dB;(As>0);
%  ^^^^^^^^^^^^^^^^^^^^
if Wp<=0
    error('passband edge must be larger than 0')
end
if Ws<=Wp
    error('stopband dege must be larger than passband edge')
end
if(Rp<=0)|(As<0)
    error('PB ripple and/or SB attenuation must be larger than 0')
end
ep=sqrt(10^(Rp/10)-1);
A=10^(As/20);
OmegaC=Wp;
```

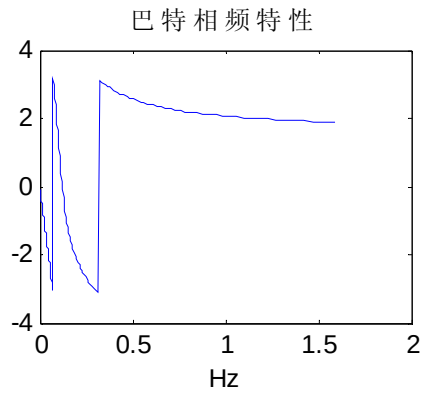
```
 OmegaR=Ws/Wp;
 g=sqrt(A*A-1)/ep;
 N=ceil(log10(g+sqrt(g*g-1))/log10(OmegaR+sqrt(OmegaR*OmegaR-1)));
 fprintf('\n***Chebyshev-1 filter order=%2.0f\n',N)
 [b,a]=u_chb2ap(N,As,OmegaC);
```

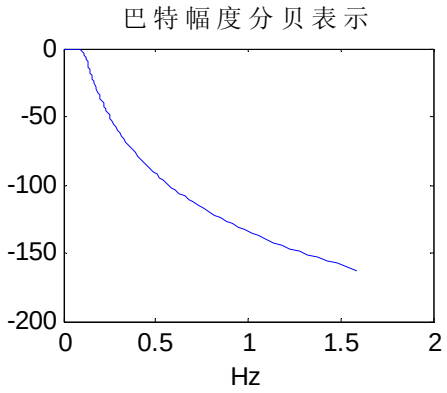
(4) afd_elip.m

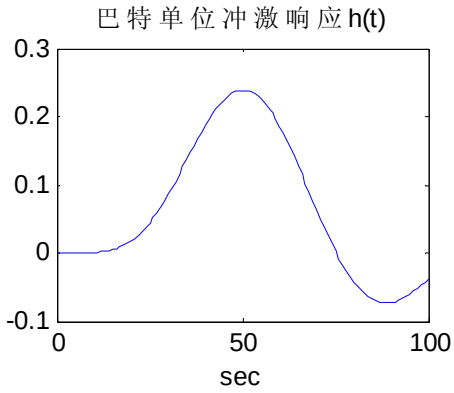
```
%椭圆模拟低通滤波器原型设计
%afd_elip.m
function [b a]=afd_elip(Wp,Ws,Rp,As);
%Anolog lowpass filter design:Elliptic
%^^^^^^^^^^^^^^^^^^^^^^^^^^^^
%[b a]=afd_elip(Wp,Ws,Rp,As);
%b=Numberator coefficients of Ha(s)
% a=denominator polynomial coefficients of Ha(s);
% Wp=passband edge frequency in rad/sec;Wp>0;
%  Ws=stopband edge frequency in rad/sec;Ws>Wp>0;
%  Rp=passband ripple in +dB;(Rp>0);
%  As=stopband attenuation in + dB;(As>0);
%%%%%%%%%%%%%%%%%%%%%%%%%%
if Wp<=0
     error('passband edge must be larger than 0')
 end
 if Ws<=Wp
     error('stopband dege must be larger than passband edge')
 end
 if(Rp<=0)|(As<0)
     error('PB ripple and/or SB attenuation must be larger than 0')
 end
 ep=sqrt(10^(Rp/10)-1);
 A=10^(As/20);
 OmegaC=Wp;
 k=Wp/Ws;
 k1=ep/sqrt(A*A-1);
 capk=ellipke([k.^2 1-k.^2]);
 capk1=ellipke([k1.^2 1-k1.^2]);
 N=ceil(capk(1)*capk1(2)/(capk(2)*capk1(1)));
 fprintf('\n***Elliptic Filter Order=%2.0f\n',N)
 [b a]=u_elipap(N,Rp,As,OmegaC)
```

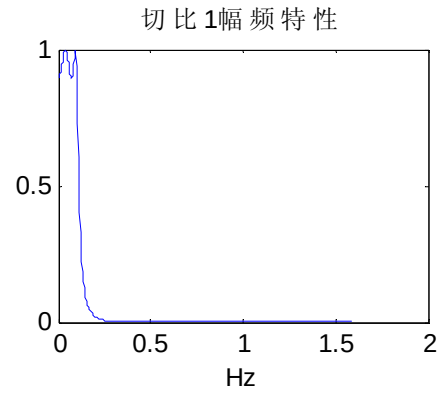
结果：

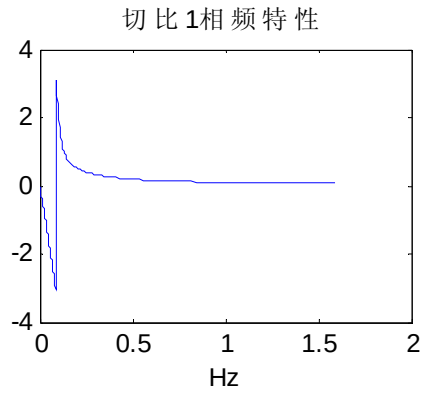

巴特幅频特性
1
0.5
0
0
0.5
1
1.5
2
Hz

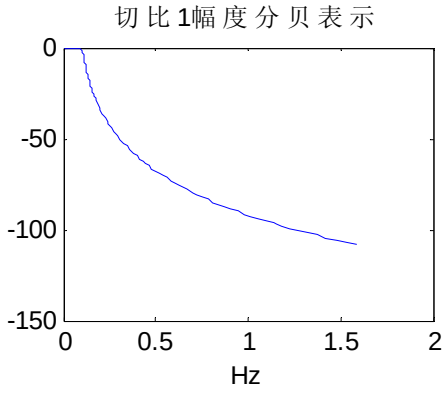

巴特相频特性
4
2
0
-2
-4
0
0.5
1
1.5
2
Hz

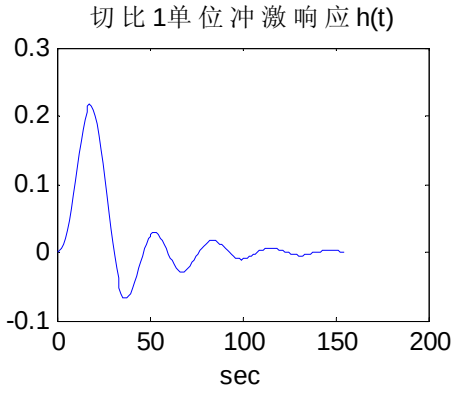

巴特幅度分贝表示
0
-50
-100
-150
-200
0
0.5
1
1.5
2
Hz

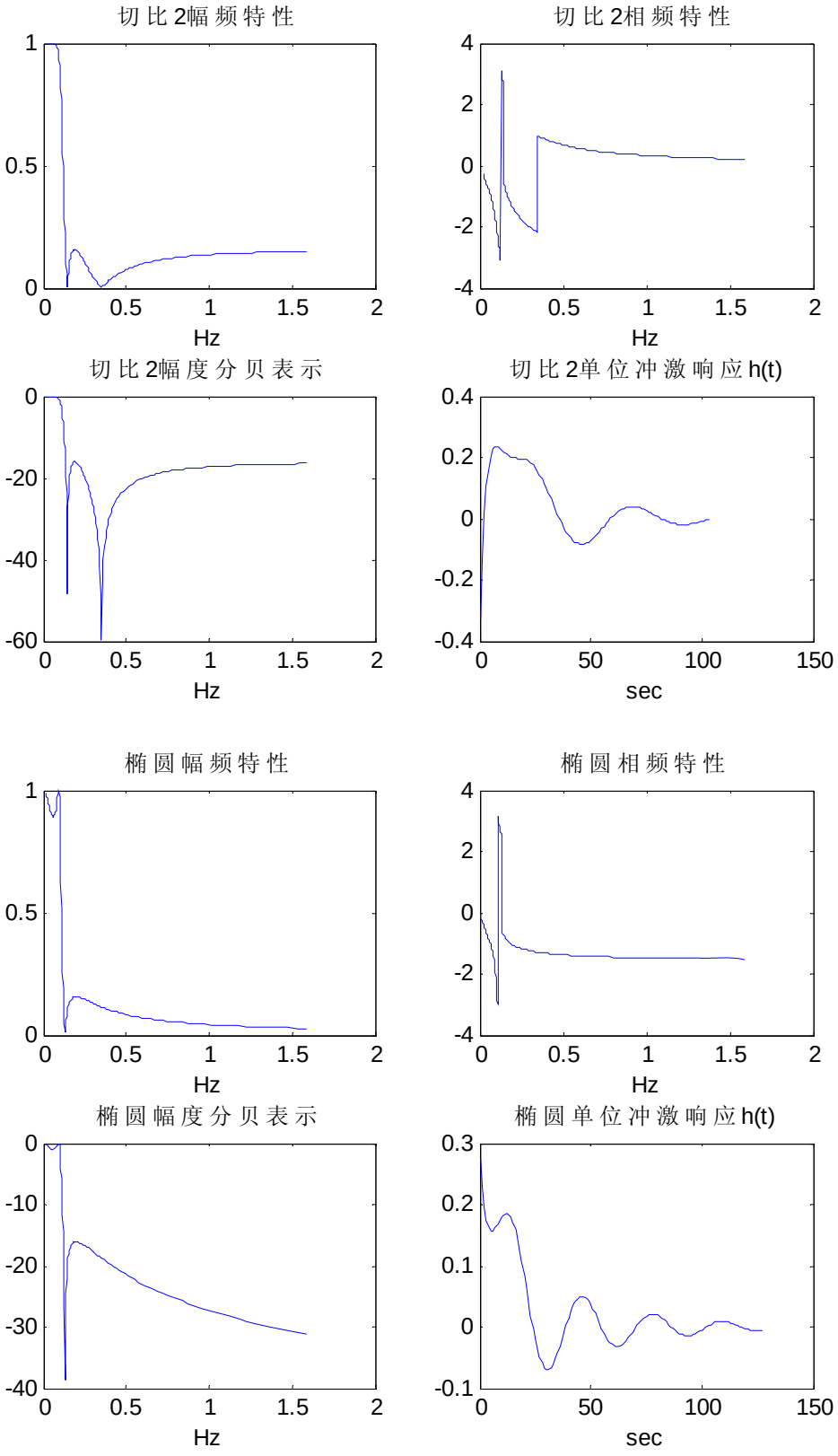

巴特单位冲激响应h(t)
0.3
0.2
0.1
0
-0.1
0
50
100
sec


切比1幅频特性
1
0.5
0
0
0.5
1
1.5
2
Hz


切比1相频特性
4
2
0
-2
-4
0
0.5
1
1.5
2
Hz


切比1幅度分贝表示
0
-50
-100
-150
0
0.5
1
1.5
2
Hz


切比1单位冲激响应h(t)
0.3
0.2
0.1
0
-0.1
0
50
100
150
200
sec


切比2幅频特性
切比2相频特性
Hz
切比2幅度分贝表示
切比2单位冲激响应h(t)
sec
椭圆幅频特性
椭圆相频特性
Hz
椭圆幅度分贝表示
椭圆单位冲激响应h(t)
sec

实验二十四

程序如下：

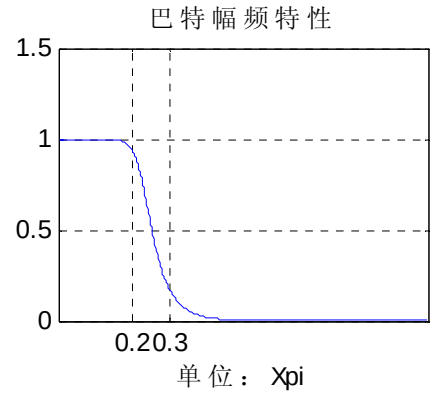
实验二十五

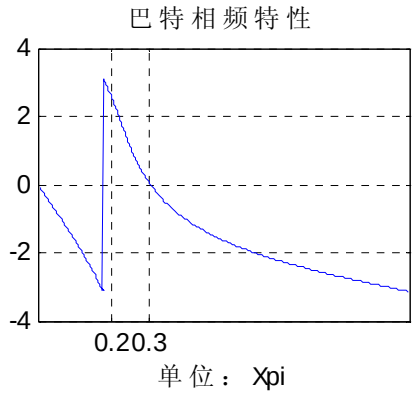
程序如下：

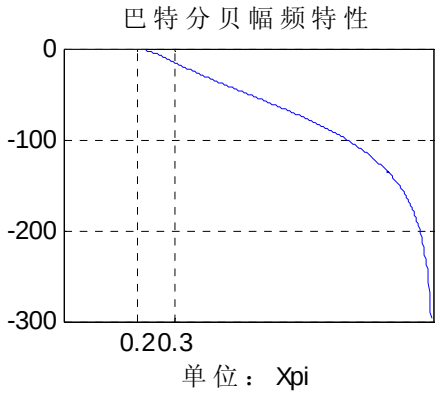
```
wp=0.2*pi;
ws=0.3*pi;
rp=1;
as=15;
Fs=1000;
T=1/Fs;
op=(2/T)*tan(wp/2);
os=(2/T)*tan(ws/2);

figure;
[n,oc]=buttord(op,os,rp,as,'s');
[z,p,k]=buttap(n);
b=k*real(poly(z));
a=real(poly(p));
[b,a]=lp2lp(b,a,oc);
[b,a]=bilinear(b,a,Fs);
[H,w]=freqz(b,a);
subplot(221),plot(w/pi,abs(H));
title('巴特幅频特性');xlabel('单位：Xpi');
set(gca,'Xtick',[0.2,0.3]);grid;
subplot(222),plot(w/pi,angle(H));title('巴特相频特性');xlabel('单位：Xpi');
set(gca,'Xtick',[0.2,0.3]);grid;
subplot(223),plot(w/pi,20*log10(abs(H)/max(abs(H))));title('巴特分贝幅频特性');
xlabel('单位：Xpi');
set(gca,'Xtick',[0.2,0.3]);grid;
subplot(224),grpdelay(b,a);

figure;
[n,oc]=cheb1ord(op,os,rp,as,'s');
[z,p,k]=cheb1ap(n,rp);
b=k*real(poly(z));
a=real(poly(p));
[b,a]=lp2lp(b,a,oc);
[b,a]=bilinear(b,a,Fs);
[H,w]=freqz(b,a);
subplot(221),plot(w/pi,abs(H));
title('切比1幅频特性');xlabel('单位：Xpi');set(gca,'Xtick',[0.2,0.3]);grid;
subplot(222),plot(w/pi,angle(H));title('切比1相频特性');xlabel('单位：Xpi');
set(gca,'Xtick',[0.2,0.3]);grid;
subplot(223),plot(w/pi,20*log10(abs(H)/max(abs(H))));title('切比1分贝幅频特性');
xlabel('单位：Xpi');
set(gca,'Xtick',[0.2,0.3]);grid;
```

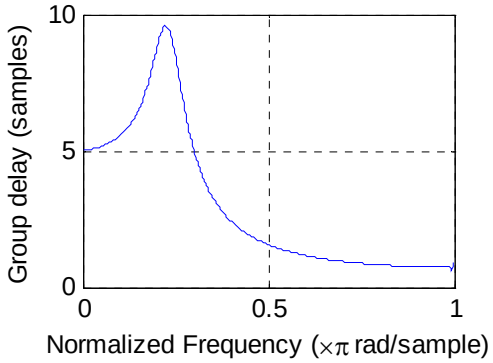
```
subplot(224),grpdelay(b,a);

figure;
[n,oc]=cheb2ord(op,os,rp,as,'s');
[z,p,k]=cheb2ap(n,as);
b=k*real(poly(z));
a=real(poly(p))
[b,a]=lp2lp(b,a,oc);
[b,a]=bilinear(b,a,Fs);
[H,w]=freqz(b,a);
subplot(221),plot(w/pi,abs(H));
title('切比2幅频特性');xlabel('单位：Xpi');set(gca,'Xtick',[0.2,0.3]);grid;
subplot(222),plot(w/pi,angle(H));title('切比2相频特性');xlabel('单位：Xpi');
set(gca,'Xtick',[0.2,0.3]);grid;
subplot(223),plot(w/pi,20*log10(abs(H)/max(abs(H))));title('切比2分贝幅频特性');
xlabel('单位：Xpi');set(gca,'Xtick',[0.2,0.3]);grid;
subplot(224),grpdelay(b,a);


figure;
[n,oc]=ellipord(op,os,rp,as,'s');
[z,p,k]=ellipap(n,rp,as);
b=k*real(poly(z));
a=real(poly(p));
[b,a]=lp2lp(b,a,oc);
[b,a]=bilinear(b,a,Fs);
[H,w]=freqz(b,a);
subplot(221),plot(w/pi,abs(H));
title('椭圆幅频特性');xlabel('单位：Xpi');set(gca,'Xtick',[0.2,0.3]);grid;
subplot(222),plot(w/pi,angle(H));title('椭圆相频特性');xlabel('单位：Xpi');
set(gca,'Xtick',[0.2,0.3]);grid;
subplot(223),plot(w/pi,20*log10(abs(H)/max(abs(H))));title('椭圆分贝幅频特性');
xlabel('单位：Xpi');set(gca,'Xtick',[0.2,0.3]);grid;
subplot(224),grpdelay(b,a);
```

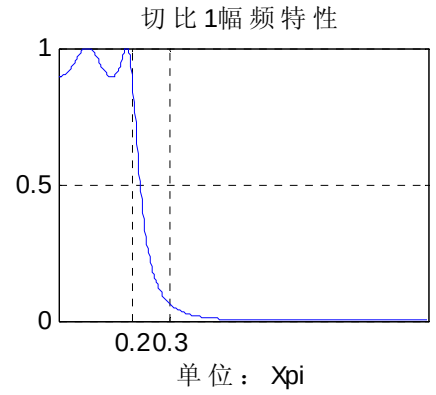
结果：

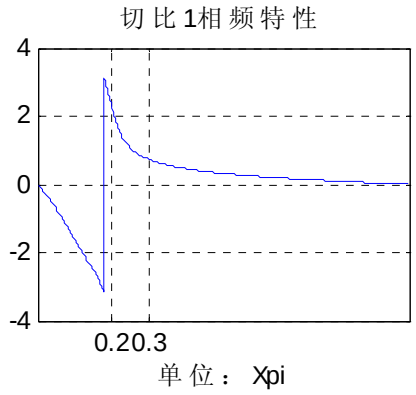

巴特幅频特性
1.5
1
0.5
0
0.20.3
单位： Xpi

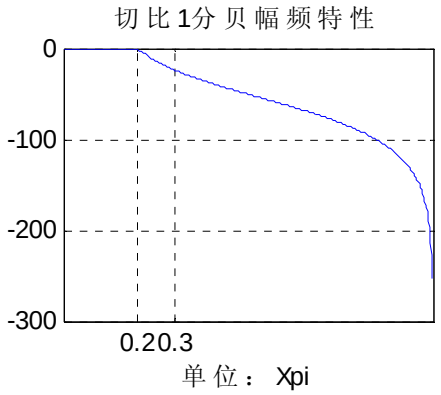

巴特相频特性
4
2
0
-2
-4
0.20.3
单位： Xpi

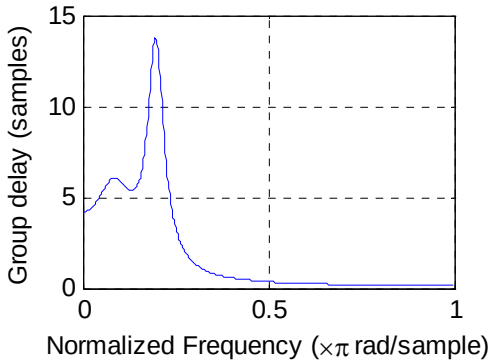

巴特分贝幅频特性
0
-100
-200
-300
0.20.3
单位： Xpi

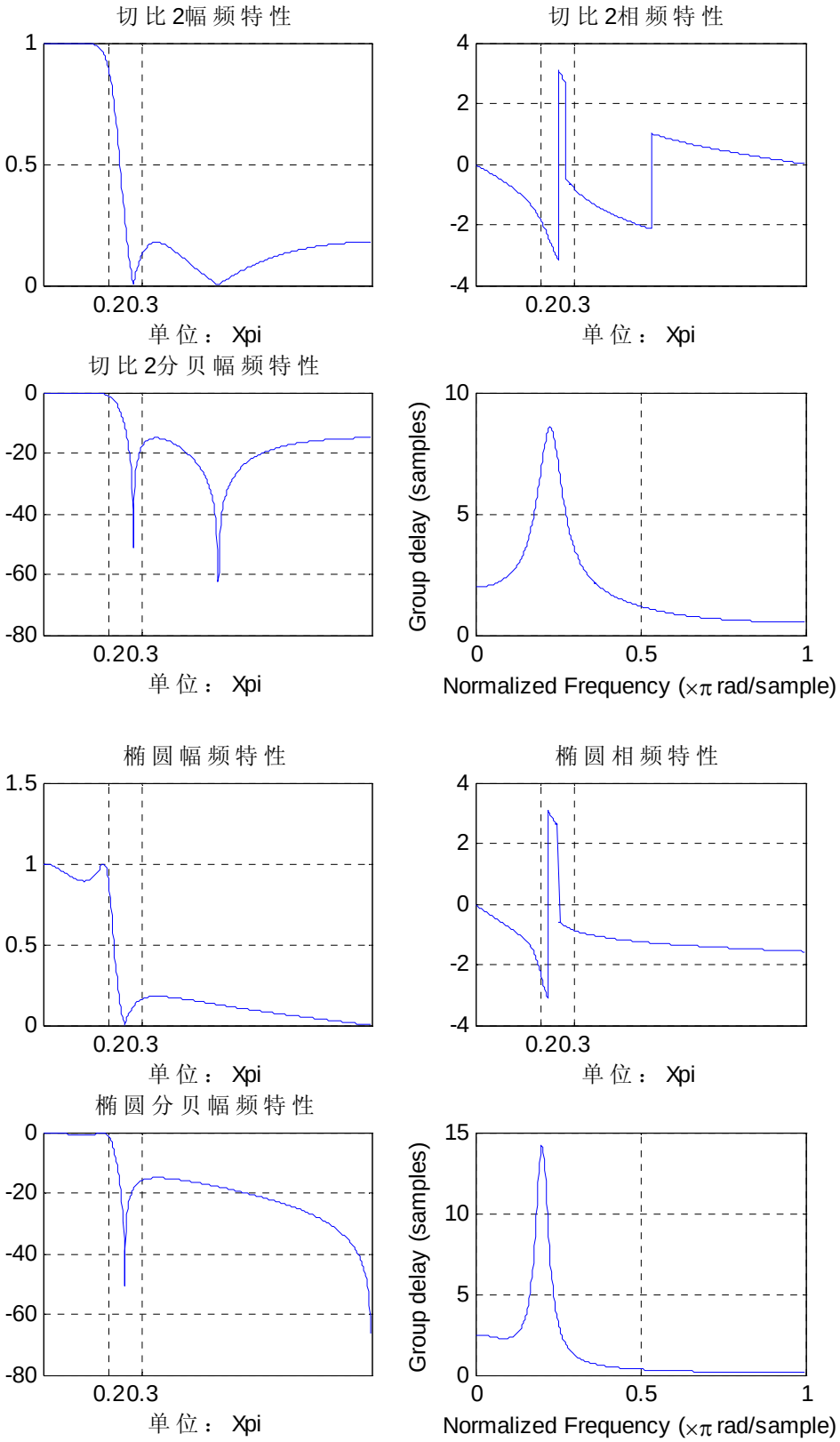

Group delay (samples)
10
5
0
0
0.5
1
Normalized Frequency (×π rad/sample)


切比1幅频特性
1
0.5
0
0.20.3
单位： Xpi


切比1相频特性
4
2
0
-2
-4
0.20.3
单位： Xpi


切比1分贝幅频特性
0
-100
-200
-300
0.20.3
单位： Xpi


Group delay (samples)
15
10
5
0
0
0.5
1
Normalized Frequency (×π rad/sample)



试验二十六

程序如下：

```
wp=0.2*pi;
ws=0.3*pi;
```

```
wc=0.6*pi;
rp=1;
as=15;
Fs=1000;
T=1/Fs;
op=(2/T)*tan(wp/2);
os=(2/T)*tan(ws/2);
omc=(2/T)*tan(wc/2);

figure;
[n,oc]=cheb1ord(op,os,rp,as,'s');
[z,p,k]=cheb1ap(n,rp);
b=k*real(poly(z));
a=real(poly(p));
[b,a]=lp2lp(b,a,oc);
[b,a]=bilinear(b,a,Fs);
[H,w]=freqz(b,a);
subplot(221),plot(w/pi,abs(H));
title('切比1低通幅频特性');xlabel('单位：Xpi');set(gca,'Xtick',[0.2,0.3]);grid;
subplot(222),plot(w/pi,angle(H));title('切比1低通相频特性');xlabel('单位：Xpi');
set(gca,'Xtick',[0.2,0.3]);grid;
subplot(223),plot(w/pi,20*log10(abs(H)/max(abs(H))));title('切比1低通分贝幅频特性
');
xlabel('单位：Xpi');
set(gca,'Xtick',[0.2,0.3]);grid;
subplot(224),grpdelay(b,a);



az=-cos((wp+wc)/2)/cos((wp-wc)/2);
Nz=[-az,-1];
Dz=[1,az];
[b,a]=zmapping(b,a,Nz,Dz);
[H,w]=freqz(b,a);
figure;
subplot(221),plot(w/pi,abs(H));
title('切比1数字频带变换');xlabel('单位：Xpi');ylabel('高通幅频特性
');set(gca,'Xtick',[0.6]);grid;
subplot(222),plot(w/pi,angle(H));title('切比1数字频带变换');ylabel('高通相频特性
');xlabel('单位：Xpi');
set(gca,'Xtick',[0.6]);grid;
subplot(223),plot(w/pi,20*log10(abs(H)/max(abs(H))));title('切比1数字频带变换');
ylabel('高通分贝幅频特性');
```

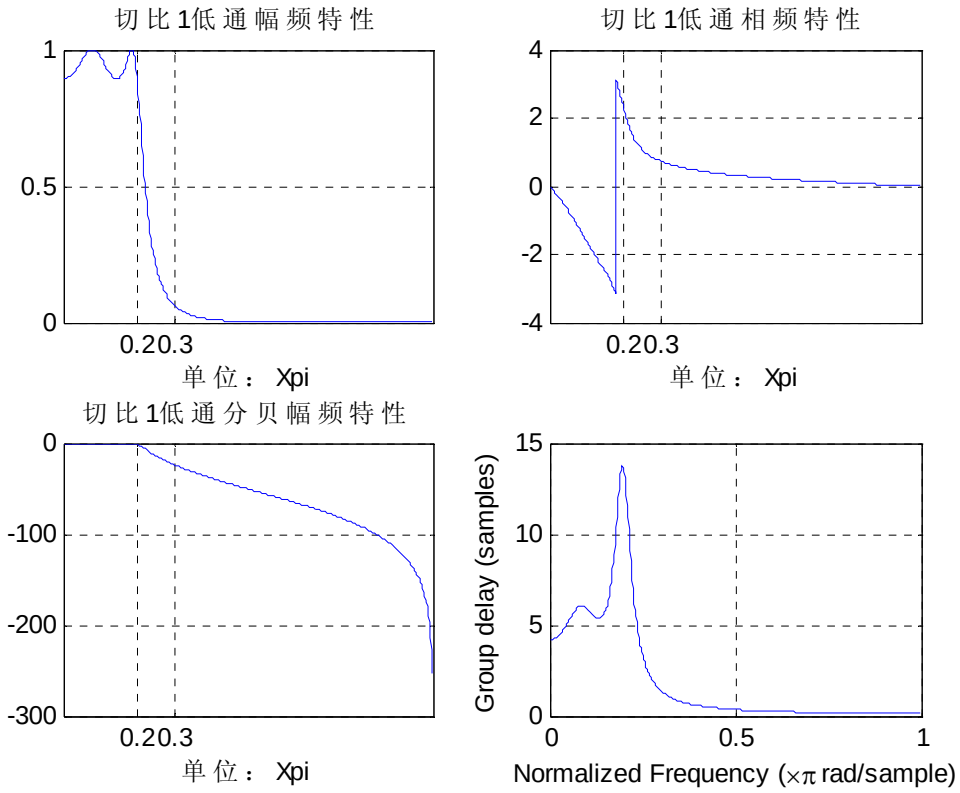
```
xlabel('单位：Xpi');
set(gca,'Xtick',[0.6]);grid;
subplot(224),grpdelay(b,a);


figure;
[n,oc]=cheb1ord(op,os,rp,as,'s');
[z,p,k]=cheb1ap(n,rp);
b=k*real(poly(z));
a=real(poly(p));
[b,a]=lp2hp(b,a,omc);
[b,a]=bilinear(b,a,Fs);
[H,w]=freqz(b,a);
subplot(221),plot(w/pi,abs(H));
title('切比1模拟频带变换');xlabel('单位：Xpi');ylabel('高通幅频特性
');set(gca,'Xtick',[0.6]);grid;
subplot(222),plot(w/pi,angle(H));title('切比1模拟频带变换');ylabel('高通相频特性
');xlabel('单位：Xpi');
set(gca,'Xtick',[0.6]);grid;
subplot(223),plot(w/pi,20*log10(abs(H)/max(abs(H))));title('切比1模拟频带变换');
ylabel('高通分贝幅频特性');
xlabel('单位：Xpi');
set(gca,'Xtick',[0.6]);grid;
subplot(224),grpdelay(b,a);
```

调用的函数：zmapping.m

```
%%数字滤波器频率变换
%zmapping.m
function [bz az]=zmapping(bZ,aZ,Nz,Dz)
%Frequency band Trandformation from z-domain to z-domain
%______++++++++++_____________
% [bz az]=zmapping(bZ,aZ,Nz,Dz);
% performs:
% b(z)     b(Z) |
% --------------|      N(z)
% a(z)     a(Z) | Z=----------------
%               |      D(z)
%               |
% hi,you little ass
bzord=(length(bZ)-1)*(length(Nz)-1);
azord=(length(aZ)-1)*(length(Dz)-1);
bz=zeros(1,bzord+1);
for k=0:bzord
    pln=[1];
    for l=0:k-1
```

```
        pln=conv(pln,Nz);
    end
    pld=[1];
    for l=0:bzord-k-1
        pld=conv(pld,Dz);
    end
    bz=bz+bZ(k+1)*conv(pln,pld);
end
az=zeros(1,azord+1);
for k=0:azord
    pln=[1];
    for l=0:k-1
        pln=conv(pln,Nz);
    end
    pld=[1];
    for l=0:bzord-k-1
        pld=conv(pld,Dz);
    end
    az=az+aZ(k+1)*conv(pln,pld);
end
az1=az(1);
az=az/az1;
bz=bz/az1;
```

结果：



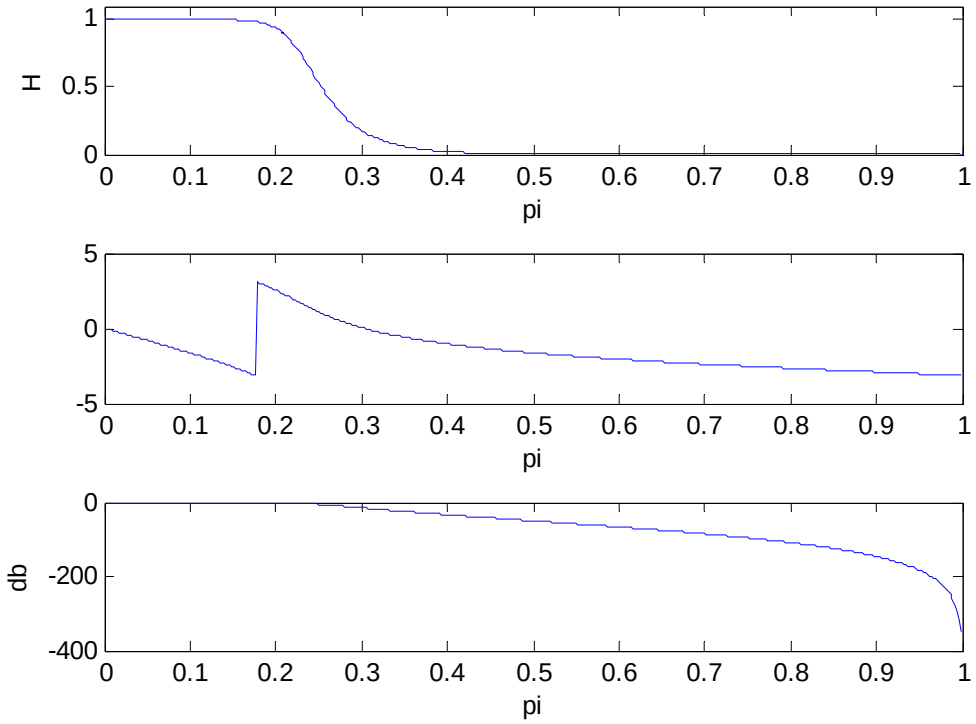
实验二十七

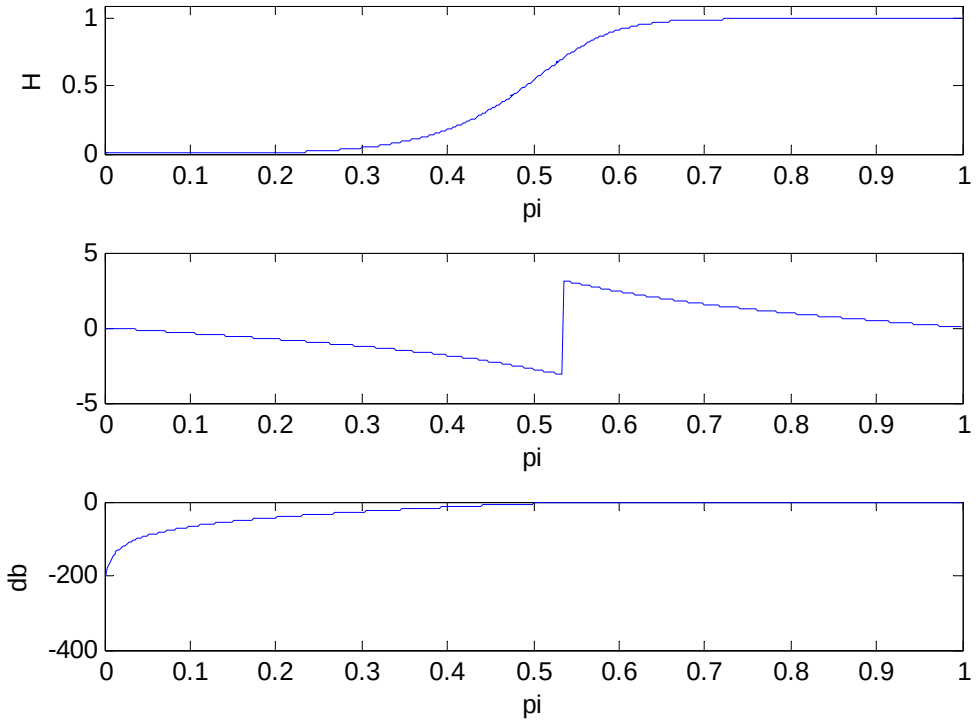
程序如下：

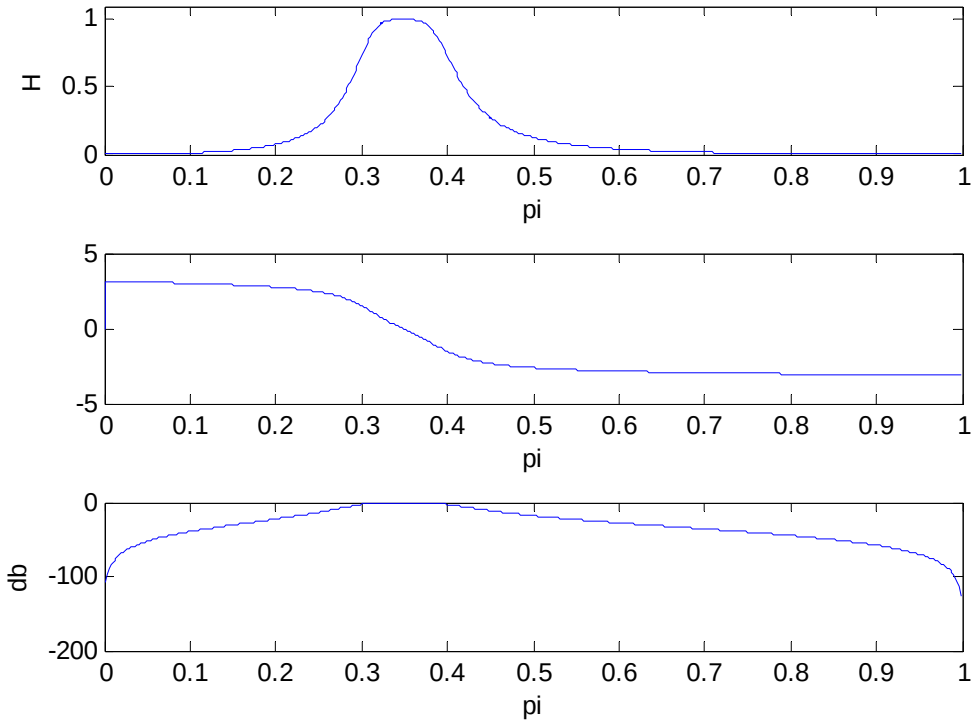
```
wp=0.2;
ws=0.3;
rp=1;
as=15;
[n1,wc1]=buttord(wp,ws,rp,as);
[b1,a1]=butter(n1,wc1);
[h1,w1]=freqz(b1,a1);
db1=20*log10(abs(h1)/max(abs(h1)));
subplot(311),plot(w1/pi,abs(h1));
xlabel('pi');ylabel('H');
axis([0,1,0,1.1]);
subplot(312),plot(w1/pi,angle(h1));
xlabel('pi');
subplot(313),plot(w1/pi,db1);
xlabel('pi');ylabel('db');


wp=0.6;
ws=0.4;
rp=1;
as=15;
[n1,wc1]=buttord(wp,ws,rp,as);
[b1,a1]=butter(n1,wc1,'high');
figure;
[h1,w1]=freqz(b1,a1);
db1=20*log10(abs(h1)/max(abs(h1)));
subplot(311),plot(w1/pi,abs(h1));
xlabel('pi');ylabel('H');axis([0,1,0,1.1]);
subplot(312),plot(w1/pi,angle(h1));
xlabel('pi');
subplot(313),plot(w1/pi,db1);
xlabel('pi');ylabel('db');

wp=[0.3,0.4];
ws=[0.2,0.5];
rp=3;
as=18;
ts=1;
[n1,wc1]=buttord(wp,ws,rp,as);
[b1,a1]=butter(n1,wc1);
figure;
[h1,w1]=freqz(b1,a1);
```

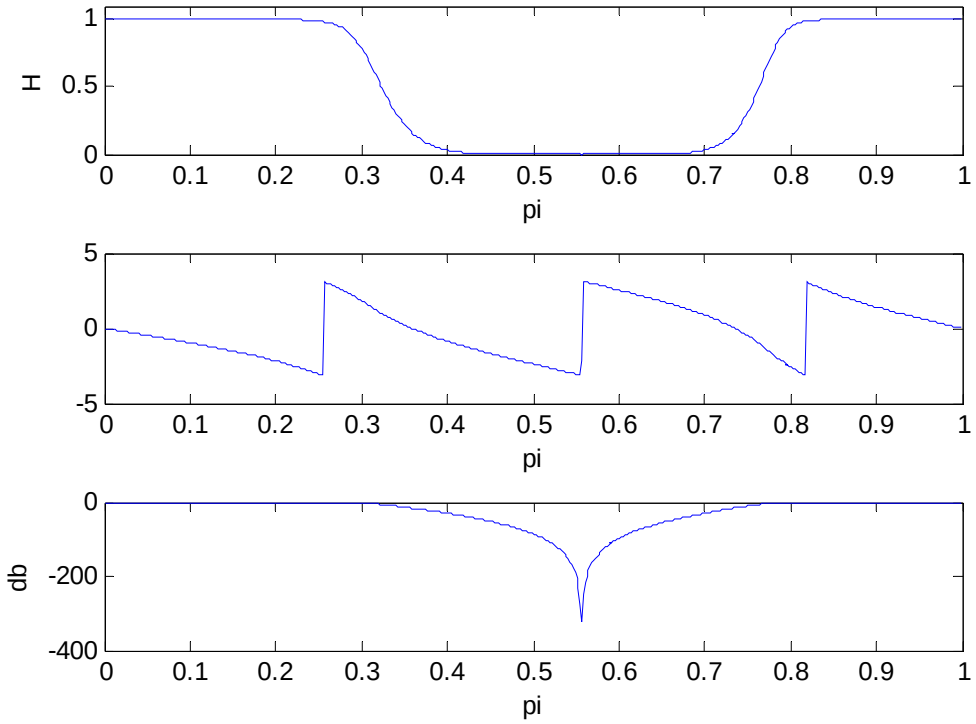
```
db1=20*log10(abs(h1)/max(abs(h1)));
subplot(311),plot(w1/pi,abs(h1));
xlabel('pi');ylabel('H');axis([0,1,0,1.1]);
subplot(312),plot(w1/pi,angle(h1));
xlabel('pi');
subplot(313),plot(w1/pi,db1);
xlabel('pi');ylabel('db');

wp=[0.2,0.8];
ws=[0.4,0.7];
rp=1;
as=30;
ts=1;
[n1,wc1]=buttord(wp,ws,rp,as);
[b1,a1]=butter(n1,wc1,'stop');
figure;
[h1,w1]=freqz(b1,a1);
db1=20*log10(abs(h1)/max(abs(h1)));
subplot(311),plot(w1/pi,abs(h1));
xlabel('pi');ylabel('H');axis([0,1,0,1.1]);
subplot(312),plot(w1/pi,angle(h1));
xlabel('pi');
subplot(313),plot(w1/pi,db1);
xlabel('pi');ylabel('db');
```

结果：


H
1
0.5
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
pi
5
0
-5
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
pi
db
0
-200
-400
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
pi


H
1
0.5
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
pi
5
0
-5
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
pi
db
0
-200
-400
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
pi


H
1
0.5
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
pi
5
0
-5
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
pi
db
0
-100
-200
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
pi


H
1
0.5
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
pi
5
0
-5
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
pi
db
0
-200
-400
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
pi

实验二十八

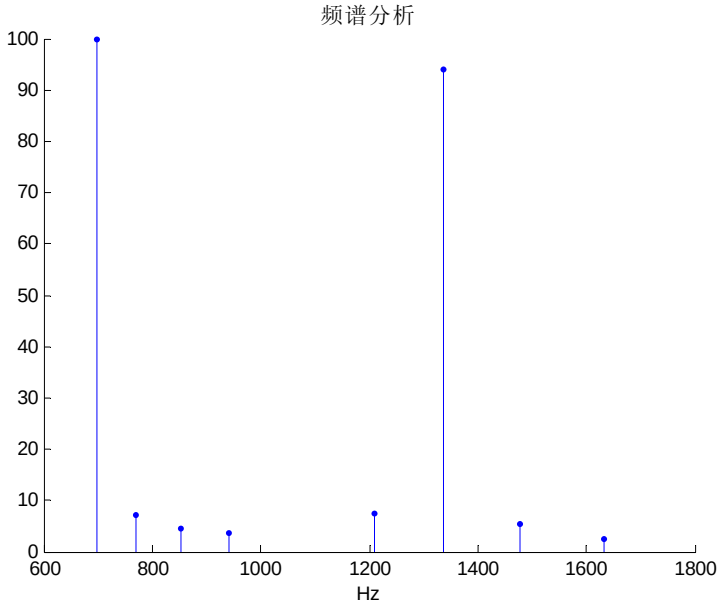
程序如下：

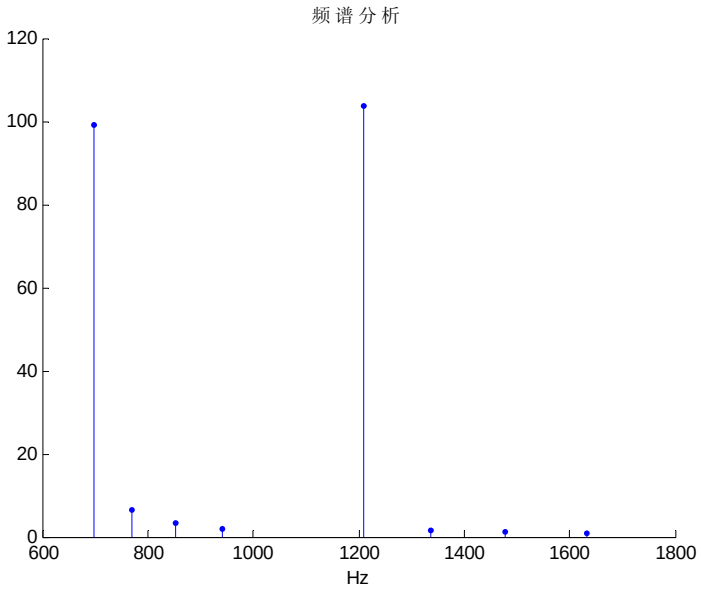
```
f1=697;
f2=770;
f3=852;
f4=941;
F1=1209;
F2=1336;
F3=1477;
F4=1633;
N=205;
tmin=40/1000;
fs=8000;
dt=1/fs;
N1=floor(tmin/dt);
if N<=N1
    t=[0:N-1]*dt;
else
    error('The time is not enough!');
end

k1=sin(2*pi*f1*t)+sin(2*pi*F1*t);
k2=sin(2*pi*f1*t)+sin(2*pi*F2*t);
k3=sin(2*pi*f1*t)+sin(2*pi*F3*t);
ka=sin(2*pi*f1*t)+sin(2*pi*F4*t);
k4=sin(2*pi*f2*t)+sin(2*pi*F1*t);
k5=sin(2*pi*f2*t)+sin(2*pi*F2*t);
k6=sin(2*pi*f2*t)+sin(2*pi*F3*t);
kb=sin(2*pi*f2*t)+sin(2*pi*F4*t);
k7=sin(2*pi*f3*t)+sin(2*pi*F1*t);
k8=sin(2*pi*f3*t)+sin(2*pi*F2*t);
k9=sin(2*pi*f3*t)+sin(2*pi*F3*t);
kc=sin(2*pi*f3*t)+sin(2*pi*F4*t);
km=sin(2*pi*f4*t)+sin(2*pi*F1*t);
k0=sin(2*pi*f4*t)+sin(2*pi*F2*t);
kj=sin(2*pi*f4*t)+sin(2*pi*F3*t);
kd=sin(2*pi*f4*t)+sin(2*pi*F4*t);

key=['1','2','3','a';'4','5','6','b';'7','8','9','c';'*','0','#','d'];
k=[18,20,22,24,31,34,38,42];

num=input('please enter the key:','s');
num=num-48;
nn=length(num);
```

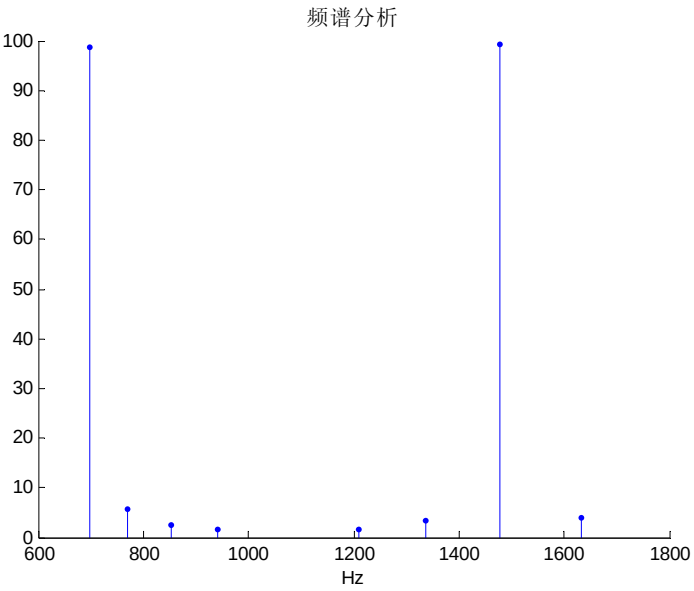
```
disp('The number of the key is: ');
disp(nn);
number=zeros(nn,length(t));
for i=1:nn
switch num(i)
    case 1
        number(i,1:N)=k1;
    case 2
        number(i,1:N)=k2;
    case 3
        number(i,1:N)=k3;
    case 4
        number(i,1:N)=k4;
    case 5
        number(i,1:N)=k5;
    case 6
        number(i,1:N)=k6;
    case 7
        number(i,1:N)=k7;
    case 8
        number(i,1:N)=k8;
    case 9
        number(i,1:N)=k9;
    case 0
        number(i,1:N)=k0;
    case 49
        number(i,1:N)=ka;
    case 50
        number(i,1:N)=kb;
    case 51
        number(i,1:N)=kc;
    case 52
        number(i,1:N)=kd;
    case -6
        number(i,1:N)=km;
    case -13
        number(i,1:N)=kj;
    otherwise
        error('The key is not right!');
end
end
disp('The key is: ');

for i=1:nn
```

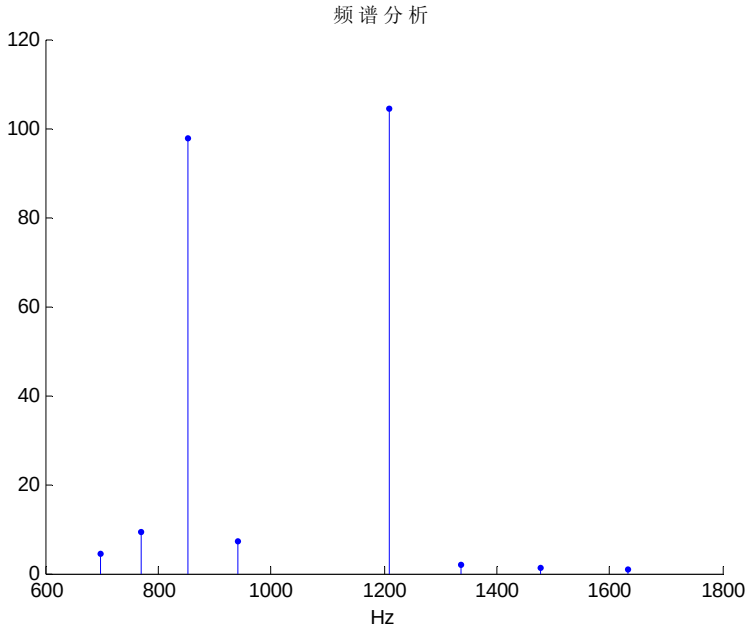
```
xgk=goertzel(number(i,1:N),k+1);
figure;
x=[697,770,852,941,1209,1336,1477,1633];
stem(x,abs(xgk),'.');
xlabel('Hz');
title('频谱分析');
zb=find(abs(xgk)>50);
disp(key(zb(1),zb(2)-4));
end
```

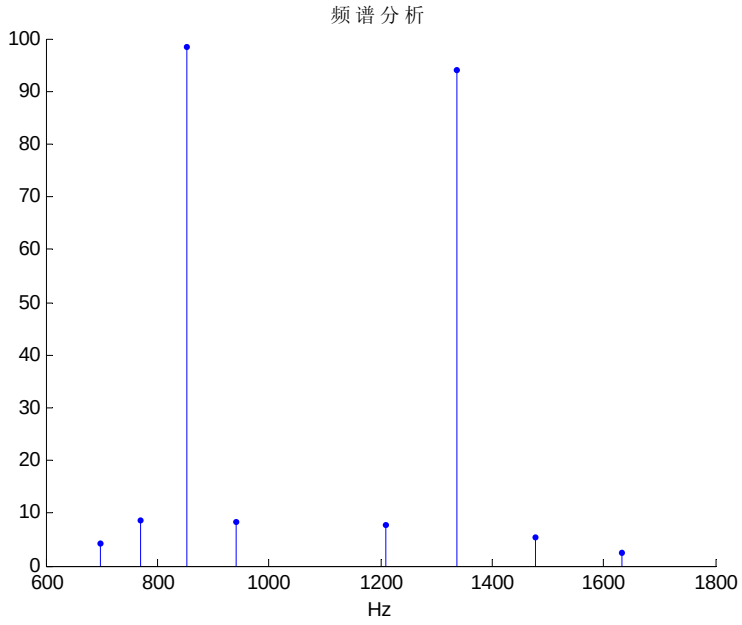
结果：随机输入数字:12378






频谱分析
100
90
80
70
60
50
40
30
20
10
0
600
800
1000
1200
1400
1600
1800
Hz


频 谱 分 析
120
100
80
60
40
20
0
600
800
1000
1200
1400
1600
1800
Hz


频谱分析
100
90
80
70
60
50
40
30
20
10
0
600
800
1000
1200
1400
1600
1800
Hz

Thank you!