数字信号处理第二次 Matlab 实验报告

515021910446 彭嘉辉

练习题 1

Matlab 代码：

```
%%

clear;
clc;
close all;

%%

fc = 300; fr = 200;
fs = 1000;
rp = 0.8; rs = 20;

%%

wc = 2*fs * tan(2*pi*fc/(2*fs));
wr = 2*fs * tan(2*pi*fr/(2*fs));

%%

[N, wn] = cheb1ord(wc, wr, rp, rs, 's');
[B, A] = cheby1(N, rp, wn, 'high', 's');
[bz, az] = bilinear(B, A, fs);
[h, w] = freqz(bz, az);
f = w * fs / (2*pi);

%%

bz
az

figure(1);
plot(f, 20*log10(abs(h)));
 axis([0 fs/2 -80 10]);
% axis([200 fs/2 -1 0.2]);
```

```
grid;
xlabel('Freq/Hz');
ylabel('Amp/dB');

%%
```

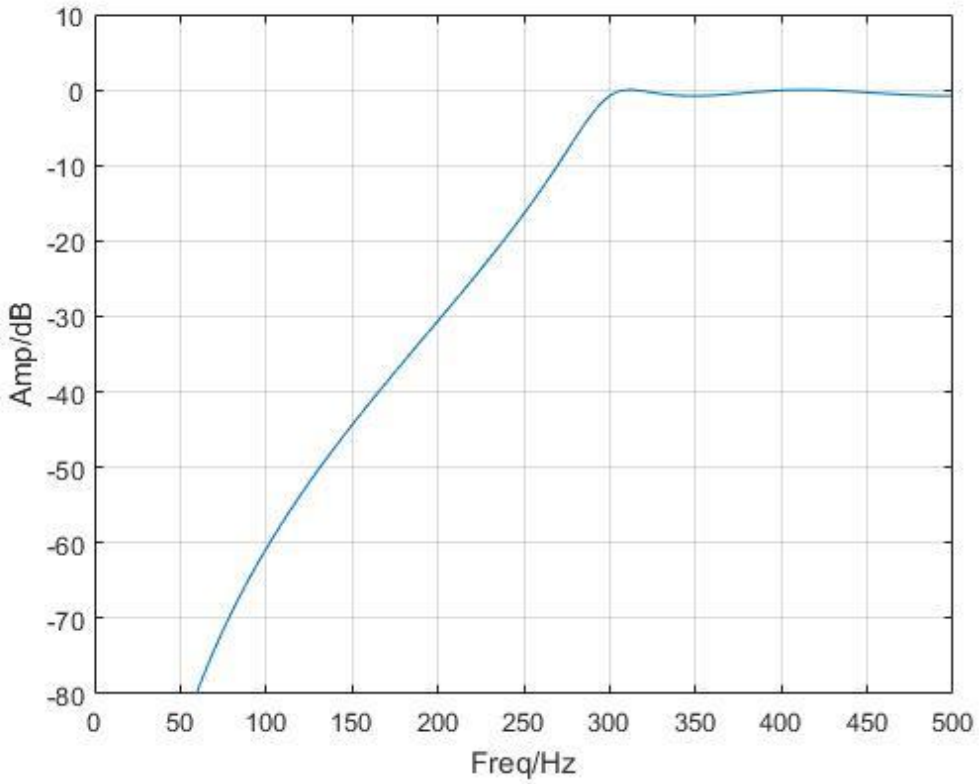
结果：

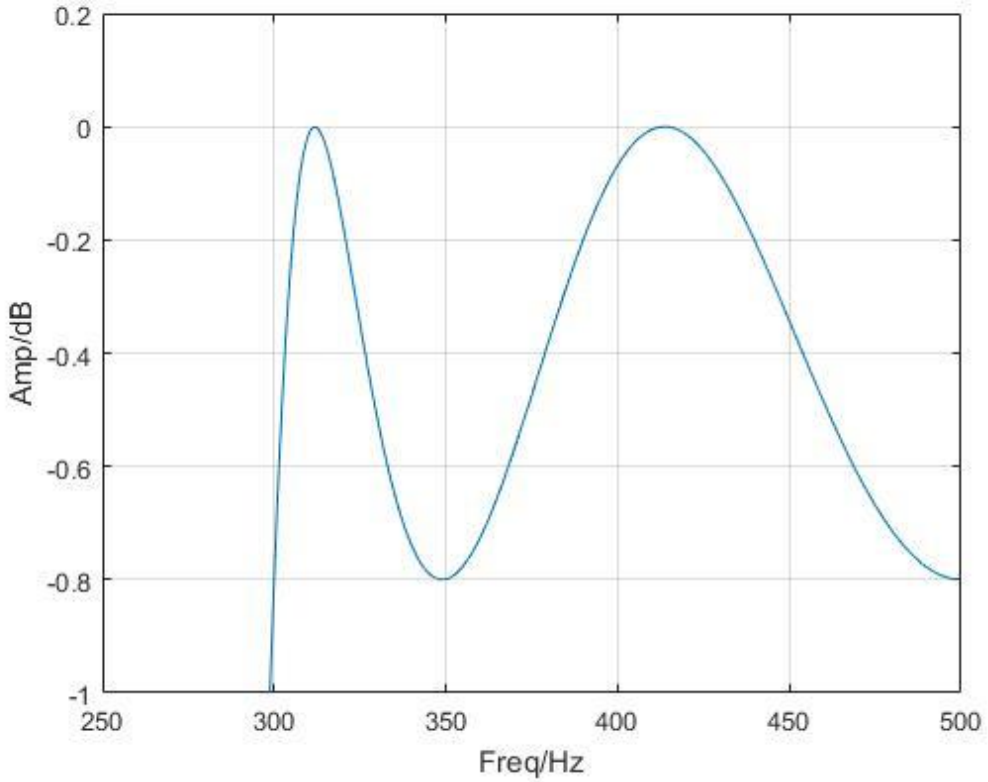
bz =

0.0262 -0.1047 0.1570 -0.1047 0.0262

az =

1.0000 1.5289 1.6537 0.9452 0.2796





通带波动小于 0.8 。
可知系统函数为：

$$H(z) = \frac{0.0262 - 0.1047z^{-1} + 0.1570z^{-2} - 0.1047z^{-3} + 0.0262z^{-4}}{1.0000 + 1.5289z^{-1} + 1.6537z^{-2} + 0.9452z^{-3} + 0.2796z^{-4}}$$

练习题 2

Matlab 代码：

```
%%

close all;
clear;
clc;

%%

fc = 200; fr = 300;
fs = 1000;
```

```
rp = 1; rs = 25;

%% Impinvar

wp = 2 * pi * fc;
ws = 2 * pi * fr;
[N, wn] = buttord(wp, ws, rp, rs, 's');
[b1, a1] = butter(N, wn, 's');
[bz1, az1] = impinvar(b1, a1, fs);
[h1, w] = freqz(bz1, az1);

%% Bilinear

wp = 2 * fs * tan(2*pi*fc/(2*fs));
ws = 2 * fs * tan(2*pi*fr/(2*fs));
[N, wn] = buttord(wp, ws, rp, rs, 's');
[b2, a2] = butter(N, wn, 's');
[bz2, az2] = bilinear(b2, a2, fs);
[h2, w] = freqz(bz2, az2);

f = w * fs / (2*pi);

%%

bz1
az1
bz2
az2

figure(2);
plot(f, abs(h1), '-r', f, abs(h2), '-b');
grid;
xlabel('Freq/Hz');
ylabel('Amp/dB');
legend('Impinvar', 'Bilinear');

%%
```

结果：

bz1 =

0.0000 0.0002 0.0153 0.0995 0.1444 0.0611 0.0075 0.0002

0.0000 0

az1 =

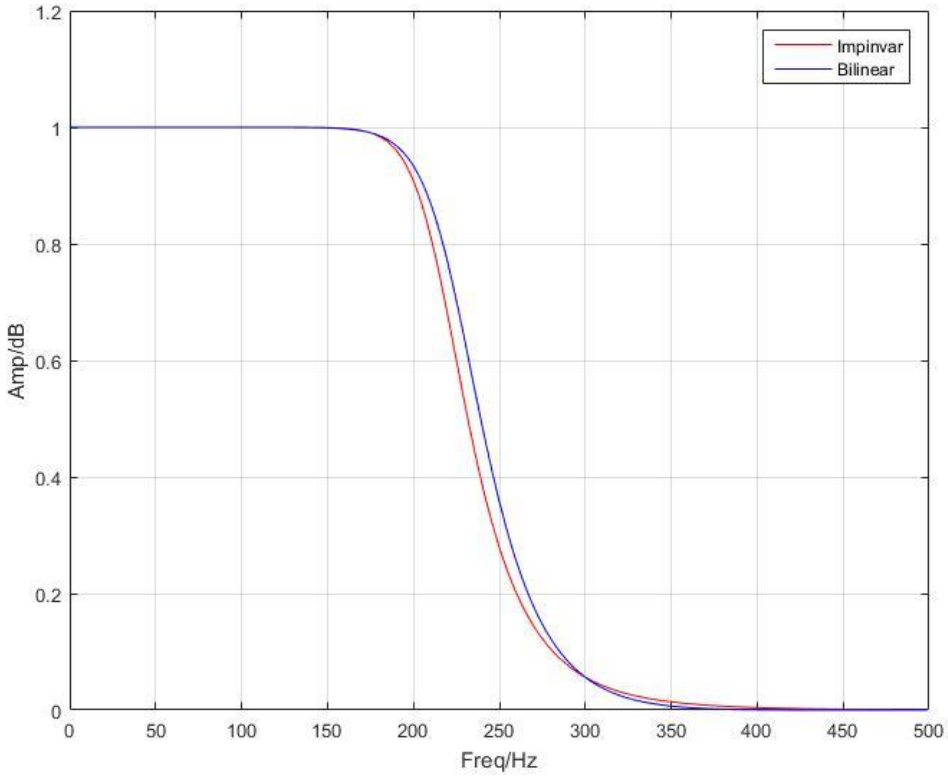
1.0000 -1.9199 2.5324 -2.2053 1.3868 -0.6309 0.2045 -0.0450 0.0060 -0.0004

bz2 =

0.0179 0.1072 0.2681 0.3575 0.2681 0.1072 0.0179

az2 =

1.0000 -0.6019 0.9130 -0.2989 0.1501 -0.0208 0.0025



脉冲响应不变法的系统函数：

$$H_{imp}(z) = \frac{0.0002z^{-1} + 0.0153z^{-2} + 0.0995z^{-3} + 0.1444z^{-4} + 0.0611z^{-5} + 0.0075z^{-6} + 0.0002z^{-7}}{1 - 1.9199z^{-1} + 2.5324z^{-2} - 2.2053z^{-3} + 1.3868z^{-4} - 0.6309z^{-5} + 0.2045z^{-6} - 0.0450z^{-7} + 0.0060z^{-8} - 0.0004z^{-9}}$$

双线性变换法：

$$H_{imp}(z) = \frac{0.0179 + 0.1072z^{-1} + 0.2681z^{-2} + 0.3575z^{-3} + 0.2681z^{-4} + 0.1072z^{-5} + 0.0179z^{-6}}{1 - 0.6019z^{-1} + 0.9130z^{-2} - 0.2989z^{-3} + 0.1501z^{-4} - 0.0208z^{-5} + 0.0025z^{-6}}$$

比较：脉冲响应不变法的阶数为 9，双线性变换法的阶数为 6。双线性变换法的过渡带比较窄，脉冲响应的衰减比较快。

练习题 3

Matlab 代码：

```
%%

close all;
clear;
clc;

%%

fs = 8000;
fc = 1200; fr = 2000;
rp = 0.5; rs = 40;

%% Buttord

wp = 2 * fs * tan(2*pi*fc/(fs*2));
ws = 2 * fs * tan(2*pi*fr/(fs*2));
[N, wn] = buttord(wp, ws, rp, rs, 's');
[b1, a1] = butter(N, wn, 's');
[bz1, az1] = bilinear(b1, a1, fs);
[h1, w] = freqz(bz1, az1);

%% Cheby

wc = 2 * fs * tan(2*pi*fc/(2*fs));
wt = 2 * fs * tan(2*pi*fr/(2*fs));
[N, wn] = cheb1ord(wc, wt, rp, rs, 's');
[b2, a2] = cheby1(N, rp, wn, 'low', 's');
[bz2, az2] = bilinear(b2, a2, fs);
[h2, w] = freqz(bz2, az2);
```

```
%% Ellipse

wp = 2 * fs * tan(2*pi*fc/(fs*2));
ws = 2 * fs * tan(2*pi*fr/(fs*2));
[N, wn] = ellipord(wp, ws, rp, rs, 's');
[b3, a3] = ellip(N, rp, rs, wp, 'low', 's');
[bz3, az3] = bilinear(b3, a3, fs);
[h3, w] = freqz(bz3, az3);

f = w*fs / (2*pi);

%%

bz1
az1
bz2
az2
bz3
az3

figure(3);
plot(f, 20*log10(abs(h1)), '-r', f, 20*log10(abs(h2)), '-b', f,
20*log10(abs(h3)), '-g');
axis([0 fs/2 -100 10]);
grid;
xlabel('Freq/Hz');
ylabel('Amp/dB');
legend('Buttord', 'Cheby', 'Ellipse');

%%
```

结果：

bz1 =

0.0004 0.0032 0.0129 0.0302 0.0453 0.0453 0.0302 0.0129 0.0032 0.0004

az1 =

1.0000 -2.7996 4.4582 -4.5412 3.2404 -1.6330 0.5780 -0.1370 0.0197 -0.0013

bz2 =

0.0026 0.0132 0.0264 0.0264 0.0132 0.0026

az2 =

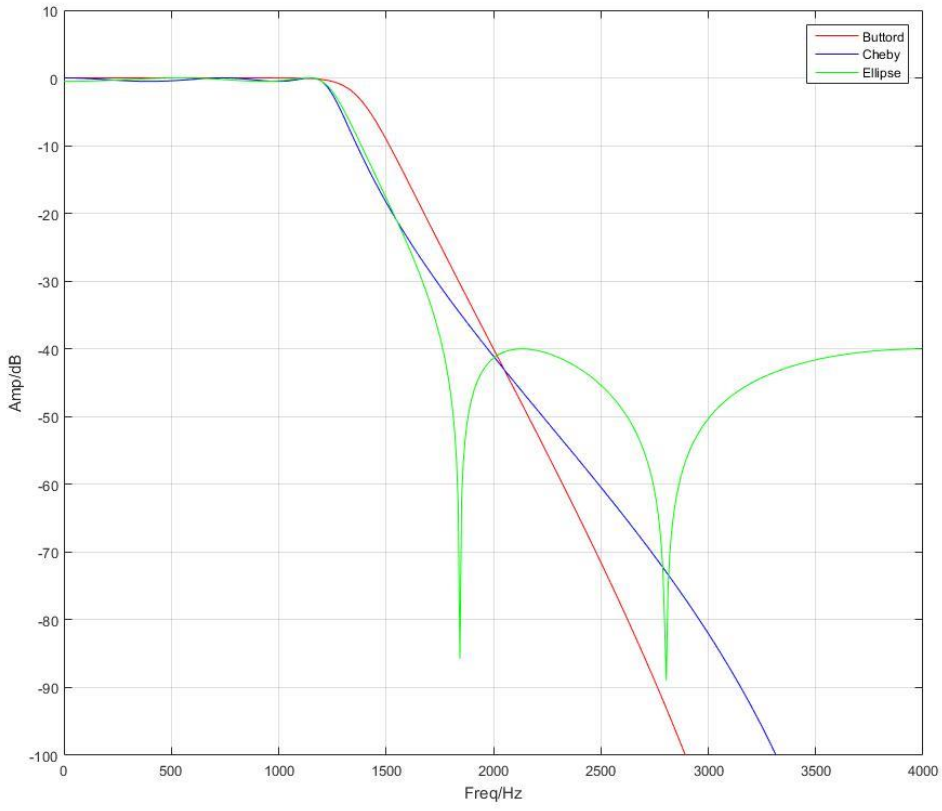
1.0000 -2.9775 4.2932 -3.5124 1.6145 -0.3334

bz3 =

0.0389 0.0363 0.0665 0.0363 0.0389

az3 =

1.0000 -2.1444 2.3658 -1.3250 0.3332



巴特沃斯法的系统函数：(阶数为 9)

$$H_{imp}(z) = \frac{0.0004 + 0.0032z^{-1} + 0.0129z^{-2} - 0.0302z^{-3} + 0.0453z^{-4} + 0.0453z^{-5} + 0.0302z^{-6} + 0.0129z^{-7} + 0.0032z^{-8} + 0.0004z^{-9}}{1.0000 - 2.7996z^{-1} + 4.4582z^{-2} - 4.5412z^{-3} + 3.2404z^{-4} - 1.6330z^{-5} + 0.5680z^{-6} - 0.1370z^{-7} + 0.0197z^{-8} - 0.0013z^{-9}}$$

切比雪夫法的系统函数：(阶数为 5)

$$H_{imp}(z) = \frac{0.0026 + 0.0132z^{-1} + 0.0264z^{-2} + 0.0264z^{-3} + 0.0132z^{-4} + 0.0026z^{-5}}{1.0000 - 2.9775z^{-1} + 4.2932z^{-2} - 3.5124z^{-3} + 1.6154z^{-4} - 0.3334z^{-5}}$$

椭圆型的系统函数：(阶数为 4)

$$H_{imp}(z) = \frac{0.0389 - 0.0363z^{-1} + 0.0665z^{-2} - 0.0363z^{-3} + 0.0389z^{-4}}{1.0000 - 2.1444z^{-1} + 2.3658z^{-2} - 1.3250z^{-3} + 0.3332z^{-4}}$$

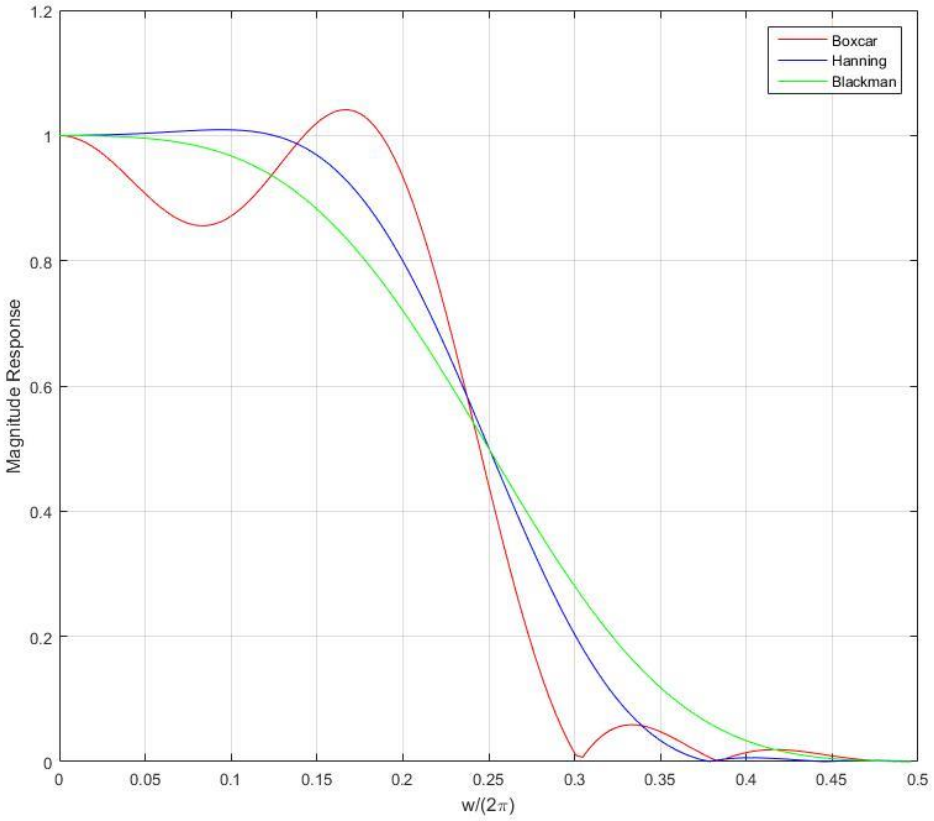
练习题 4

Matlab 代码：

```
%%

close all;
clear;
clc;

%%

N = 11; M = 128;

b1 = fir1(N, 0.5, boxcar(N+1));
b2 = fir1(N, 0.5, hanning(N+1));
b3 = fir1(N, 0.5, blackman(N+1));

h1 = freqz(b1, 1, M);
h2 = freqz(b2, 1, M);
h3 = freqz(b3, 1, M);

f = 0: 0.5/M: 0.5-0.5/M;
```

```
%%

figure(4)
plot(f, abs(h1), '-r', f, abs(h2), '-b', f, abs(h3), '-g');
legend('Boxcar', 'Hanning', 'Blackman');
grid;
xlabel('w/(2\pi)');
ylabel('Magnitude Response');
axis([0 0.5 0 1.2]);

%%
```

结果：



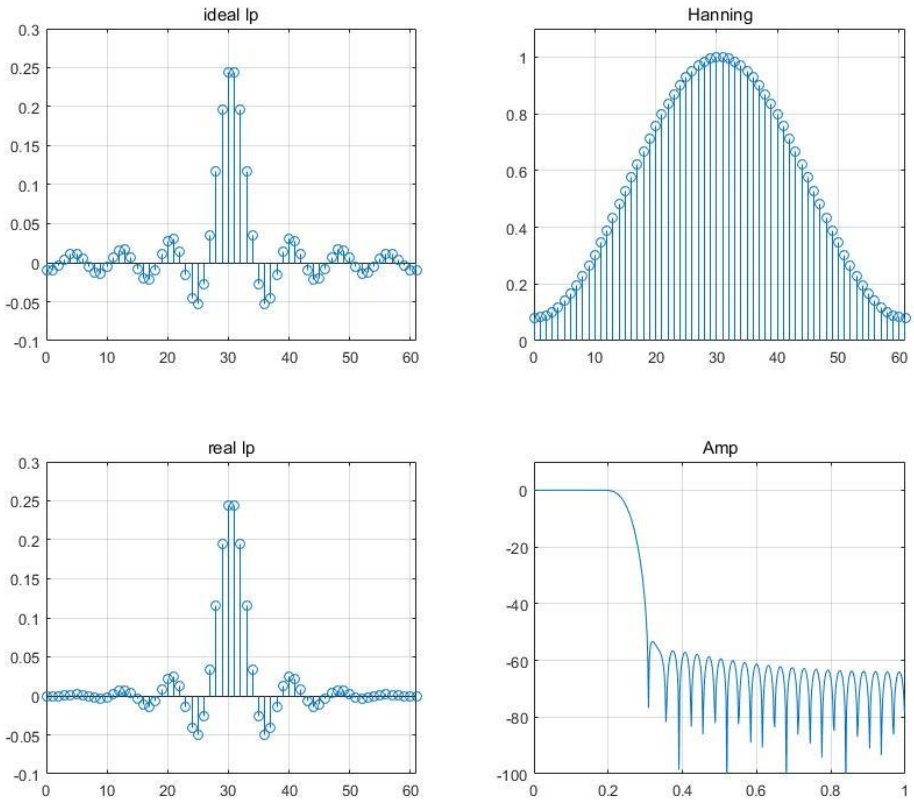
练习题 5

Matlab 代码：

```
%%

close all;
clear;
clc;

%%

wp = 0.2 * pi;
ws = 0.3 * pi;
as = 50;

tr_width = ws - wp;
M = ceil(6.2*pi / tr_width); % For Hanning
n = 0: 1: M-1;
wc = (ws+wp) / 2;
hd = ideallp(wc, M);
w_han = (hamming(M))';
h = hd.*w_han;

[H, W] = freqz(h, 1);

%%

figure(5);

subplot(2, 2, 1);
stem(n, hd);
title('ideal lp');
axis([0 M-1 -0.1 0.3]);
grid;

subplot(2, 2, 2);
stem(n, w_han);
title('Hanning');
axis([0 M-1 0 1.1]);
grid;

subplot(2, 2, 3);
stem(n, h);
title('real lp');
axis([0 M-1 -0.1 0.3]);
```

```
grid;

subplot(2, 2, 4);
plot(W/pi, 20*log10(abs(H)));
title('Amp');
axis([0 1 -100 10]);
grid;

%%
```

结果：



练习题 6

Matlab 代码：

```
%%

close all;
clear;
clc;

%%

wp1 = 0.35*pi;
wp2 = 0.8*pi;
ws1 = 0.5*pi;
ws2 = 0.65*pi;

dert_w = min((ws1 - wp1), (wp2 - ws2));
N = ceil(6.2*pi / dert_w);
n = 0: 1: N-1;
wc1 = (wp1+ws1) / 2;
wc2 = (wp2+ws2) / 2;

hd = ideallp(pi, N) - ideallp(wc2, N) + ideallp(wc1, N);
B = hanning(N)';
h = hd.*B;
[H, m] = freqz(h, 1);
mag = abs(H);
db = 20*log10((mag+eps) / max(mag));
pha = angle(H);
w = m/pi;

%%

figure(6);
subplot(2, 2, 1);
stem(n, hd);
title('ideal lp');
grid;
xlabel('n');
ylabel('sa(n)');

subplot(2, 2, 2);
stem(n, B);
title('Hanning');
grid;
xlabel('n');
ylabel('B');
```

```
subplot(2, 2, 3);
plot(w, mag);
title('Amp');
grid;
xlabel('f/Hz');
ylabel('amp');

subplot(2, 2, 4);
plot(w, db);
title('Fading');
grid;
xlabel('f/Hz');
ylabel('DB/db');

%%
```

结果：