Design FIR Filters

1. Window Method
2. Optimal equiripple Mehtod
3. Frequency Samling Method

Design Steps

1. **Filter Specification**
2. **Coefficient Calculations**
3. **Realisation**
4. **Implementation**

Summary of ideal impulse responses for standard frequency selective filters

Filter type	$h_D(n),\ n \neq 0$	$h_D(0)$
Lowpass	$2 f_c \dfrac{\sin(nw_c)}{nw_c}$	$2 f_c$
Highpass	$-2 f_c \dfrac{\sin(nw_c)}{nw_c}$	$1-2 f_c$
Bandpass	$2 f_2 \dfrac{\sin(nw_2)}{nw_2} - 2 f_1 \dfrac{\sin(nw_1)}{nw_1}$	$2(f_2 - f_1)$
Bandstop	$2 f_1 \dfrac{\sin(nw_1)}{nw_1} - 2 f_2 \dfrac{\sin(nw_2)}{nw_2}$	$1-2(f_2 - f_1)$

Summary of important features of common window functions

Name of Window function	Normalized transition width(HZ)	Passband ripple (db)	Main lobe relative to side lobe(dB)	Stopband attenuation(dB) (maximum)	Window function $w(n), \lvert n \rvert \le (N-1)/2$
Rectangular	0.9 / N	0.7416	13	21	1
Hanning	3.1 / N	0.056	31	44	$0.5 \cos\left(\frac{2\pi n}{N}\right)$
Hamming	3.3 /N	0.0194	41	53	$0{,}54+0.46 \cos\left(\frac{2\pi n}{N}\right)$
Blackman	5.5 /N	0.0017	57	75	$0.42+0.5 \cos\left(\frac{2\pi n}{N-1}\right)+0.08 \cos\left(\frac{4\pi n}{N-1}\right)$
Kaiser	$2.93/N(\beta=4.54)$	0.0274		50	$\frac{I_0\left(\beta\left\{1-\left[2n/(N-1)\right]^2\right\}^{1/2}\right)}{I_0(\beta)}$
	$4.32/N(\beta=6.76)$	0.00275		70	
	$5.71/N(\beta=8.96)$	0.000275		90	

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	$4.32/N(\beta=6.76)$	0.00275		70	
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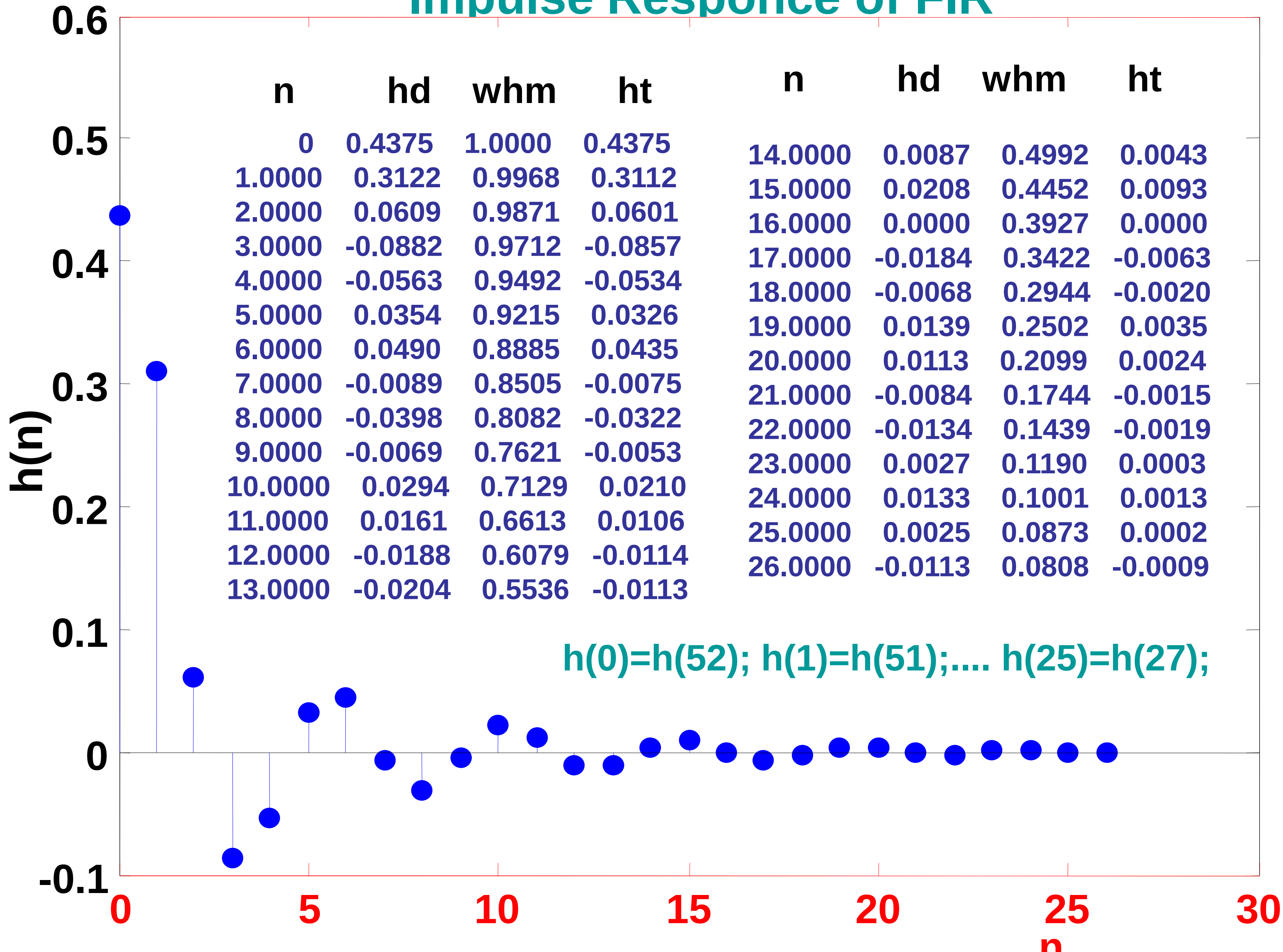
Design FIR Using Hamming Window

```
fp=1.5;
df=0.5;
as=50;
ft=8;
df1=df/ft;
N=3.3/df1;
N=ceil(N)
n=0:(N-1)/2;
fc1=(fp+(df/2))/ft
w=2*pi*fc1;
hd=2*fc1*sinc(2*fc1*n);
whm=0.54+0.46*cos(2*pi*n/53);
ht=hd.*whm;
[h f]=freqz(ht,1,512,ft);
g=20*log10(abs(h));
plot(f,g)
xlabel('frequency, Hz')
ylabel('Gain,dB')
```

```
[n' ht']
stem (n,ht,'fill')
xlabel('n')
ylabel('h(n)')
```

Impulse Responce of FIR

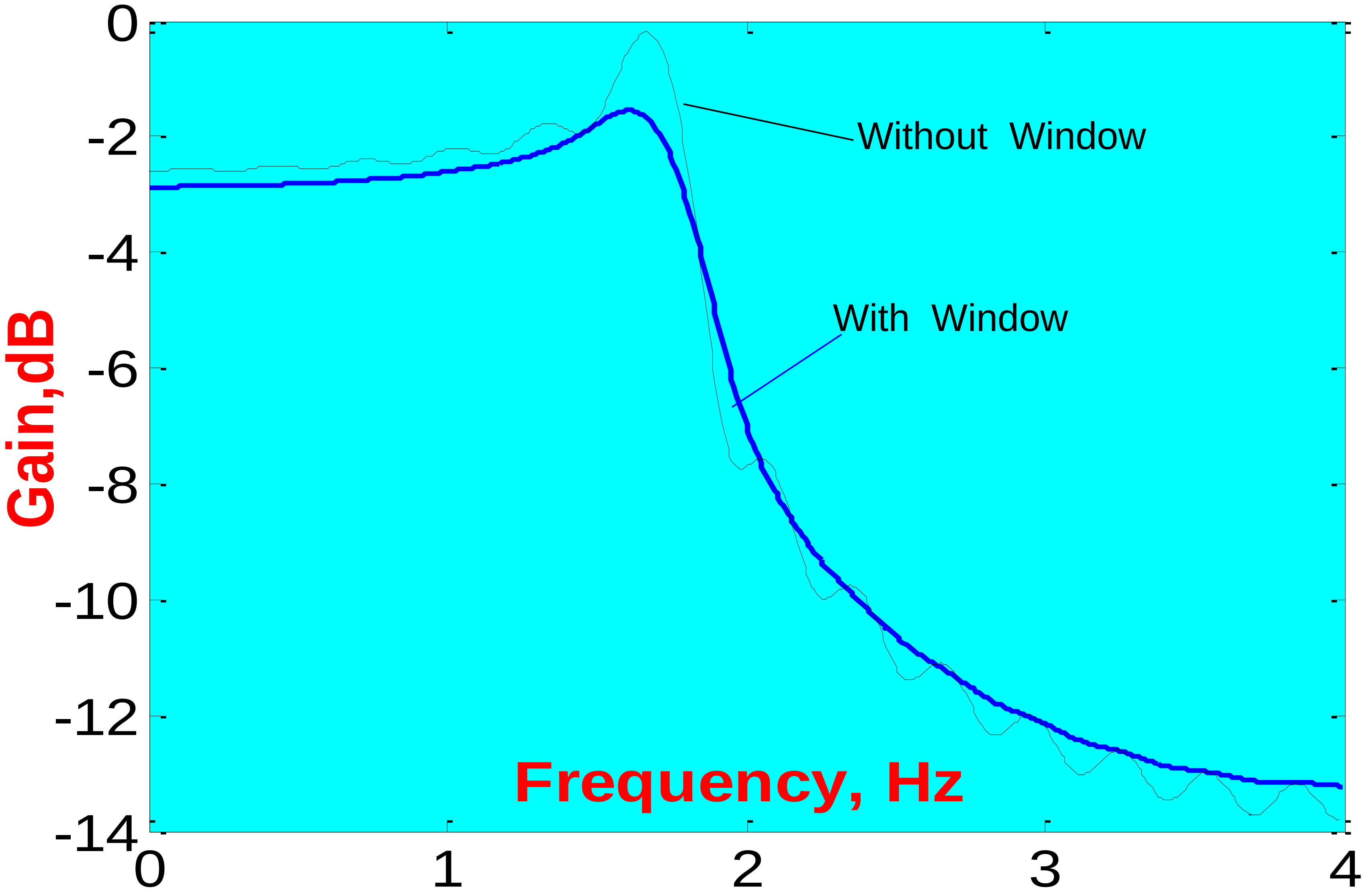


n	hd	whm	ht
0	0.4375	1.0000	0.4375
1.0000	0.3122	0.9968	0.3112
2.0000	0.0609	0.9871	0.0601
3.0000	-0.0882	0.9712	-0.0857
4.0000	-0.0563	0.9492	-0.0534
5.0000	0.0354	0.9215	0.0326
6.0000	0.0490	0.8885	0.0435
7.0000	-0.0089	0.8505	-0.0075
8.0000	-0.0398	0.8082	-0.0322
9.0000	-0.0069	0.7621	-0.0053
10.0000	0.0294	0.7129	0.0210
11.0000	0.0161	0.6613	0.0106
12.0000	-0.0188	0.6079	-0.0114
13.0000	-0.0204	0.5536	-0.0113

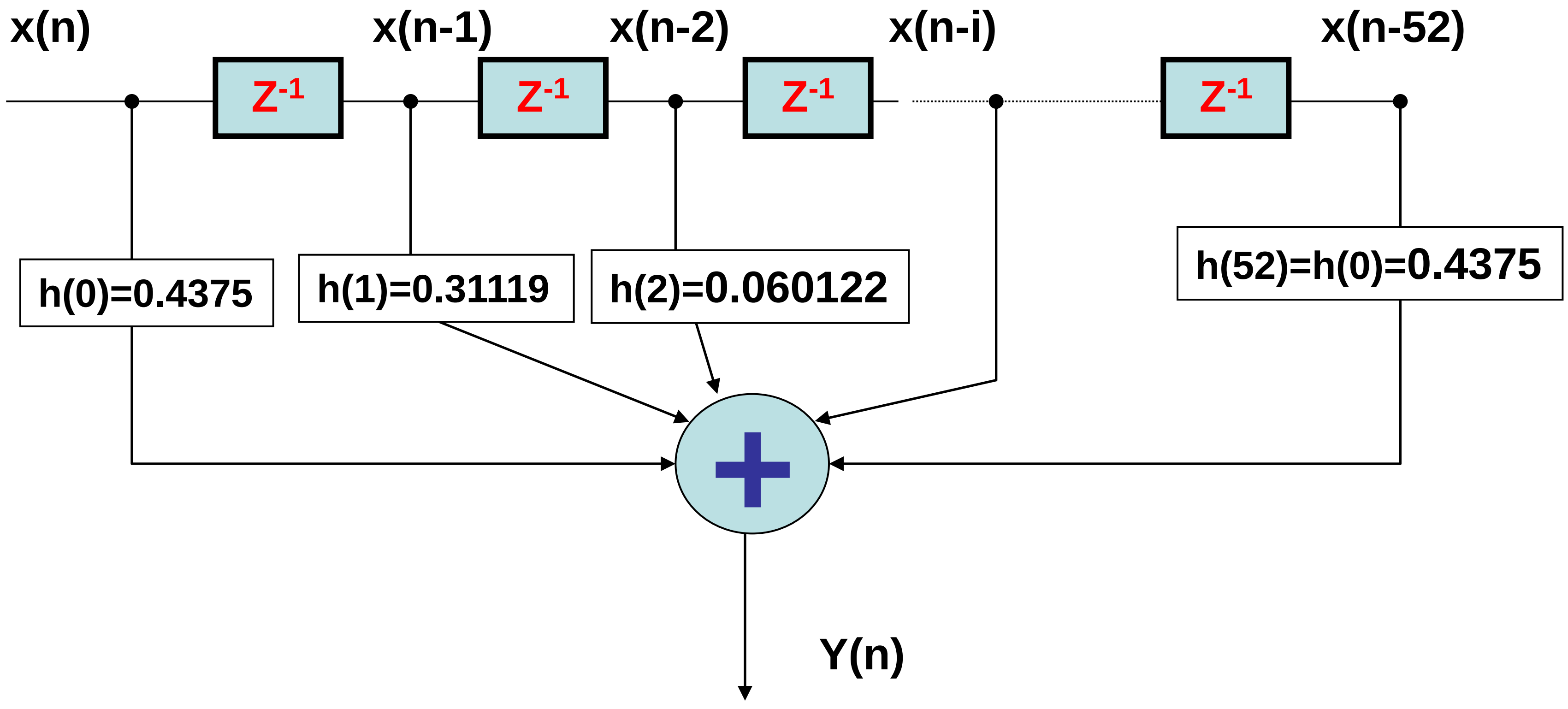
n	hd	whm	ht
14.0000	0.0087	0.4992	0.0043
15.0000	0.0208	0.4452	0.0093
16.0000	0.0000	0.3927	0.0000
17.0000	-0.0184	0.3422	-0.0063
18.0000	-0.0068	0.2944	-0.0020
19.0000	0.0139	0.2502	0.0035
20.0000	0.0113	0.2099	0.0024
21.0000	-0.0084	0.1744	-0.0015
22.0000	-0.0134	0.1439	-0.0019
23.0000	0.0027	0.1190	0.0003
24.0000	0.0133	0.1001	0.0013
25.0000	0.0025	0.0873	0.0002
26.0000	-0.0113	0.0808	-0.0009

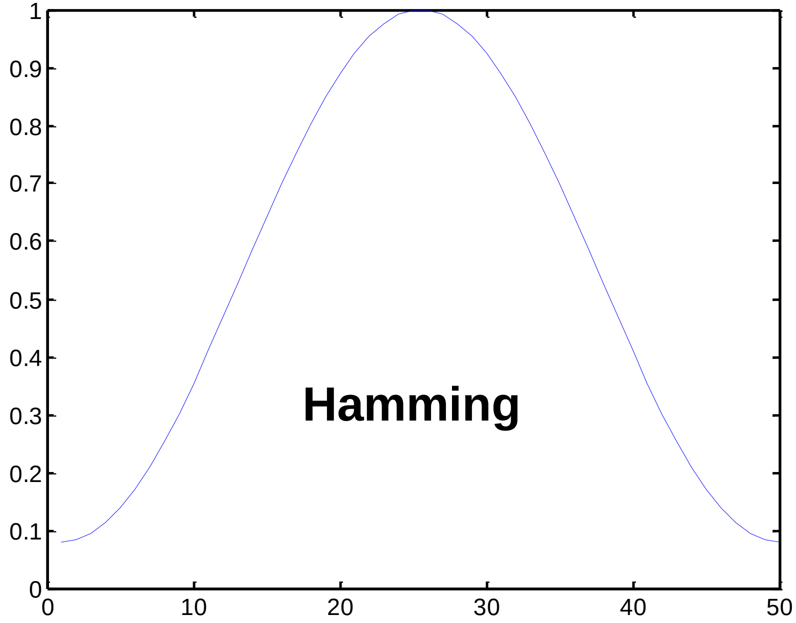
h(0)=h(52); h(1)=h(51);.... h(25)=h(27);

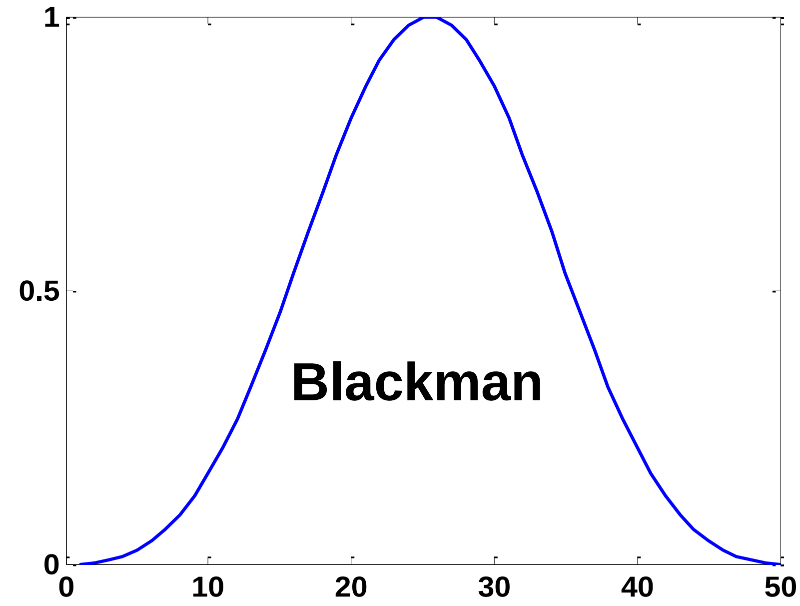
Frequency Responce of FIR

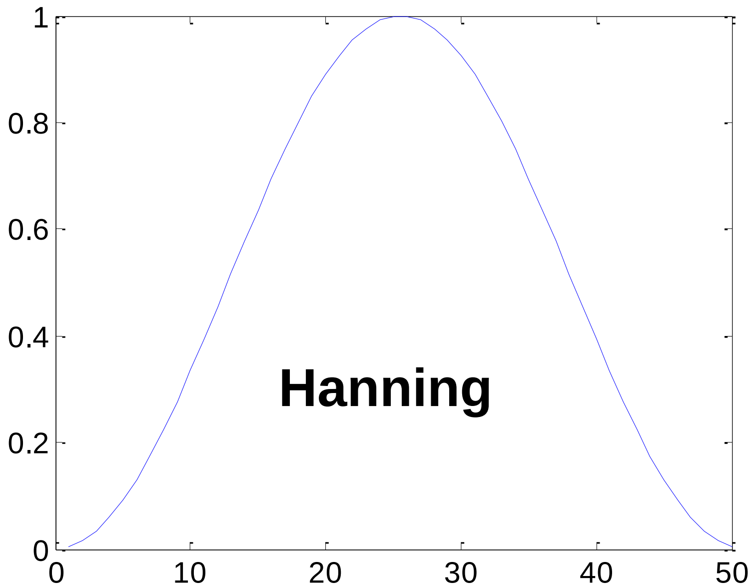


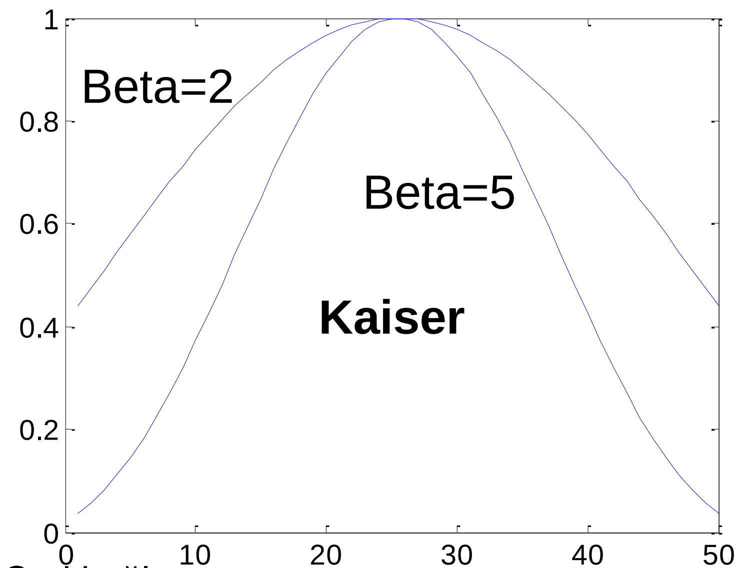
Realization of FIR




Hamming
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
10
20
30
40
50


Blackman
0
0.5
1
0
10
20
30
40
50

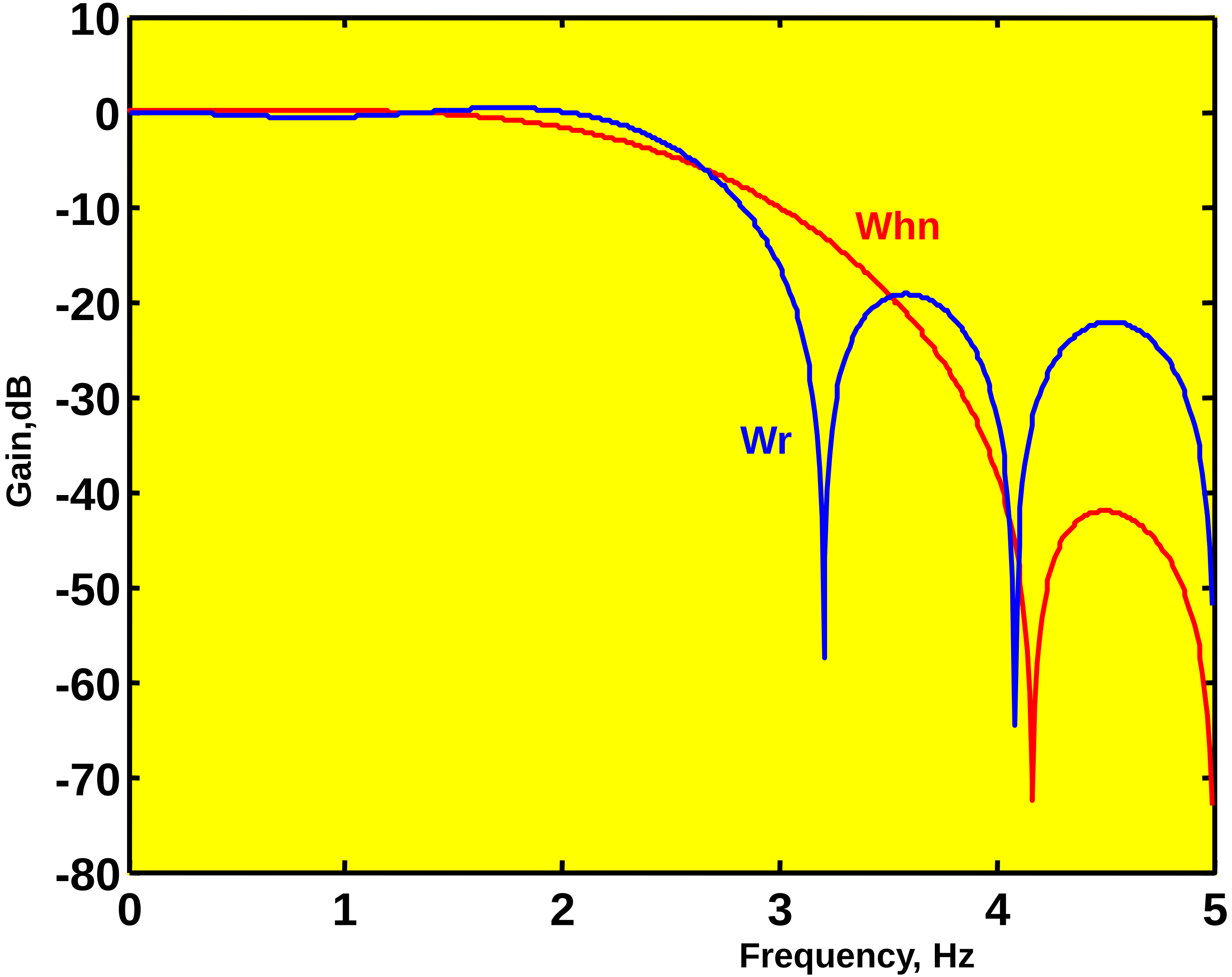

Hanning
0
0.2
0.4
0.6
0.8
1
0
10
20
30
40
50

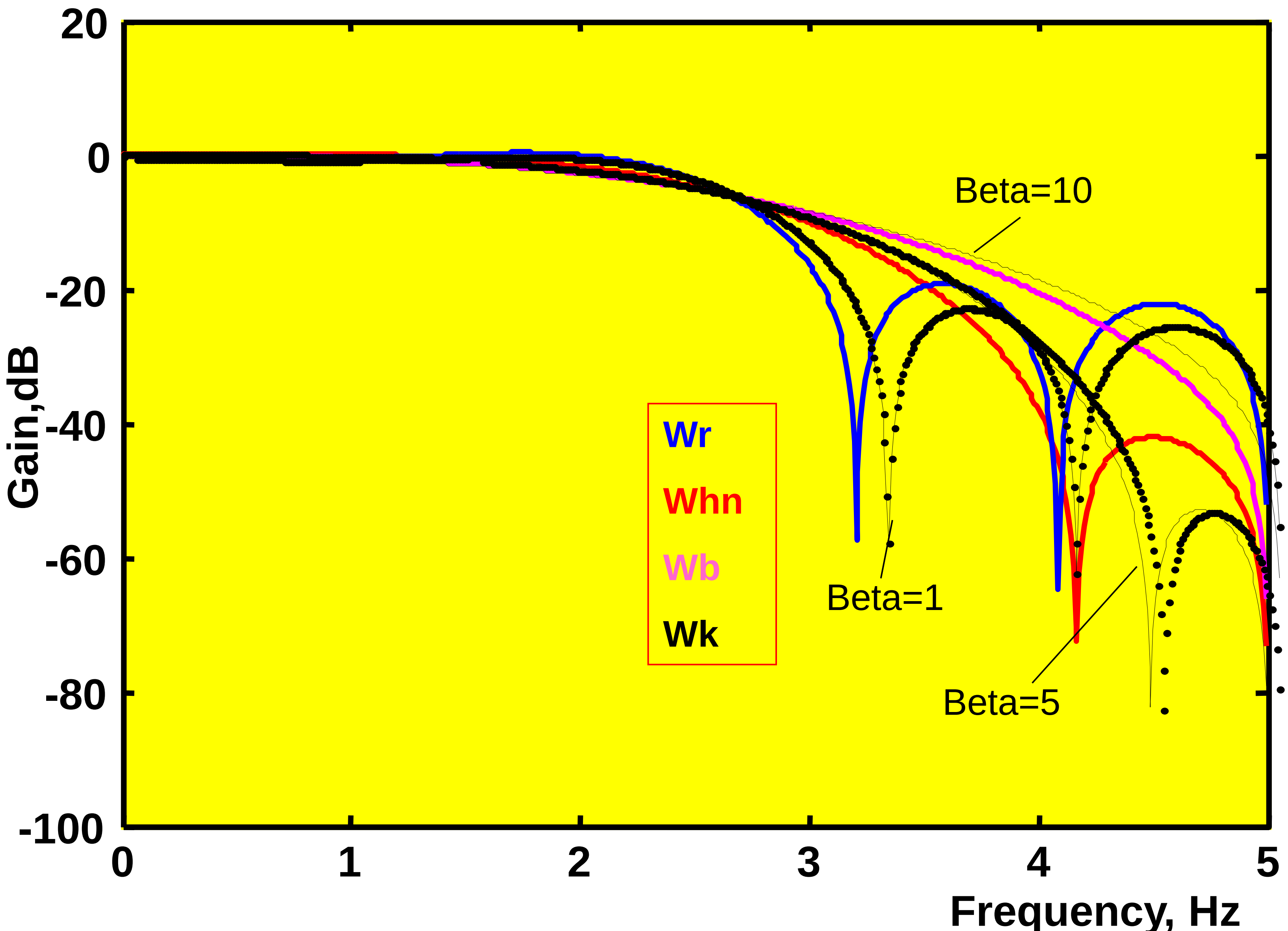

Beta=2
Beta=5
Kaiser
0
0.2
0.4
0.6
0.8
1
0
10
20
30
40
50

Comparison different FIR

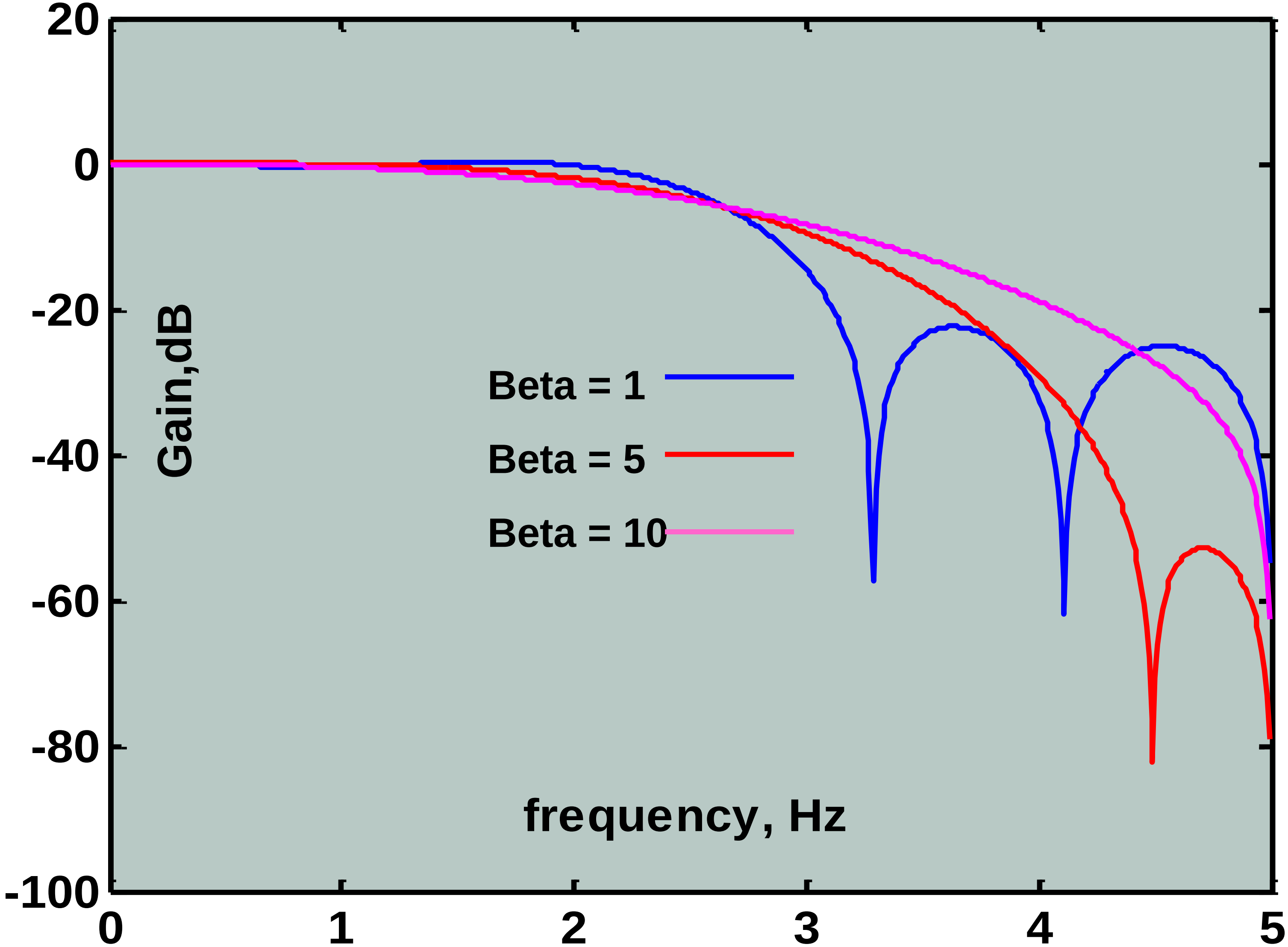
```
fp=1;
fs=4.3;
ft=10;
df1=(fs-fp)/ft;
N=3.3/df1;
N=ceil(N)
fc=fp+(fs-fp)/2
fcn=fc/(0.5*ft);
wr=boxcar(N);
hd=fir1(N-1,fcn,wr);
whm=hanning(N);
ht=fir1(N-1,fcn,whm);
[h f]=freqz(ht,1,512,ft);
g=20*log10(abs(h));
plot(f,g)
xlabel('frequency, Hz')
ylabel('Gain,dB')
```

n	wr	whn	hd	ht
1.0000	1.0000	0.0794	0.0641	0.0053
2.0000	1.0000	0.2923	-0.0388	-0.0117
3.0000	1.0000	0.5712	-0.1052	-0.0622
4.0000	1.0000	0.8274	0.1235	0.1058
5.0000	1.0000	0.9797	0.4564	0.4629
6.0000	1.0000	0.9797	0.4564	0.4629
7.0000	1.0000	0.8274	0.1235	0.1058
8.0000	1.0000	0.5712	-0.1052	-0.0622
9.0000	1.0000	0.2923	-0.0388	-0.0117
10.0000	1.0000	0.0794	0.0641	0.0053


10
0
-10
-20
-30
-40
-50
-60
-70
-80
Gain,dB
0
1
2
3
4
5
Frequency, Hz
Whn
Wr



20
0
-20
-40
-60
-80
-100
Gain,dB
0
1
2
3
4
5
Frequency, Hz
Beta=10
Beta=1
Beta=5
Wr
Whn
Wb
Wk


20
0
-20
-40
-60
-80
-100
0
1
2
3
4
5
Gain,dB
frequency, Hz
Beta = 1
Beta = 5
Beta = 10

Design PB Remez filter

```
f1=0; f2=500; f3=1000;
f4=1500; f5=2000;
f6=5000;
ft=10000; N=41;
w1=f1/(0.5*ft);
w2=f2/(0.5*ft);
w3=f3/(0.5*ft);
w4=f4/(0.5*ft);
w5=f5/(0.5*ft);
w6=f6/(0.5*ft);
F=[w1 w2 w3 w4 w5 w6];
M=[0 0 1 1 0 0];
h=remez(N-1,F,M);
[H f]=freqz(h,1,512,ft);
mag=20*log10(abs(H));
plot(f,mag);
xlabel('Frequency (Hz)')
ylabel('Gain (dB)')
```