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Assignment 2
Design of Low pass filters using windowing method

Part 1

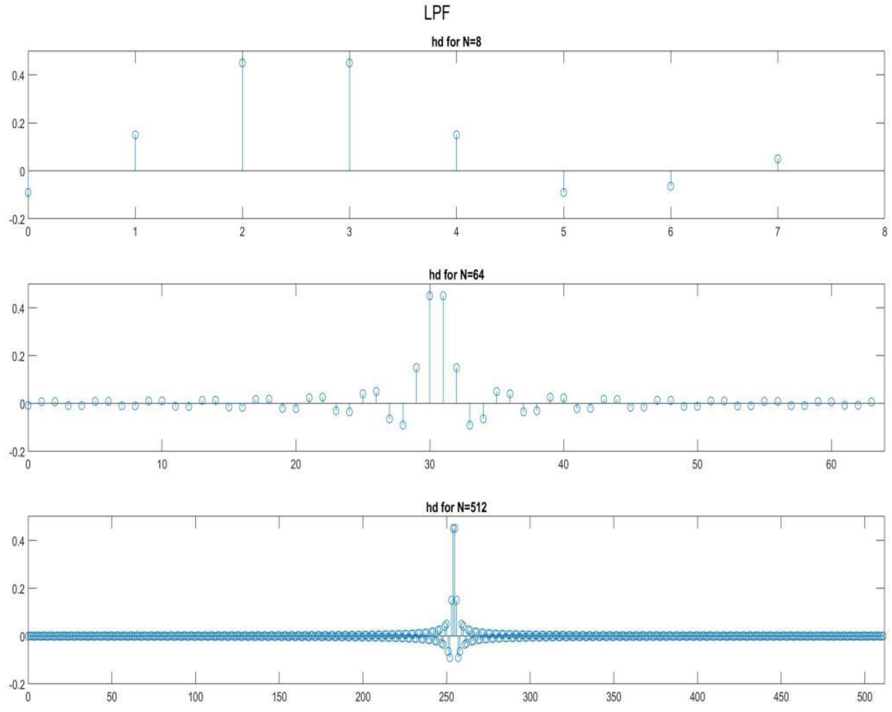
Aim :- To designed FIR filter responses for 5 different window functions.

The low pass filter signal used is given below for differnt values of N.

Code we used to obtain it :-

```
clc
clear all
close all
N=128;
n = 0:1:N-1;
wc=pi*0.5;
w1=linspace(-pi,pi,1024);
k=(8-1)/2;
for i=1:8
if i==k
hd8(i)=wc/pi;
else
hd8(i)=sin(wc*(i-k))/(pi*(i-k));
end
end;
k=(64-1)/2;
for i=1:64
if i==k
hd64(i)=wc/pi;
else
hd64(i)=sin(wc*(i-k))/(pi*(i-k));
end
end;
k=(64-1)/2;
for i=1:64
if i==k
hd64(i)=wc/pi;
else
hd64(i)=sin(wc*(i-k))/(pi*(i-k));
end
end;
k=(512-1)/2;
for i=1:512
if i==k
hd512(i)=wc/pi;
else
hd512(i)=sin(wc*(i-k))/(pi*(i-k));
end
end;



n8 = 0:1:8-1;
subplot(3,1,1);
stem(n8,hd8);
```

```
  axis([0 8 -0.2 0.5]);
  title(['hd for N=8']);


  subplot(3,1,2);
  n64 = 0:1:64-1;


  stem(n64,hd64);
  axis([0 64 -0.2 0.5]);
  title(['hd for N=64']);


  subplot(3,1,3);
  n512 = 0:1:512-1;
  stem(n512,hd512);
  axis([0 512 -0.2 0.5]);
title(['hd for N=512']);
sgtitle('LPF');
```



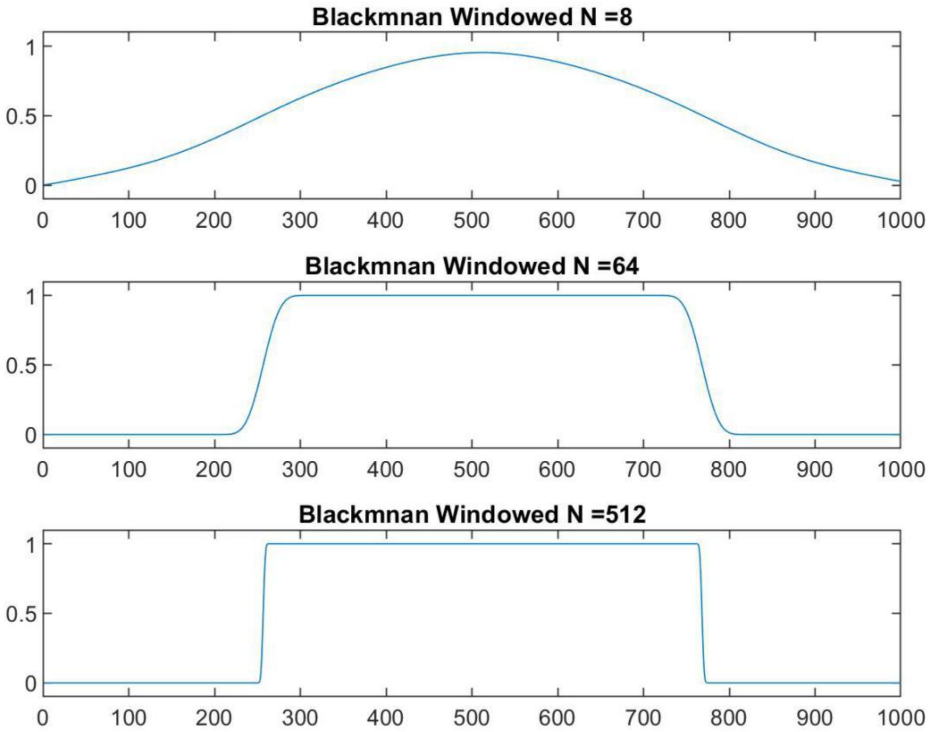
Code for the filter response over differnt windows results shown below:-

```
clc
clear all
close all
N=128;
n = 0:1:N-1;
wc=pi*0.5;
w1=linspace(-pi,pi,1024);
k=(8-1)/2;
for i=1:8
    if i==k
```

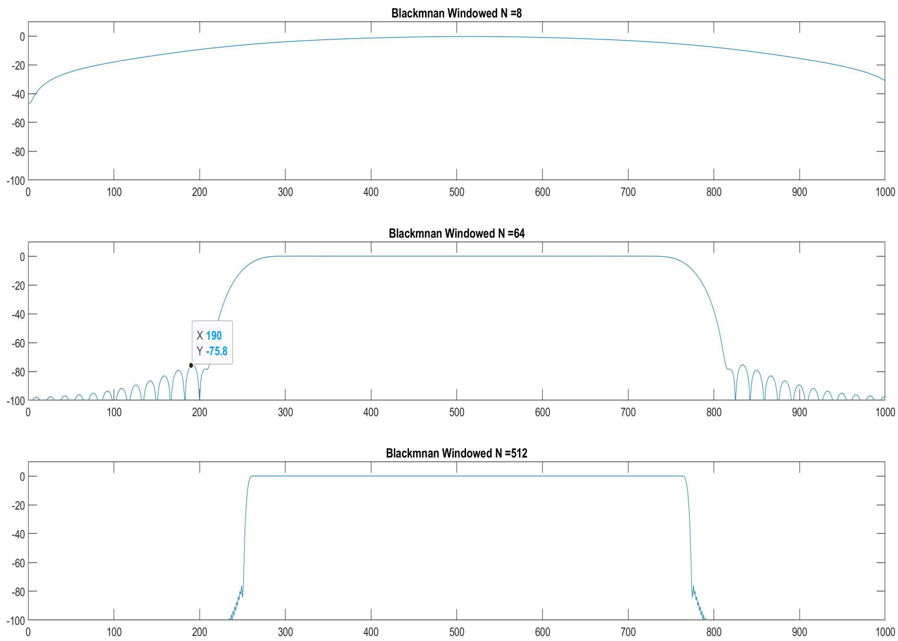
```
        hd8(i)=wc/pi;
    else
        hd8(i)=sin(wc*(i-k))/(pi*(i-k));
    end
end;
k=(64-1)/2;
for i=1:64
    if i==k
        hd64(i)=wc/pi;
    else
        hd64(i)=sin(wc*(i-k))/(pi*(i-k));
    end
end;
%t=0:1/1:length(H1)-1;
figure(1);
c=0;
for j=[8 64 512]
    c=c+1;
    k=(j-1)/2;
    for i=1:j
        if i==k
            hd1(i)=wc/pi;
        else
            hd1(i)=sin(wc*(i-k))/(pi*(i-k));
        end
    end;

    rw=ones(1,j);
    h1=hd1.*rw;
    H1=freqz(h1,1,w1);
    H=20*log10(abs(H1));
H1=H(1:(size(H,2)/2));
B=(H1<-3).*(H1>-30);
A=sum(B);
TW=A*2*pi/size(H,2);
disp(TW)
    subplot(3,1,c);
    plot(abs(H1));
    axis([0 1000 -0.1 1.1]);
    title(['Rectangular Windowed N =',num2str(j)]);
end;

figure(2);
c=0;
for j=[8 64 512]
    c=c+1;

    k=(j-1)/2;
    for i=1:j
        if i==k
            hd2(i)=wc/pi;
        else
            hd2(i)=sin(wc*(i-k))/(pi*(i-k));
        end
    end;


    %triangular window
    for i=1:j
        tw(i)=1-2*[i-(j-1)/2]/(j-1);
    end;
```

```
    h2=hd2.*tw;
    H2=freqz(h2,1,w1);
    H=20*log10(abs(H2));
H1=H(1:(size(H,2)/2));
B=(H1<-3).*(H1>-30);
A=sum(B);
TW=A*2*pi/size(H,2);
disp(TW)
    subplot(3,1,c);
    plot(abs(H2));
    axis([0 1000 -0.1 1.1]);
    title(['Triangular Windowed N =',num2str(j)]);
end;

figure(3);
c=0;
for j=[8 64 512]
    c=c+1;
    k=(j-1)/2;
    for i=1:j
        if i==k
            hd3(i)=wc/pi;
        else
            hd3(i)=sin(wc*(i-k))/(pi*(i-k));
        end
    end;

    for i=1:j
        hnw(i)=0.5-0.5*cos(2*pi*i/(j-1));
    end;
    h3=hd3.*hnw;
    H3=freqz(h3,1,w1);
    H=20*log10(abs(H3));
H1=H(1:(size(H,2)/2));
B=(H1<-3).*(H1>-30);
A=sum(B);
TW=A*2*pi/size(H,2);
disp(TW)
    subplot(3,1,c);
    plot(abs(H3));
    axis([0 1000 -0.1 1.1]);
    title(['Hanning Windowed N =',num2str(j)]);
end;

figure(4);
c=0;
for j=[8 64 512]
    c=c+1;
    k=(j-1)/2;
    for i=1:j
        if i==k
            hd4(i)=wc/pi;
        else
            hd4(i)=sin(wc*(i-k))/(pi*(i-k));
        end
    end;

    for i=1:j
        hmw(i)=0.54-0.46*cos(2*pi*i/(j-1));
    end;
```

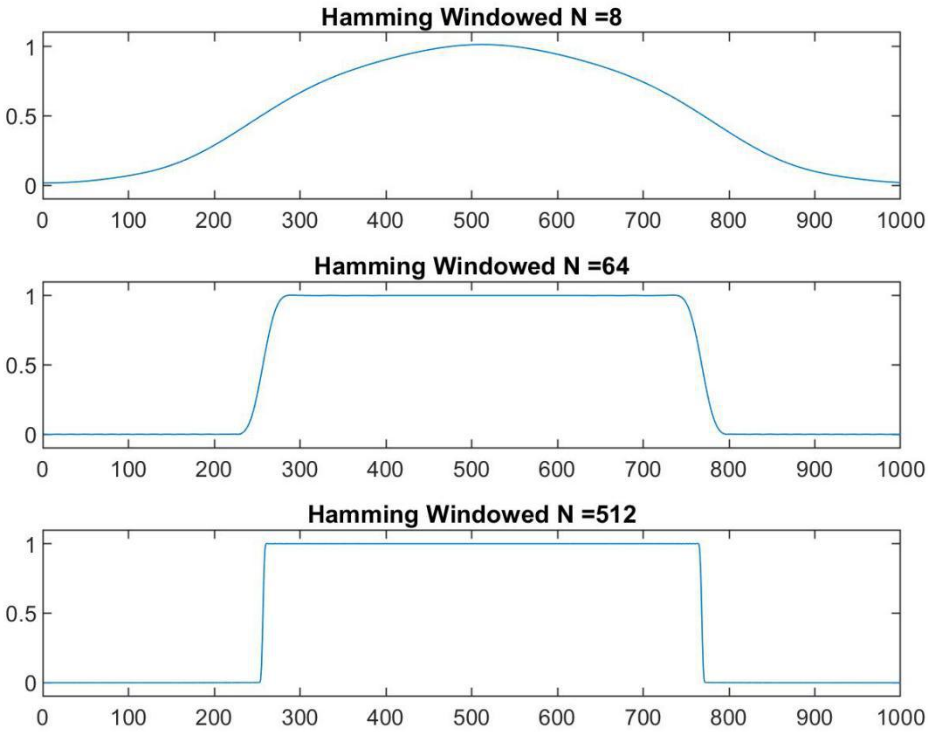
```
    h4=hd4.*hmw;
    H4=freqz(h4,1,w1);
    H=20*log10(abs(H4));
H1=H(1:(size(H,2)/2));
B=(H1<-3).*(H1>-30);
A=sum(B);
TW=A*2*pi/size(H,2);
disp(TW)
    subplot(3,1,c);
    plot(abs(H4));
    axis([0 1000 -0.1 1.1]);
    title(['Hamming Windowed N =',num2str(j)]);

end;

figure(5);
c=0;
for j=[8 64 512]
    c=c+1;
    k=(j-1)/2;
    for i=1:j
        if i==k
            hd5(i)=wc/pi;
        else
            hd5(i)=sin(wc*(i-k))/(pi*(i-k));
        end
    end;

    for i=1:j
        bw(i)=0.42-0.5*cos(2*pi*i/(j-1))+0.08*cos(4*pi*i/(j-1));
    end;
    h5=hd5.*bw;
    H5=freqz(h5,1,w1);
    H=20*log10(abs(H5));
H1=H(1:(size(H,2)/2));
B=(H1<-3).*(H1>-30);
A=sum(B);
TW=A*2*pi/size(H,2);
disp(TW)
    subplot(3,1,c);
    plot(abs(H5));
    axis([0 1000 -0.1 1.1]);
    title(['Blackmnan Windowed N =',num2str(j)]);
end;
```



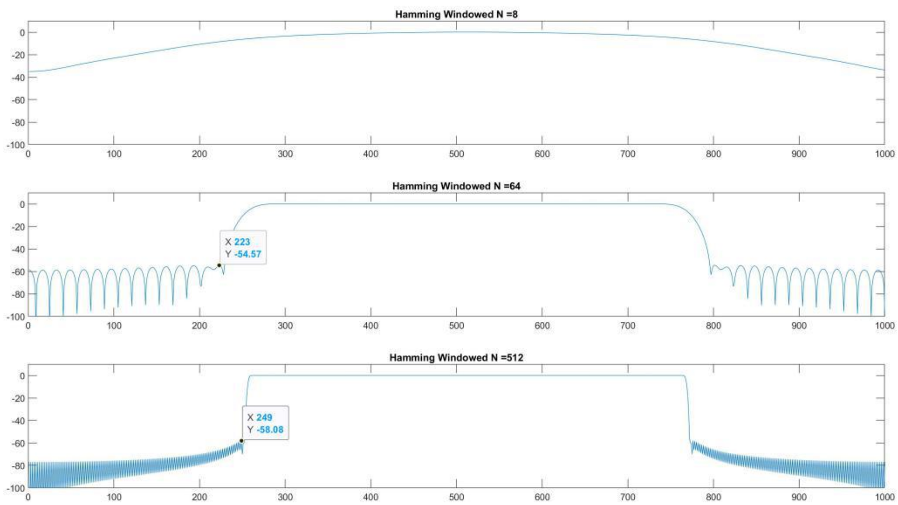
Amplitude in log Scale



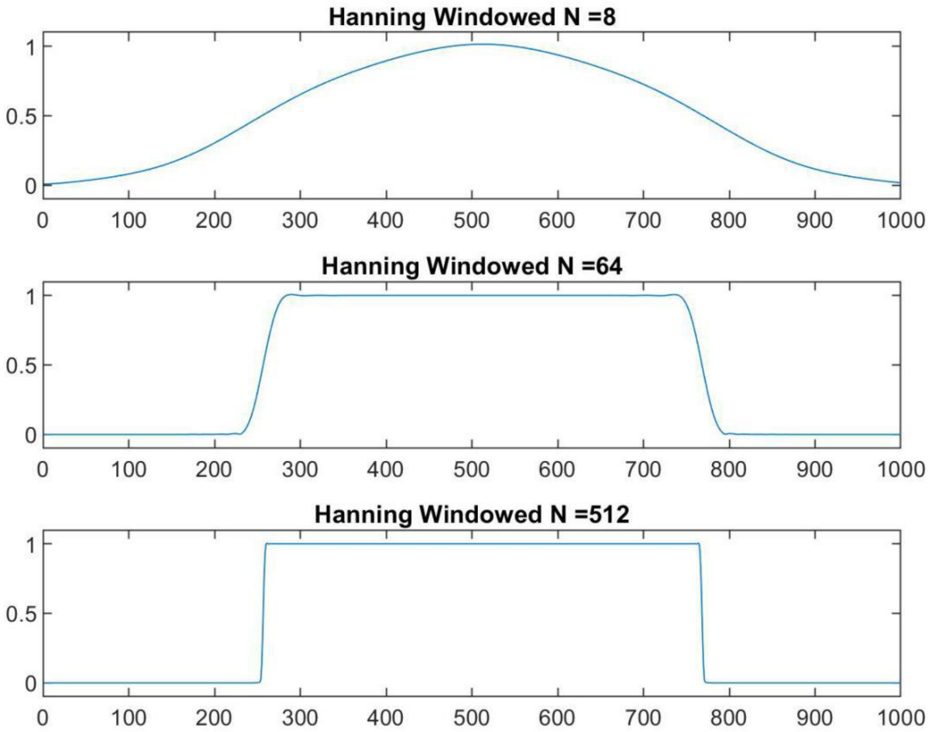
N	Transition Width	Side lobe peak	Maximum Stop band attenuation
8	1.8592	No side lobes	-44.14 dB
64	0.2209	-75.8 dB	-117.24 dB
512	0.0245	-76.02 dB	-158.12 dB



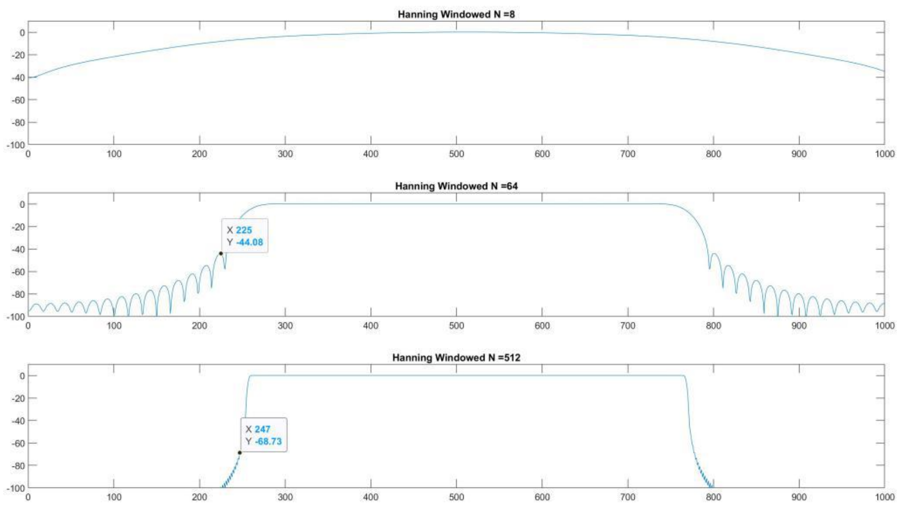
AMPLITUDE IN LOG SCALE



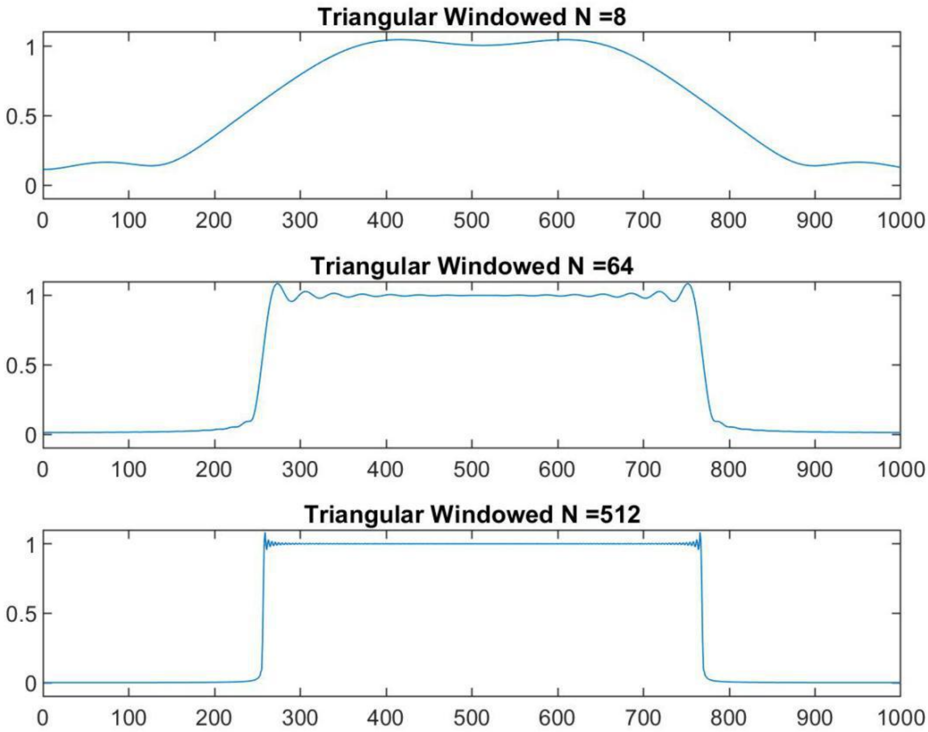
N	Transition Width	Side lobe peak	Maximum Stopband attenuation
8	1.6015	No side lobes observed	-38.1 dB
64	0.1657	-54.57 dB	-111.6 dB
512	0.0184	-58.08 dB	-128.2 dB



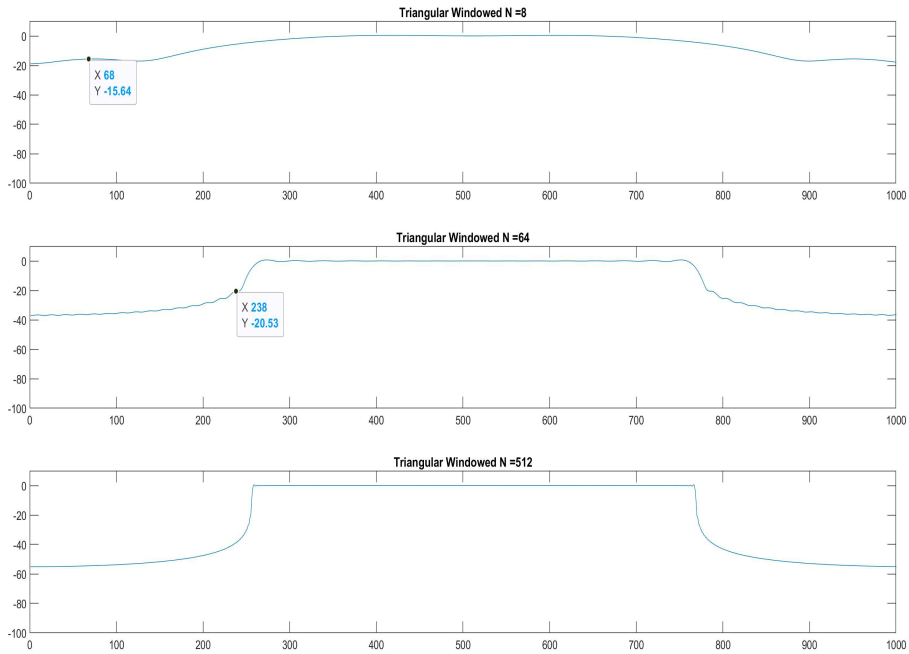
AMPLITUDE IN LOG SCALE



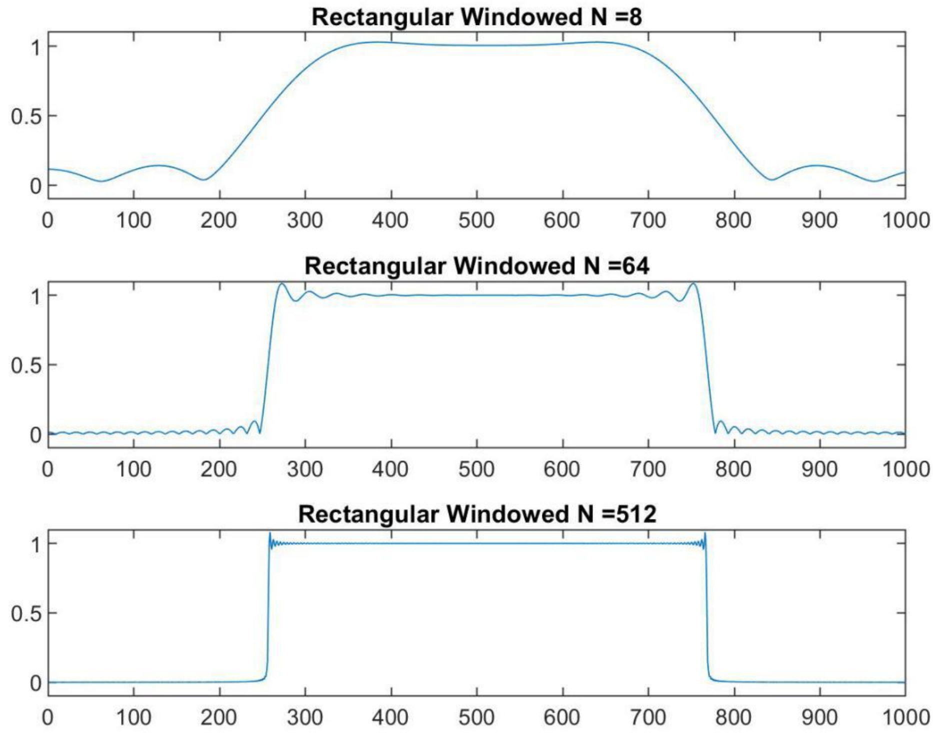
N	Transition Width	Side lobe peak	Maximum stopband attenuation
8	1.6015	No side lobes observed	-40.2 dB
64	0.1657	-44.08 dB	-108 dB
512	0.0184	-68.73 dB	-148 dB



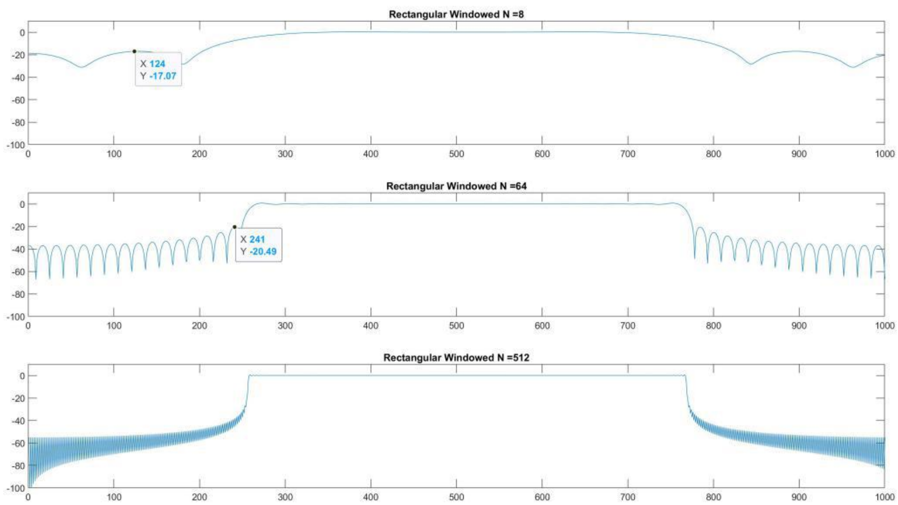
AMPLITUDE IN LOG SCALE



N	Transition Width	Side lobe peak	Maximum stop band attenuation
8	1.6015	-15.64 dB	-19 dB
64	0.1657	-20.53 dB	-38 dB
512	0.0184	0.08 dB	-57 dB



AMPLITUDE IN LOG SCALE



N	Transition Width	Side lobe peak	Maximum stop band attenuation
8	1.6015	-17.07 dB	-31 dB
64	0.1657	-20.49 dB	-66.2 dB
512	0.0184	0.0419 dB	-102 dB

Discussion:

1. freqz is considered as frequency response of digital signal. Whereas, fft as frequency response of an analog signal

2. Blackmnan window has relatively higher transition width than the other windows

3 .There are no ripples for the FIR filter response designed by triangular windowing(N=512).

3 .If we observe the maximum stop band attenuation is high for blackmnan window

4 .Main lobe affects the pass band whereas side lobs affects the stop band. So, the lowest peak in the side band has the higher stop band attenuation, same in the case of blackmnan window.

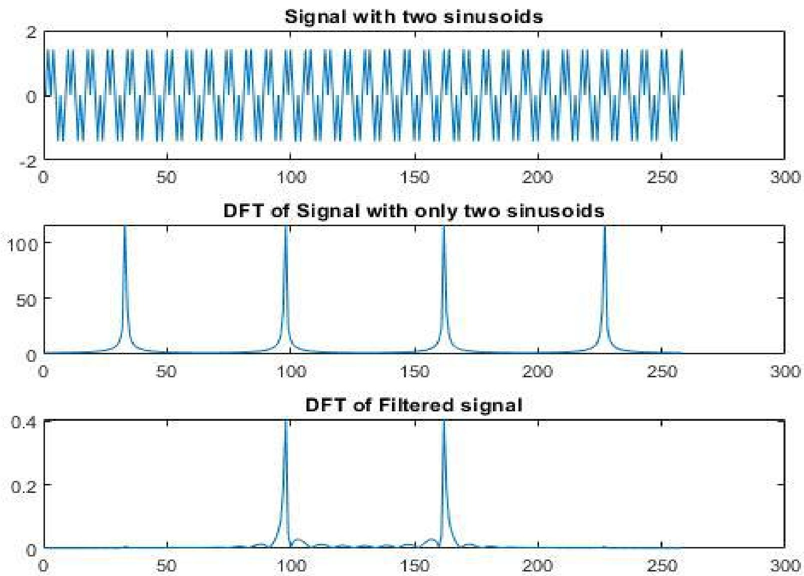
5. Triangular window has relatively higher transition width than the other windows

Part 2 :-

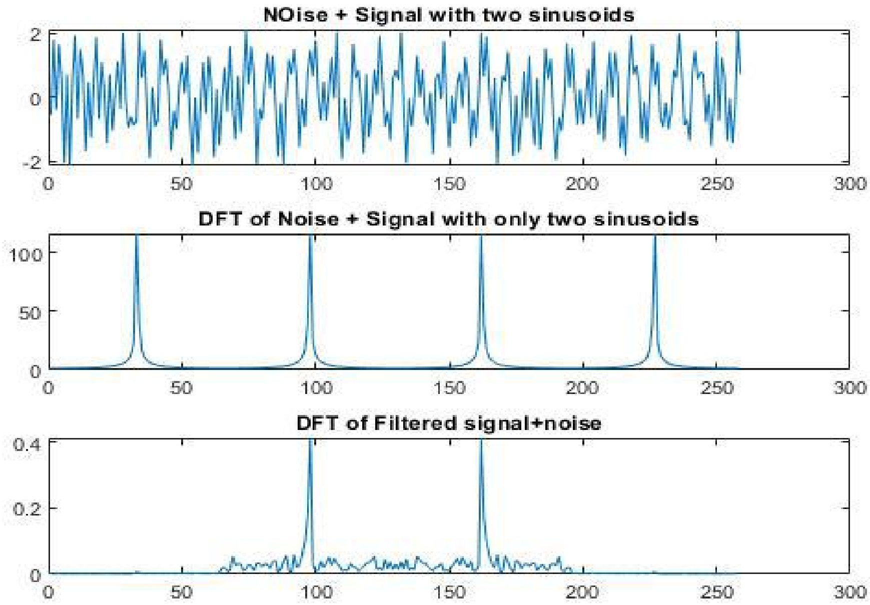
Aim :-

Evaluation of filter performance using a signal containing two sinusoids with and without noise.

RECTANGULAR



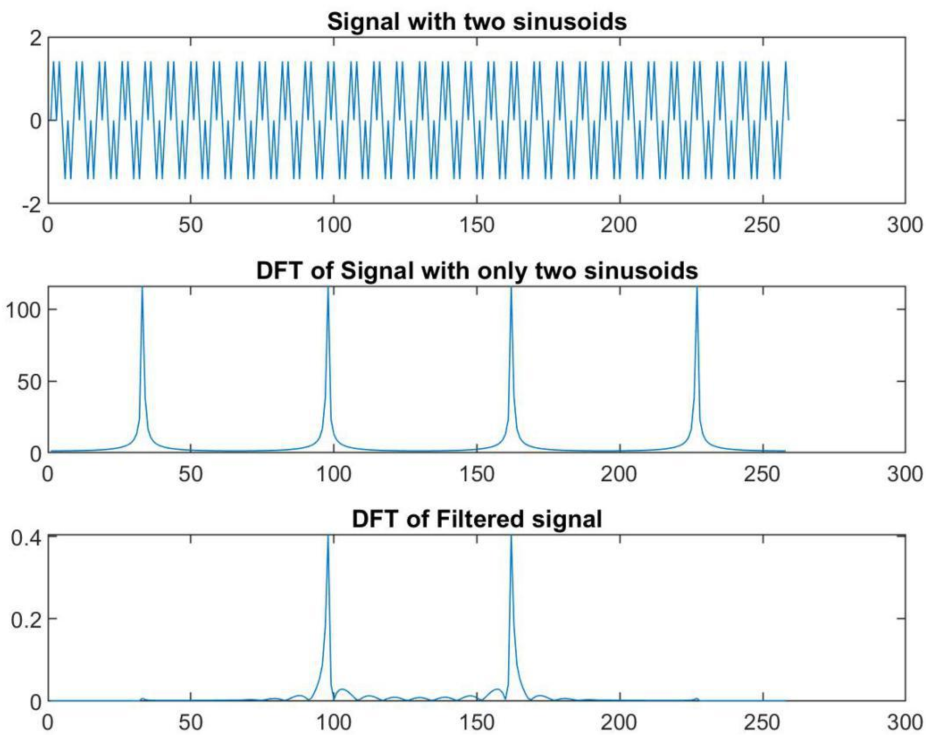
Rectangular window without noise



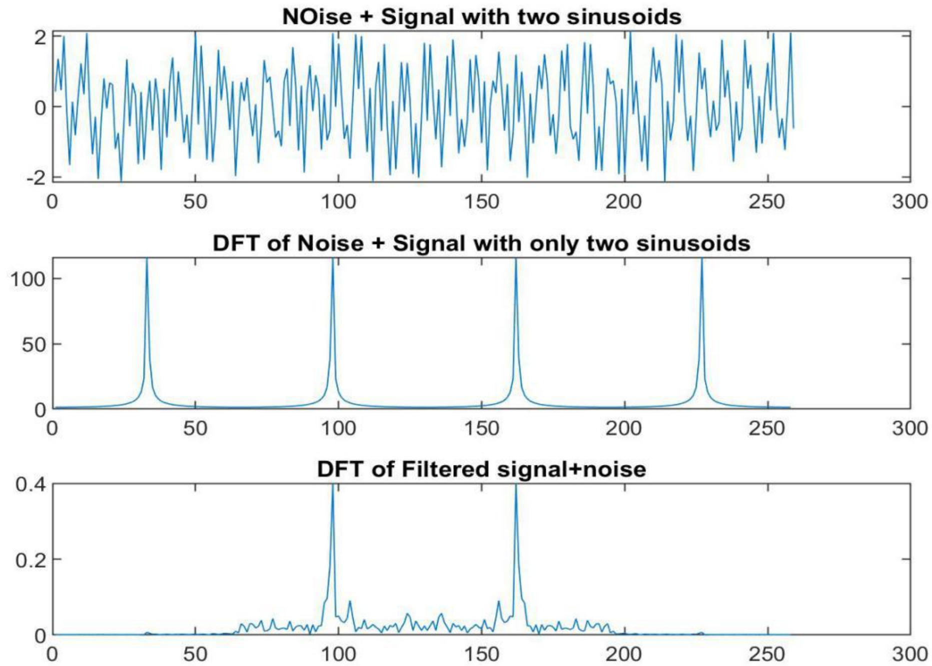
Rectangular window with noise

N	8	64	512
SNR in	10.2710	7.9272	7.9238
SNR out	10.6814	7.2186	7.4720

TRIANGULAR



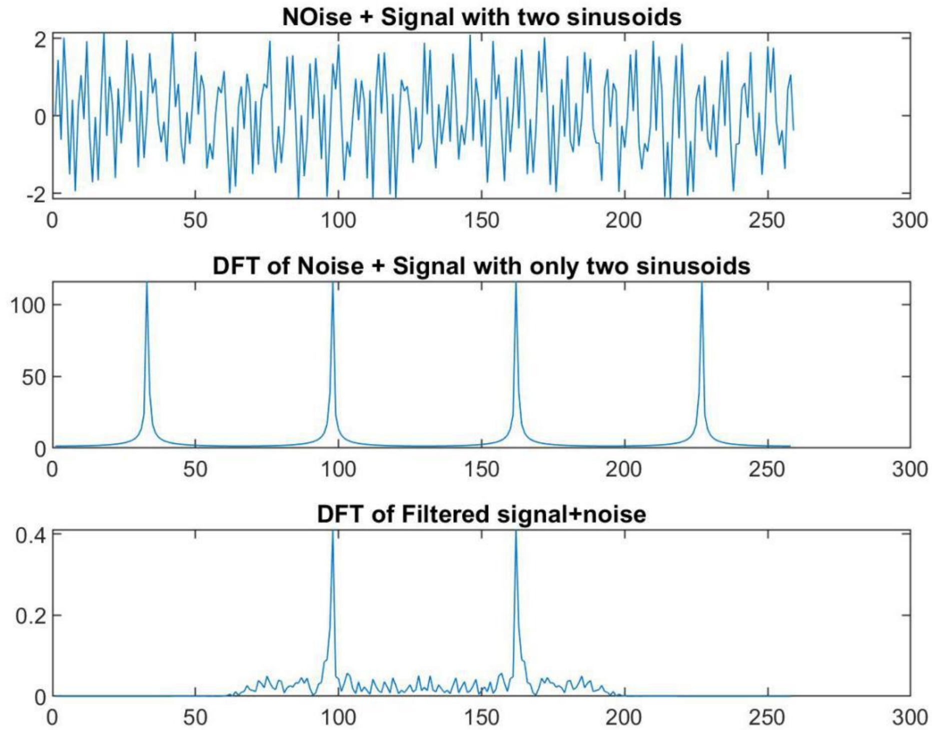
Triangular Window without noise

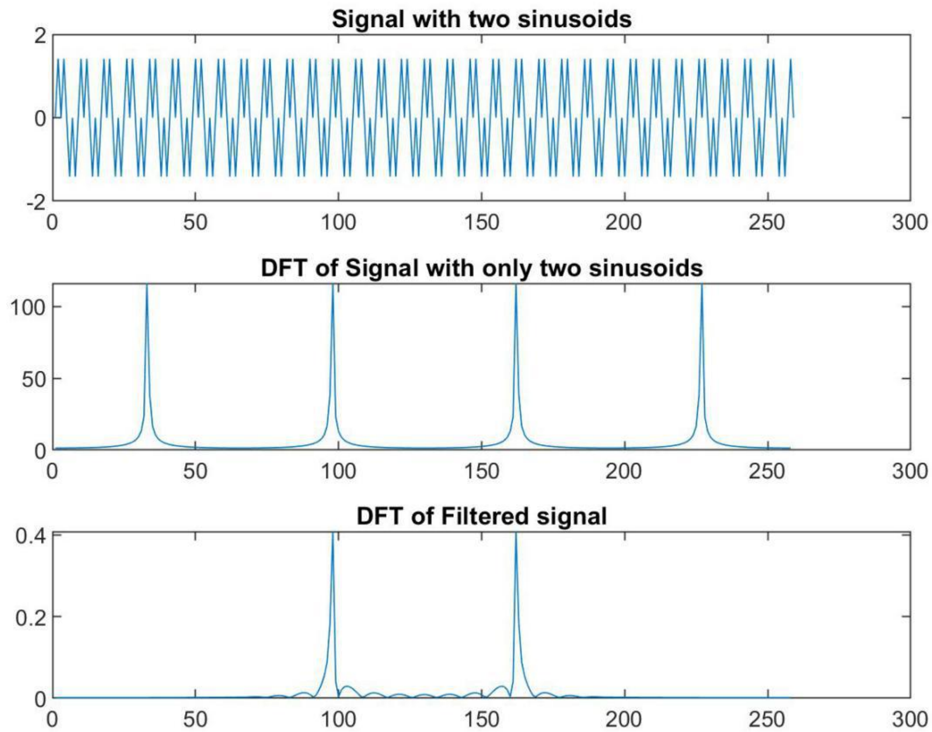


Triangular Window without noise

N	8	64	512
SNR in	6.2525	7.9320	8.4647
SNR out	6.5951	5.8544	8.8935

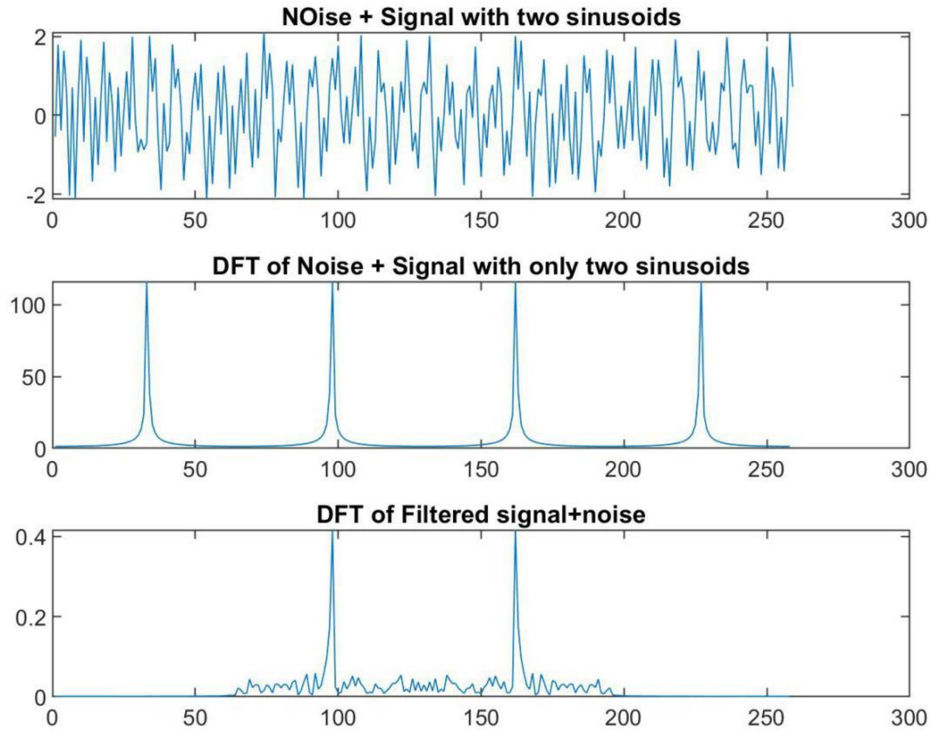
HANNING

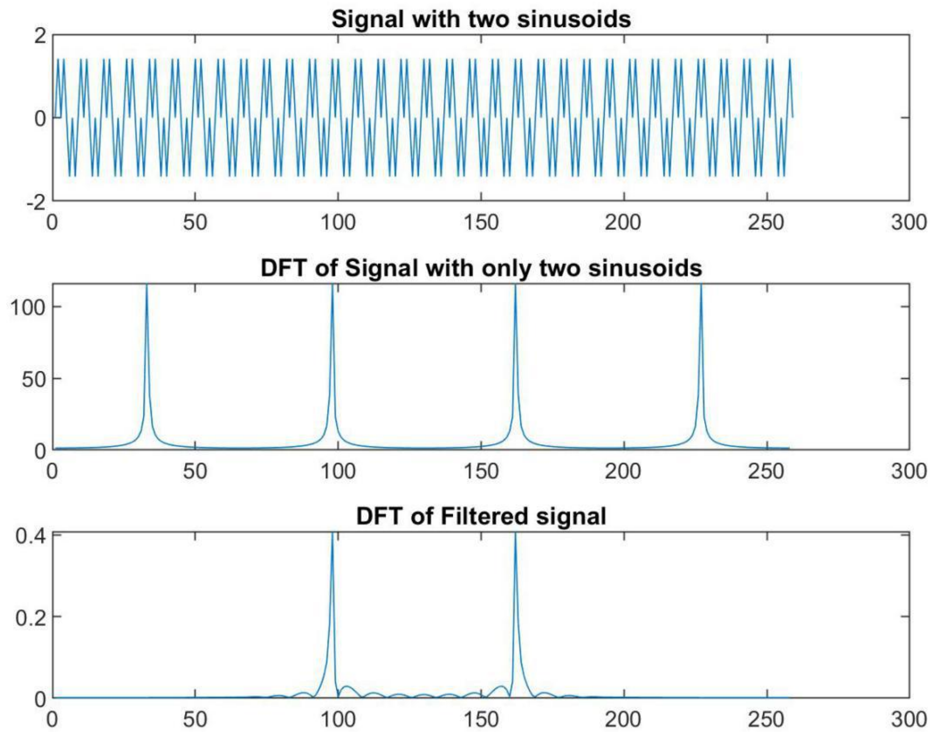




N	8	64	512
SNR in	7.6808	8.3614	7.5341
SNR out	7.9669	9.6262	8.1547

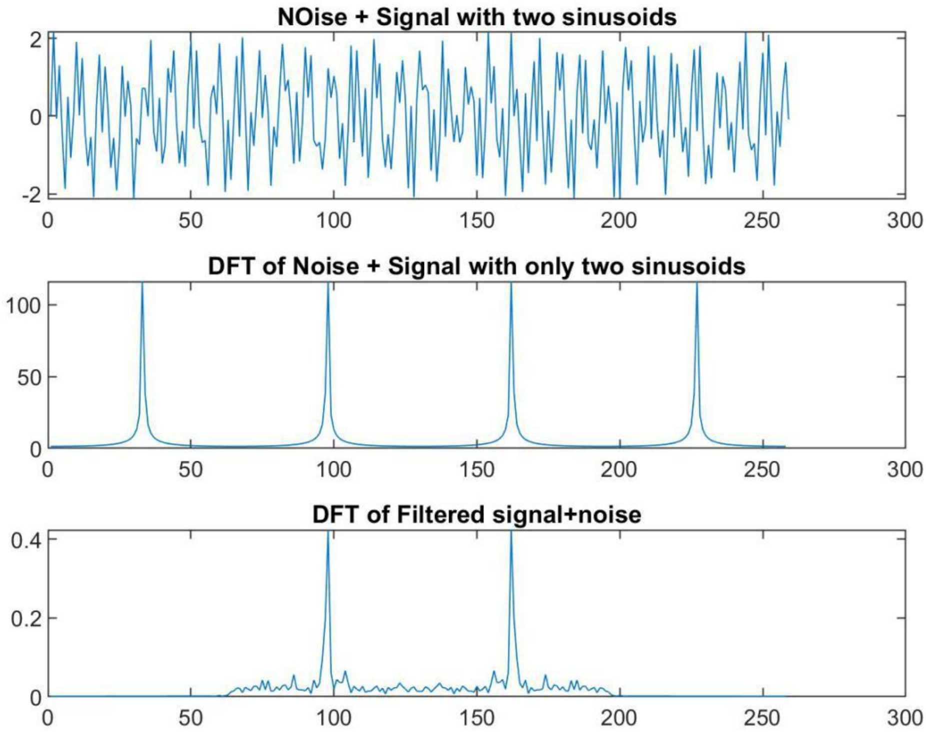
HAMMING

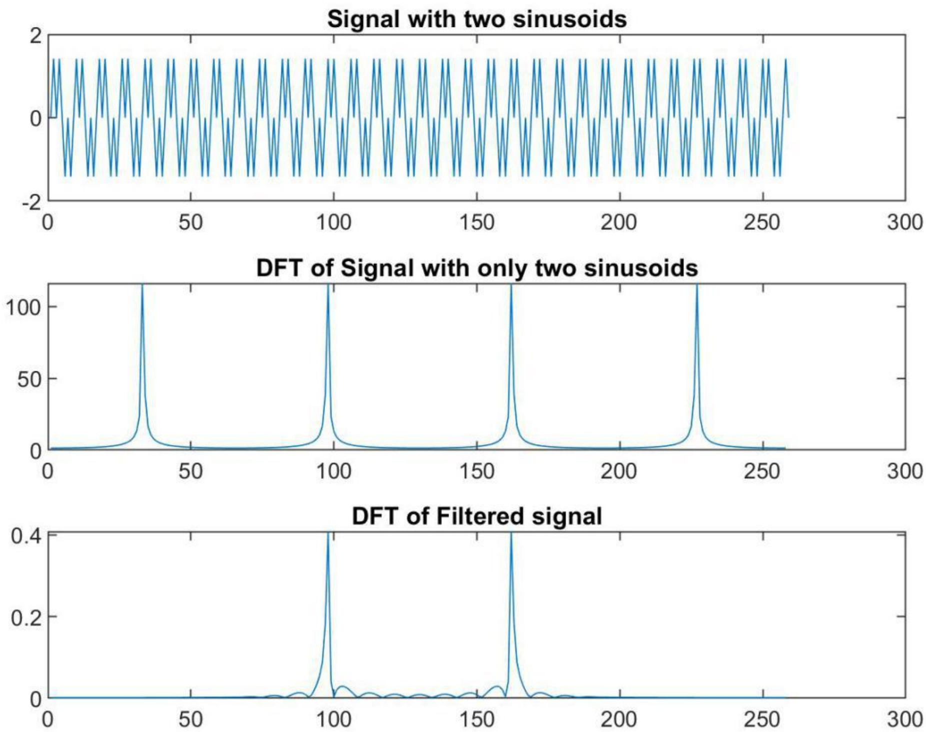




N	8	64	512
SNR in	5.1034	7.1386	7.5341
SNR out	6.3977	8.1771	8.1547

BLACKNMAN WINDOW





N	8	64	512
SNR in	8.6154	8.1665	8.0258
SNR out	9.1927	9.6919	8.5147

CODE :-

```
clc
clear all
close all

wc=pi*0.5;
w1=linspace(-pi,pi,1024);
c=0;

for j=[8,64,512]
    c=c+1;
    k=(j-1)/2;
    for i=1:j
        if i==k
            hd5(i)=wc/pi;
        else
            hd5(i)=sin(wc*(i-k))/(pi*(i-k));
        end
    end;

    %rw=ones(1,j);
    for i=1:j
        bw(i)=0.42-0.5*cos(2*pi*i/(j-1))+0.08*cos(4*pi*i/(j-1));
        %tw(i)=1-2*[i-(j-1)/2]/(j-1);
        %hnw(i)=0.5-0.5*cos(2*pi*i/(j-1));
        %hmw(i)=0.54-0.46*cos(2*pi*i/(j-1));
    end;


    h5=hd5.*bw;
    H5=freqz(h5,1,w1);
    %subplot(3,1,c);
    %plot(abs(H5));
    %axis([0 1000 -0.1 1.1]);
    %title(['Blackmnan Windowed N =',num2str(j)]);

n1=j;
n=0:1:n1;
x=sin(0.5*wc*n)+sin(1.5*wc*n);
y1 = fft(x,n1);           %taking fft of the signal
y1 = fftshift(y1);        %fft shift to get in -fs to +fs range
m1 = abs(y1);          %absolute value / n
%figure(1);
%subplot(3,1,1);
%plot(x);
%title('Signal with two sinusoids');
%subplot(3,1,2);
%plot(m1);
%title('DFT of Signal with only two sinusoids');

fin= filter(h5,1,x);
y2 = fft(fin,n1);          %taking fft of the signal
y2 = fftshift(y2);        %fft shift to get in -fs to +fs range
m2 = abs(y2)/n1;          %absolute value / n
%subplot(3,1,3);
%plot(m2);
%title('DFT of Filtered signal');

no=1.5*(rand(size(x))-0.5);
yn=x+no;
```

```
%figure(2);
%subplot(3,1,1);
%plot(yn);
%title('NOise + Signal with two sinusoids');
%subplot(3,1,2);
%plot(m1);
%title('DFT of Noise + Signal with only two sinusoids');

nfin= filter(h5,1,yn);
yn2 = fft(nfin,n1);          %taking fft of the signal
yn2 = fftshift(yn2);       %fft shift to get in -fs to +fs range
mn2 = abs(yn2)/n1;         %absolute value / n
%subplot(3,1,3);
%plot(mn2);
%title('DFT of Filtered signal+noise');


snr(yn,yn-x)
snr(nfin,nfin-fin)
end;
```

(keep changing the window (bw(i)) function with different windows to obtain respective result)

Discussion:

1 .As, the value of N increases signal and noise power increases whereas the SNR change is not significant.

2. If we observe the density of points in the above plots,those having higher N have higher density compared to that of lower value of N.

3. We added noise by the command randn, same can be done by using awgn command.
4 .Filter designed by blacknman window has relatively higher snr compared to the remaining filters