EXPERIMENT-9

Aim:

Using Matlab, design the digital linear phase low-pass filter and high-pass filter with cutoff frequency pi/4 with M=61 and M=109 using the following window techniques: Rectangle, Hamming, Hanning, Bartlett, and Blackman. Comment on the effect of the main lob with the values M = 61 and M = 109. Apparatus:

- MATLAB Software
- Computer Theory:

Digital linear phase filters are essential in signal processing for maintaining the shape of signals while filtering. These filters can be designed using the windowing method, which involves multiplying an ideal filter's impulse response by a window function. The choice of window affects the filter's characteristics, particularly its main lobe width and side lobe levels.

For both low-pass and high-pass filters with a cutoff frequency of π/4\pi/4π/4, we can define the ideal filter and apply various window functions.

We can use the following window functions to modify the ideal filter:

1. Rectangular Window: Simple, but leads to high side lobes.
2. Hamming Window: Reduces side lobes more than the rectangular window.
3. Hanning Window: Similar to Hamming, with slightly different characteristics.
4. Bartlett Window: Triangular window, provides moderate side lobe suppression.
5. Blackman Window: Offers the best side lobe suppression among the listed windows.

Effects of M (Filter Order)

- M = 61: This smaller filter order results in a wider main lobe and higher side lobes. The main lobe width is directly related to the filter's ability to resolve frequencies; a wider main lobe means less frequency selectivity.
- M = 109: A larger filter order leads to a narrower main lobe and lower side lobes. This results in better frequency selectivity and less distortion in the passband and stopband.

Code:

```
clc;
 clear all;
close all;
M1=61;
wc=pi/4;
wn=wc/pi;
fc=wc/(2*pi);
n1=0:M1-1;

a1=bartlett(M1); b1 =
fir1(M1-1,wn,'low',a1);
a2=hamming(M1);
b2 = fir1(M1-1,wn,'low',a2);
a3=hann(M1); b3 =
fir1(M1-1,wn,'low',a3);
a4=blackman(M1);
b4 = fir1(M1-1,wn,'low',a4);
a5=rectwin(M1); b5 =
fir1(M1-1,wn,'low',a5);
wvtool(b1,b2,b3,b4,b5);


a11 = bartlett(M1); b11 =
fir1(M1-1,wn,'high',a11); a12 =
hamming(M1); b12 = fir1(M1-
1,wn,'high',a12); a13 =
hann(M1); b13 = fir1(M1-
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```
1,wn,'high',a13); a14 =
blackman(M1);
b14 = fir1(M1-1,wn,'high',a14);
a15 = rectwin(M1); b15 =
fir1(M1-1,wn,'high',a15);
wvtool(b11,b12,b13,b14,b15);



M1=109; a21 = bartlett(M1); b21 =
fir1(M1-1,wn,'low',a21); a22 =
hamming(M1); b22 = fir1(M1-
1,wn,'low',a22); a23 = hann(M1);
b23 = fir1(M1-1,wn,'low',a23);
a24 = blackman(M1); b24 =
fir1(M1-1,wn,'low',a24); a25 =
rectwin(M1); b25 = fir1(M1-
1,wn,'low',a25); wvtool(b21, b22,
b23, b24, b25);

a31 = bartlett(M1); b31 = fir1(M1-
1,wn,'high',a31); a32 =
hamming(M1); b32 = fir1(M1-
1,wn,'high',a32); a33 = hann(M1);
b33 = fir1(M1-1,wn,'high',a33);
a34 = blackman(M1); b34 =
fir1(M1-1,wn,'high',a34); a35 =
rectwin(M1); b35 = fir1(M1-
1,wn,'high',a35); wvtool(b31,
b32, b33, b34, b35);
```

Outputs:

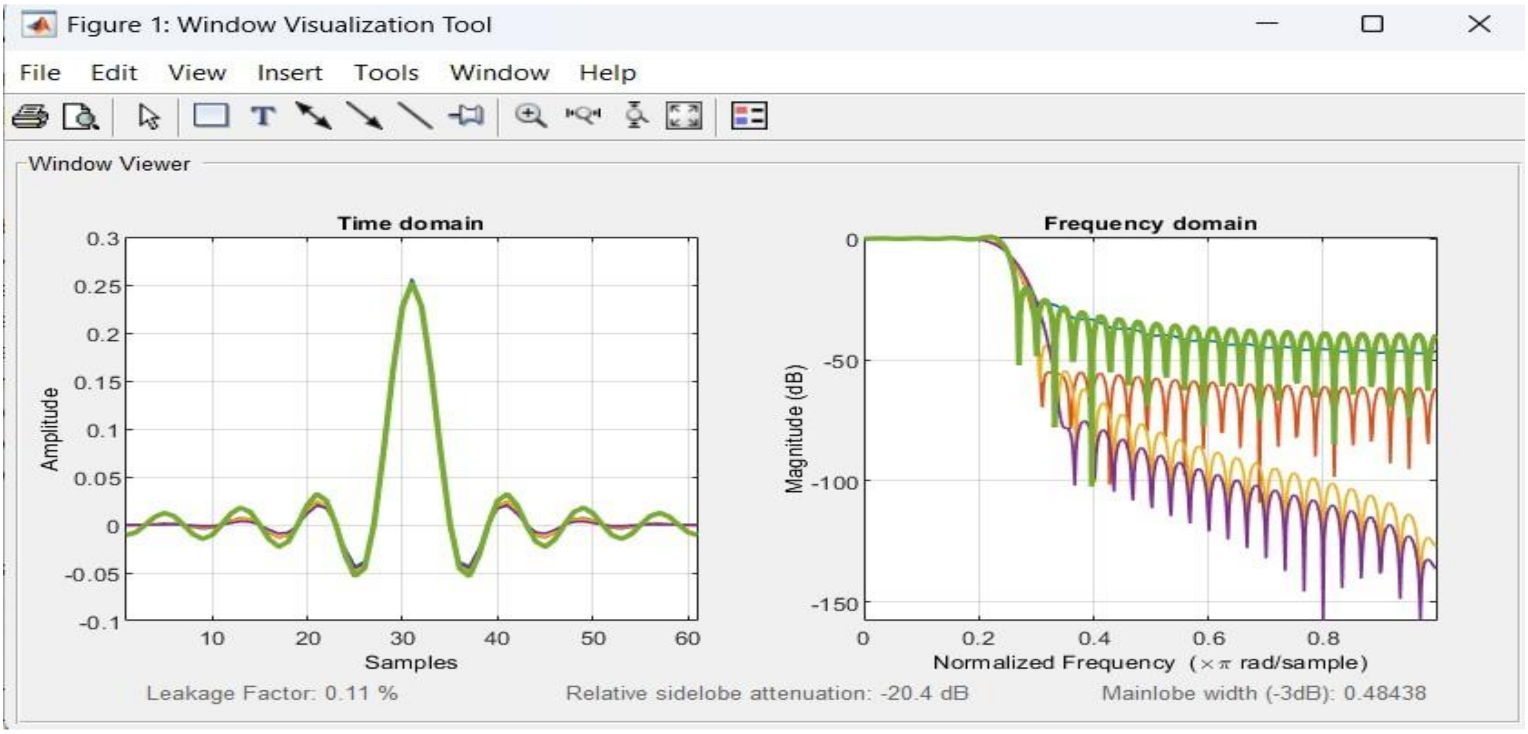
Figure 1: Window Visualization Tool
File Edit View Insert Tools Window Help
Window Viewer
Time domain
Amplitude
Samples
Frequency domain
Magnitude (dB)
Normalized Frequency (×π rad/sample)
Leakage Factor: 0.11 %
Relative sidelobe attenuation: -20.4 dB
Mainlobe width (-3dB): 0.48438

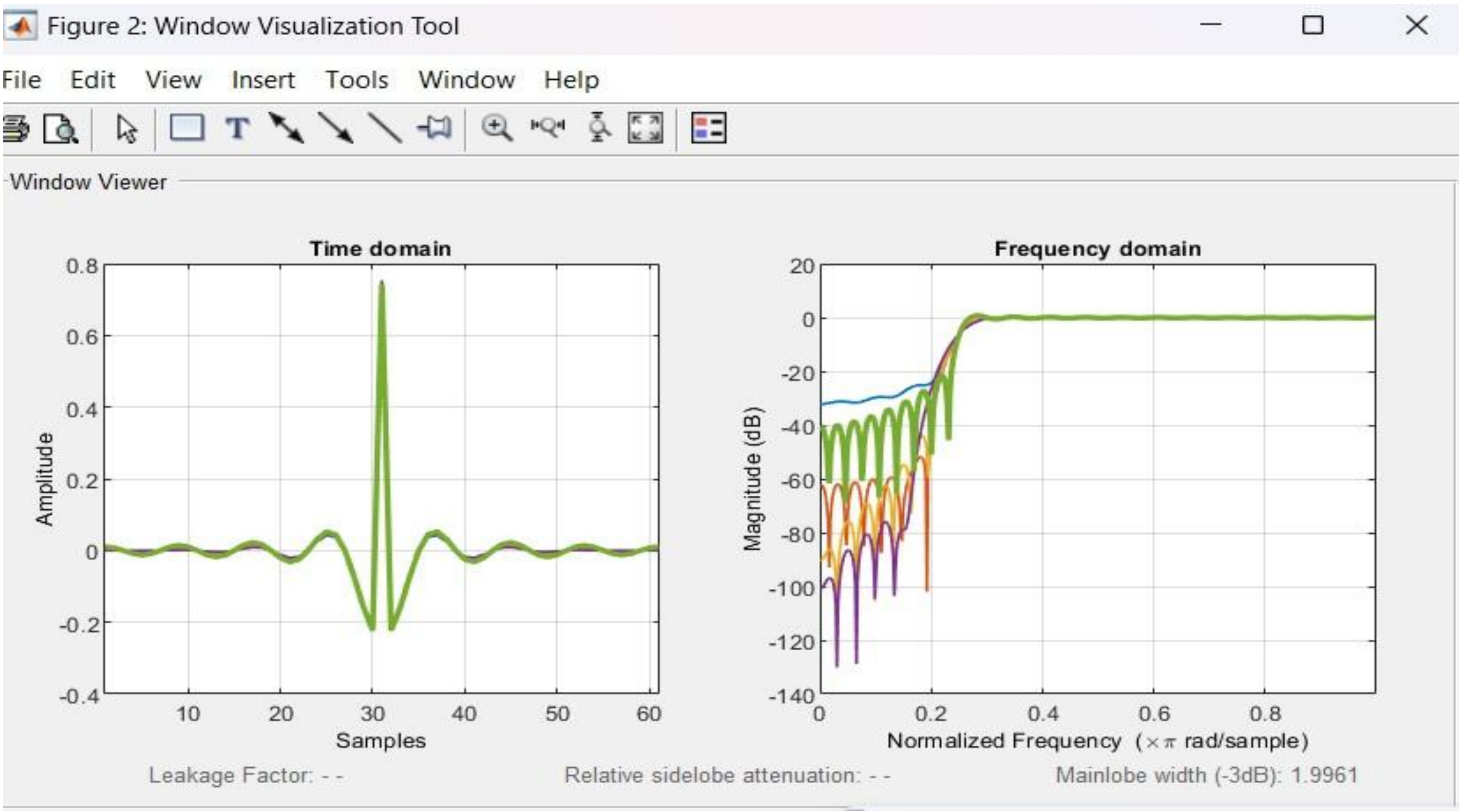
Figure 2: Window Visualization Tool
File Edit View Insert Tools Window Help
Window Viewer
Time domain
Amplitude
Samples
Frequency domain
Magnitude (dB)
Normalized Frequency (×π rad/sample)
Leakage Factor: - -
Relative sidelobe attenuation: - -
Mainlobe width (-3dB): 1.9961

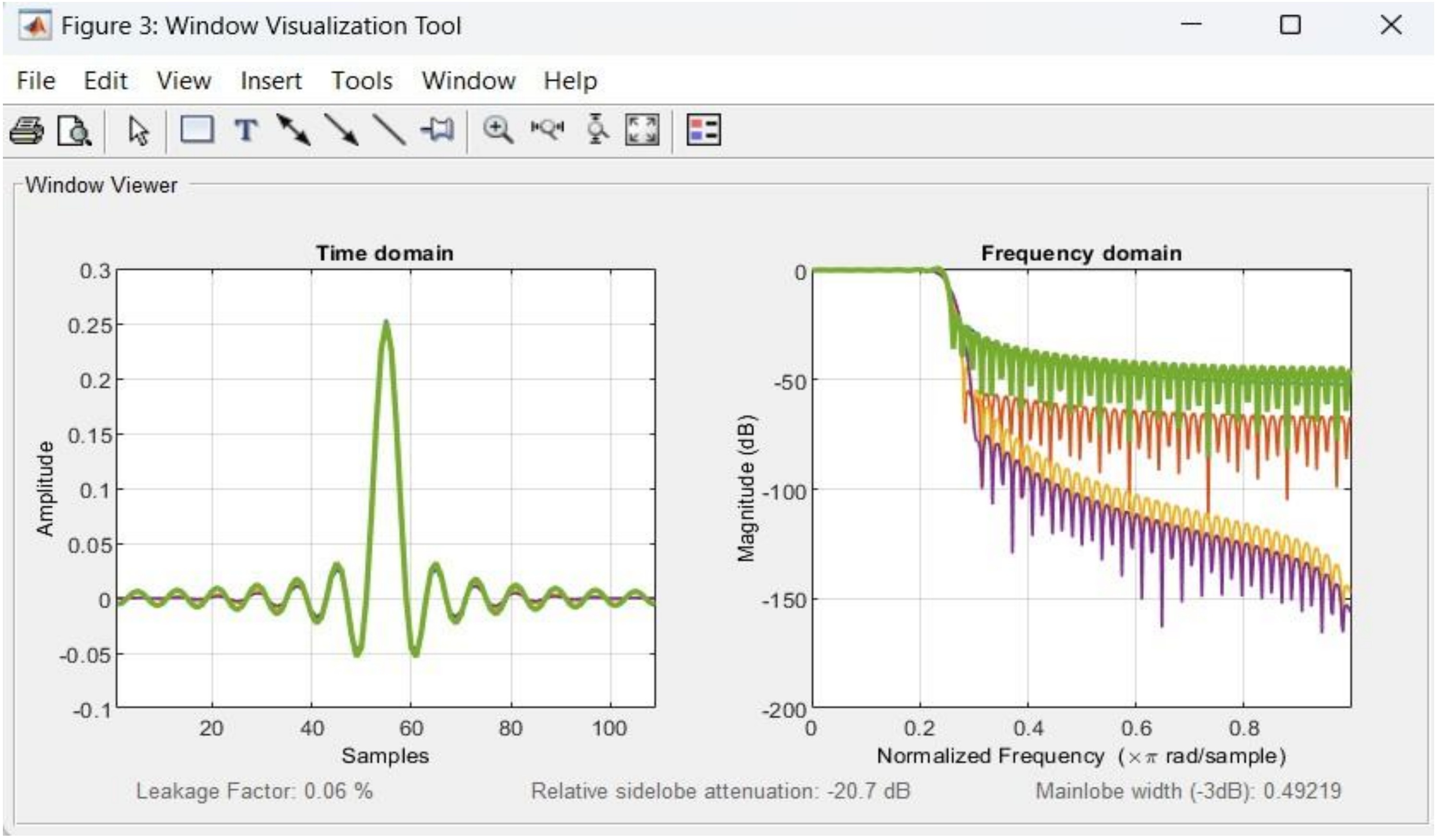
Figure 3: Window Visualization Tool
File Edit View Insert Tools Window Help
Window Viewer
Time domain
Amplitude
Samples
Frequency domain
Magnitude (dB)
Normalized Frequency (×π rad/sample)
Leakage Factor: 0.06 %
Relative sidelobe attenuation: -20.7 dB
Mainlobe width (-3dB): 0.49219

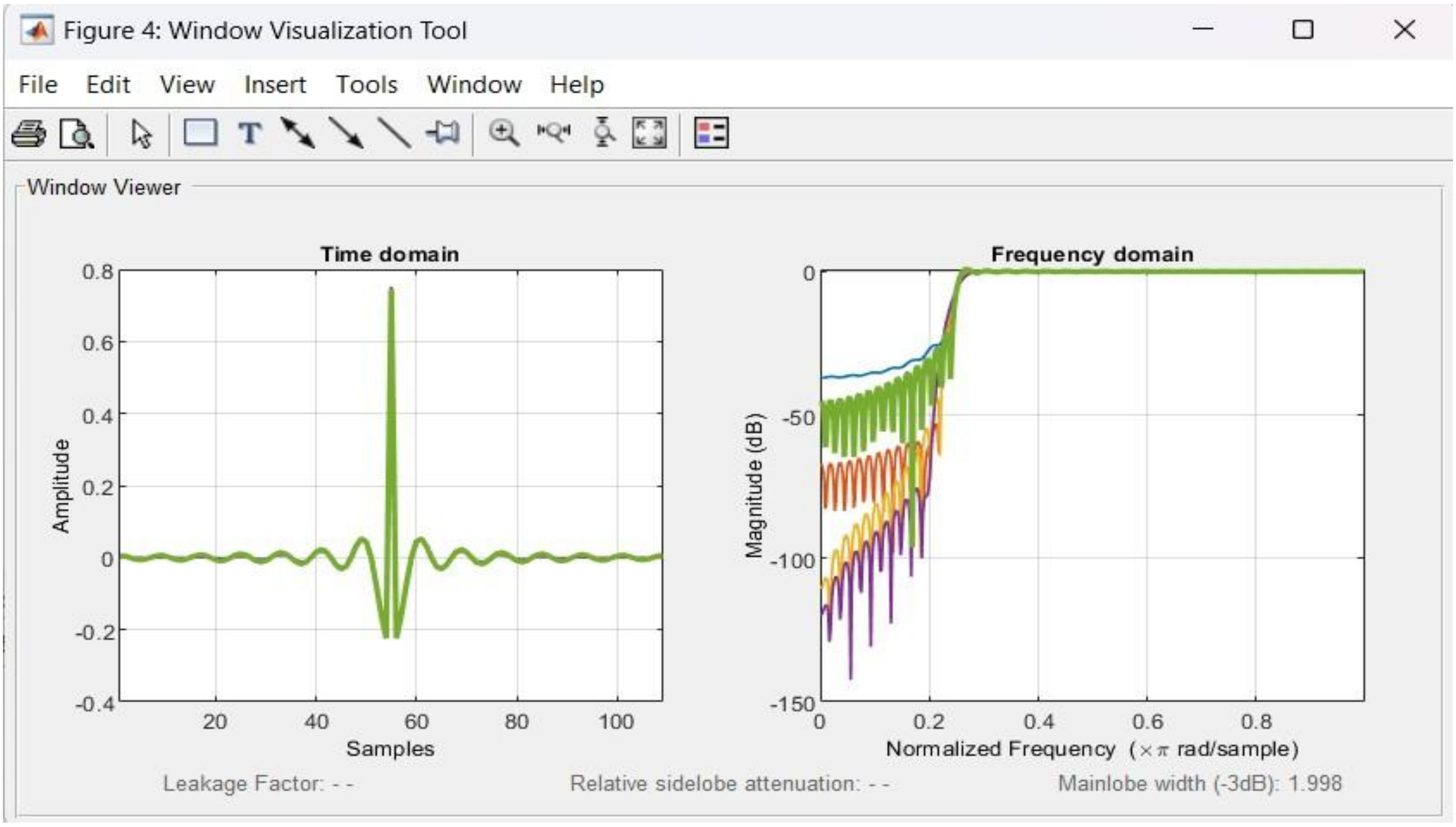
Figure 4: Window Visualization Tool
File Edit View Insert Tools Window Help
Window Viewer
Time domain
Amplitude
Samples
Frequency domain
Magnitude (dB)
Normalized Frequency (×π rad/sample)
Leakage Factor: - -
Relative sidelobe attenuation: - -
Mainlobe width (-3dB): 1.998

Conclusion:

Using larger filter orders like M=109M=109M=109 provides better performance in terms of frequency resolution and attenuation of side lobes. The choice of window also significantly affects the filter's response. Rectangular windows lead to high-side lobes, while Blackman windows improve the overall response, demonstrating the importance of window selection in filter design.