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FIR High pass Filter for Improving performance Characteristics of Various Windows

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Abstract— *Digital filters can be classified two types finite impulse response and infinite impulse response filters.FIR low pass filter design using Kaiser window is presented. FIR low pass filter digital filter design using Kaiser window for given specifications is compare. Digital Signal Processing is used in many areas where analogue method was difficult. Filters are used to separate or combine different frequencies. FIR high pass filter has been designed and simulated using different windows techniques. Hamming, Hanning, Kaiser and Bartlett Windows techniques are used along with Rectangular window technique for the design analysis by using Matlab.Beta is increase then main lobe width is increase.*

Keywords— FIR Filters, High pass filters, Window Function, MATLAB, Simulink, Hamming, Kaiser, Rectangular, Hanning and Bartlett windows.

I. INTRODUCTION

Filter removes unwanted signal and passes useful information. Filters used in communications systems and signal processing applications such as noise reduction biomedical, audio processing, video processing. Digital signal processing is used in spectral analysis, image processing, sonar processing, speech analysis; data communication DSP has many advantages such as accuracy, perfect reproducibility, and greater flexibility. The signal used in DSP is derived from analog signal which have sampled at certain interval to convert into digital signal [1]. Digital filters are important class of Linear time invariant DSP system designed to modify the frequency characteristics of the input signal x (n) to meet certain specific design requirements. Digital filters have for removing noise, and minimizing inter-symbol Interference (ISI) in communication architectures [2]. Digital filters have been classified into Finite Impulse response (FIR) and Infinite Impulse Response (IIR) filters. The FIR has an impulse response h (n) of finite duration, defined over the interval $0 \le m \le M$ has finite number of terms,

$$\mathbf{y}\,(\mathbf{n}) = \sum_{m=0}^{M} \mathbf{h}(\mathbf{m}).\mathbf{x}(\mathbf{n}-\mathbf{M}) \qquad (1)$$

Infinite impulse response (IIR) filter has impulse response h (n) of infinite duration, infinite interval $0 \le n \le \infty$, now infinite number of terms,

$$\mathbf{y}\,(\mathbf{n}) = \sum_{m=0}^{\infty} \mathbf{h}(\mathbf{m}).\mathbf{x}(\mathbf{n}-\mathbf{M}) \qquad (2)$$

II. FIR FILTER DESIGN METHODS BY VARIOUS WINDOW TECHNIQUES

FIR Filter design method is simplest method is called window method. Window method is begins with an ideal desired frequency response which is represented as

$$\mathbf{H}_d(\boldsymbol{w}) = \sum_{n=0}^{\infty} \mathbf{h}_d(\mathbf{n})\mathbf{e}^{-jwn} \qquad \text{(2a)}$$

Where

$$\boldsymbol{h_d}\,(\mathbf{n}) = \frac{1}{2\pi}\int_{-\pi}^{\pi} \boldsymbol{H}_d(\mathbf{w})\,\mathbf{e}^{jwn}\,\mathbf{dw} \qquad \text{(2b)}$$

Commonly used windows are Bohman window, Blackman window, Blackman-Haris window, Gaussian window, Chebyshev window, Hamming window,Hanning window,Nutall window, Rectangular window, Kaiser window, Triangular window and Taylor window.

2.1 Hamming Window:

To eliminate the some pass band and stop band ripples, Hamming window technique is used [3]. The coefficients of a Hamming window are computed from the equation (5)

$$\mathbf{w}\,[\mathbf{n}] = 0.54 - 0.46\cos\left(2\pi\frac{n}{N}\right),\ 0 \le n \le N \qquad \text{(2.1a)}$$

2.2 Kaiser Window:

Kaiser window has an adjustable shape parameter that allows the window to achieve any desired value of ripple or attenuation.Kaiser window is minimizing the side lobe energy of the window as well as having the simplest implementation [4]. The equation of Kaiser Window is expressed in below equation which is depending on two parameter α and N.

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$$w(n) = \frac{I_0(\alpha\sqrt{1-(n-M)^2/M^2}}{I_0(\alpha)} \quad \textbf{(2.2b)}$$

Kaiser window is also defined in terms of β, where β is the Kaiser Window parameter that affects the side lobe attenuation of the Fourier transform of the window [5]. The Kaiser window that design an FIR filter with side lobe attenuation of α and β is expressed as

$$\beta\begin{cases} 0.1102(\alpha-8.7), & \alpha > 50 \\ 0.5842(\alpha-21)^{0.4}) \\ +0.07886(\alpha-21), & 50 \geq \alpha \geq 21 \\ 0, & \alpha < 21 \end{cases} \quad \textbf{(2.2c)}$$

2.3 Hanning Window:
Hanning Window is raised cosine window .Equation of Hanning window is written as [5].

$$W_{hn}(n) = \begin{cases} 0.5-0.5cos\frac{2\pi n}{N-1} \\ 0;\ other\ n \end{cases} \quad ;\ \textbf{for n=0 to N-1}$$

(2.3)
Where N=Number of samples of window.

2.4 Bartlett Window:
Description:
Bartlett suggested a more gradual transition in the form of a triangular window is given below:

$$w(n)=\begin{cases} \frac{2n-1}{M-1}, & 0 \leq n \leq \frac{M-1}{2} \\ 2-\frac{2n}{M-1}, & \frac{M-1}{2} \leq n \leq M-1 \\ 0, & otherwise \end{cases} \quad \textbf{(2.4a)}$$

Bartlett window is given by:

$$w(n)=1-\left|\frac{n-\frac{N-1}{2}}{\frac{L}{2}}\right| \quad \textbf{(2.4b)}$$

Where L can be N, N-1 or N+1. This window also known as triangular window.

2.5 Rectangular Window:
Description:
The weighting function for the Rectangular window is to be defined [6] by

$$w_R(n)=1, \text{ for} |n| \leq \frac{M-1}{2} \quad \textbf{(2.5a)}$$

$$w_R(n)=0, \text{ otherwise} \quad \textbf{(2.5b)}$$

This function is provided for completeness; a rectangular window .This is the simplest window function but provides the worst performance from the viewpoint of stop band attenuation. It is defined by:

$$w(n) = \begin{cases} 1, & 0 \leq n \leq M-1 \\ 0, & elsewhere \end{cases} \quad \textbf{(2.5c)}$$

III. FILTER DESIGN SIMULATIONS

Table.1: Parameter Specification

Parameters	Values
Sampling Frequency	48000 Hz
Cut off Frequency	10800 Hz
Order	60
β	β =0.5,2,4,6 (for Kaiser window)

Interpretation of above Table: Table 1 show parameter specification of windows designing of low pass filter using hamming, rectangular window, Kaiser Window, Hanning window and Bartlett window. Sampling frequency is 48000 Hz and cut off frequency is 10800 Hz.Filter order is 60. Kaiser window parameter beta value is take 0.5,2,4,6.

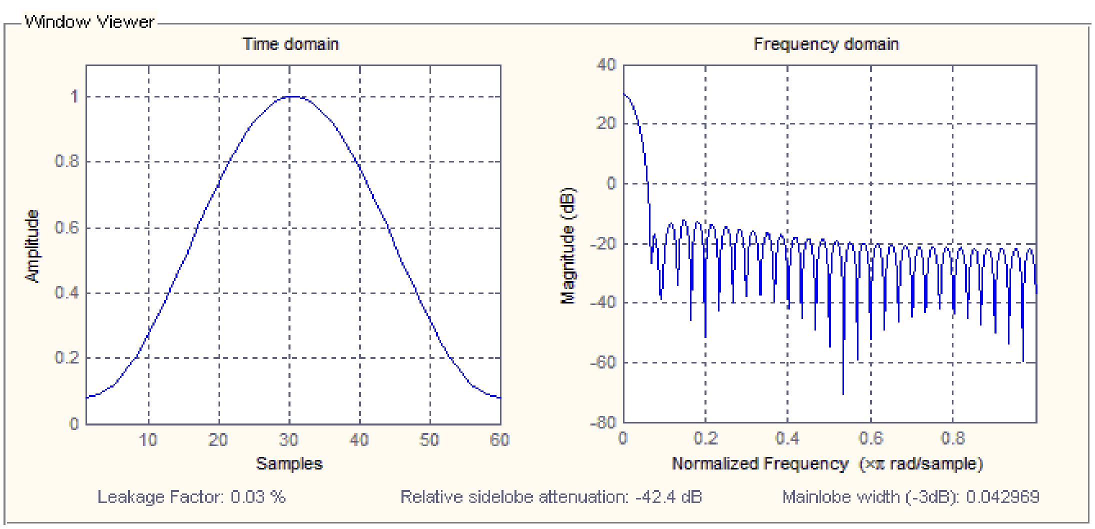

Fig.3: (a) Amplitude and Magnitude response of Hamming window function at N=60 (FIR HPF)

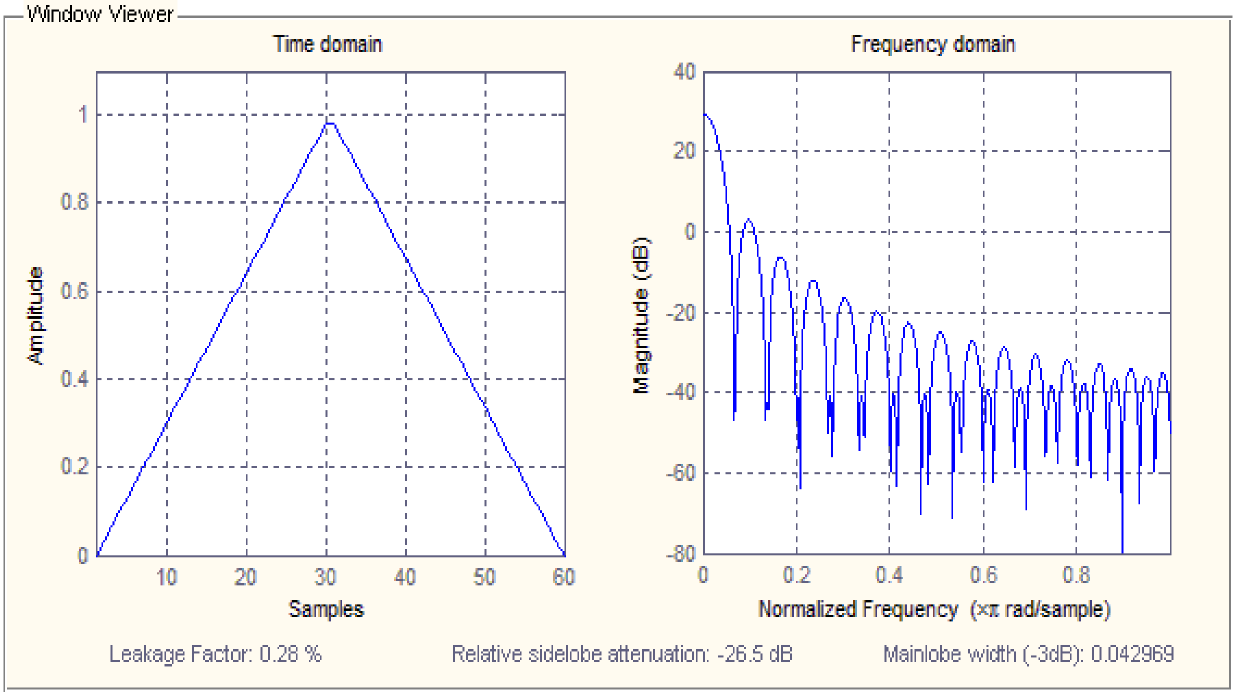

Fig.3: (b) Amplitude and Magnitude response of Bartlett window function at N=60 (FIR HPF)

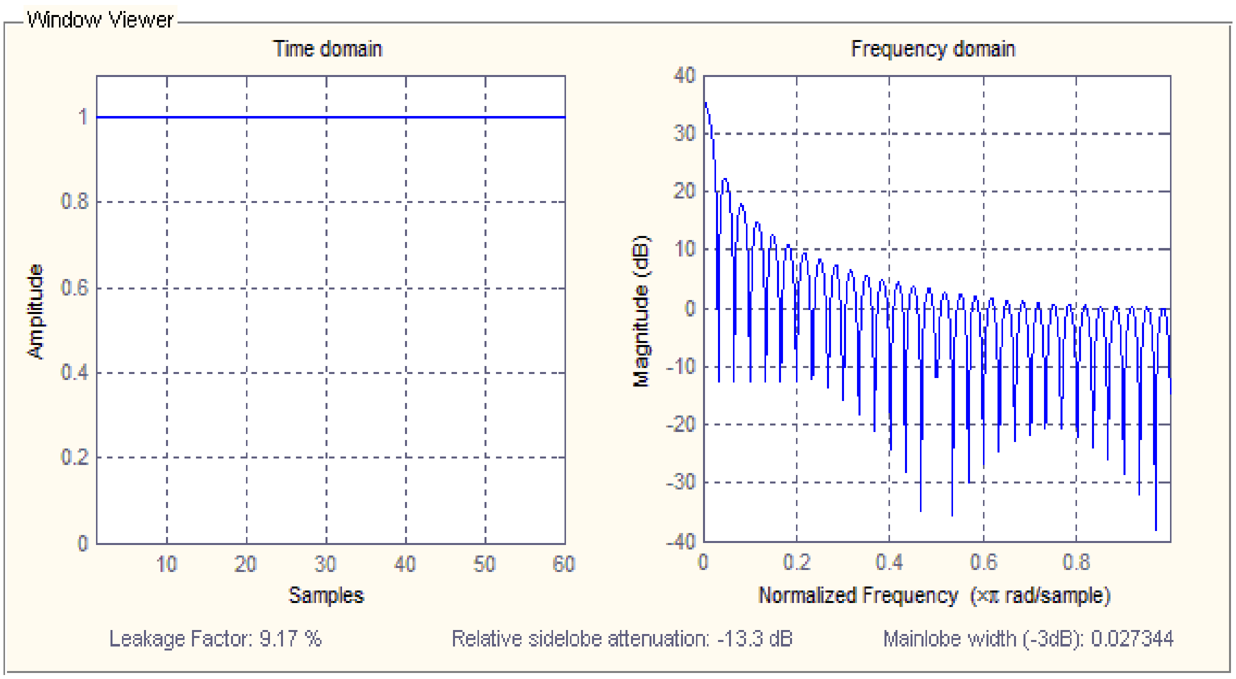

Fig.3: (c) Amplitude and Magnitude response of Rectangular window function at N=60 (FIR HPF)

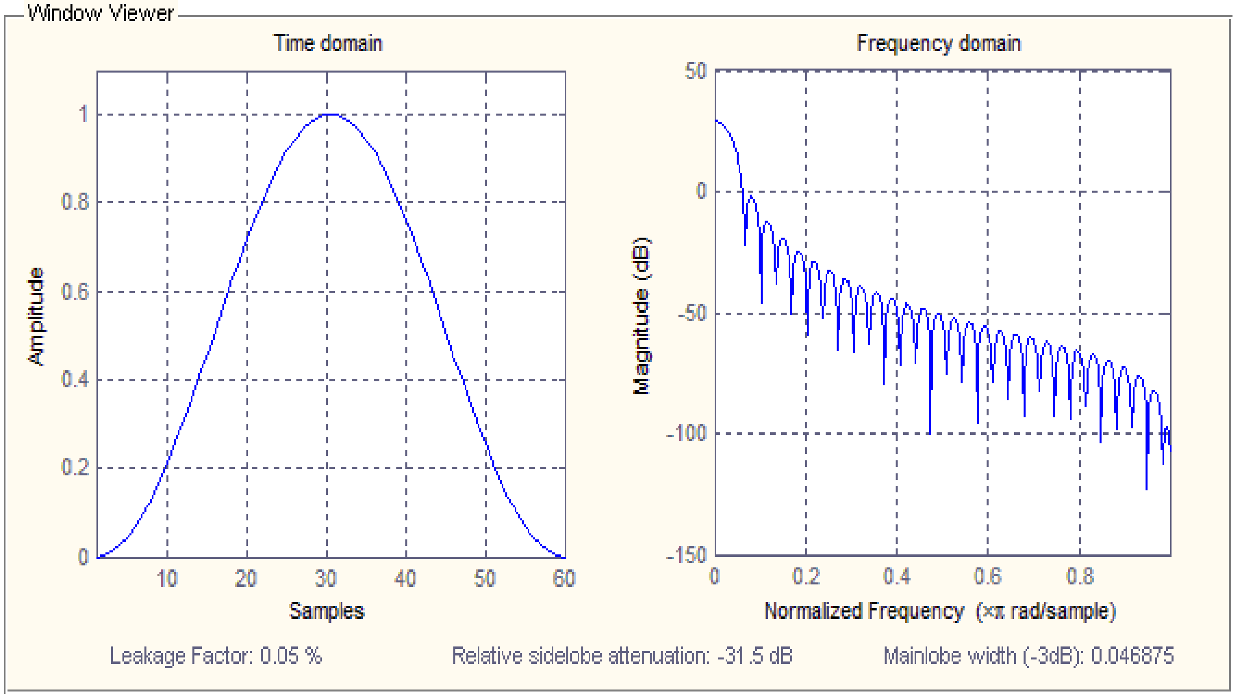

Fig.3: (d) Amplitude and Magnitude response of Hanning window function at N=60 (FIR HPF)

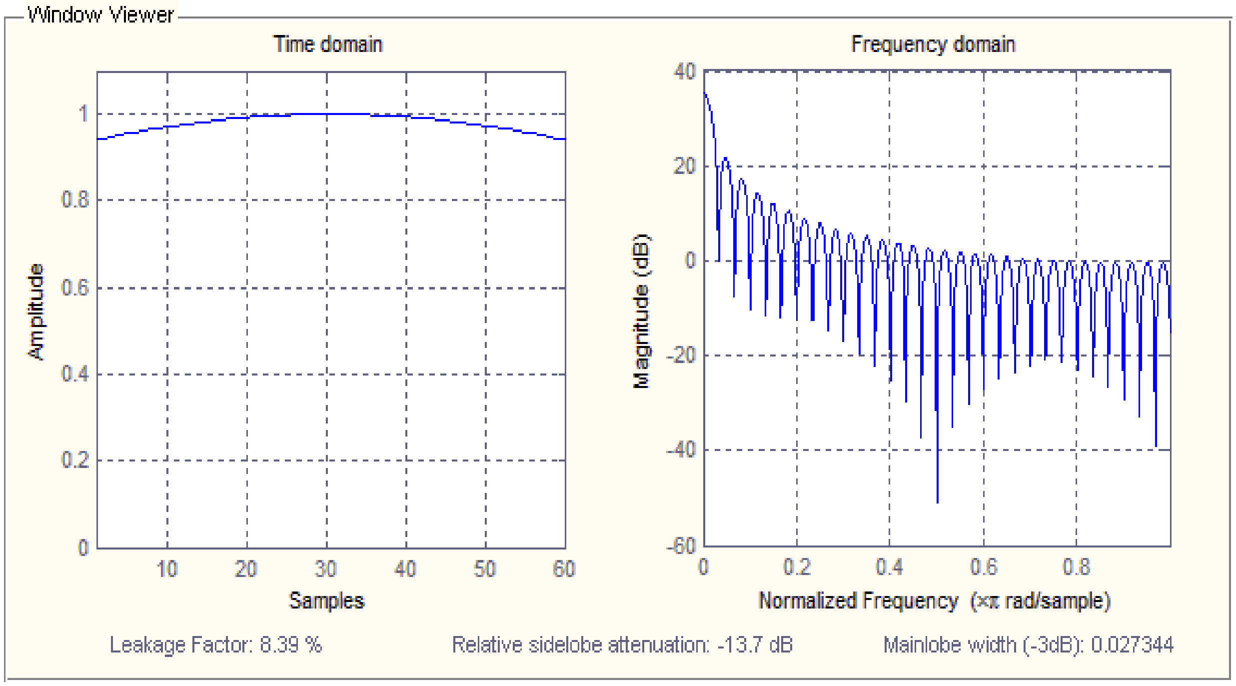

Fig.3: (e) Amplitude & Magnitude response High pass FIR filter using Kaiser Window (Beta=0.5)

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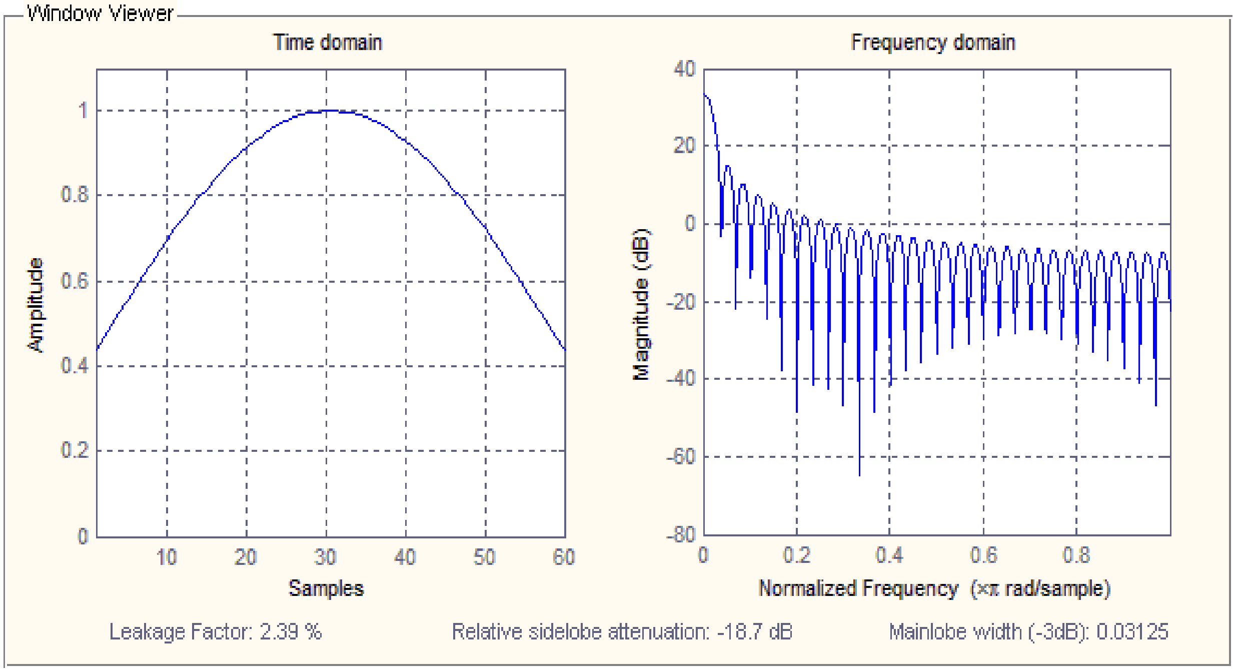

e

Fig.3: (f) Amplitude &Magnitude response high pass FIR filter using Kaiser Window (Beta=2)

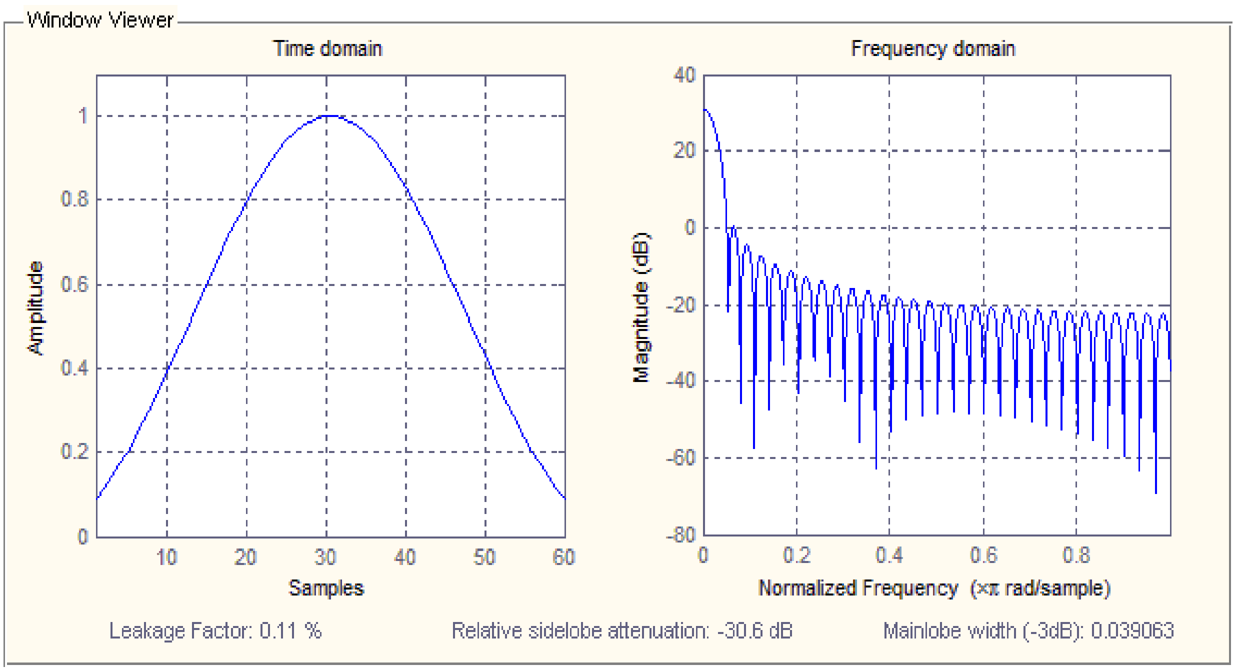

Fig.3: (g) Amplitude &Magnitude response high pass FIR filter using Kaiser Window (Beta=4)

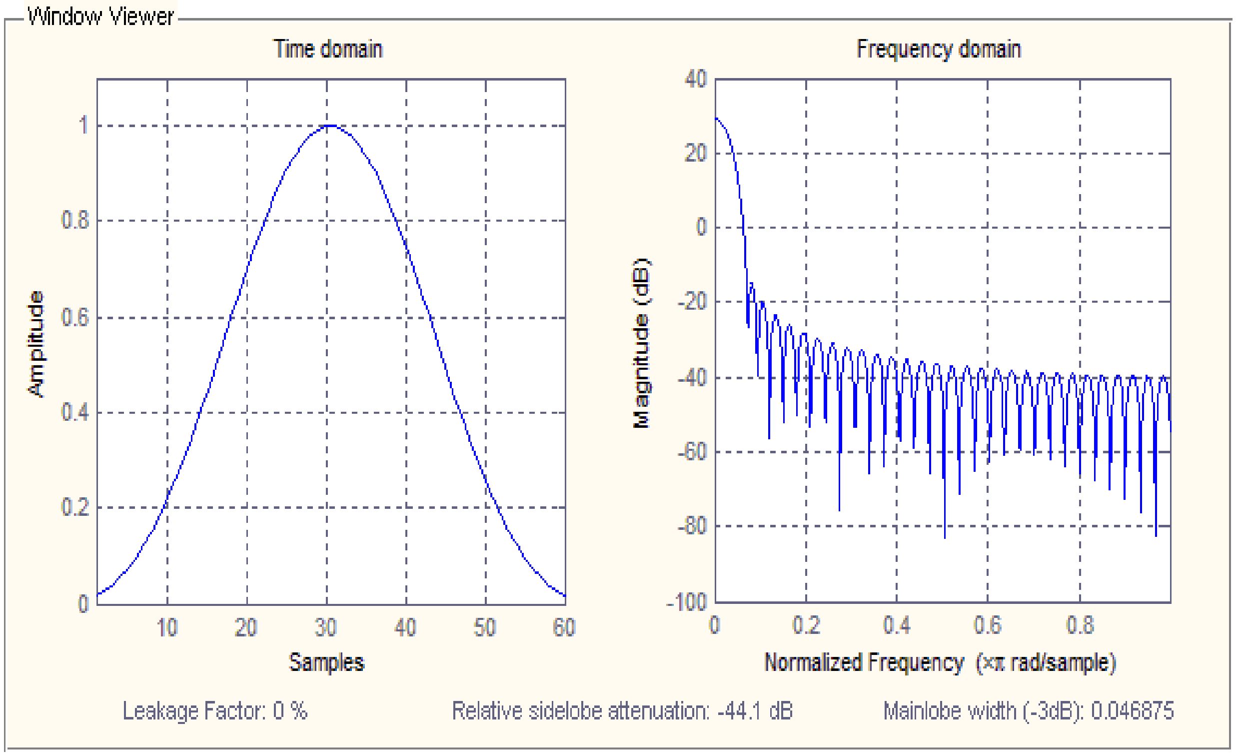

Fig.3: (h) Amplitude &Magnitude response high pass FIR filter using Kaiser Window (Beta=6)

3.1 Interpretation of Above Result:

In **Fig:3 (a)** Hamming window has amplitude in time domain is 1.Main lobe width of Hamming window is 0.042969 and filter order is 60.Hamming window has relative side lobe attenuation is -42.4 dB and leakage factor is 0.03% .

In **Fig: 3(b)** Bartlett window has amplitude is 1 in time domain. Relative side lobe attenuation of Bartlett window is -26.5 dB and its leakage factor is 0.28%.

In **fig. 3 (c)** Rectangular window has less main lobe width (0.027344).Rectangular window has highest leakage factor (9.17%) to other windows.

In **fig. 3(d)** Hanning window has amplitude is 1 in time domain.

In fig. 3 (e) Kaiser Window beta value is less so main lobe width is less.

In **fig. 3 (f)** Kaiser Window beta value is increase so main lobe width is increase.

In **fig. 3 (g)** Kaiser Window beta value is higher so main lobe width is higher.

In **fig. 3 (h)** Kaiser Window beta value is higher so main lobe width is higher.

IV. COMPARATIVE ANALYSIS OF VARIOUS WINDOWS

Hamming and Kaiser Windows techniques are used along with Rectangular window for design analysis and compared these five windows. Table 2 shows the comparison of these five windows in terms of leakage factor, relative side lobe attenuation and main lobe width. The leakage factor is minimum and main lobe width is maximum of Kaiser Window than the Hamming window. When beta is increase then main lobe width is increase but leakage factor is decrease.

Table.2: Matlab Simulated result of Rectangular, Hamming, Kaiser Window& Other windows

Windows	Leakage Factor	Relative Side-Lobe Attenuation	Main-Lobe width (-3 dB)
Hamming	0.03%	-42.4 dB	0.042969
Bartlett	0.28%	-26.5 dB	0.042969
Rectangular	9.17%	-13.3 dB	0.027344

Hanning	0.05%	-31.5 dB	0.046875
Kaiser (β=0.5)	8.39%	-13.7 dB	0.027344
Kaiser (β=2)	2.39%	-18.7 dB	0.03125
Kaiser (β=4)	0.11%	-30.6 dB	0.039063
Kaiser (β=6)	0%	-44.1 dB	0.046875

4.1 Interpretation of Above Table 2:

In Kaiser Window beta value is increase then main lobe width is increases but leakage factor is decreases. When leakage factor is 0% in Kaiser Window then wider main lobe width (0.046875)

V. DISCUSSIONS

The low pass FIR filter design with sampling frequency =48000 Hz, cut off frequency =10800 Hz, based on Kaiser window design with three value of beta (0.5,2,4,6) and specify order is 60.These filters remove high frequency noise from ECG signal. The design of FIR high pass filter based on adjustable window design method implementing by using filter design and analysis tool (**FDATool**) from MATLAB (R2010a) programs. **Table 2** shows various windows simulated results of Hamming, Bartlett, Rectangular, Hanning and Kaiser Windows.

Leakage factor is equal to ratio of power in side lobes to total window power. Side lobe attenuation is equal to difference in height from main lobe peak to the highest side lobe peak. Main lobe width (-3 dB) is equal to the width of main lobe at 3 dB below the main lobe peak.

VI. CONCLUSIONS

In this paper FIR high pass filter has been designed and simulated using Rectangular, Hamming and Kaiser Windows techniques. FIR Low pass filter has been designed for the different value of Kaiser Window parameter β. It has been compared leakage factor, main lobe width and relative side lobe attenuation of the three windows from the simulated result.Kaiser Window parameter β widens then main lobe width is increase and decreases the amplitude of side lobes that is increases the attenuation. Kaiser window main lobe width (-3dB) is 0.046875 at sampling frequency 48000 Hz, cut off frequency 10800 Hz and order 60 and beta is 6. Kaiser window has greater main lobe width and less leakage factor in comparison of Hamming window.

REFERENCES

[1] Emmanuel C. Ifeacher, Barrie W.Jervis Digital Signal Processing", Second Edition, Pearson Publication, pp. 02-40, 2004

[2] Keshab.K.Parhi, "VLSI Digital Signal Processing Systems Design and Implementation". First edition, Wiley Interscience Publication,pp.10-50,1999

[3] F. J. Harris, "On the use of Windows for Harmonic Analysis with the Discrete Fourier Transform", Proc. IEEE, 1978

[4] Sophocles J. Orfanidis, "Introduction to Signal Processing" Prentice Hall, First Edition, pp.532-558, 1996

[5] Kaiser, J.F, "No recursive Digital Filter Design Using the IO-Sinh Window Function", Proc. IEEE symp. Circuit and Systems, pp.20-23, 1974

[6] S Salivahanan, C Gnanapriya, "Digital Signal Processing, Second Edition, Mc Graw Hill, pp.445 - 475, 2011

[7] Sanjay Sharma,"Digital Signal Processing"

[8] P. Ramesh Babu", Digital Signal Processing"

[9] S.Salivahnan, A Vallavaraj,C Gnanapriya,Digital Signal Processing, Tata McGraw Hill,2000

[10] Greenested, A.,"FIR filters by windowing –The lab book pages www.labbookpages.co.uk/audio/ fir win

[11] L.B.Javkson,digital filter and signal processing,Kluver academic publisher,MA,1990.

[12] F.J. Harris, "On the use of window functions for harmonic analysis with discrete Fourier transform", Proc. IEEE, Vol.66, January 1978, pp. 51-83

[13] Kemal Avci and Arif Nacaroglu, "Cosine Hyperbolic Window Family with its Application to FIR Filter Design", Information and Communication Technologies: From Theory to Applications, 2008.ICTTA 2008. 3rd International Conference.

[14] Mahdi Mottaghi-Kashtiban and Mahrokh G. Shayesteh, "A New Window Function for Signal Spectrum Analysis and FIR Filter Design" Electrical Engineering (ICEE), 2010 18th Iranian Conference.

[15] Jamal, R. Cerna, M. Hanks, J. "Designing Filters Using the Digital Filter Design Toolkit", National Instruments Application Note097, 1996.

[16] Fatima, W. "Design and Analysis of Non recursive Digital Filters (FIR)", thesis, University of technology, 1999.