High Pass Filter Design and Analysis Using Nuttall and Parzen Windows

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ABSTRACT

Digital Signal Processing is concerned with the digital representation, transformation and manipulation of signals and the information they contain. The use of digital processors to analyze, modify or extract information from signals. In this paper high pass filter has been designed and simulated using different window techniques. Nuttall and Parzen windows techniques are used along with Rectangular windows techniques for design analysis and comparison by using matlabs. The simulated result show that Nuttall window has very good side lobe behavior and this technique gives 6.248% improvement in main lobe width.

Key Words: *DSP, FIR Digital Filter, Nuttall window, Parzen window, Rectangular Window.*

1. INTRODUCTION

Digital signal Processing is used in various applications such as digital set top box, cable modems, video compression, robotic vision, image enhancement, facsimile, speech recognition, radar processing, spread spectrum, digital cameras, ECG, EEG. The attraction of DSP comes from key advantages such as guaranteed accuracy, perfect reproducibility, greater flexibility and superior performance [1]. Digital filter are important class of Linear time invariant DSP systems designed to modify the frequency characteristics of the input signal x(n) to meet certain specific design requirements. Digital filters are widely used because of certain advantages over Analog filters. Digital filters have the potential to attain much better signal to noise ratios than Analog filters. Digital Filters have emerged as a strong option for removing noise, shaping spectrum 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 selection of FIR or IIR digital filters is depending on the nature of the problem and specification of the desired frequency response. To design the Digital filters, it is desirable to have approximately flat frequency response, magnitude in pass band. Another important feature of digital filters is of linear phase. The FIR filter of length M is described by the convolution of unit sample response h(n) of the system with input signal x(n) and is represented by the equation (1)

$$Y(n) = \sum_{K=0}^{M-1} h(k).\, x(n-k) \qquad (1)$$

Where the lower and upper limits on the convolution sum reflects the causality and finite duration characteristics of the filter [3].

2. FIR DESIGN METHODS

FIR filter design consists of Approximation problem and Realization problem. The approximation stage gives transfer function. Realization part deals with choosing the structure to implement the transfer function which may be in the form of circuit diagram or in the form of a program. There are various methods to design FIR filter such as 'Window Technique' and 'Optimal Filter Design Method'. The Window Design technique is simple and convenient method to design FIR. In window method, the desired frequency response specification $H_d(w)$, corresponding unit sample response $H_d(n)$ is determined using the following relation.

$$H_d(w) = \sum_{n=0}^{\infty} h_d(n) e^{-jwn} \qquad (2)$$

Where $h_d(n) = \frac{1}{2\pi}\int_{-\pi}^{\pi} H_d(w)\, e^{jwn} dw \qquad (3)$

Some of windows commonly used are Blackman Window, Blackman-Haris window, Bohman window, Chebyshew, Flat Top window, Gaussian window, Hamming window, Hanning window, Nuttall window, Parzen window, Rectangular window and the Kaiser window. In optimal filter design method various methods are used to design the filter coefficient. Various methods are Least square method, Equiripple method, Maximally flat, Generalized equiripple and Constrained equiripple.

The Nuttall window has the widest main lobe and lowest maximum side lobe level among the Blackman, Exact Blackman, and the Blackman-Harris window.
The equation for the Nuttall window is [4].

$$w(n) = a_0 - a_1\cos\left(2\pi\frac{n}{N-1}\right) + a_2\cos\left(4\pi\frac{n}{N-1}\right) - a_3\cos\left(6\pi\frac{n}{N-1}\right)$$

Where n = 0, 1, 2…... N-1 (4)

The equation for the periodic Nuttall window is

$$w(n) = a_0 - a_1\cos\left(2\pi\frac{n}{N}\right) + a_2\cos\left(4\pi\frac{n}{N}\right) - a_3\cos\left(6\pi\frac{n}{N}\right)$$

Where n = 0, 1, 2 ……..N-1 (5)

The periodic window is N-periodic. The coefficients for this window are

a0 = 0.3635819, a1 = 0.4891775, a2 = 0.1365995, a3 = .0106411

The Parzen window is a piecewise cubic curve window obtain from the convolution of two triangles of half-length or four rectangles of one fourth length. The following equations defines the N- point Parzen window [5] over the interval $-\frac{(N-1)}{2} \leq n \leq \frac{(N-1)}{2}$

$$w(n) = 1-6\left(\frac{|n|}{N/2}\right)^2 + \left(\frac{|n|}{N/2}\right)^3$$

When $0 \leq |n| \leq (N-1)/4$ (6)

$$w(n) = 2\left(1 - \frac{|n|}{N/2}\right)^3$$

When $(N-1)/4 < |n| \leq \frac{(N-1)}{2}$ (7)

The Rectangular Window has the highest amount of spectral leakage. The rectangular function truncates the signal to within a finite time interval. The weighting function for the Rectangular window is to be defined [6] by

$w_R(n) = 1$, for $|n| \leq \frac{M-1}{2}$ (8)

$w_R(n) = 0$, otherwise (9)

3. DESIGN SIMULATIONS

Table 1 shows the parameter specifications to design the High pass FIR filter using Nuttall,Parzen and Rectangular Windows.

Table 1: Parameter Specification

Parameter	Values
Sampling Frequency	48000 Hz
Cutoff Frequency	10800 Hz
Order	30

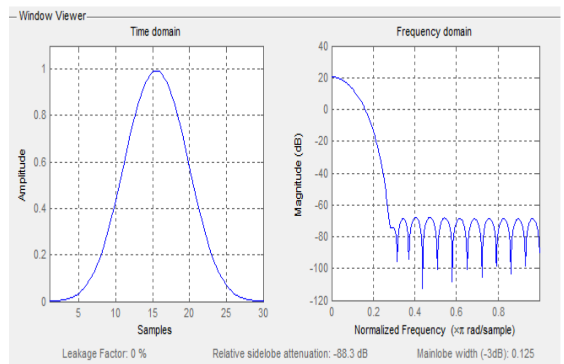

Figure1.Time domain & frequency domain of Nuttall window

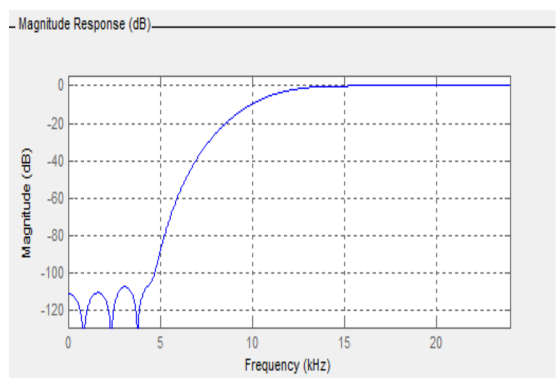

Figure 2: High Pass FIR filter using Nuttall window

Figure 1 shows the time domain and frequency domain of Nuttall window. The relative side lobe attenuation is -88.3 dB and mainlobe width (-3dB) is 0.125 and figure 2 show the High Pass FIR Filter using Nuttall window.

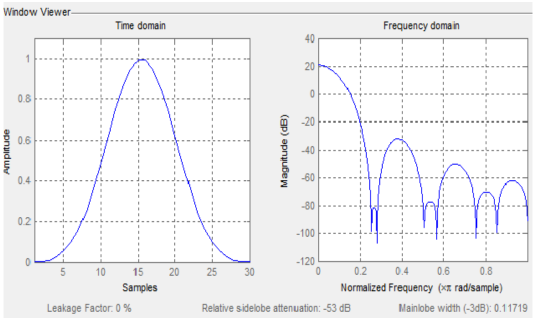

Figure3: Time domain & frequency domain of Parzen window.

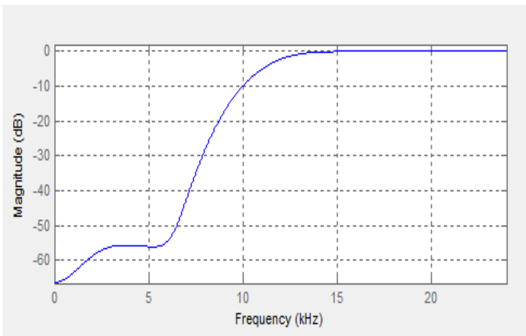

Figure 4: High Pass FIR filter using Parzen window

Figure 3 shows the time domain and frequency domain of Parzen window. The relative side lobe attenuation is -53 dB and main lobewidth (-3dB) is 0.11719. Figure 4 shows the High Pass FIR Filter using Parzen window.

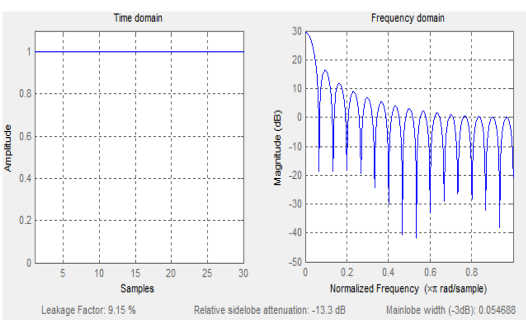

Figure5: Time domain and frequency domain of Rectangular window.

Figure 5: Shows the time domain and frequency domain of Rectangular window at sampling frequency 48000Hz, cut off frequency 10800 Hz. The relative side lobe attenuation is -13.3 dB and main lobe width (-3dB) is 0.054688. Figure 6 shows the High Pass FIR Filter using Rectangular window.

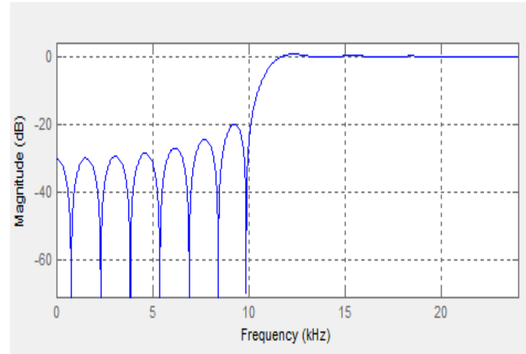

Figure 6: High Pass FIR Filter using Rectangular Window

4. COMPARATIVE ANALYSIS

Nuttall and Parzen windows techniques are used along with Rectangular windows techniques for design analysis and comparison by using matlabs. Figure 7 shows the High Pass FIR filter Comparison of Nuttall, Parzen and Regtangular windows at sampling frequency 48000Hz, cut off frequency 10800 Hz and order 30

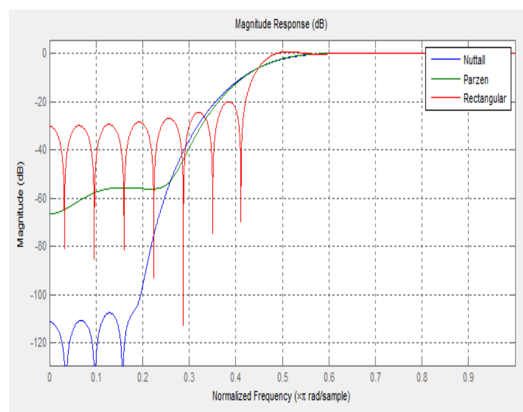

Figure7: High Pass FIR Filter comparison of Nuttall, Parzen and Rectangular Windows

Table 2: Matlab simulated result

Windows	Main lobe width (-3dB)	Relative Side lobe attenuation
Nuttall	0.125	-88.3 dB
Parzen	0.11719	-53 dB
Rectangular	0.054688	-13.3 dB

Table 2 Shows the comparison from the Matlab

simulated result of Nuttall, Parzen and Rectangular Windows at sampling frequency 48000Hz, cut off frequency 10800 Hz and order 30. From the table it is clear that Nuttall window has Good Side lobe behavior.

5. CONCLUSIONS

In this paper high pass filter has been designed and simulated using Nuttall, Parzen and Rectangular windows techniques. It has been compared main lobe width and relative side lobe attenuation from the matlab simulation. The relative side lobe attenuation of Nuttal Window is -88.3 dB and main lobe width of this window is 0.125 at sampling frequency 48000Hz, cut off frequency 10800 Hz. The simulated result show that Nuttall window has very good side lobe behavior and this technique gives 6.248% improvement in main lobe width. Hence Nuttall window technique is better for designing the FIR filter as compared to Parzen and Rectangular windows.

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