High Pass Filter Design and Analysis Using Hamming, Hanning and Nuttall Windows

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***Abstract*-Digital Signal Processing is an alternative method for processing the analog signal. It concerned with the digital signal representation, transformation and manipulation of signals and the information they contain. In this paper high pass filter has been designed and simulated using different windows techniques. Hamming and Hanning windows techniques are used along with Nuttall window technique for the design analysis and has been compared these three windows by using matlabs. The simulated result shows that Nuttall window has greater mainlobe width and less Peak–to-Sidelobe Level Ratio (PSLR) in comparison of Hamming and Hanning windows.**

***Key Words: DSP, FIR Digital Filter, Hamming Window, Hanning Window and Nuttall window*.**

I. INTRODUCTION

Digital signal Processing is used in various applications such as equalization, cable modems, video compression, spread spectrum, image enhancement, facsimile, speech recognition, video conferencing, digital cameras, etc. The attraction of DSP comes from key advantages such as accuracy, perfect reproducibility, greater flexibility and superior performance. The signal used in most popular form of DSP is derived from analog signal which have sampled at certain interval to convert into digital signal [1]. The specific reason for processing a signal is to remove interference or noise from the signal. Digital filter 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 the potential to attain much better signal to noise ratio 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 are classified into Finite Impulse response (FIR) and Infinite Impulse Response (IIR) filters. 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 expressed 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 casuality and finite duration characteristics of the filter [3].

II. FIR DESIGN METHODS

Designing a digital filter the major issue are stability, sharp cutoff characteristics, order of the filter and linear phase characteristics. FIR filter design consists of Approximation problem and Realization problem. The approximation stage gives transfer function. Realization part is concerned 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 method is simple and convenient to design FIR filter. In window method, the desired frequency response Hd(w), corresponding unit sample response $H_d(n)$ is determined using the relation.

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

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

Some of windows commonly used are Blackman Window, Blackman-Haris window, Bohman window, Chebyshew window, Flat Top window, Gaussian window, Hamming window, Hanning window, Nuttall window, Kaiser window, Rectangular window, Taylor window and Triangular window. The optimal filter design methods are Least square method, Equiripple method and Maximally flat, Generalized equiripple and Constrained equiripple.

To eliminate the some pass band and stop band ripples, Hamming window technique is used [4]. The coefficients of a Hamming window are computed from the equation

$$w(n) = 0.54 - 0.46\cos\left(2\pi\frac{n}{N}\right),\ 0 \le n \le N \qquad (4)$$

The coefficient of Hanning window is computed from the equation [5].

$w(n) = 0.5(1-\cos(2\pi\frac{n}{N}))$, $0 \leq n \leq N$ (5)

The Nuttall window has the widest mainlobe and lowest maximum sidelobe level among the Blackman, Exact Blackman, and the Blackman-Harris window. The equation for the Nuttall window is [6].

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

Where n = 0, 1, 2…... N-1 (6)

The equation for the periodic Nuttall window is

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

Where n = 0, 1, 2 …..…N-1 (7)

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

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

Peak-to-Sidelobe Ratio

The peak-to-sidelobe ratio of a code of length N with aperiodic autocorrelation function c(*l*) measures the ratio of the inphase value c(0) to the maximum side lobe magnitude |c (*l*)| of the autocorrelation function.

$PSLR = 20\log_{10}\frac{|C(0)|}{Max\,|C(l)|}$ $1 \leq l \leq N$

III. DESIGN SIMULATIONS

Table 1 shows the parameter specifications to design the High pass FIR Filter using Hamming, Hanning and Nuttall Windows.

Table 1: Parameter Specification

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

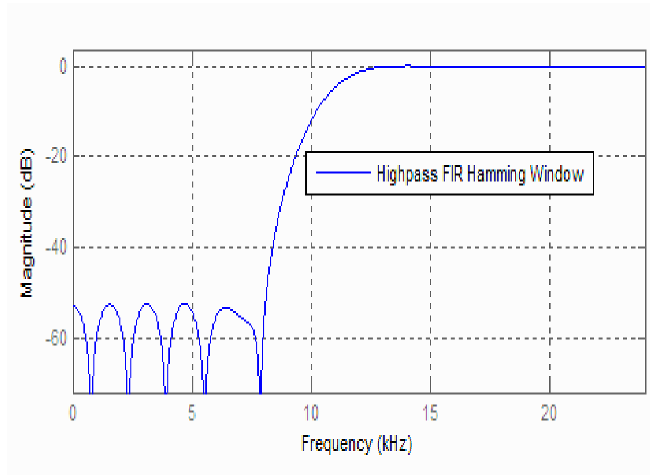

Figure 1: High Pass FIR filter using Hamming window

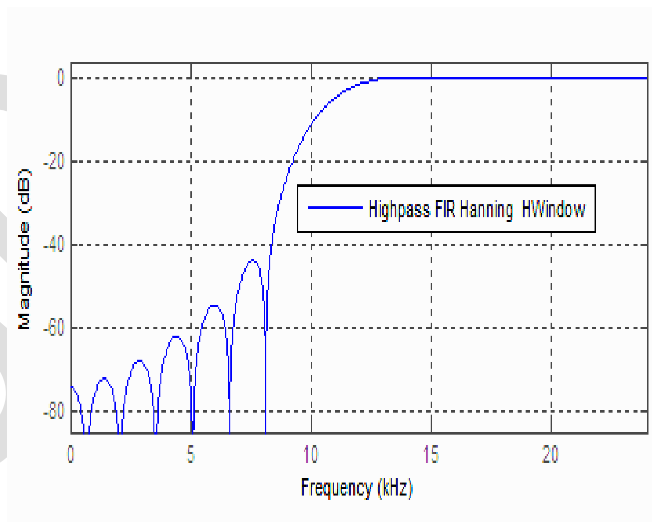

Figure 2: High Pass FIR filter using Hanning window

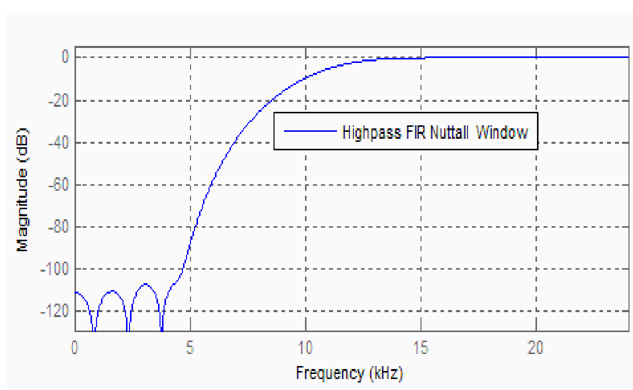

Figure 3: High Pass FIR filter using Nuttall window

Figure 1, 2, & 3 show the magnitude and frequency response of High Pass FIR filter using Hamming, Hanning and Nuttall window of order 30.

IV. COMPARATIVE ANALYSIS

Hamming, Hanning windows techniques are used along with Nuttall window technique for design analysis and comparison by using matlabs. Figure 4 shows the amplitude versus samples of Hamming, Hanning and Nuttall window in time domain. Dotted line shows Hamming, dashed line show Hanning and bold line shows Nuttall windows respectively. Nuttall window is narrower than Hanning and Hamming. Figure 5 shows the High Pass FIR filter comparison using three windows, Hamming, Hanning and Nuttall Windows.

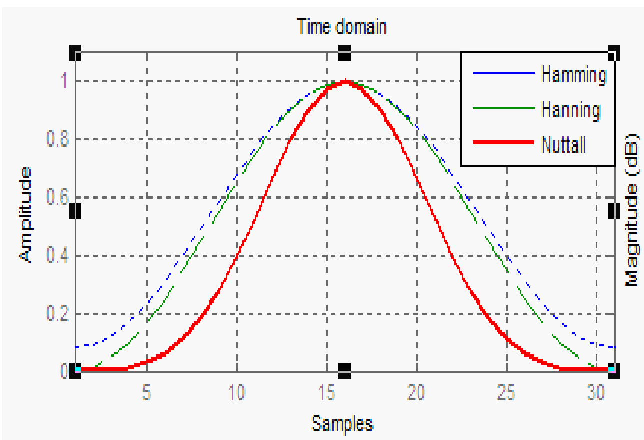

Figure 4: Time domain of Hamming, Hanning and Nuttal windows.

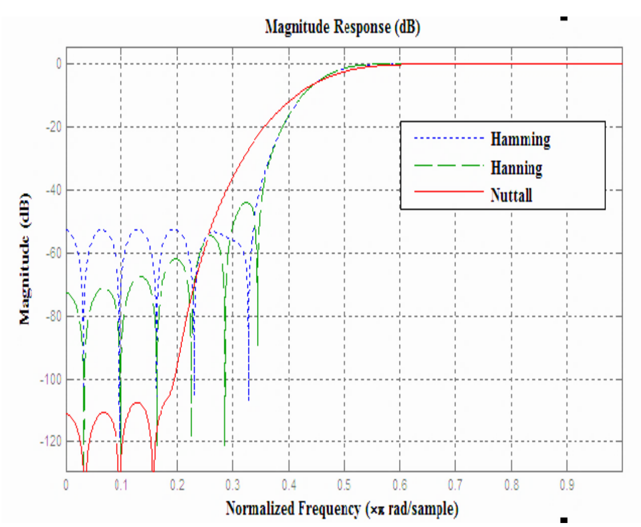

Figure 5: High Pass FIR Filter comparison of Hamming, Hanning and Nuttall windows.

Table 2: Matlab simulated result of three windows.

Windows	Main lobe width (-3dB)	Relative Side lobe attenuation
Hamming	0.085938	-41.7 dB
Hanning	0.09375	-31.5 dB
Nuttall	0.125	-88.3 dB

V. CONCLUSIONS

In this paper high pass filter has been designed and simulated using Hamming, Hanning and Nuttall windows techniques. It has been compared mainlobe width and relative sidelobe attenuation of the three windows Hamming, Hanning and Nuttall from the matlab simulation. The result show that the relative side lobe attenuation of Nuttal Window is -88.3 dB and mainlobe width of this window (-3dB) is 0.125 at sampling frequency 48000Hz, cut off frequency 10800 Hz and order 30. The simulated result also shows that Nuttall window has greater mainlobe width and less Peak-to-sidelobe Ratio (PSLR) in comparison of Hamming and Hanning windows.

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