A New Window Function to Design FIR Filter with an Improved Frequency Response for Suppressing Side-Lobe Attenuation and Study Comparison with the Other Windows

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Abstract

In both digital filter design and spectral estimation, the choice of a windowing function can play an important role in determining the quality of overall results. The main role of the window is to damp out the effects of the Gibbs phenomenon that results from truncation of an infinite series. There are various types of window techniques. In many applications like filter design, FFT, beam forming, signal processing and measurements it is seen that particular one type of filter is not applicable for all purpose. This paper presents a new window technique which has better performance compared to commonly used window like Hamming, Hanning & Blackman window. The simulation result where the advantage of this proposed window is shown is actually the minimization of side lobes& ripples. The simulation is done in Matlab 12. The Matlab program returns with a satisfactory result with proper magnitude plotting& filter response.

***(Keywords:*FIR, Hamming, Hanning, Blackman, Proposed Window, Window method)**

1. INTRODUCTION

Digital filter plays an important role in digital signal processing applications such as digital signal filtering, noise filtering, signal frequency analysis, speech and audio compression, biomedical signal processing and image enhancement etc. A digital filter is a system which passes some desired signals more than others to reduce or enhance certain aspects of that signal. It can be used to pass the signals according to the specified frequency pass-band and reject the frequency other than the pass-band specification. The basic filter types can be classified into four categories: low-pass, high-pass, band-pass, and band-stop. On the basis of impulse response, there are two fundamental types of digital filters: Infinite Impulse Response (IIR) filters, and Finite Impulse Response (FIR) filters [1].

FIR filters are filters having a transfer function of a polynomial in z^{-} and is an all-zero filter inthe sense that the zeroes in the z-plane determine the frequency response magnitudecharacteristic. The z transform of aN-point FIR filter is given by[9]

$$\mathbf{H(z)} = \sum_{n=0}^{N-1} h(n) z^{-n} \text{---------(1)}$$

FIR filters are particularly useful for applications where exact linear phase response is required. The FIR filter is generally implemented in a non-recursive way which guarantees a stable filter. FIR filter design essentially consists of two parts[5][6][7]

(i) Approximation problem
(ii) Realization problem

The approximation stage takes the specification and gives a transfer function through four steps. They are as follows:
(i) A desired or ideal response is chosen, usually in the frequency domain.
(ii) An allowed class of filters is chosen (e.g. the length N for a FIR filters).
(iii) A measure of the quality of approximation is chosen.
(iv)A method or algorithm is selected to find the best filter transfer function.

The 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 essentially three well-known methods for FIR filter design namely:

(1) The window method
(2) The frequency sampling technique
(3) Optimal filter design methods

In this paper attention is given only for window method. Here proposed window method is compared with the commonly used window like Hamming, Hanning&Blackman window along with their frequency responses in case of various types of FIR filter.

2. DIFFERENT WINDOW TECHNIQUE

Window technique involves a function called window function or apodization function which states that if some interval is chosen, it returns with finite non-zero value inside that interval and zero value outside that interval[8]. So, if the window with chosen interval is applied on the IIR system, it will obviously return with a finitenon-zero value inside that interval producing a FIR system and all other value that is outside the interval willbe zero. So, we can view the finite response inside some predefined interval.Some of the windows [2] commonly used are as follows:

2.1 HANNING WINDOW

The Hanning window is one type of raised cosine window. The equation for Hanning window sequence is written as [3][4][10]

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

---------(2)

Where N= no. of sample of the window.In this paper for all type of window response N is taken as 63. The Hanning window sequence&its frequency response is presented in Fig.2.1.a & Fig.2.1.b respectively using MATLAB 2012 software package.

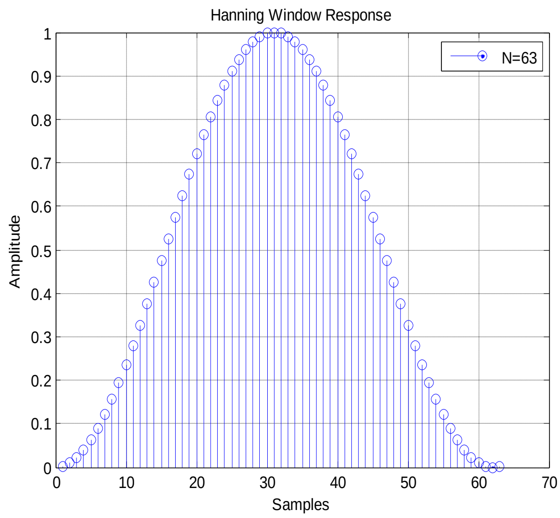

Fig.2.1.a

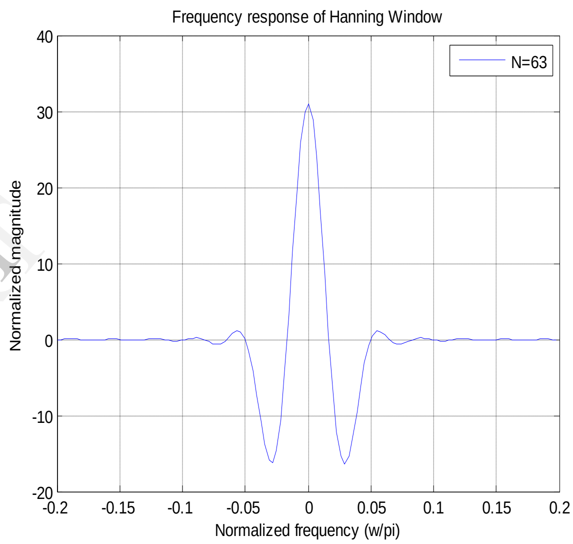

Fig.2.1.b

2.2 HAMMING WINDOW

Hamming window is most commonly used window in speech processing. It is given as: [3][4][10]

$$w_h(n) = \begin{cases} 0.54 - 0.46\cos\frac{2\pi n}{N-1} & ; for\ n = 0\ to\ N-1. \\ 0 & ; \ other\ n \end{cases}$$

---------(3)

The Hamming window sequence is shown in Fig.2.2.a. Its first & last samples are not zero. The frequency response of this window for N (no. of samples) = 63, is shown in Fig.2.2.b.

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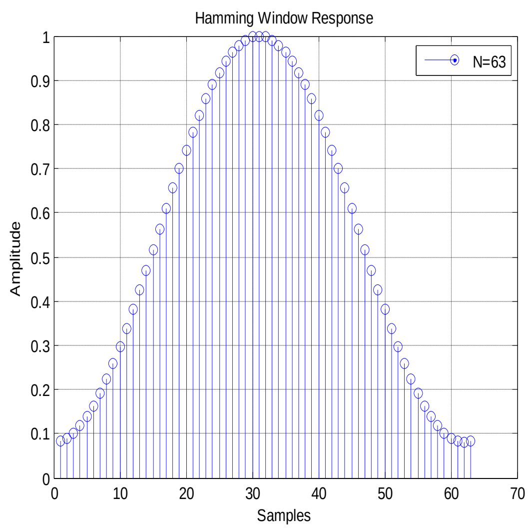

Fig.2.2.a

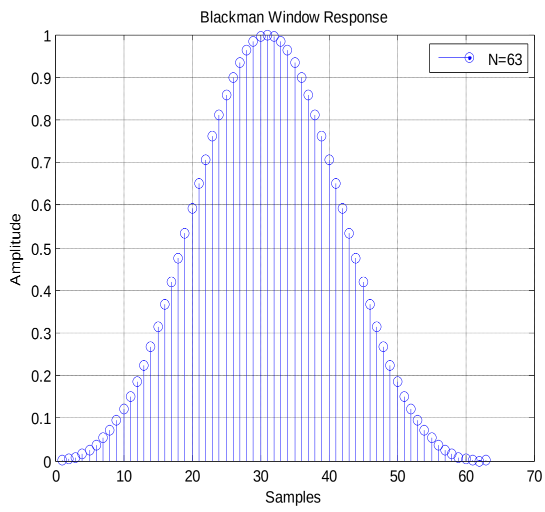

Fig.2.3.a

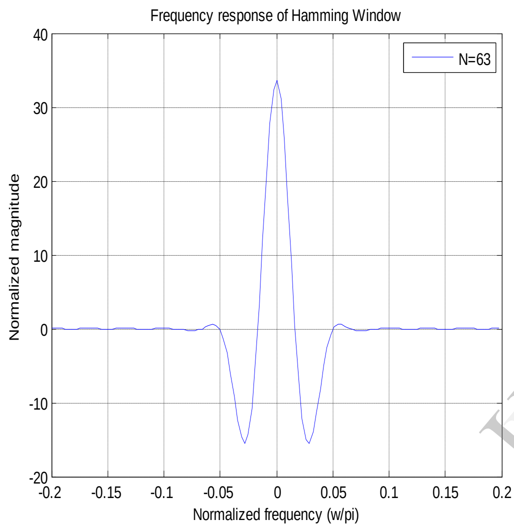

Fig.2.2.b

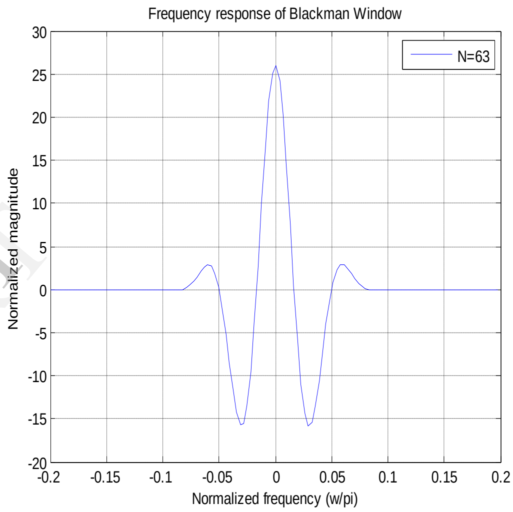

Fig.2.3.b

2.3 BLACKMAN WINDOW

The Blackman window$w_B(n)$ is another type of cosine window defined by the equation[3][4][10]

$$\mathbf{w_B(n)= 0.42- 0.5 \cos\frac{2\pi n}{N-1} +0.08\cos\frac{4\pi n}{N-1};}$$

for n=0 to N-1---------(4)

Blackman window sequence &its frequency response for N= 63 is presented in Fig.2.3.a & Fig.2.3.b respectively.

2.4 PROPOSED WINDOW

In this section proposed window function is presented. It is defined as [3][4][10]

$$\mathbf{w(n) = 0.58 - 0.66 \cos\frac{2\pi n}{N-1} + 0.088 \cos\frac{4\pi n}{N-1}}$$

$$\mathbf{for\ n = 0\ to\ N-1} \quad \text{---------(5)}$$

The proposed window sequence & its frequency response for N= 63 is presented in Fig.2.4.a & Fig.2.4.b respectively.

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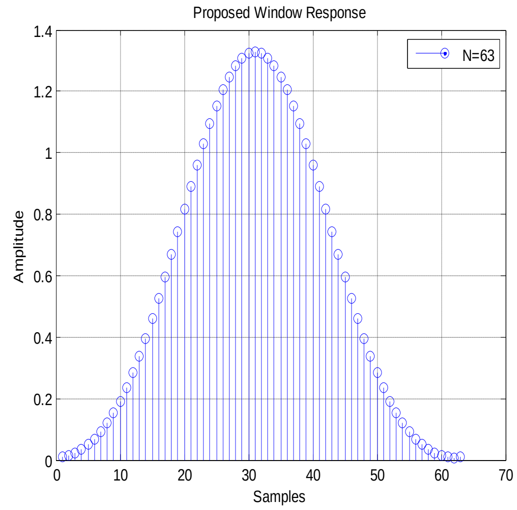

Fig.2.4.a

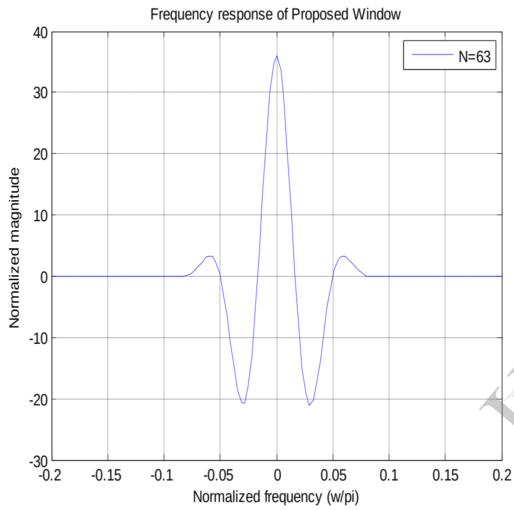

Fig.2.4.b

3. COMPARE BETWEEN PROPOSED WINDOW & OTHER WINDOWS

In this section, performance of the proposed window with several commonly used windows is compared using Matlab12 which is shown in Fig.3.a

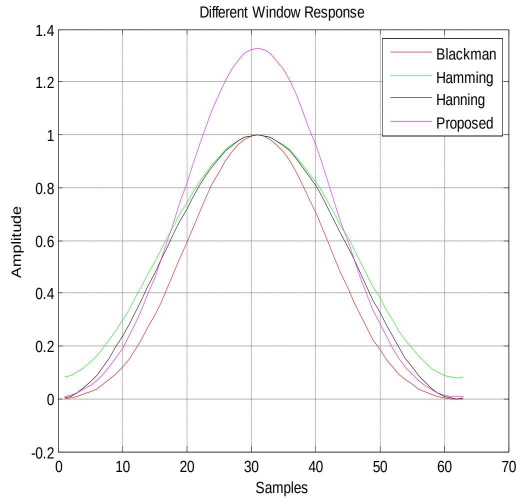

Fig.3.a

According to Fig.3.a, the specification of different window sequence is given in Table.1.

Table.1

Type of Window (for N=63)	*Maximum Amplitude of Window*	*Minimum Amplitude of Window*
Blackman	1.0	0
Hanning	1.0	0.08
Hamming	1.0	0
Proposed	1.36	0

Now to verify the specifications of proposed window more briefly,frequency domain analysis is required & this is done in MATLAB 12 by using proper command.

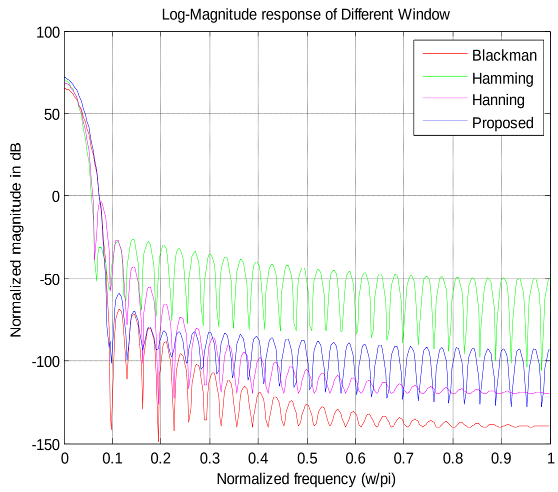

Fig.3.b

The value which is collected from Fig.3.b is shown in Table.2.

Table.2

Type of Window (for N=63)	*Approximate Width of Main Lobe*	*Magnitude of 1st side Lobe*	*Range of Stopband Ripple*
Blackman	0.064(w/π)	-70dB	-70 to -140 dB
Hanning	0.057(w/π)	-5dB	-5 to -120 dB
Hamming	0.057(w/π)	-30dB	-25 to -110 dB
Proposed	0.067(w/π)	-61dB	-61 to -124 dB

4. PERFORMANCE ANALYSIS OF PROPOSED WINDOW WITH OTHER WINDOWS

In this section the modified window function w(n), as in equation (5) is compared with the other windows along with their frequency responses in case of various types of digital FIR filter. To study the efficiency of the proposed window we have compared the results by observing the Fourier Transform of a low pass, high pass, band pass & band stop FIR filter designed by truncating of an ideal IIR low pass filter.

4.1 LOW PASS FILTER RESPONSE

The impulse response of an ideal low pass filter is taken as [1],[3]:

$h_d(n) = \sin A\omega_c / A\pi$---------(6)

where, **A= n-a+k**

k=0.001, a=(N-1)/2, n=1,2,-----,N-1

N= 63 (no. of sample)

$\omega_c = 0.5\pi$ **(cut-off frequency)**

The low pass filter response is shown in Fig.4.1.a & detailed specifications are given in Table.3.

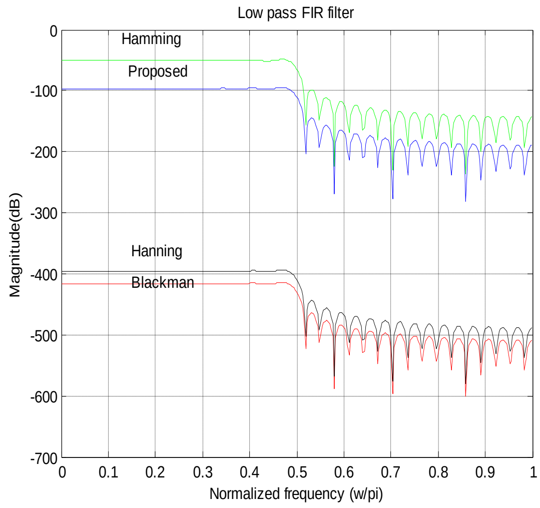

Fig.4.1.a

Table.3

Type of window for low pass FIR filter	*Cut-off frequency (ω_c)*	*Stop-band attenuation range (Approx.)*	*Roll-off rate*
Hanning	0.5π	-450 to -583dB	Low
Hamming	0.5π	-100 to -245dB	Low
Blackman	0.5π	-465 to -600dB	Medium
Proposed	0.5π	-150 to -280dB	Medium

4.2HIGH PASS FILTER RESPONSE

The impulse response of an ideal high pass filter is taken as: [1],[3]

$h_d(n) = (\sin A\pi - \sin A\omega_c) / A\pi$---------(7)

where,**A= n-a+k**

The high pass filter response using various window techniques along with proposed window is shown in Fig.4.2.a & detailed specifications are given in Table.4.

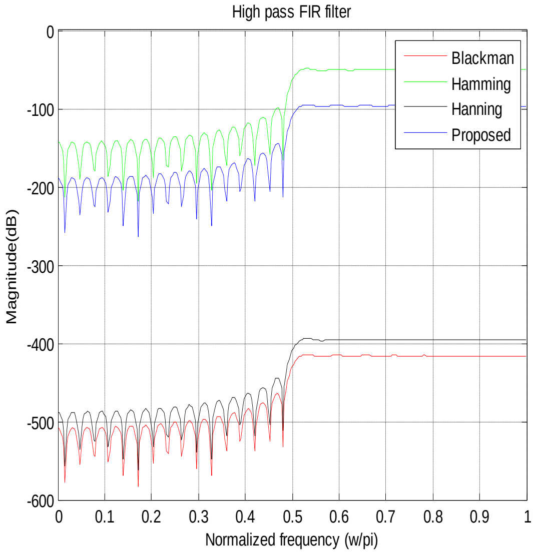

Table.4

Window for high pass FIR filter	*Cut-off frequency (ω_c)*	*Stop-band attenuation* Fig.4.2.a	*Roll-off rate*
Hanning	0.5π	-440 to -560dB	Low
Hamming	0.5π	-100 to -215dB	Low
Blackman	0.5π	-465 to -580dB	Medium
Proposed	0.5π	-150 to -260dB	Medium

4.3 BAND PASS FILTER RESPONSE

The impulse response of an ideal band pass filter is taken as: [1],[3]

$h_d(n) = (\sin A\omega_{c2} - \sin A\omega_{c1}) / A\pi$ ------------(8)

where, A=n-a+k

ω_{c1} = Lower cut-off frequency

ω_{c2} = Upper cut-off frequency

The band pass filter response using various window techniques along with proposed window is shown in Fig.4.3.a & detailed specifications are given in Table.5

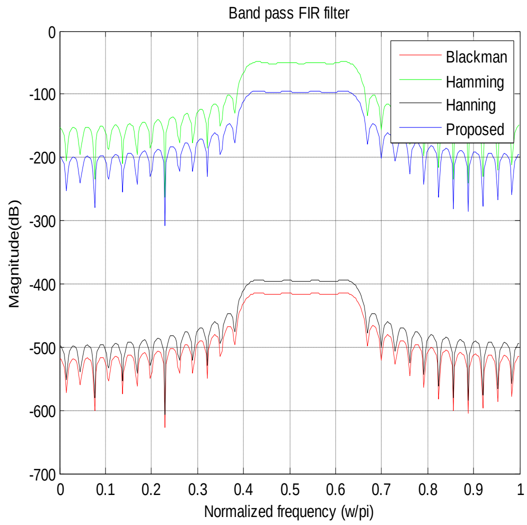

Fig.4.3.a

Table.5

Window for Bandpass FIR filter	ω_{c1}	ω_{c2}	*Stop-band attenuati-on range (Approx.)*	*Roll off rate*
Hanning	0.4π	0.65 π	-450 to -600dB	Low
Hamming	0.4π	0.65 π	-100 to -230dB	Low
Blackman	0.4π	0.65 π	-470 to -615dB	Medium
Proposed	0.4π	0.65 π	-160 to -305dB	Medium

4.4 BAND STOP FILTER RESPONSE

The impulse response of an ideal band pass filter is taken as: [1],[3]

$h_d(n) = (\sin A\pi - (\sin A\omega_{c1} - \sin A\omega_{c2}))/ A\pi$ ------(9)

where, A= n-a+k

ω_{c1} = Lower cut-off frequency

ω_{c2} = Upper cut-off frequency

The band stop filter response using various window techniques along with proposed window is shown in Fig.4.4.a & detailed specifications are given in Table.6

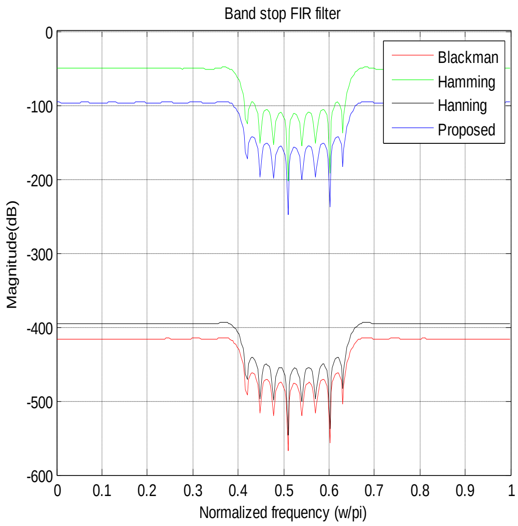

Fig.4.4.a

Table.6

Window for Bandstop FIR filter	ω_{c1}	ω_{c2}	***Stop-band attenuation range (Approx.)***	***Roll off rate***
Hanning	0.4π	0.65π	-445 to -550dB	Low
Hamming	0.4π	0.65π	-98 to -200dB	Low
Blackman	0.4π	0.65π	-460 to -570dB	Medium
Proposed	0.4π	0.65π	-140to -240dB	Medium

5. CONCLUSION

Performancecomparisonoftheproposedwindowcomparedtothatofthe Hanning, HammingandBlackmanwindowshows thattheproposed windowofferssuppressedstop band attenuationwiththeother window techniques. This is the major advantage of proposed window. Also this window has slightly greater main lobe width compared to Hanning, Hamming & Blackman window. Again it is known to us that if roll-off rate increases the sharpness of window increases. It is seen that the proposed window offers faster roll-off rate compared to Hanning& Hamming window but its roll-off rate is same like Blackman window.

6. FUTURE WORK

In this paper we have designed a new window function which minimizes the side lobe ripples as well as produces good frequency response for low pass, high pass, band pass & band stop FIR filter. But the power consumption rate of this proposed window is not better than Blackman window. Therefore in future, stress will be given for the improvement of this proposed window function so that power consumption rate is decreased than other window techniques.

7. REFERENCES

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