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A window function with modified co-efficients for FIR filter design with an improved frequency response and its comparison with the Bartlett-Hann window

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***Abstract* — In this paper a window function with modified co-efficients for Finite Impulse Response(FIR) filter design with an improved frequency response has been presented. The window function is generated and has been utilized to compute the frequency response of various types of FIR filter i.e. high pass, low pass, band pass and band stop types. Noticeable improvement is observed when the newly generated frequency response is compared with various other frequency responses using the other existing windows in perspective of stop band attenuation, which is justified by relevant simulations and plots. In this paper the frequency response of the modified window is compared with that of Bartlett-Hann window with quantized and generalized experimental results. Comparison of the modified window with the other common window functions as well as responses will be taken up in near future.**

(*Keywords*—Finite, Impulse, Response, Bartlett-Hann, filter, window, function, frequency, attenuation)

I. INTRODUCTION

Digital filters can be classified either as finite duration unit impulse response (FIR) filters or infinite duration unit impulse response (IIR) filters. In FIR systems, the impulse response sequence is of finite duration or in other words, if the impulse response of a digital filter is determined for some finite number of sample points, then these filters are known as Finite Impulse Response or FIR digital filters.[1]-[4]

There are mainly three methods used for FIR filter design:

- FIR filter design using windows.
- FIR filter design using frequency sampling method.
- Optimal or rminimax FIR filter design.

Let us consider that the digital filter which has to be designed is to be designed has the frequency response, $H_d(\omega)$. This is also known as desired frequency response. Let the corresponding unit sample response be $h_d(n)$ *i.e.*

$$H_d(\omega) = \sum_{0}^{\infty} h_d(n)\, e^{-j\omega n} \quad \ldots(1)$$

Ref. [1]-[3]

In FIR filter design using window method, the common window functions that are commonly used are Rectangular window, Triangular window, Bartlett window, Bartlett-Hann window, Hanning window, Bartlett-Hann window etc.[5]

In this context the Bartlett-Hann window function will be discussed in brief following which a modified window will be presented whose frequency response characteristics will be compared with the previous one.

II. BARTLETT-HANN WINDOW

The Bartlett-Hann window is defined as,

$w(n)=0.62-0.48|(n/N-0.5)| + 0.38\cos(2\pi(n/N-0.5))$....(2)

where,

$0 \le n \le N$and

n = Number of samples

N = Total number of sample points[6]-[8]

The Bartlett-Hann window has been pictorially represented in Fig. 1 using MATLAB R2012a software package.

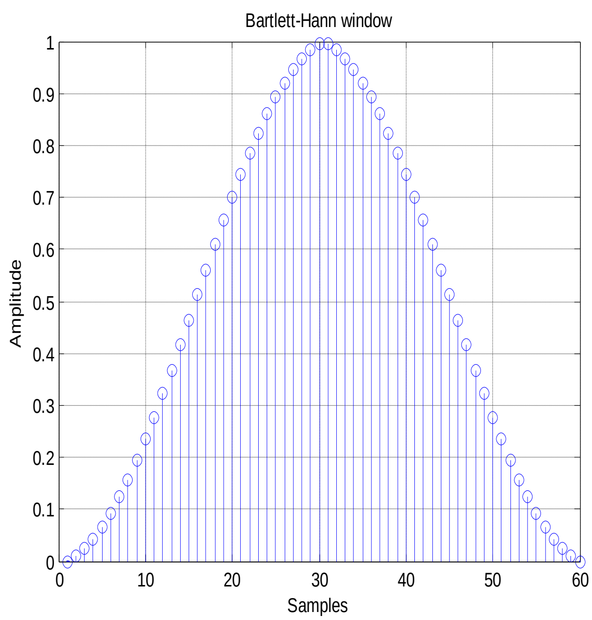

Fig. 1

III. THE MODIFIED WINDOW FUNCTION

In this section the modified window method has been presented. The window sequence has been defined as,

$w(n) = a - b\cos(2\pi(n+0.1)/N) + c\cos(4\pi(n+0.3)/N) - d\cos(6\pi(n+0.5)/N) + e\cos(8\pi(n+0.7)/N) - f\cos(10\pi(n+0.9)/N)$…(3)

where,

$0 \le n \le N$ Ref. [11]

and the modified co-efficients are,

a= 0.501

b= 0.489

c= 0.001

d= 0.002

e = 0.003

f= 0.004

The modified window sequence has been presented in Fig. 2

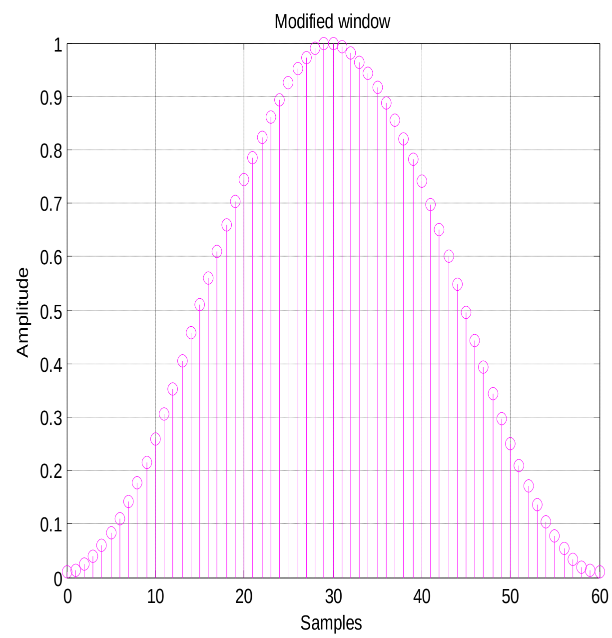

Fig. 2

Fig. 2 shows the proposed window function where the number of samples is represented along *x-axis*and amplitude along*y-axis* respectively.

IV. FREQUENCY RESPONSES

This window function ***w(n)***,as in equation (3)has been utilized to compute the frequency response of various types of FIR filter i.e. low pass, high pass, band pass and band stop types.

Low pass filter:

The order of the filter has been taken as N = 60 and the cut-off frequency, *wc*as 0.3. The frequency response of a low pass FIR filter simulated using *w(n)*is represented in Fig. 3. Significantly less stop band ripplesand fair attenuation level have been observed.

Minimum stop band attenuation observed is -105 dB.

Detailed specifications are given in [i].

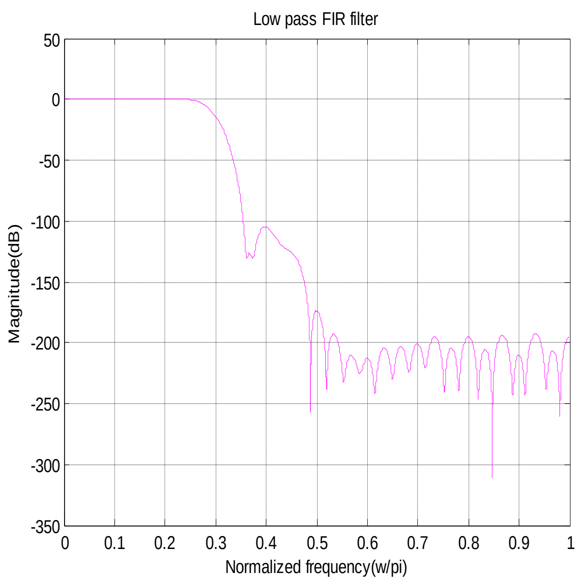

Fig. 3

Selected cut-off frequency	0.3
Min. stop band attenuation	-105dB
Max. stop band attenuation	-300dB

[i]. Low pass filter specs.

High pass filter:

For a FIR high pass FIR filter the response is shown in Fig. 4

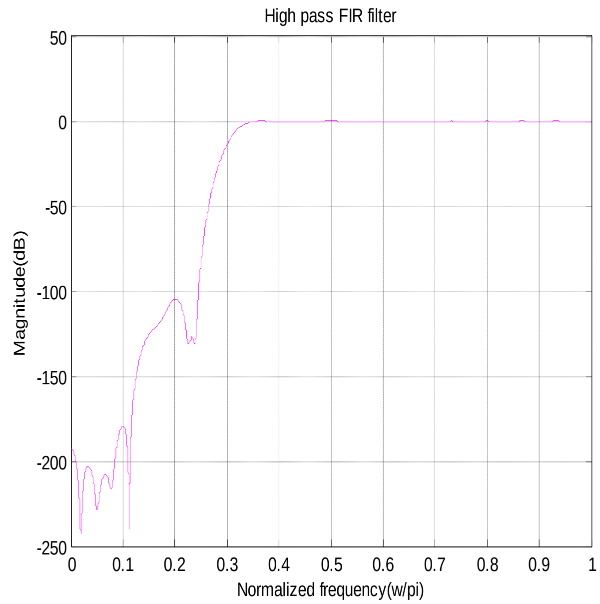

Fig. 4

Minimum stop band attenuation observed is -105 dB.

Very accurate type of response has been observed tallying with prescribed cut-off frequency range.Detailed specifications are given in [ii].

Selected cut-off frequency	0.3
Min. stop band attenuation	-105dB
Max. stop band attenuation	-240dB

[ii]. High pass filter specs.

Band pass filter:

For Band pass, the cut-off frequencies are taken as 0.4 and 0.6 respectively and the simulated frequency response has been shown in Fig. 5 Accurate attenuation is observed between prescribed cut-off frequencies.

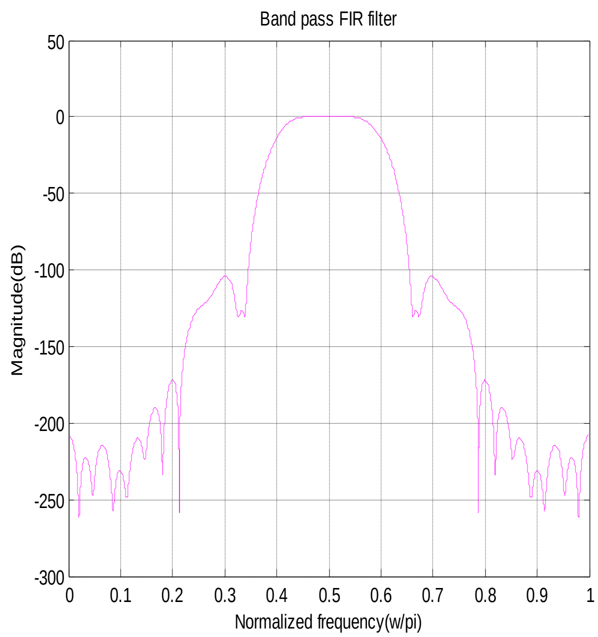

Fig. 5

Minimum stop band attenuation observed is -105 dB.

Detailed specifications are given in [iii].

Selected cut-off frequencies	0.4 &0.6
Min. stop band attenuation	-105dB
Max. stop band attenuation	-260dB

[iii]. Band pass filter specs.

Band stop filter:

For band stopfilter, the response is shown in Fig. 6. Minimum attenuation is -138dB in this case which is clear from the filter response.

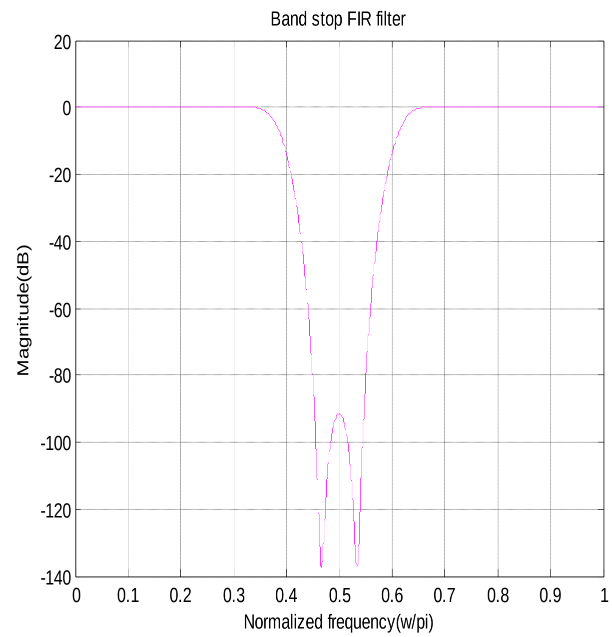

Fig. 6

Accurate frequency response is also observed in this case. Effective attenuation lies between 0.4 and0.6. Detailed specifications are given in [iv].

Selected cut-off frequencies	0.4 &0.6
Min. stop band attenuation	-95dB
Max. stop band attenuation	-138dB

[iv]. Band stop filter specs.

V. COMPARISON

In this section the modified window will be compared with the Bartlett-Hann window along with their frequency responses in case of various types of FIR filter. The window sequences have been plotted as in Fig. 7.

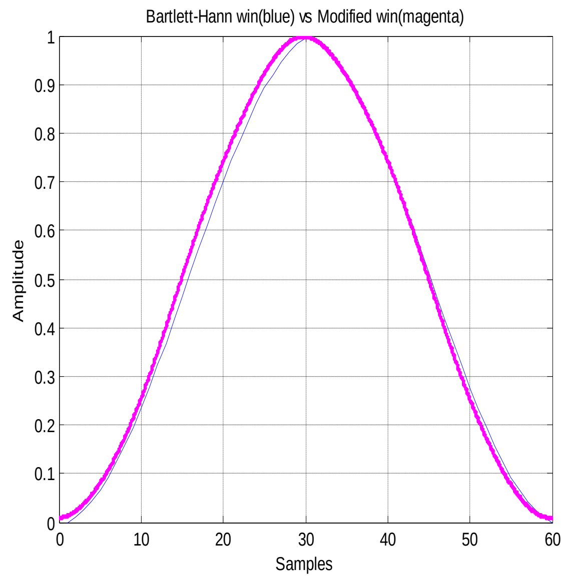

Fig. 7

Low pass filter responses:

Comparatively much more effective attenuation than that using Bartlett-Hann window shown in Fig. 8. We can observe that it has resulted in much more reduced side lobes in low pass filter response. From the response it is clear that the stop-band attenuation is excessively of low degree in case of Bartlett-Hann window response which can be considered as a major draw back.[7]

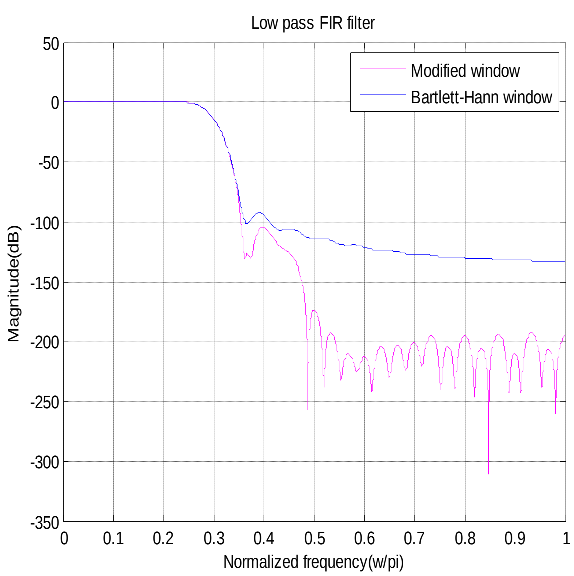

Fig. 8

Detailed specifications are given in [v].

Specifications (Low pass FIR filter)	***Bartlett-Hann window***	***Modified window***
Selected cut-off frequency	0.3	0.3
Avg. stop band attenuation range	-90dB -- -135dB	-105dB -- -310dB
Presence of stop band ripples	Very low	Low

[v]. Low pass filter response comparison

High pass filter responses:

Much more effective response than Bartlett-Hannwindow in designing FIR band stop filters, shown in Fig. 9. Attenuation level is excessively high in case of the modified window response in comparison with the Bartlett-Hann window response.

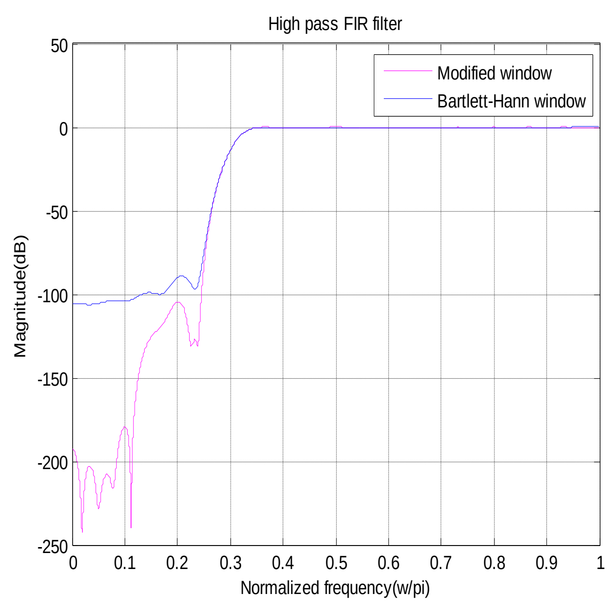

Fig. 9

Detailed specifications are given in [vi].

Specifications (High pass FIR filter)	***Bartlett-Hann window***	***Modified window***
Selected cut-off frequency	0.3	0.3
Avg. stop band attenuation range	-90dB -- -105dB	-105dB -- -245dB
Presence of stop band ripples	Very low	Low

[vi]. High pass filter response comparison

Attenuation level is much more increased in the modified window response.

Band pass filter responses:

Noticeable improvement in FIR band pass filter design compared to Bartlett-Hann window as shown in Fig. 10

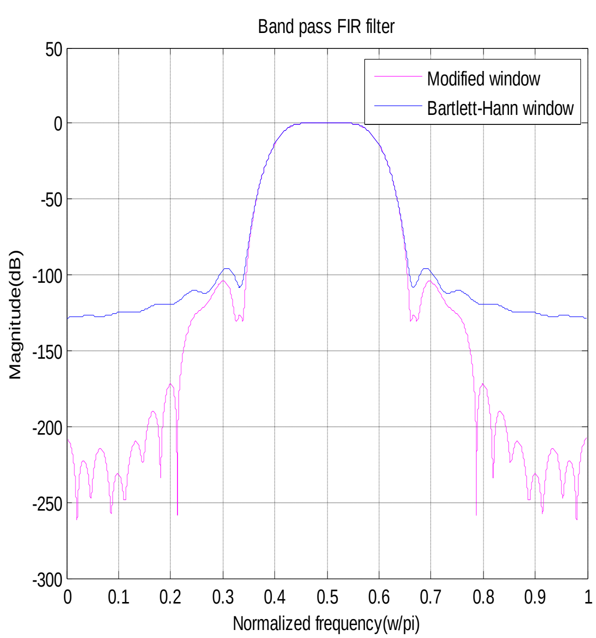

Fig. 10

From the figure we can observe that the attenuation level is reduced to a huge extent in the modified window response. Detailed specifications are given in [vii].

Specifications (Band pass FIR filter)	***Bartlett-Hann window***	***Modified window***
Selected cut-off frequencies	0.4 &0.6	0.4 &0.6
Avg. stop band attenuation range	-90dB -- -130dB	-105dB -- -260dB
Presence of stop band ripples	Very low	Low

[vii]. Band pass filter response comparison

Band stop filter responses:

Likewise, superior response compared to Bartlett-Hann window method for band pass FIR filter design as shown in Fig. 11 along with detailed specifications in [viii].

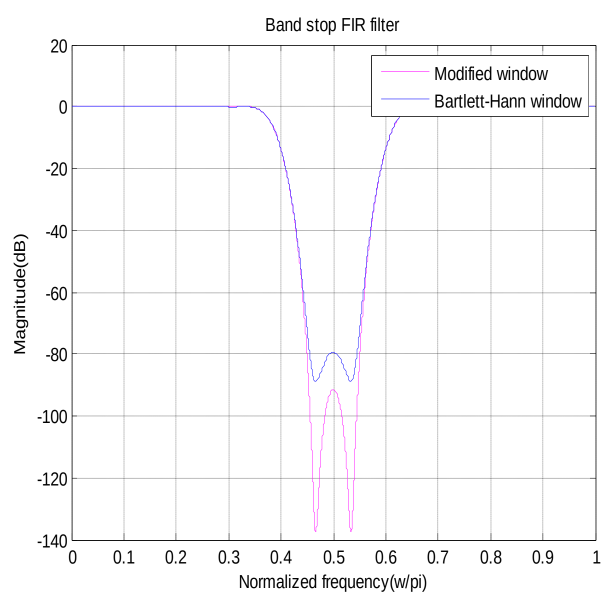

Fig. 11

Specifications (Band stop FIR filter)	***Bartlett-Hann window***	***Modified window***
Selected cut-off frequencies	0.4 &0.6	0.4 &0.6
Avg. stop band attenuation range	-80dB -- -85dB	-90dB -- -138dB
Presence of stop band ripples	Very low	Low

[viii]. Band stop filter response comparison

VI. FUTURE WORK

It has been observed that the modified window function indeed produces much more effective type of frequency responses compared to the Bartlett-Hann window, except the presence of ripples at moderate level. In future, stress will be given for the improvement of this window function for further accurate type of responses with reduced side lobes and comparatively less pass-band and stop-band ripples and frequency responses of the other common window types will be compared with the modified one.

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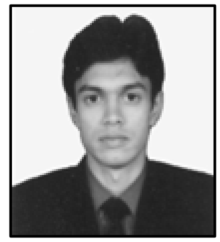
ABOUT THE AUTHOR



Ankan Bhattacharya obtained B.Tech (2010) and M.Tech (2012) degrees in Electronics and Communication Engineering under West Bengal University of Technology. His area of interests include design of filters for optimum response, antenna design etc. He has an International Journal publication on FIR filter design using window technique. He is presently serving as an Asst. Professor of Department of Electronics and Communication Engg. at Mallabhum Institute of Technology; Campus: Braja-Radhanagar, P.O: Gosaipur, P.S: Bishnupur, Dist: Bankura-722122, W.B., India.