# Improved Spectral Characteristics of Bandpass FIR Filter using a Novel Adjustable Window Function

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*Abstract*— The window method is a very simpler and popular procedure to design a Finite impulse response (FIR)filter. Of the existing window techniques, the Kaiser window outperforms in main lobe width but fails in computational complexity and higher relative side lobe attenuation. This paper presents a novel adjustable window function formed by combining Gaussian window, Lanczos window and Dolph-Chebyshev window (GLC) with a controlling parameter to meet the specifications for various applications. This parameter adjusts the spectral characteristics and shape of the window function according to the desire of the designer. The spectral characteristics of the proposed window have been analyzed and its performance has been compared with Gaussian Hann and Lanzcos Blackman windows. From MATLAB simulation results, it is observed that the proposed GLC window results in greater performance with respect to relative side lobe attenuation. Furthermore, it has been used to design a FIR bandpass filter to justify its performance and their comparative analysis is presented. The FIR bandpass filter designed with the proposed GLC window provided better results in terms of ripple ratio.

*Keywords*— Dolph-Chebyshev window, Gaussian window, Lanczos window, spectral characteristics. Window function.

## I. Introduction

DIGITAL filters are extensively used in a variability of applications. Mostly, the final goal is to filter the input signal to obtain a kind of frequency selectivity on the spectrum. Digital filters are broadly classified as: the recursive filter and the non-recursive filter. These are frequently stated as infinite impulse response (IIR) filters and finite impulse response (FIR) filters, respectively[1].

For designing digital FIR filters, one of the simplest and convenient method is window method. A window is sequence of coefficients that satisfy certain requirements and is finite in nature[2]. In this procedure an ideal frequency -selective filter is chosen and its impulse response is obtained which is infinite. It is essential to make this infinite impulse response finite. In order to

obtain this, the ideal response must be truncated.

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The desired frequency response $H_d(e^{j\omega})$ and its corresponding impulse response $h_d(n)$ are determined using the relation (1)[3]

$$h_d(n) = \frac{1}{2\pi}\int_{-\pi}^{\pi} H_d(\omega)\, e^{j\omega n} d\omega \quad (1)$$

The infinite duration impulse response $h_d(n)$ is made finite by multiplying with a window function $w_f(n)$ of finite length N given by (2)

$$h(n) = h_d(n) \times w_f(n) \quad (2)$$

where

$$w_f(n) = \begin{cases} w(n), & 0 \le n \le N \\ 0, & Otherwise \end{cases} \quad (3)$$

The two desired specifications of a window function are lesser main lobe width and ripple ratio. But these specifications are contrary. A window with a thinner main lobe has a poor side lobe rejection and vice versa.[4]. There are many window functions like hamming window, Hanning window, Blackman window and adjustable window functions like Kaiser window, Gaussian window, Dolph-chebyshev filter and Lanczos window.

In literature, to achieve better performance, the combination of different windows was done. A new variable window function obtained by a combination of Lanczos and Blackman window was proposed by Tapash et al.(2017)[5] and its spectral performance was compared with Gaussian and Kaiser windows. It is observed that the main lobe width is almost same as that of the other windows but the ripple ratio is smaller than Gaussian and Lanczos window. A product of Gaussian and Hanning window was proposed by Vivek Kumar et al.[6] and its spectral performance was compared with Kaiser window. Mitun Shil et al.[7] proposed a adjustable window in combination with tan hyberbolic function and a weighted cosine series. The results are compared with hamming and Kaiser window. The proposed window[7] has a good linear phase and 0% leakage factor. Hrishi Rakshit et al.[8] given comaprision of various window functions for designing a low pass filter. [8] stated that Kaiser window is the most supercilious among other windows in terms of main lobe width and Dolph-Chebyshev window shows better response in stop band attenuation. From the literature, it is observed that out of all the windows, Kaiser window outperforms other windows in terms of main lobe width, but is computationally complex due to the calculation of Bessel functions.