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Comparison of FIR Filter Using Different Window Functions

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Abstract—*The paper presents FIR filter design by different window functions such as, Gaussian window, Kaiser window, Hamming window, and Blackman window. In the design procedure of FIR filter, we determine its side love peak by the help of different window function. The side love of Gaussian window, Hamming window, Kaiser window and Blackman window are -57.2, -42.5, -58.3, and -58.1 respectively. The design procedure done in the MATLAB software. It is concluded that Black man window is the best window, because its side lobe is the better than another window.*

Key words—*FIR filter, hamming window, Kaiser window, Gaussian window, and window.*

I. INTRODUCTION

In the digital signal processing the window function is widely use for the denoising the signal, and signal estimation and signal analysis. Digital filter is also use for image processing, speech processing, data processing and so many applications.

Digital filters are more accurate, more versatile and highly stable, so it is more preferable the analog filters. Two types of digital filters are there, first one is finite impulse response (FIR) filter and second one is infinite Impulse response (IIR) filter. In the digital signal processing (DSP) the FIR filter is most frequently use. FIR filter has linear phase response in pass band and stop band of filter. The IIR filter has lower side lobe in pass band and fewer parameters are require for design. So,

According to requirement we can prefer which filter can be used. There are four basics categories of the filter: -

1. Low-pass filter
2. High-pass filter
3. Band-pass filter
4. Band-stop filter

These types of filters are frequency dependent filter. According to the cut-of frequency we can go which filter should to be use.

There are different types of FIR filter design such as, Frequency sampling technique, optimal filter design method,

Windowing technique. The most use full technique is window technique because we can easily find the coefficient of the desired frequency response.

II. FIR FILTER

FIR filter is the type of digital filter for the digital input. The impulse response of the FIR filter is of finite duration. It is also known as non-recursive filters because it has no feedback.

Output of the FIR filter is: -

$$Y[n] = X[n] * H[n] \qquad (1)$$

For M order FIR Filter, each value of the filter is the weighted sum of the most recent values of the input as:

$$Y[n] = \sum_{k=o}^{M-1} h(k)x(n-k) = \sum_{k=o}^{M-1} x(k)h(n-k) \qquad (2)$$

Here,

$x(n)$ = Output sequence

h(n) = coefficients of filter

Y(n) = output response

The FIR filter design into two-way structures, direct form and transposed form. Direct form FIR filter is more efficient than transposed form FIR filter.

III. FIR FILTER DESIGN

The design specification of FIR filter in following five steps: -

(a) Specification of the filter: -This is the starting point of the filter.

(b) Coefficient calculation of the filter: - It is calculated by the help of transfer function **H(z)**, which will satisfy the given coefficient.

(c) Realization: - in this step we convert the transfer function into suitable filter network or structure.

(d) Analysis of finite word length effects: - In this step we filter the input signal, coefficient data.

(e) Implementation: - In this step we do software code and/or hardware and performing the actual code.

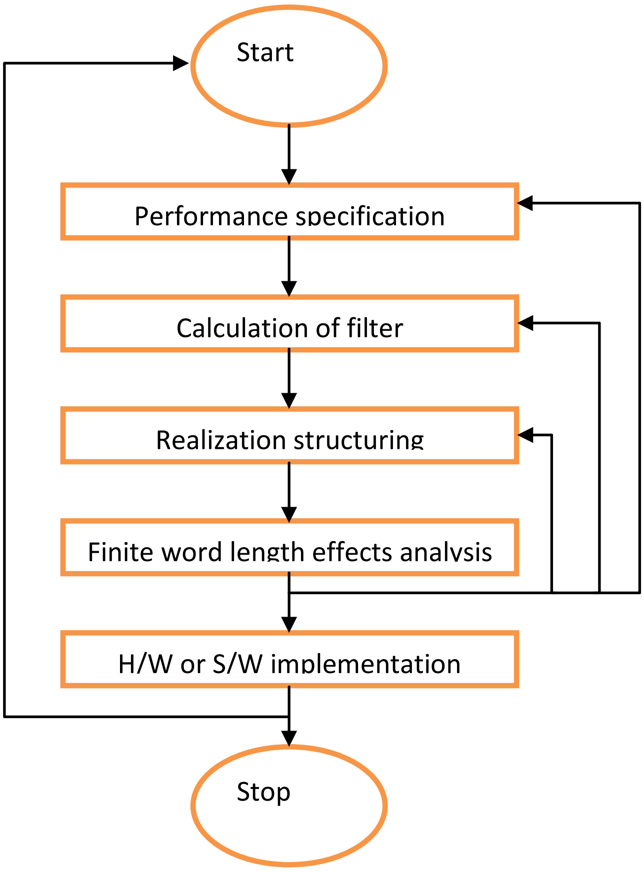

Fig 1. Flow diagram of FIR filter design.

IV. WINDOW METHODE FOR FIR FILTER DESIGN STEPS

1. Describe filter specification.
2. According to specifications define window functions.
3. For given set of specifications we compute filter order.
4. Compute window function Coefficients.
5. According to filter order coefficient compute ideal filter.

According to window function and ideal filter we compute FIR filter.

V. PROPOSED WORK

In this paper FIR filter design by different window functions such as, Gaussian window, Kaiser window, Hamming window, and Blackman window. FIR filter designed using different window functions provides Good main lobe width and smaller side lobe width but, among the above window Kaiser window is provide good side lobe than another window.

Paper presents the following window functions which are being used for designing a FIR filter.

1. **Kaiser window: -**

Kaiser window mathematically defined as in the time domain [3].

$$w(n) = \left[\frac{I_0\left[\alpha\pi\sqrt{1-\left(\frac{n}{M/2}\right)^2}\right]}{I_0[\alpha\pi]} \right] 0 \le |n| \le M/2 \qquad (3)$$

where

$$I_0(x) = \sum_{k=0}^{\infty} \left[\frac{(x/2)^k}{k!} \right]^2$$

From the fig.2, we have analyzed that for M=64, and α =8.0, the average side lobe peak of gaussian window is -58.3dB.

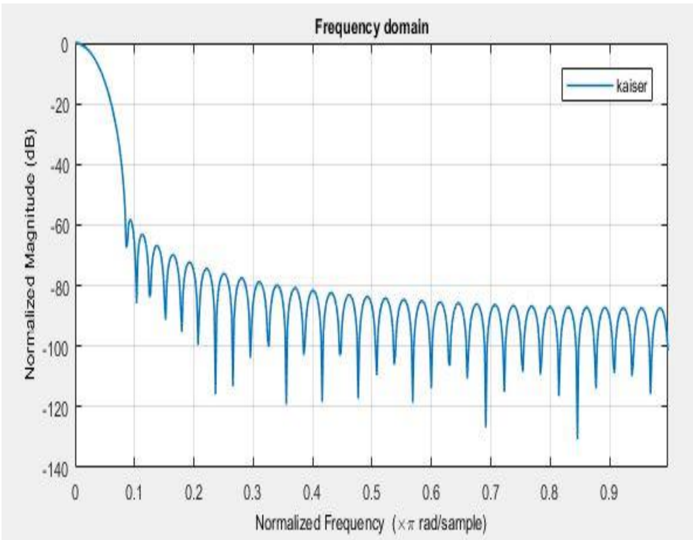

Fig.2. Amplitude spectrum of Kaiser window for M=64.

2. **Hamming window: -**

It has the modified version of the Hanning window. Hamming window mathematically defined as in the time domain [3].

$$w(n) = 0.54 - 0.04cos^{2\pi n}/_M \; n = 0,1,2,.....M-1 \qquad (4)$$

In frequency domain [3]

$$w(\omega) = 0.54D(\omega) + 0.46\left[D\left(\omega - \frac{2\pi}{M}\right) + D\left(\omega + \frac{2\pi}{M}\right)\right] \qquad (5)$$

Where

$$D(\omega) = e^{j\omega/2}\frac{\sin M^{\omega}/2}{\sin^{\omega}/2} = \text{Drichlet kernel}$$

From the fig.3, we have analyzed that M=64, the average side lobe peak of hamming window is -42.5dB.

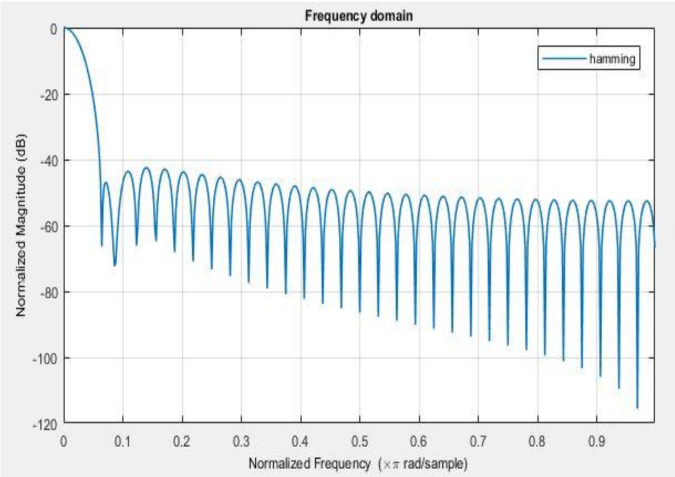

Fig.3. Amplitude spectrum of Hamming window for M=64.

3.Gaussian window: -

Gaussian window mathematically defined as in the time domain [3]

$$w(n) = e^{\left[-\frac{1}{2}\left(\frac{\alpha|n|}{M/2}\right)^2\right]} \; 0 \le |n| \le M/2$$

(6)

In the gaussian window α is the adjustable function. When we increase the value of α then main lobe width will increase and side lobe attenuation will decrease.
From the fig.4, we have analyzed that for M=64, and α =3.001, the average side lobe peak of gaussian window is -57.2dB.

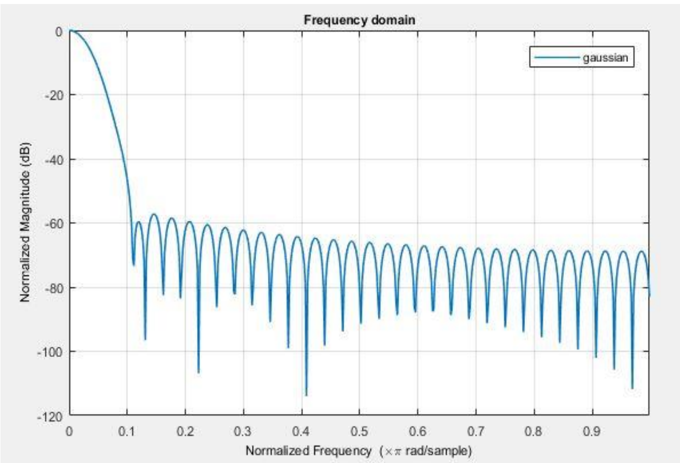

Fig.4. Amplitude spectrum of Gaussian window for M=64.

4. Blackman window: -

It is the modify version of cosine window. Blackman window mathematically defined as in the time domain [3].

$$w(n) = \sum_{k=0}^{M/2}(-1)^k a_k \cos\left(\frac{2\pi nk}{M}\right) \quad (7)$$

In frequency domain [3]
$K = 2, a_0 = 0.42, a_1 = 0.50, a_2 = 0.08$

$$w(\omega) = \sum_{k=0}^{M/2}(-1)^k\left(\frac{a_k}{2}\right)\left[D\left(\omega - \frac{2\pi}{M}k\right) + D\left(\omega + \frac{2\pi}{M}k\right)\right] \quad (8)$$

From the fig.5, we have analyzed that M=64, the average side lobe peak of Blackman window is -58.1dB.

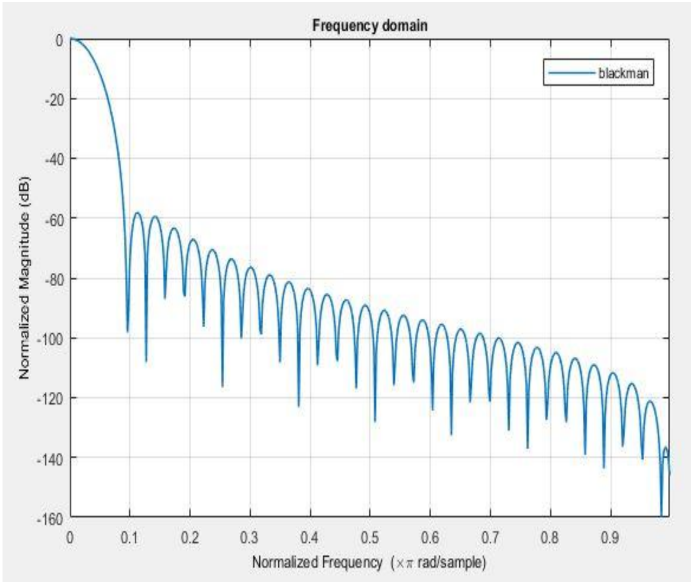

Fig.5. Amplitude spectrum of new Blackman window for M=64.

VI. CONCLUSION

The paper presents a window methodology for the design of FIR filters, based on an approximation of the desired filter frequency response by using different window functions, with a simple procedure that starts from the usual design specifications. The proposed method aims to satisfying two conflicting requirements: Simplicity of implementation, comparable to that of window-based design methods and accuracy in the fulfillment of design requirements. The side love of Gaussian window, Hamming window, Kaiser window and Blackman window are -57.2, -42.5, -58.3, and -58.1 respectively. So, we conclude that Kaiser window is better than the other window.

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