

# Comparison of Band-stop FIR Filter using Modified Hamming Window and Other Window functions and Its Application in Filtering a Mutitone Signal

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**Abstract**—In this paper Matlab program is used to implement a Band-stop FIR filter using modified coefficient of the Hamming window function and its application in filtering a Multitone input signal. FIR filter designed using modified coefficient of the Hamming window function provides smaller main lobe width and sharp transition band compare to Hamming window. This type of filter plays very important role in spectral analysis of different types of signal. In spectral analysis applications a small main lobe width of the window function in frequency domain is required for increasing the ability to distinguish two closely spaced frequency components. Experimental results show that the band frequency component of the mixed input signal successively eliminates by using this band-stop FIR filter. Comparison of band-stop FIR filter using modified window, Hanning window and Hamming window are shown in fig. Further, we compare of the input and output signal in frequency and time domain using modified window, Hanning window and Hamming window functions. The simulation results show that the filter designed using modified window function is more efficient than Hanning and Hamming window function.

**Keywords**-FIR filters, Hanning Window, Hamming Window, Modified Hamming Window, Band stop filter, FFT, IFFT

## I. INTRODUCTION

In the digital world, the digital signal processing has become an extremely important subject. A fundamental aspect of digital signal processing is filtering. A digital filter is a system that performs mathematical operations on a sampled, discrete-time signal to reduce or enhance certain aspects of that signal. There are two types of digital filters on the basis of the impulse response of the filter: Infinite Impulse Response (IIR) filters, and Finite Impulse Response (FIR) filters. FIR filters are preferred over IIR filters, because FIR digital filters have a strictly linear phase, highly stable, non-recursive structure and arbitrary amplitude-frequency characteristic etc. [1],[2]. The design and simulation analysis of the digital filter is quickly and efficiently achieved by using powerful computing capabilities of MATLAB [3].

FIR filter is described by the difference equation.

$$y(n) = \sum_{k=0}^{N-1} (h(k)x(n-k)) \quad (1)$$

$x(n)$  is the input signal and  $h(n)$  is the impulse response of FIR system.

The transfer function of a causal FIR filter is described by:

$$H(z) = \sum_{k=0}^{N-1} (h(k)z^{-k}) \quad (2)$$

The direct-form realization is the simplest structure in several realization structures of FIR digital filters. The direct-form I realization structure is shown in Fig.1 [2].

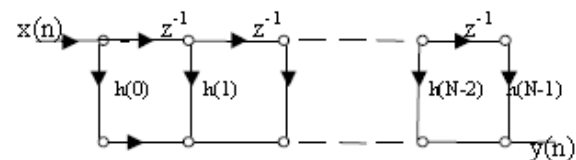


Figure1. Direct form realization structure of an FIR system

A simple and effective way to design digital FIR filter is window method. In this method infinite impulse response of the ideal prescribed filter is truncated by using a Window function. The main advantage of this design technique is that the impulse response coefficient can be obtained in closed form and can be determined very quickly [4]. The Window method is simple in operation, easy to understand and very convenient method for designing digital FIR filter.

The most popular and widely used window functions are; Rectangular window, Hanning window, Hamming window and Kaiser window. In the literature survey, different windows are used for the applications of Digital FIR filter design and spectral performance analysis [5]-[6]. An adjustable Kaiser window function is used for performance enhancement study of FIR filters in [7].

Implementation of Linear FIR Low-pass Filter Based on Kaiser Window Function and its application in filtering a signal is given in [8]. A new window function is described in [9]. In the analysis of Fourier transform of these different window functions, for the fixed length the Hanning and Hamming window have significantly lower side-lobe amplitude but the main lobe width is wider compare to Rectangular window. The Kaiser window is a kind of adjustable window function which provides independent control of the main lobe width and ripple ratio. But the Kaiser window has the disadvantage of higher computational complexity due to the use of Bessel functions [9].

In this paper a band-stop FIR filter is designed using modified coefficient of Hamming window and its application in filtering a Multitone signal. FIR filter designed using modified coefficient of the Hamming window function provides smaller main lobe width and sharp transition band compare to Hamming window. This type of filter is very useful in spectral analysis of different types of signals. Further, we compare of the input and output signal in frequency and time domain using modified window, Hanning window and Hamming window functions. The simulation results show that the filter designed using modified window function is more efficient than Hanning and Hamming window function.

## II. FIR FILTER DESIGN TECHNIQUES

To design an FIR filter means to determine the coefficients of a causal FIR filter whose frequency response closely approximates the specific frequency response characteristics. The required characteristics are stated in the given filter specifications. There are different methods for design of FIR digital filter.

- (I) Fourier series method
- (II) The window method
- (III) Frequency sampling method
- (IV) Optimal filter design method

Window method is widely used for the design of FIR filter, because of its simple operation, convenient and intuitive physical meaning. In this method, the impulse response of ideal filter was obtained by applying inverse Fourier transform to the ideal frequency characteristics of digital filter. This infinite impulse response of ideal filter must to multiply by a finite length window function for obtaining the impulse response of FIR filters.

Different kinds of window functions are used in different digital signal processing applications. Efficient window function is selected according to desired requirements. Hanning window, Hamming window and Kaiser Window are widely used in different digital signal

processing applications. The Kaiser window is a kind of adjustable window function which provides independent control of the main lobe width and ripple ratio. But the Kaiser window has the disadvantage of higher computational complexity due to the use of Bessel functions. In this paper a modified window function based on Hamming window function is used for designing an FIR band-stop filter in an efficient manner of spectral analysis applications.

*Design procedure of FIR filters using the window method [11];*

1. Suppose the transfer function of ideal desired filter is given by the equation.

$$H_d(e^{jw}) = \sum_{n=-\infty}^{n=+\infty} (hd(n)e^{-jnw}) \quad (3)$$

2. Impulse response  $h_d(n)$  of ideal filter was obtained by applying inverse Fourier transform to the ideal frequency response  $H_d(e^{jw})$  of digital filter.

$$h_d(n) = \frac{1}{2\pi} \int_{-\pi}^{\pi} H_d(e^{jw}) e^{jnw} dw \quad (4)$$

3. In the window method design procedure, we developed a causal linear-phase FIR filter by multiplying an infinite-duration impulse response (IIR) by a finite-duration window function.

$$h(n) = h_d(n) \cdot w(n) \quad (5)$$

4. In the digital FIR filter design procedure shape and length of Window function sequence were very critical aspect. The window function  $w(n)$  is selected according to requirements of transition bandwidth and stop-band attenuation of FIR filter.

5. The frequency response of designed FIR filter is expressed by

$$H(e^{jw}) = \sum_{n=0}^{N-1} (h(n)e^{-jnw}) \quad (6)$$

## III. DESIGNING PROCEDURE OF BAND-STOP FIR FILTER

*(A) Design steps of fir band stop filter [2,11]:*

1. Specify the ideal frequency response:

$$\begin{aligned} H_d(e^{jw}) &= 1, \text{ when } 0 \leq |w| \leq w_{c1} \\ H_d(e^{jw}) &= 0, \text{ when } w_{c1} \leq |w| \leq w_{c2}, \\ H_d(e^{jw}) &= 1, \text{ when } w_{c2} \leq |w| \leq w_s/2 \end{aligned} \quad (7)$$

The cutoff frequency band of the ideal band stop filter is  $[w_{c1} w_{c2}]$  and  $w_s$  is sampling frequency.

2. The impulse response  $h_d(n)$  of ideal filter was obtained by applying inverse Fourier transform to the ideal frequency response  $H_d(e^{jw})$  of digital filter.

$$h_d(n) = \frac{1}{2\pi} \left[ \int_{-w_{c1}}^{w_{c1}} e^{jnw} dw + \int_{-w_{c2}}^{\pi} e^{jnw} dw + \int_{-\pi}^{-w_{c2}} e^{jnw} dw \right] \quad (8)$$

3. The window function  $w(n)$  and window length  $N$  were identified according to the main lobe width and side lobe attenuation of the window function.

In this paper three common window functions are used for designing a FIR filter.

(i). Hanning window function

$$w(n) = \begin{cases} 0.5 - 0.5 \cos\left(\frac{2n\pi}{N-1}\right), & 0 \leq n \leq N-1 \\ 0, & \text{otherwise} \end{cases} \quad (9)$$

(ii). Hamming window function

$$w(n) = \begin{cases} 0.54 - 0.46 \cos\left(\frac{2n\pi}{N-1}\right), & 0 \leq n \leq N-1 \\ 0, & \text{otherwise} \end{cases} \quad (10)$$

(iii). A Generalized Hamming window function

$$w(n) = \begin{cases} \alpha - (1 - \alpha) \cos\left(\frac{2n\pi}{M-1}\right), & 0 \leq n \leq N-1 \\ 0, & \text{otherwise} \end{cases} \quad (11)$$

Modified coefficient of Hamming window function for  $\alpha = 0.72$

$$w(n) = \begin{cases} 0.72 - 0.28 \cos\left(\frac{2n\pi}{N-1}\right), & 0 \leq n \leq N-1 \\ 0, & \text{otherwise} \end{cases} \quad (12)$$

4. Obtain values of causal linear phase FIR coefficients  $h(n)$  by multiplying  $h_d(n)$  and  $w(n)$ .

$$h(n) = h_d(n) \cdot w(n) \quad (13)$$

5. the frequency response of designed FIR filter is obtained by taking the Fourier transform of  $h(n)$ .

$$H(e^{jw}) = \sum_{n=0}^{N-1} (h(n) e^{-jnw}) \quad (14)$$

(B) Parameter specification:

Take a mixed input signal is defined as;

$$s(t) = \sin 2\pi f_1 t + \sin 2\pi f_2 t + \sin 2\pi f_3 t + \sin 2\pi f_4 t \quad (15)$$

where  $f_1=400\text{HZ}$ ,  $f_2=1380\text{HZ}$ ,  $f_3=1620\text{HZ}$ ,  $f_4=2600\text{HZ}$

A filter was designed to filter band-frequency signal components in the range  $f_{\text{stop}}=[1200 \text{ } 1800]$  Hz. According to the Nyquist-Shannon sampling theorem, the sampling frequency  $f_s$  should be greater than or equal to the double of the maximum frequency in all the signal frequency components.

A cutoff frequency of stop-band filter is  $f_{\text{stop}}=[1200 \text{ } 1800]$  Hz. Take Sampling frequency is 6000 Hz, Assume order of filter is 21.

#### IV. MATLAB SIMULATION RESULT

Amplitude-frequency characteristic curve of band-stop FIR filter using Hanning, Hamming and Modified window function are shown in fig2.

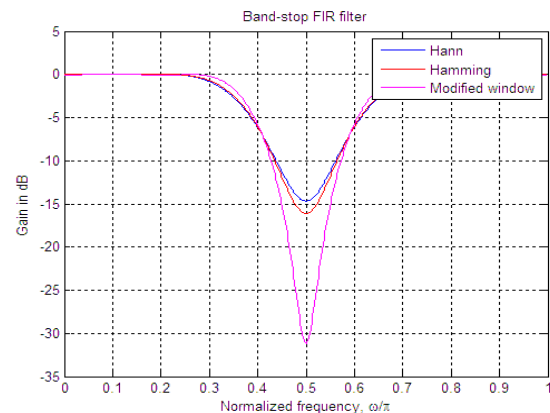


Figure2. The amplitude frequency characteristic curve of Band-stop FIR filter using different window function.

In Fig.3 four frequency components  $f_1$ ,  $f_2$ ,  $f_3$  and  $f_4$  are shown in the frequency spectrum of the input signal, the below plot is the frequency spectrum of filtered signal using the Hanning window function. The frequency spectrum of filtered signal using Hamming window and Modified window function is shown in fig. 4. Two band frequency components  $f_2$  and  $f_3$  of the input signal were greatly suppressed after filtering using the FIR band-stop filter designed using Modified window function comparing to Hanning and Hamming window function because it provides small main lobe width and sharp transition band comparing to Hanning and Hamming window function.

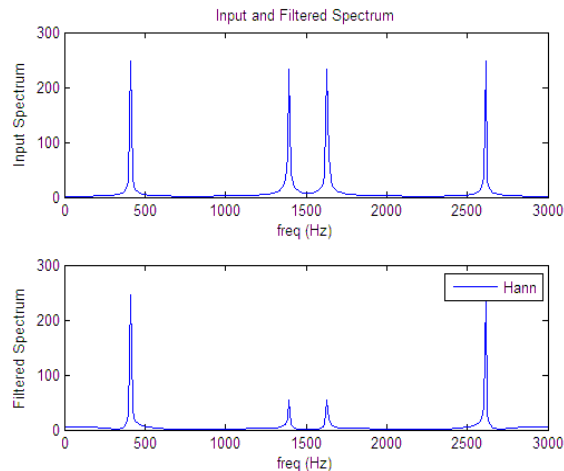


Figure3 Frequency spectrum of input and filtered signal using the Hanning window function.

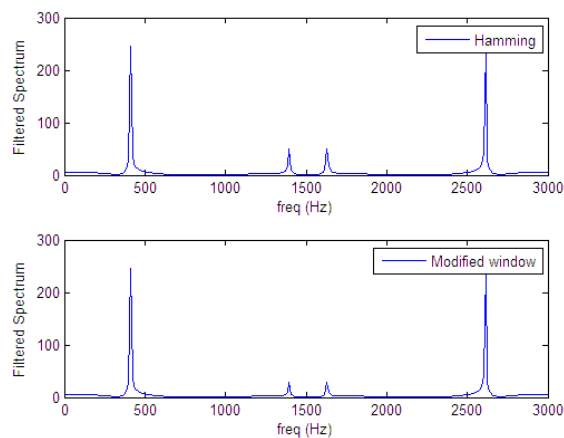


Figure 4 Frequency spectrum of filtered signal using Hamming and Modified window function.

Time domain waveforms of input mixed signals and output filtered signal using different window function are shown in fig5.

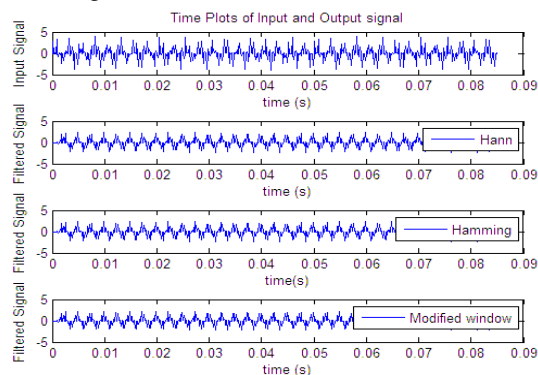


Figure 5 time domain waveforms of the signal before filtering and after filtering using different windows.

Through the spectral analysis of before and after filtering of input mixed signal, the input signal before filtering was composed of four kinds of frequency spectrum. In the output filtered signal only two kinds of the frequency spectrum are exist. In the time-domain input signal before filtering was very messy, while the filtered signal is very clean.

## V. CONCLUSION

Digital filters play a major role in digital signal processing applications. These types of filters are easily designed and also easy to use in various types of signal filtering applications. In this paper band-stop FIR filter has been designed using Modified coefficient of the Hamming window function and simulated with MATLAB programs. The experimental results show that the filter design using Modified window function has a small main lobe width and sharp transition band compared to Hamming and Hanning window function. So that for same length this window function provides efficient results compare to Hanning and Hamming window function and this type of filters are very useful in spectral analysis and many other applications. On the bases of the desired filter characteristics, different parameters can be easily changed in the Matlab program to meet the engineering requirements in the FIR filter design process.

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