

Design of Lowpass Fir Filter Using Rectangular and Hamming Window Techniques

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ABSTRACT

The aim of our paper is to design FIR filter using Rectangular and Hamming Window Techniques of order 10. In this paper, we represent the importance of filter in our daily life. The analysis of magnitude and phase response of proposed FIR low pass filter is performed using MATLAB simulation. The result window technique provides better result in term of magnitude and phase response of low pass FIR filter.

Keywords- DSP, Digital filter, low pass filter, FIR filter, Rectangular window and Hamming window

1. INTRODUCTION

A signal carries information, and the objective of signal processing is to extract useful information carried by the signal. The method of information extraction depends on the type of signal and the nature of the information being carried by the signal [1].

Digital Signal Processing (DSP) is an important (imp) field of study that has come about due to advances in communication theory, digital computer technology, and consumer devices. There is always a driving need to make things better and DSP provides many techniques for doing this. For example, people enjoy music and to download new songs. However, with slow Internet connection speeds (typically 56 kilobits per second for a dial-up modem), downloading a song could take hours. With MP3 compression software, though, the size of the song is reduced by as much as 90%, and can be downloaded in a matter of minutes. The MP3 version of the song is not the same as the original, but is a “good enough” approximation that most users cannot distinguish from the original [1][2].

Digital signal processing (DSP) is the most powerful technologies that will shape science and engineering in the 21st century. One of the important DSP applications is digital filter. The performance of digital filter in most cases better than the equivalent analog filter. Various methods of filter designing and analysis have been developed over past three decades. Digital filters are playing a very important role in DSP. Filter de-signing is the process of transformation of input sequence to obtain desired output sequence. Filter designing process can be described as an optimization problem where each requirement terms to an error function which should be minimized. Digital filter are of two types, Finite Impulse Response (FIR) filter and Infinite Impulse response (IIR) filter [3].

In Digital Signal Processing (DSP), an essential part is Filter. For different purposes Different types of filters are used *i.e.*

Table-1. Type of Filter and Purpose

S.N	Filter	Purpose
1	Low pass filter	Passes low frequency band
2	High pass filter	Passes high frequency band
3	Band pass filter	Passes selected range of frequency band
4	Band stop filter	Stops selected range of frequency

There are two types of filters *i.e.*

1. Finite Impulse Response (FIR) filter,
2. Infinite Impulse Response (IIR) filter,

FIR filters have the following advantages over IIR filters-

1. They can have an exact linear phase.
2. They are always stable.
3. The design methods are generally linear.
4. They can be realized efficiently in hardware.
5. The filter start-up transients have finite duration

FIR filters are employed in filtering problems where linear phase characteristics within the passband of the filter are required. If this is not required, either an IIR or an FIR filter may be employed. An IIR filter has lesser number of side lobes in the stopband than an FIR filter with the same number of parameters. For this reason, if some phase distortion is tolerable, an IIR filter is preferable. Also, the implementation of an IIR involves fewer parameters, less memory requirements and lower computational complexity.

2. FIR FILTER SIMULATION USING MATLAB

The windowing method requires minimum amount of computational effort; so window method is simple to implement. For the given window, the maximum amplitude of ripple in the filter response is fixed. Thus the stop band attenuation is fixed in the given window, but there is some drawback also of this method [2]. The design of fir filter is not flexible. The frequency response of fir filter shows the convolution of spectrum of window function & desired frequency response because of this; the pass band & stop band edge frequency cannot be precisely specified [4]. In this work we use rectangular window method.

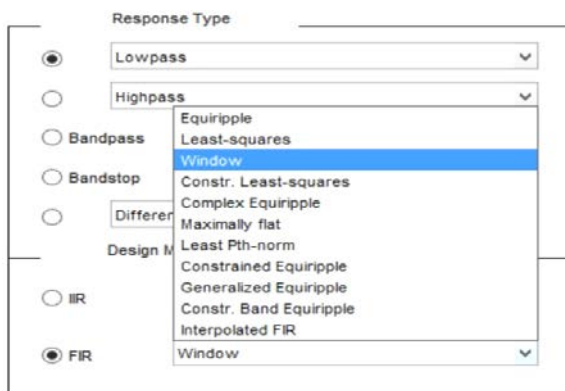


Fig.1 FIR filter simulation using MATLAB

Applications of DSP in area wise are as following: -

1).Telecommunication - Echo cancellation in telephone networks, equalization, telephone dialing application, modems, line repeaters, channel multiplexing, data encryption, video conferencing, cellular phone and FAX.

2).Military - Radar signal processing, sonar signal processing, navigation, secure communications and missile guidance.

3).Consumer electronics - Digital Audio/TV, electronic music synthesizer, educational toys, FM stereo application and sound recording applications.

4).Instrument and control – Spectrum analysis, position and rate control, noise reduction, data compression, digital filter, PPL, function generator.

5).Image processing- Image representation, image compression, image enhancement, image restoration and image analysis.

6).Speech processing- Speech analysis methods are used in automatic speech recognition, speaker verification and speaker identification.

7).Medicine- Medical diagnostic instrumentation such as computerized tomography (CT), X-ray scanning, Patient monitoring and X-ray storage/enhancement.

8).Signal filtering- Removing of unwanted background noise, removal of interference, separation of frequency bands and shaping of the signal spectrum. [3]

3. WINDOW METHOD

The desired frequency response of any digital filter is periodic in frequency and can be expanded in a Fourier series, i.e.

$$H_d(e^{j\omega}) = \sum_{n=-\infty}^{\infty} h_d(n) e^{-j\omega n} \dots\dots\dots (1)$$

$$\text{Where, } h(n) = \frac{1}{2\pi} \int_0^{2\pi} H(e^{j\omega}) e^{j\omega n} d\omega \dots\dots (2)$$

The Fourier coefficient of the series h(n) are identical to the impulse response of a digital filter. There are two difficulties with the implementation of above equation for designing a digital filter. First, the impulse response is of infinite duration and second, the filter is non-causal and unrealizable. No finite amount of delay can make the impulse response realizable. Hence the filter resulting from a Fourier series representation of H (e^{jω}) is an unrealizable IIR filter.

The windowing method requires minimum amount of computational effort; so window method is simple to implement. For the given window, the maximum amplitude of ripple in the filter response is fixed. Thus the stop band attenuation is fixed in the given window, but there is some drawback also of this method. The design of FIR filter is not flexible. The frequency response of FIR filter shows the convolution of spectrum of window function & desired frequency response because of this; the pass band & stop band edge frequency cannot be precisely specified [8][9].

Table-2 Parameter specification

Parameter	Values
Sampling Frequency(Fs)	48000Hz
Cut off Frequency(Fc)	10800Hz
Order(N)	10

3.1 RECTANGULAR WINDOW FUNCTION

The rectangular window (sometimes known as the **boxcar** or **Dirichlet window**) is the simplest window, equivalent to replacing all but N values of a data sequence by zeros, making it appear as though the waveform suddenly turns on and off.

1. $W(n)=1$
2. $W_R(n) = \begin{cases} 1 & \text{for } |n| \leq \frac{M-1}{2} \\ 0, & \text{otherwise} \end{cases}$

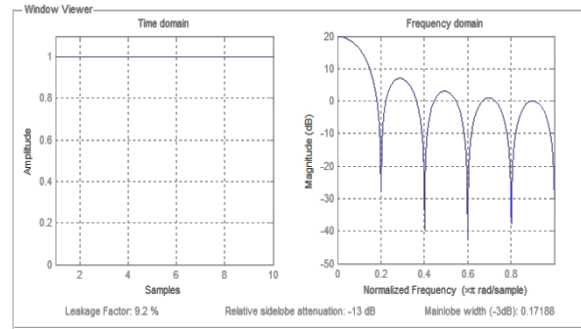


Fig.2 Time domain & frequency domain of Rectangular window

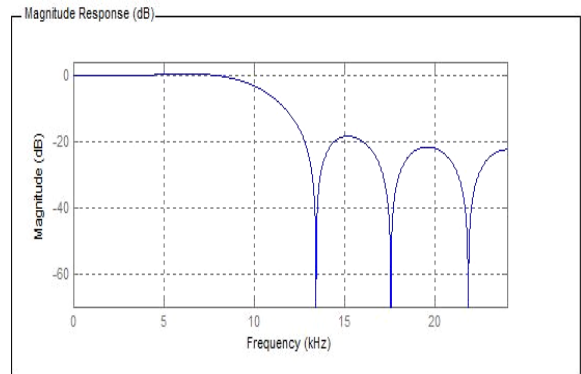


Fig.3 Magnitude response of Rectangular Window

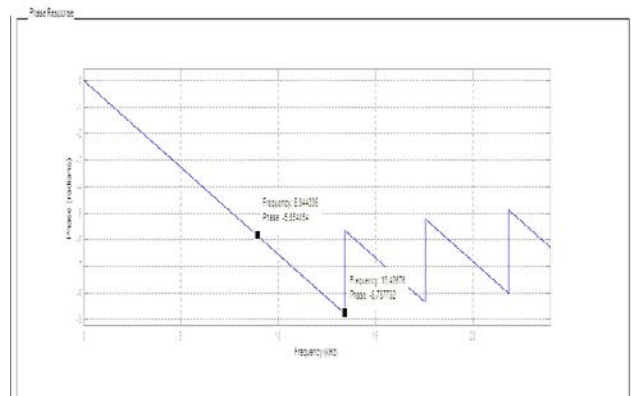


Fig.4 Phase response of Rectangular Window

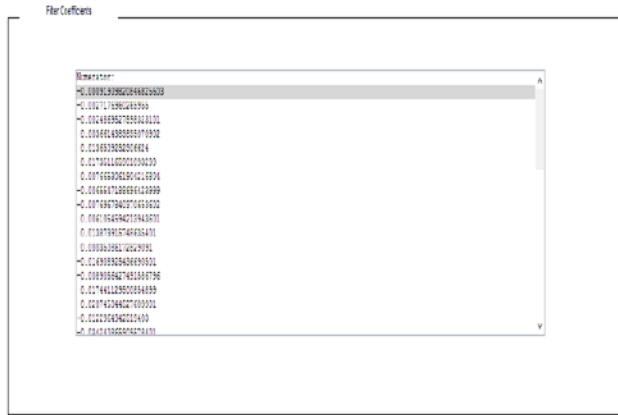


Fig.5 Filter coefficient of rectangular window

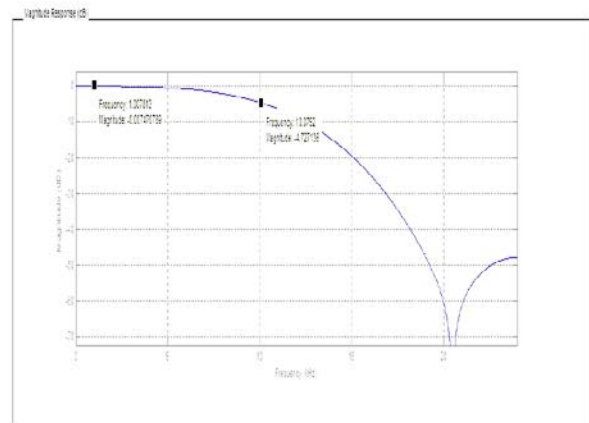


Fig. 7 Magnitude response of hamming window

Fig 3 shows the time domain and frequency domain of Rectangular window in which the relative side lobe attenuation is (-13dB) and main lobe width (-3dB) is 0.17188, Fig 4 shows the magnitude response of Rectangular window and Fig 5 shows phase response of Rectangular.

3.2 HAMMING WINDOW FUNCTION

The window with these particular coefficients was proposed by **Richard W. Hamming**. The window is optimized to minimize the maximum (nearest) side lobe, giving it a height of about one-fifth that of the Hann window.

1. $Y(n) = x(n) \cdot W(n)$
2. $W(n) = \alpha - \beta \cos\left(\frac{2\pi n}{N-1}\right)$

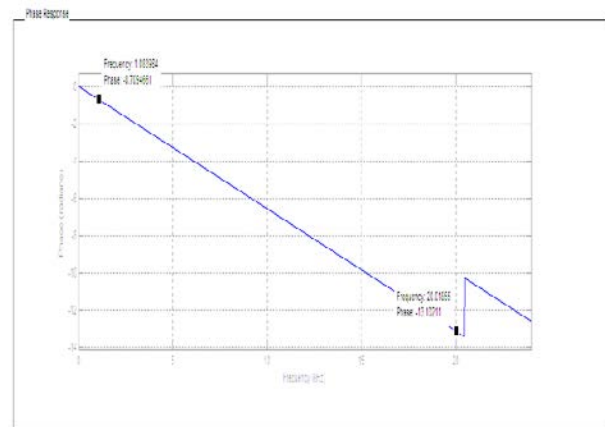


Fig. 8 Phase response of Hamming window

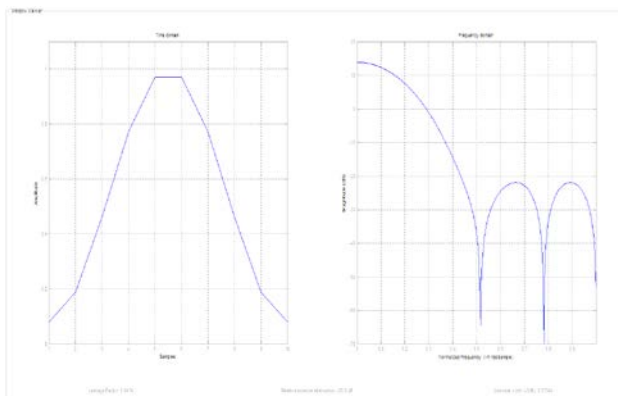


Fig.6 Time domain & Frequency domain of Hamming window

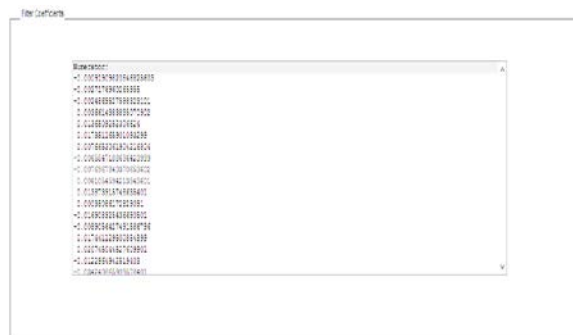


Fig.9 filter coefficient of Hamming window

Fig 6 shows the time domain and frequency domain of Hamming window in which the relative side lobe attenuation is (-35.8dB) and main lobe width (-3dB) is 0.27344, Fig 7 shows the magnitude response of Hamming window and Fig 8 shows phase response of Hamming.

4. COMPARATIVE ANALYSIS

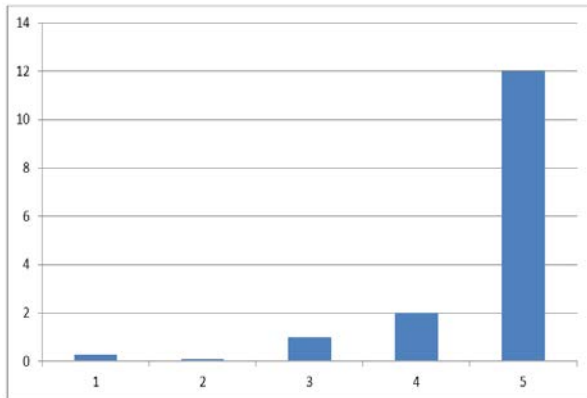


Fig. 10 Magnitude and Frequency plot of Rectangular Window

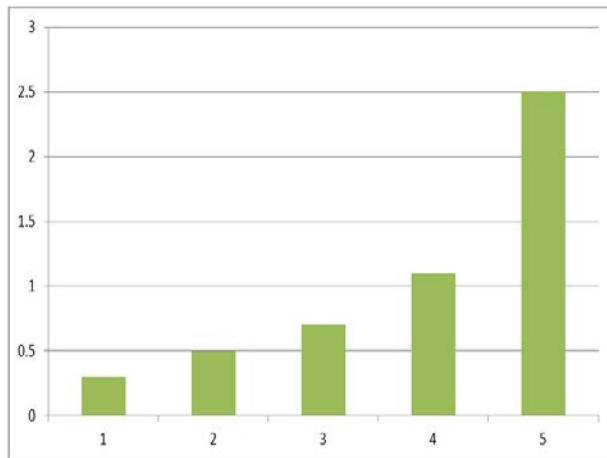


Fig.11 Magnitude and Frequency plot of Hamming Window

5. RESULT

Table 4: Simulation Result in MATLAB

Window Technique	Relative side lobe attenuation	Main lobe width (-3dB)
RECTANGULAR	(-13dB)	0.17188
HAMMING	(-35.8dB)	0.27344

Table 5: Magnitude and Frequency Result of Rectangular and Hamming window

Frequency (KHz)	Rectangular Window	Hamming Window
1	-0.003792	0.052435
2	0.01072	0.237656
3	0.08174	-0.037966
4	0.25219	-0.175526
5	0.47977	-0.397879
6	0.63071	-0.749774
7	0.56213	-1.306225

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CONCLUSION

In this paper, an FIR filter has been designed using Hamming window function and Rectangular window. Rectangular window function is simple in operation and provides greater flexibility in digital signal processing applications. In frequency resolution problems a small main lobe width of window function in frequency domain is required. The digital filters are easily designed and also easy to use in several of signal filtering applications. The choice of technique to design the filter depends heavily on the decision of designer whether to compromise accuracy of approximation. FIR filter design by using Hamming window is stable as compare to Rectangular and Rectangular window techniques ripples in pass band are less in hamming as compared to Rectangular window.

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