A Review Paper on Designing FIR Digital Filter using Window Functions

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Abstract: Digital filters play an important role in digital signal processing applications. They are widely used in digital signal processing applications, such as digital signal filtering, noise reduction, frequency analysis, multimedia compression, biomedical signal processing and image enhancement etc.. A simple and effective way to design digital FIR filter is window method. In this method, the infinite impulse response of the 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 easily and quickly. This paper reviewed some papers on comparing different window techniques and how to design FIR filters using these window functions.

***Index Terms* - FIR, MLW, ENBW,RSA, As.**

I. INTRODUCTION

Finite Impulse Response (FIR) Filter

A discrete-time filter produces a discrete-time output sequence y(n) for the discrete-time input sequence x(n). A filter may be required to have a given frequency response, or a specific response to an impulse, step, or ramp, or simulate an analog system. Digital Filters are classified either as finite duration unit pulse response (FIR) filters or infinite duration unit pulse response (IIR) filters, depending on the form of the unit pulse response of the system. In the FIR system, the impulse response sequence is of finite duration, i.e. it has a finite no. of non-zero terms. [1]
An FIR filter of length M is described by the difference equation, i.e.

$$y(n) = b_0x(n)+b_1x(n-1)+b_2x(n-2)+\ldots..+b_{M-1}x(n-M-1)$$

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

Why FIR Filters?

They are inherently stable. These filters can be designed to have a linear phase with a great flexibility in shaping their magnitude response. They are easy and convenient to implement also.[1]

II. FIR FILTER DESIGN METHOD

- Impulse response truncation – the simplest design method, has undesirable frequency domain-characteristics
- Windowing design method –simple and convenient
- Optimal filter design methods

III. DIFFERENT WINDOW FUNCTIONS

- Rectangular window function

$$w(n) = \begin{cases} 1 & ,0 \le n \le N-1 \\ 0 & , \text{otherwise} \end{cases} \quad (2)$$

- Hanning window function

$$w(n) = \begin{cases} 0.5 - 0.5\cos(2n\pi/N-1) & , 0 \le n \le N-1 \\ 0 & , \text{otherwise} \end{cases} \quad (3)$$

- Hamming window function

$$w(n) = \begin{cases} 0.54 - 0.46\cos(2n\pi/N-1), & 0 \le n \le N-1 \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

- Blackman window function

$$w(n) = \begin{cases} 0.42 - 0.5\cos\frac{2\pi n}{N-1} + 0.08\cos\frac{4\pi n}{N-1}, & 0 \le n \le N-1 \\ 0, & \text{otherwise} \end{cases} \quad (5)$$

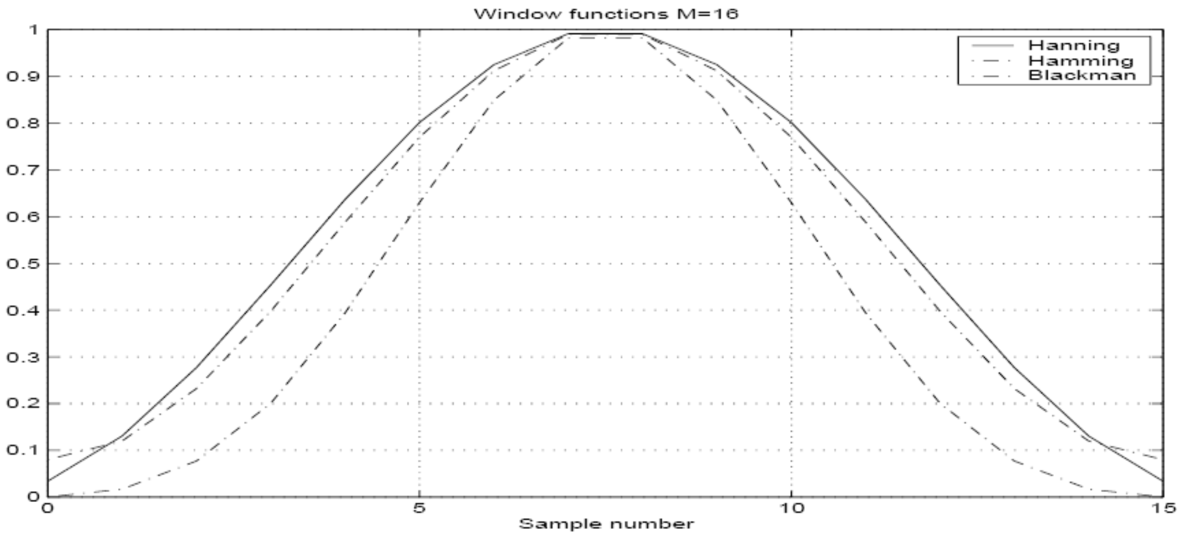

Figure -1- Time response of Hanning, Hamming and Blackman window function

The frequency response of window can be achieved by Discrete Fourier Transform of above time Equations.[2]

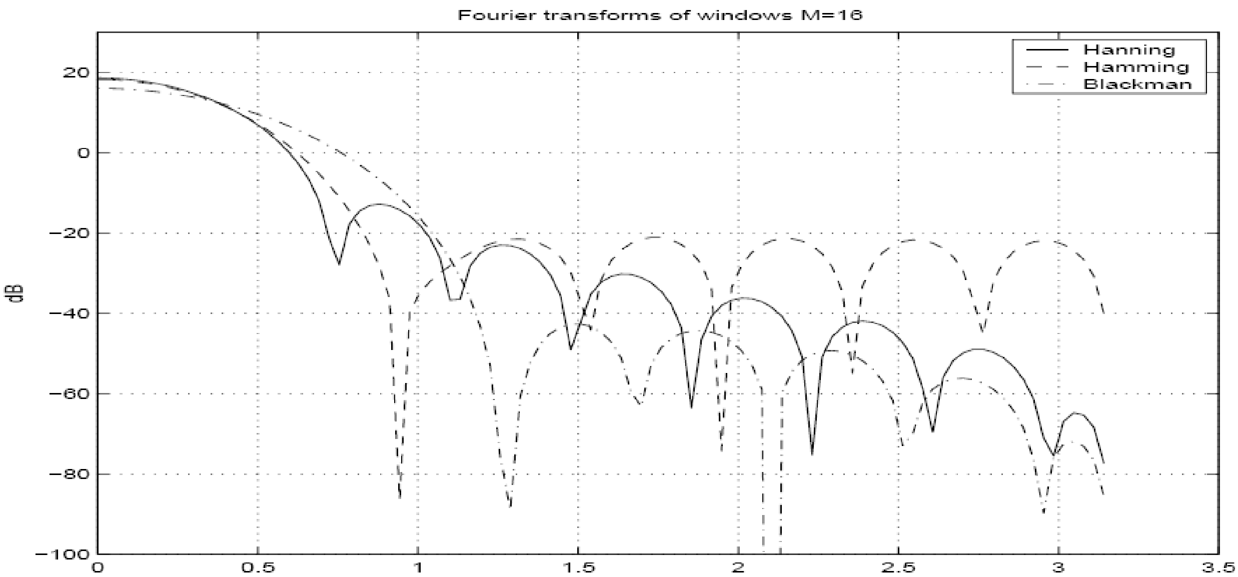

Figure 2- Frequency spectrum of Hanning, Hamming and Blackman window function

IV. PARAMETERS OF FREQUENCY RESPONSE

For comparison between window functions we have some frequency response parameters which will examine the performance of any window. Some of them are Relative Side-lobe Attenuation (RSA), Main-lobe width (MLW), Leakage Factor, Side-lobe amplitude, Roll-off, Main-lobe Amplitude, etc.

Some of these parameters are related to each other as Main-lobe width is dependent on system order. [3]

V. FIR FILTER DESIGN PROCEDURE VIA WINDOW METHOD

- Define filter specifications.

- Specify the window functions according to the filter specifications.
- Compute the filter order required for a given set of specifications.
- Compute the window function coefficients.
- Compute the ideal filter coefficients according to the filter order.
- Compute FIR filter coefficients according to the obtained window function and ideal filter coefficients.
- If the resulting filter has too wide or too narrow transition region, it is necessary to change the filter order by increasing or decreasing it according to needs, and after that above steps are iterated as many times as needed.

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

$$H(w) = \sum_{n=-\infty}^{\infty} h(n) e^{-jwn} \quad (6)$$

where

$$h(n) = \frac{1}{2\pi}\int_0^{2\pi} H(w) e^{jwn} dw \quad (7)$$

The impulse response of infinite duration is a difficulty with the implementation of Equation (6). The infinite duration impulse response can be converted to a finite duration impulse response by truncating the infinite series at n = -+N. But this results in undesirable oscillations in the pass-band and stop-band of the digital filter. This is due to the slow convergence of the Fourier series near the point of discontinuity. these undesirable oscillations can be reduced by using a set of time-limited weighting function , w(n), referred to as window functions, to modify the Fourier coefficients. [4]

Some of the design specifications of FIR low pass filters are Pass-band ripple, Stop-band ripple, Pass-band frequency (F_{pass}), Stop-band frequency (F_{stop}), Sampling frequency (Fs), Minimum stop-band attenuation (As), A_{pass}, A_{stop} ,etc.

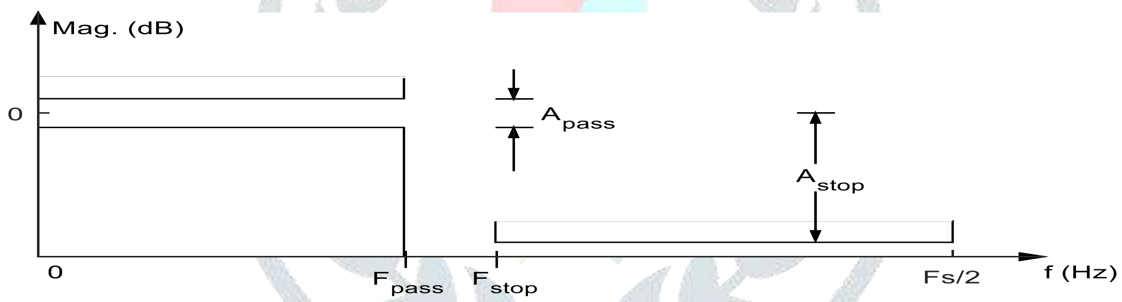

Figure 3- FIR low-pass filter specifications

VI. FUTURE WORK

After studying different window techniques and their implementation in digital FIR filters, it became clear that by changing some coefficients of these window functions we can enhance their performance and can produce desirable results. Parameters like Relative Side-lobe Attenuation (RSA), Main-lobe width (MLW), Leakage Factor, Side-lobe amplitude, Roll-off, Main-lobe Amplitude, minimum stop-band attenuation (As) helps in deciding the effectiveness of filtering process. These parameters are also helpful in comparing different window functions.

VII. ACKNOWLEDGEMENT

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VIII. REFERENCES

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