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Review: Performance Analysis of FIR Digital High Pass Filters

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ABSTRACT

In this paper, various design methods for FIR filter have been discussed and compared. This paper discusses the various design methods of high pass FIR filters using Windowing methods and optimal filter design methods. Windowing methods based on Rectangular, Hamming, Blackman and Kaiser Windows and optimal filter design method based on Least-square, Equiripple, Generalized Equiripple, and Constrained band equiripple. The magnitude responses are demonstrated for different design methods at particular cut off frequency and different filter order.

Keywords-**Blackman window, Digital filter, Equiripple filter, Fir filter FDA tool, High pass filter.**

I. INTRODUCTION

The focus of this paper will be on Finite impulse response (FIR) filters that have only a finite number of terms in their impulse response. FIR filters are digital filters with finite impulse response. They are also known as non-recursive digital filters as they do not have the feedback (a recursive part of a filter).The objective is not to achieve ideal characteristics, as it is impossible any way, but to achieve sufficiently good characteristics of a filter [1]. High pass filters are designed using Different types of FIR designed methods using the FDA tool of Matlab. Same main frequency and the Magnitude specifications are used in design but with different orders for each filter type. The transfer function of the FIR filter approaches the ideal as the filter order increases. FIR filters can have an exactly linear phase response. The implication of this is that no phase distortion is introduced in to the signal by the filter [2]. FIR filters are simple to design and they are guaranteed to be bounded input-bounded output (BIBO) stable. By designing the filter taps to be symmetrical about the center tap position, a FIR filter can be guaranteed to have linear phase. FIR filters also have a low sensitivity to filter coefficient quantization errors. This is an important property to have when implementing a filter on DSP processors or on an integrated circuit. The filter design and Analysis tool (FDA Tool) is a powerful graphical user interface (GUI) for designing and analyzing the filters quickly. FDA tool also provides tools for analyzing filters, such as magnitude and phase response [3]. Fig 1 shows the magnitude response of FIR filter in FDA tool is:

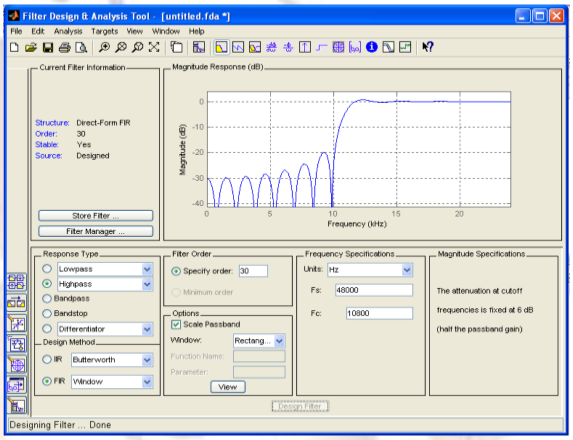

Fig.1 Magnitude response of FIR filter in FDA tool

A linear phase with integer slope corresponds to a simple delay in the time domain, and it reduces the phase distortion to a minimum in the frequency domain. The FIR filter of length M is described by the convolution of the unit sample response $h(n)$ of the system with input signal $x(n)$ and is represented by equation (1).

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

Thus impulse response of the filter denotes the coefficient of FIR filter. FIR filters specifications includes the maximum tolerable pass band ripple, maximum tolerable stop band ripple, pass band edge frequency and stop band edge frequency[1][3].

II. METHODOLOGY

1. Introduction: FIR filter is designed by two methods and implemented using MATLAB and then magnitude response is plotted.

1.1 Window techniques for digital FIR filter design: The simplest technique used to develop digital FIR filters is windowed filters. This technique is based on designing a filter using well-known frequency–domain transition functions called windows. The use of windows often involves choosing the lesser of two evils. Some windows, such as the Rectangular window, yields fast roll off in the frequency domain but have limited attenuation in the stop band along with poor group delay characteristics. Other windows, like the Blackman, have better stop band attenuation and group delay but a wide transition band. The transition band of the Hamming window is larger than the transition band of the rectangular window, due to its wider main lobe. The stop-band attenuation for the Hamming window is larger than the attenuation for the rectangular window. Windowed filters are easy to use and scalable and can be computed on the fly by the DSP [3]. In window method, the desired specification, $Hd(w)$ corresponding unit sample response $Hd(n)$ is determined using the following relation,

$$Hd(n) = \frac{1}{2\pi} \int_{-\pi}^{\pi} Hd(w)\, e^{jwn}\, dw \quad \ldots\ldots. (2)$$

Where

$$Hd(w) = \sum_{-\infty}^{\infty} hd(n) e^{-jwn} \quad \ldots\ldots.. (3)$$

In general, unit sample response $hd(n)$ obtained from the above relation is infinite in duration, so it must be truncated at some point say n=M-1 to yields an FIR filter of length M (i.e. 0 to M-1).

1.2 Optimal filter design methods for digital FIR filter design: In optimal filter design method various methods are used to design the filter coefficients again and again until a particular error is minimized. In Least square method there is no constraint on the response between the sample points, and poor results may be obtained. Least square method controls the response between the sample points by considering a number of sample points larger than the order of the filter. As the energy of the signal is related to the square of the signal, a squared error approximation criterion is appropriate to optimize the design of the FIR filter [3]. The optimal method of calculating FIR filter coefficients is very powerful, very flexible and very easy to apply. For this reason it has become the method of first choice in many FIR applications. The optimal method is based on the concept of the equiripple pass-band and stop-band [7]-[9].

III. RESULTS

Table 1 shows the parameter specifications and Table 2 shows the Orders at methods of designed the FIR filter.

Table 1 Parameter Specification

Parameter	Values
Normalized Sampling Frequency	48000 Hz
Normalized Pass-band Frequency	9600 Hz
Normalized Stop-band Frequency	12000 Hz

Table 2 Orders at FIR filter

Design Method	Type	Order
FIR (Window method)	Rectangular	10,20,30,40,50
	Blackman	10,20,30,40,50
	Kaiser (β =5)	10,20,30,40,50
	Hamming	10,20,30,40,50
FIR (Optimal method)	Least-Square	10,20,30,40,50
	Equipripple	10,20,30,40,50
	Generalized Equipripple	10,20,30,40,50
	Constrained-band Equipripple	10,20,30,40,50

All the methods of FIR filters are implemented in FDA tool at the same sampling frequency and the same pass-band and the same stop-band frequency.
In this paper different methods used for design the FIR filter at different orders. The results of Window methods at different Filters are represented in figures. Fig.2 shows the magnitude response of the Rectangular window at the different orders, Fig.3 shows the magnitude response of the Blackman window method, Fig.4 shows the magnitude response of the Kaiser Window method, and Fig.5 shows the magnitude response of the Hamming window method.

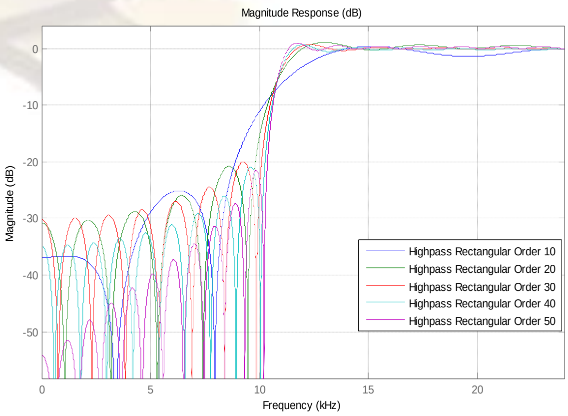

Fig.2 Magnitude response of Rectangular Window

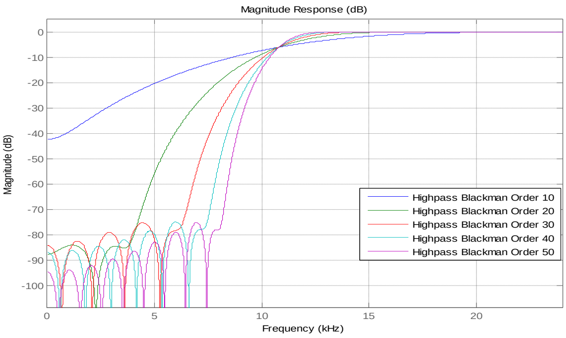

Fig.3 Magnitude response of Blackman Window

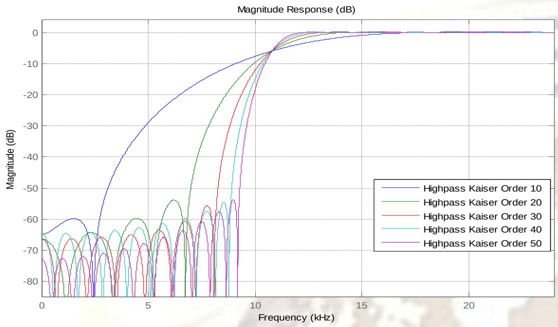

Fig.4 Magnitude response of Kaiser Window

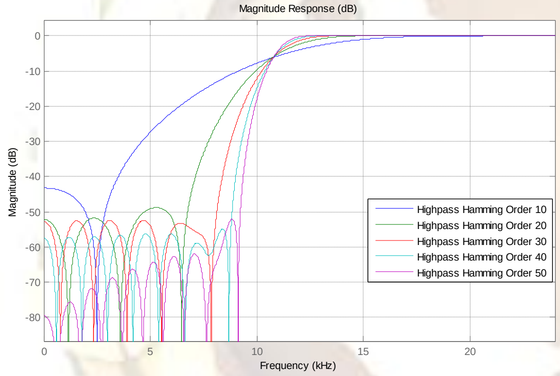

Fig.5 Magnitude response of Hamming Window

Second method of design FIR filter is optimal method. The results of methods based on optimal method are represented in figures. Fig 6 shows the magnitude response of the Least-square method, Fig 7 shows the magnitude response of the Equiripple method, Fig 8 shows the magnitude response of the Generalized Equiripple method, and Fig 9 shows the constrained-band equiripple method.

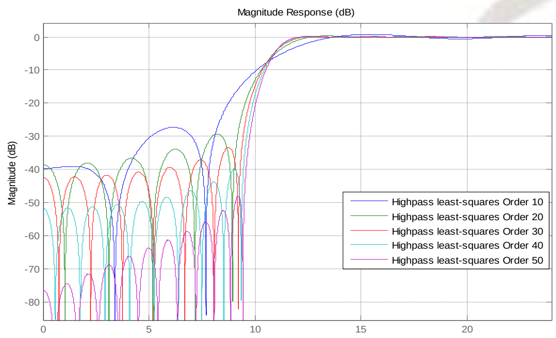

Fig.6 Magnitude response of Least-Square method

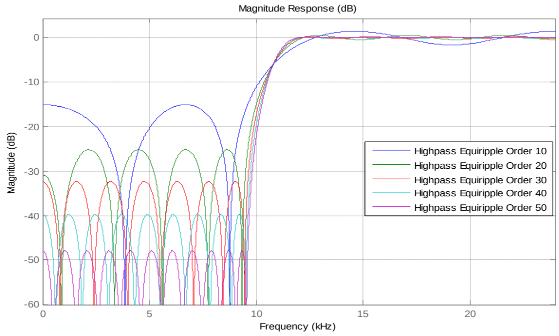

Fig.7 Magnitude response of Equiripple method

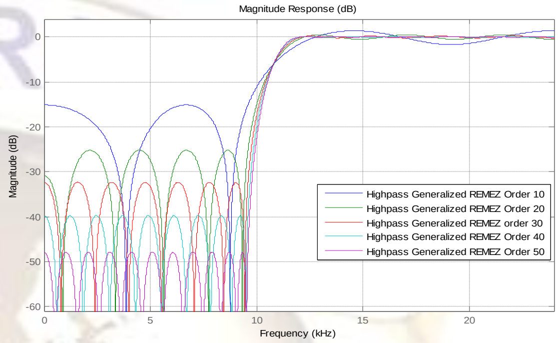

Fig.8 Magnitude response of Generalized Equiripple

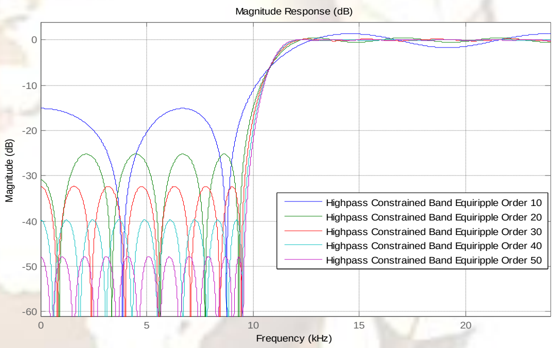

Fig.9 Magnitude response of Constrained-band equiripple method

In the case of comparison between window method and optimal method, the equiripple filter design found to be most suitable method. Fig 10 shows the comparison of the window method and optimal method at the same order of filter and frequency.

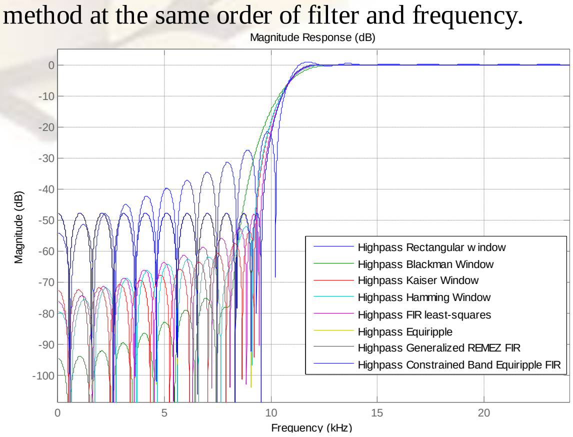

Fig.10 Comparison between different type of FIR at the same order 50

IV. CONCLUSION

This paper briefly describes the two techniques used to design FIR filter. The major advantage of window technique is its simplicity. The availability of well defined equations for calculating window coefficient has made this method preferable. But it offers very little design flexibility. Kaiser window offers very low order to meet given specification. The best digital filter design results comes for using the kaiser window from the windowing design technique, which has papameters β that allows adjustment of the compromise between the overshoot reduction and transition region width spreading. But when kaiser window is compared with optimal filter design method, equiripple filter design found to be most suitable method.

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