International Journal of Science, Engineering and Technology Research (IJSETR), Volume 4, Issue 6, June 2015

FIR FILTER DESIGN USING NEW HYBRID WINDOW FUNCTIONS

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Abstract-- One of the most widely used operations performed in DSP is digital filtering. Other than this DSP is used in numerous applications such as video compression, digital set-top box, multimedia and wireless communication. In this paper, Hybrid window function (which means combination of any two window functions) with various mathematical operations for designing a FIR low pass filter was proposed and compared the results with the designing of FIR filter with individual window function in terms of relative side lobe attenuation and peak amplitude of sidelobe. These results are simulated using MATLAB.

Index terms—**FIR filter, Hybrid windows, peak amplitude of sidelobe, RSA.**

I. INTRODUCTION

A filter is linear time invariant system, which removes unwanted noise or disturbances from desired signal [1-3]. It can be used in spectral shaping such as equalization of communication channels, signal detection in radar, sonar, biomedical applications etc. The pass band of the filter passes a band of desired frequencies without any distortion and stop band of the filter totally blocks band of unwanted frequencies. Accordingly, the digital filters are available as low pass filters, high pass filters, band pass filters and band reject filters.

Here, the designing of FIR low pass filter using hybrid window function takes place. Hybrid window is a new concept which is obtained by the combination of two different windows with different mathematical operations. The combination of Blackman and Kaiser was taken in this paper. The characteristics of FIR low pass filter, the windowing technique[4-9] and the required equations for the hybrid windows are explained. The implementation of the filters was carried out using MATLAB tool. The frequency response of FIR low pass filter using hybrid window and normal windows are shown further. Tabular forms for Relative side lobe attenuation, peak amplitude of side lobe are given in this paper for comparison

The characteristics of FIR filters, the windowing technique and the required equations for the hybrid windows are explained.

II. FIR FILTERS

Linear Time Invariant Finite impulse response filters constitute the backbone of DSP systems and are the most common digital filter. Signal separation and signal restoration are the two uses of filters. Signal restoration is used when the signal has been distorted in some way. While when the signal has been contaminated with noise or other signals, signal separation is needed. The direct form realization structure of FIR filter can be described by simple convolution operation as described by equation. where x is input signal, y is convolved output and h is filter impulse response.

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

The desired frequency response Hd(ejω) of any digital filter is periodic in frequency and can be expanded in a Fourier series, using the following relation:.

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

$$\text{Where } \; h_d(n)=1\backslash 2\pi\int_0^{2\pi} \mathrm{Hd}(e^{j\omega}) * e^{jn\omega} \quad (2)$$

Design techniques for FIR filters :

There are three well known method of design techniques for linear phase FIR filters

1.Fourier series method and window method
2.Frequency sampling method
3.Optimal filter design method

III. WINDOW FUNCTIONS

In signal processing, a window function is a mathematical function that is zero-valued outside of some chosen interval. For instance, a function that is

ISSN: 2278 – 7798

constant inside the interval and zero elsewhere is called a rectangular window, which describes the shape of its graphical representation. When another function or a signal (data) is multiplied by a window function, the product is also zero-valued outside the interval: all that is left is the part where they overlap; the "view through the window".

The following comes under the classification of the windows

- Rectangular window
- Triangular window
- Hanning window
- Hamming window
- Blackman window
- Kaiser window

Characteristics of a desired window:

1. The central lobe of the frequency response of the window should contain most of the energy and should be narrow.
2. The highest side lobe level of the frequency response should be small.
3. The side lobes of the frequency response should decrease in energy rapidly as' w' tends to π

Procedure for FIR filter design using windows :

1.Choose desired frequency response of the filter Hd(ω)

2.Take inverse fourier transform of Hd(ω) to obtain the desired response hd(n).

By definition of inverse fourier transform

$$h_d(n) = \frac{1}{2\pi}\int_{-\pi}^{\pi} e^{j\omega n} H_d(\omega) \qquad (3)$$

3.Choose window function w(n)and determine the product of hd(n) and w(n).

Let product this given by

h(n)=hd(n)*w(n) (4)

4.The transfer function H(z) of the filter is obtained by taking z-transform of h(n).

Realize the filter by a suitable structure.

Summary of windows:

The triangular window has a transition width twice that of rectangular window. The attenuation in triangular window is less. The Hamming and Hanning windows have same transition width. But the Hamming window is most widely used, because, it generates less ringing in side lobes. The Blackman window reduces the side lobe level at the cost of increase in increase in transition width. The Kaiser window superior to other windows because the transition band is small. By varying the parameter α desired side lobe level and main lobe peak can be achieved. Further the main lobe width can be varied by varying the length N.

Proposed new Hybrid window:

The hybrid window is a type of window formed due to combination of two different types of windows. The combining of the windows may be done by an operation like mathematical operations. We take addition, multiplication, averaging, Ex-or of two windows.

The windows which are taken are Blackman window and Kaiser window

Blackman window:

wb(n)=0.42+0.5cos(2*pi*n/N-1)+0.08cos(4*pi*n/N-1)

for |n|≤-(N-1)/2

=0 otherwise (5)

Kaiser window:

wk(n)=Io[alpha(1-(2*n/N-1)2)0.5]/I0[alpha]

for |n|≤-(N-1)/2

=0 otherwise (6)

where alpha is adjustable parameter

Io(x)= zeroth- order Bessel function

Addition:

wn(n)=wb(n)+wk(n) [3.18]

= 0.42+0.5cos(2*pi*n/N-1)+0.08cos(4*pi*n/N-1)+Io[alpha(1-(2*n/N-1)2)0.5]/I0[alpha] (7)

Multiplication:

wn(n)=wb(n)*wk(n)

= 0.42+0.5cos(2*pi*n/N-1)+0.08cos(4*pi*n/N-1)*Io[alpha(1-(2*n/N-1)2)0.5]/I0[alpha] (8)

Averaging:

wn(n)=(wb(n)+wk(n))/2= 0.21+0.5cos(2*pi*n/N-1)+0.04cos(4*pi*n/N-1)+0.5Io[alpha(1-(2*n/N-1)2)0.5]/I0[alpha] (9)

Ex-or:

wn(n)=k*wb(n)+(1-k)wk(n) [3.21]

=k*(0.42+0.5cos(2*pi*n/N-1)+0.08cos(4*pi*n/N-1))+(k-1)*(Io[alpha(1-(2*n/N-1)2)0.5]/I0[alpha])

where k=0 to 1. (10)

The hybrid window technique is used for improvisation of the signal response of the filter. If we consider only single window, a lot of Ripples are added to the signal. But by using this combination the ripples are decreased, and the stop band attenuation decreased, and the accuracy increases.

IV. RESULTS AND DISCUSSION

Results are generated for low pass filter using normal windows and with proposed hybrid windows. RSA and peak amplitude of side lobe for fir low pass filter is shown in tables using different new hybrid windows.

Blackman window and Kaiser window are taken here for generating new hybrid window functions using mathematical operations.

ISSN: 2278 – 7798

Table 1. **FIR low pass filter responses using normal windows**.

Window	Relative sidelobe attenutation(dB)	Peak amplitude of sidelobe (dB)
Rectangular	1.3dB	-22.03dB
Triangular	-0.1 dB	-27.71dB
Hanning	0 dB	-43.96dB
Hamming	0 dB	-50.26dB
Blackman	-75.29 dB	-75.29dB
Kaiser	-105.4 dB	-109.3 dB

Hybrid Window frequency responses:

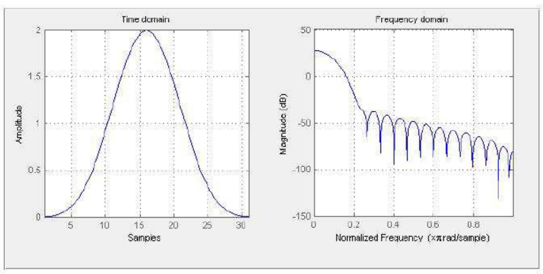

Fig 1. .Addition operator window Response

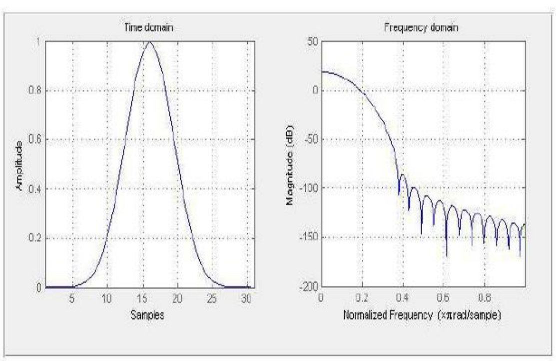

Fig 2. Multiplication operator window Response

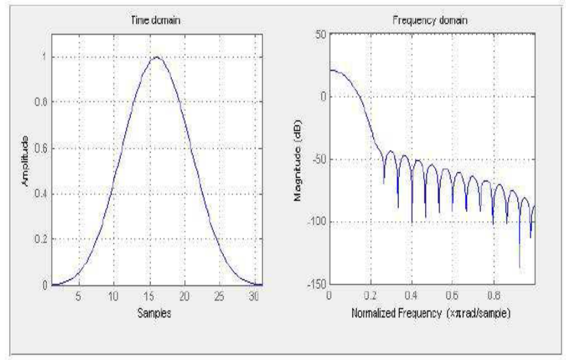

Fig 3. Average operator window Response

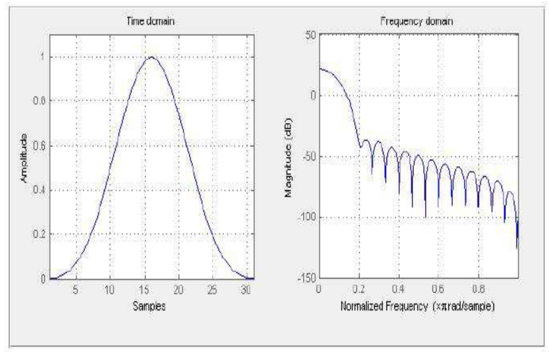

Fig 4. Ex-or operator window Response

FIR low pass Filter frequency responses:

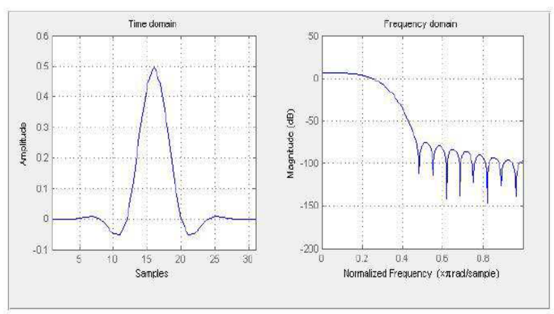

Fig 5. LPF response using Addition operator window

ISSN: 2278 – 7798

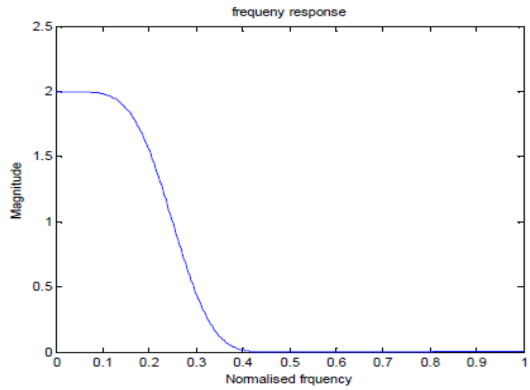

Fig 6. LPF response using Addition operator window

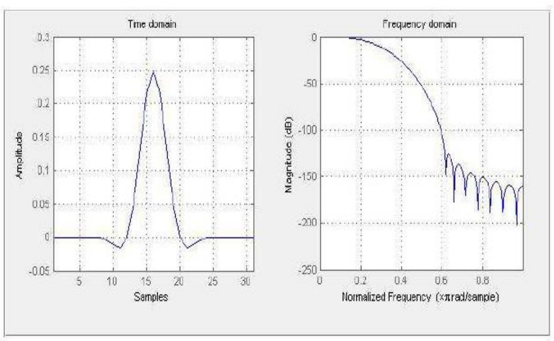

Fig 7. LPF response using multiplication operator window

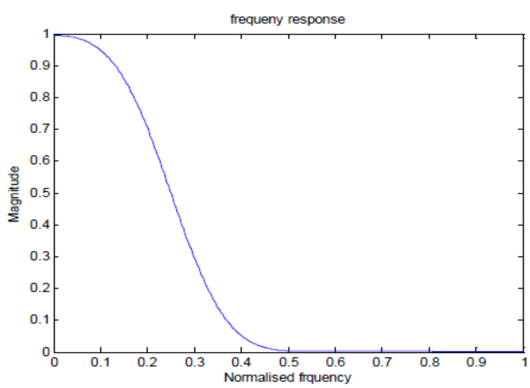

Fig 8. LPF response using multiplication operator window

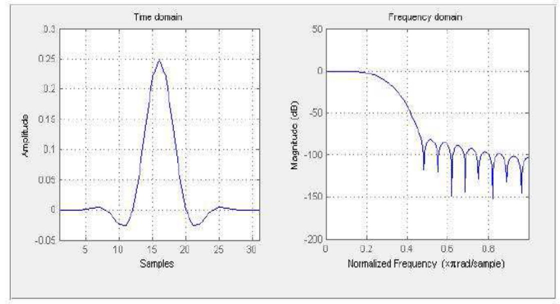

Fig 9. LPF response using Average operator window

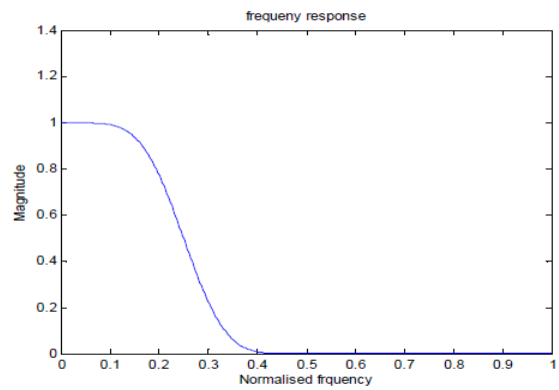

Fig 10. LPF response using Average operator window

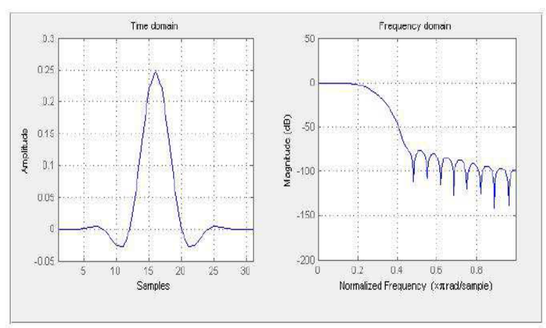

Fig 11. LPF response using Ex-or operator window

ISSN: 2278 – 7798

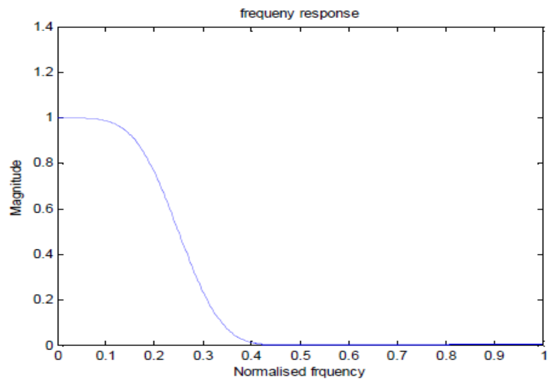

Fig 12. LPF response using Ex-or operator window

Table 2 **FIR low pass filter responses using proposed new Hybrid windows**

Window	Operation	Relative sidelobe attenutation(dB)	Peak amplitude ofside lobe(dB)
Blackman		-75.3dB	-75.29 dB
Kaiser		-107.4dB	-109.39dB
Hybrid(Kaiser	Addition	-81.5dB	-76.05dB
+Blackman)	Averaging	-81.5 dB	-81.32 dB
	Ex-or	-96.9 dB	-97.03 dB
	Multiplication	-125.6 dB	-125.6dB

V. CONCLUSION AND FUTURE SCOPE

In this paper, first new Hybrid window functions are designed with different mathematical operations performed on existing Blackman and Kaiser window functions and then FIR low pass filter was implemented using these new hybrid windows, so that the ripples in the filter can be decreased and attenuation of the stop band also increased. From figures 1 to 12 and tables 1 & 2, it is clear that out of different proposed hybrid window functions, FIR filter response using multiplication operation hybrid window gave better results compared to other operations and existing windows. This type of filter gives accurate results for real time signals. The extension for this paper can be done by Hybrid and new window types for high pass, band reject, and band pass filters.

VII. REFERENCES

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ISSN: 2278 – 7798