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A Novel Window Function for Designing FIR Low Pass and Band Pass Filter

R. Sivarajan[1], B. Elango[2]

[1, 2]Assistant Professor, Adhiparasakthi Engineering College, Melmaruvathur

Abstract: ***Generally filters are used to remove unwanted materials or particles. In signal processing, filter is used to filter the signal with undesired frequency. In most of the communication system, Low pass filters or Band pass filters are used to filter the noise signal from the original speech signal because speech signal has very low frequency compared to noise signal generated from the channel. This paper proposes a new FIR filter in order to get the near ideal response with lowest possible order.***

Keywords: Window, Passband, Stopband, gain, order

1. Introduction

Filters are essential in communication systemwhere the transmitter transmit a message to the receiver through the channel. In communication system, low frequency voice signal is transmitted through the channel. Hence low pass filter or band pass filter is preferred for this communication.

There are various approaches are there for designing low pass filter or band pass filter. They are Fourier series, windowing technique and frequency sampling technique.

The Fourier series method of FIR filter design uses truncated value of infinite Fourier series which causes abrupt changes in pass band and stop band, which is called Gibb's oscillation. So to avoid Gibb's oscillation, the resultant impulse response can be multiplied with window sequence. There are several window sequence are present namely rectangular window, Hamming Window and Hanning Window.

2. Literature Survey

The literature paper [1] suggests an advanced peak windowing method which is used to successfully over whelm the peak signals to the chosen threshold level in case those successive peaks arise in the interior half of the window length. The difference among the performance progresses is reached by the Hamming window over the Kaiser Window spectral characteristics. But in case of the ripple ratio, Kaiser Window has got better results than hamming window. This shortcoming can be overwhelmed by the combination of hamming window with cash window. So here this paper [1] reduces the further complexity by introducing a altered window having a new altering parameter similar to that also increases the main lobe width and reduces the side lobe ratio and ripple ratio.

The literature paper [2] shows that the stability of FIR filter design is very high only the design is undertaken by the hamming is stable as compare to rectangular and Hanning windows techniques. Also Ripples in pass band are very less in hamming as compare to other two techniques. Hamming window attains linear phase when compared to rectangular and Hanning windows.

The literature paper [3] proposes the neural network technique for designing linear phase FIR filter. This paper shows better results compared to all other methods. The two advantages of this paper are (1) no involvement in operation of inverse matrix, and (2) pass band and stop band ripples is minimum.

3. Existing Window Functions

For any filter, when the order of the filter increases, the magnitude response of the filter goes to ideal response. Our objective of this paper is to design a FIR filter with lower order. Reducing the order of the filter is due to the reason that if the order of the filter increases, complexity becomes very high. For practical filter, the existing window functions are

Rectangular:

$$\mathrm{w(n)} = 1, -\frac{\mathrm{M}-1}{2} \le \mathrm{n} \le \frac{\mathrm{M}-1}{2}$$

Hamming:

$$\mathrm{w(n)} = 0.54 + 0.46\cos\left(\frac{2\pi \mathrm{n}}{\mathrm{M}-1}\right), -\frac{\mathrm{M}-1}{2} \le \mathrm{n} \le \frac{\mathrm{M}-1}{2}$$

Hanning:

$$\mathrm{w(n)} = 0.5 + 0.5\cos\left(\frac{2\pi \mathrm{n}}{\mathrm{M}-1}\right), -\frac{\mathrm{M}-1}{2} \le \mathrm{n} \le \frac{\mathrm{M}-1}{2}$$

Blackmann:

$$\mathrm{w(n)} = 0.5 + 0.42\cos\left(\frac{2\pi \mathrm{n}}{\mathrm{M}-1}\right) + 0.08\cos\left(\frac{4\pi \mathrm{n}}{\mathrm{M}-1}\right), -\frac{\mathrm{M}-1}{2} \le \mathrm{n} \le \frac{\mathrm{M}-1}{2}$$

where M is the order of the filter.

4. Proposed Window Function

In order to get the high gain in the pass band and less gain in the stop band, we propose the new window function. Thus our proposed filter design has the window function as follow:

$$w(n) = 0.9 + 0.1\cos\left(\frac{2\pi n}{M-1}\right), -\frac{M-1}{2} \le n \le \frac{M-1}{2}$$

The first step to design a FIR filter is to calculate the desired impulse response. The desired impulse response of the FIR low pass filter is as follow:

$$h_d(n) = \frac{1}{n\pi}\sin(n\omega_c), n \neq 0$$

$$h_d(n) = \frac{\omega_c}{\pi}, n = 0$$

The desired impulse response of the Band pass filter is given by

$$h_d(n) = \frac{1}{(n-\alpha)\pi}(\sin(n\omega_{c2}) - \sin(n\omega_{c1})), n \neq 0$$

$$h_d(n) = \frac{\omega_{c2} - \omega_{c1}}{\pi}, n = 0$$

The next step is to multiply the desired impulse response with the window function as stated above and is given by

$$h(n) = h_d(n)w(n)$$

Finally the frequency response of the impulse response $h(n)$ can be calculated using

$$H(e^{j\omega}) = \sum_{n=-\frac{M-1}{2}}^{\frac{M-1}{2}} h(n)e^{-j\omega n}$$

5. Results and Discussion

From the figure 1 and 2, it is clear that gain is very large in passband and very small in stopband in the FIR filter design using hamming window compared to Hanning and Blackmann Window. But of course the gain is not as larger in the pass band.

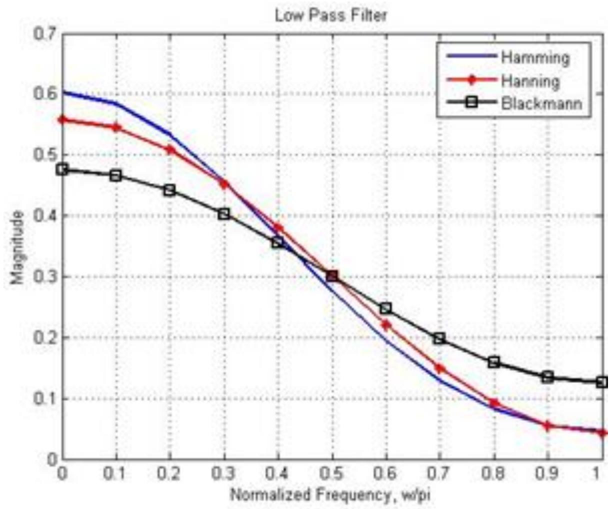

Figure 1: Responses of FIR Low Pass Filter with various existing Window

From the figure 2, it is clear that the magnitude response of the band pass filter is very poor since the gain in the pass band and stop band are very nearer to each other.

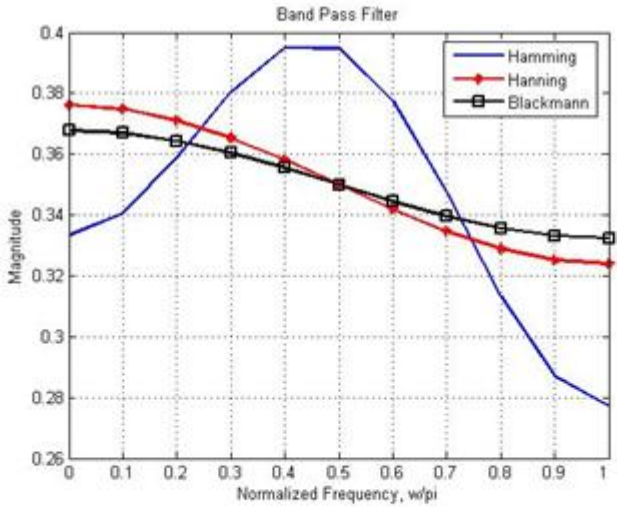

Figure 2: Responses of FIR Band Pass Filter with various existing Window

Figure 3 shows that the frequency response of the Finite Impulse Response Low Pass Filter design using Hamming, Hanning, Blackmann and our Proposed Window technique.

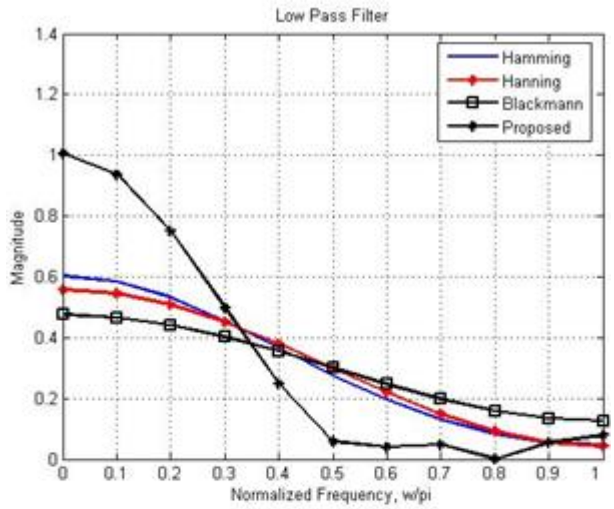

Figure 3: Comparison of Responses of FIR Low Pass Filter with various existing Window with the proposed window

From the figure 3, it is clear that gain in the pass band is very high compared to existing Hamming, Hanning, and Blackmann window and the gain in the stop band is very less compared to existing Hamming, Hanning, and Blackmann window. Thus we can achieve our objective to design a FIR Low Pass filter in efficient manner.

Figure 4 shows that the frequency response of the Finite Impulse Response Band Pass Filter design using Hamming, Hanning, Blackmann and our Proposed Window technique

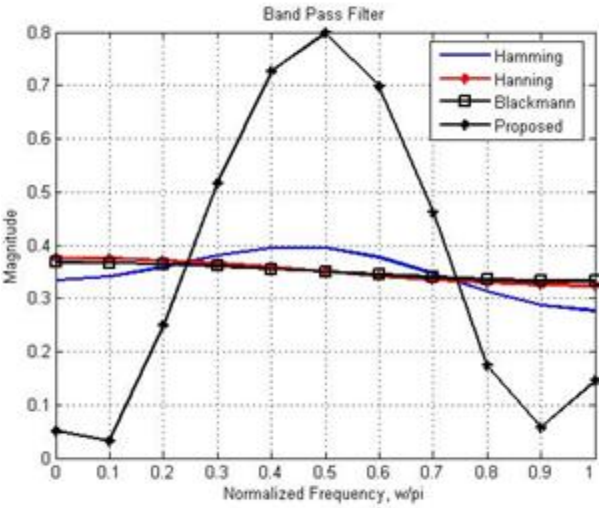

Figure 4: Comparison of Responses of FIR Band Pass Filter with various existing Window with the proposed window

From the figure 4, it is clear that gain in the pass band is very high compared to existing Hamming, Hanning, and Blackmann window and the gain in the stop band is very less compared to existing Hamming, Hanning, and Blackmann window. Thus we can achieve our objective to design a FIR Band Pass filter in efficient manner.

6. Conclusion

Thus the gain in the pass band is increased and gain in the stop band is decreased using the proposed window function compared to Hamming, Hanning and Blackmann window.

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Author Profile

R. Sivarajan is currently working as Assistant Professor in Adhiparasakthi Engineering College, Melmaruvathur

B. Elango is currently working as Assistant Professor in Adhiparasakthi Engineering College, Melmaruvathur.