

Efficient Design of Low Pass FIR Filter by Hamming, Blackman and Rectangular Window Techniques

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Abstract: Digital filtering plays a significant role in the world of technology. This paper deals with the design of finite impulse response digital filter using window techniques. Here various windows are compared and demonstration of the best window is done, which is the one with minimum side lobes. This is hence the major objective of filtering operation. The experimental results show that the FIR filters designed in this paper are effective for filtering operation. Through this paper the intricacies of the window methods are explained in a simple and a subtle manner.

Keywords: blackman window, hamming window, rectangular window, FIR filter and MATLAB.

1. INTRODUCTION

Digital filtering is one of the most powerful tools of DSP. Digital filters are capable of performing that specifications which are extremely difficult to achieve with an analog implementation. In addition the characteristics of a digital filter can be easily changed under software control. Many digital systems use signal filtering to remove unwanted noise to provide spectral shaping or to perform signal detection or analysis. Two types of filters provide these functions are finite impulse response (FIR) filters and infinite impulse response (IIR) filters. In actual procedure for designing digital FIR filters first the desired filter responses are characterized and the filter coefficient values are calculated for a causal FIR filter[1].

To design the FIR filters the simple and effective way is window method. In this method infinite impulse response of the ideal 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 quickly. The window method is simple in operation, easy to understand and very convenient method for designing digital FIR filter[2].

1.1. BASIC PRINCIPLE OF FIR WINDOW TECHNIQUE

The filter is used to describe a linear time – invariant system used to perform spectral shaping or frequency-selective filtering. Filter is used in digital signal processing is widely used in a number of ways, such as removal of undesirable noise from desired signals, spectral shaping such as equalization of communication channels, signal detection in radar, sonar and communications, and for performing analysis of the spectra of a variety of signals[3].

There are two major types of digital filters are:

1) Infinite Impulse response (IIR) filters 2) Finite Impulse response (FIR) filters. Infinite Impulse Response (IIR) digital filter has the problems of phase non-linearity. Therefore it is a low order filter which becomes highly unstable. Due to these factors, the FIR filter can be used to design a linear phase digital filter which is convenient for image processing and data transmission applications. The FIR filters are broadly used in various fields, such as long distance communication, image processing applications etc

The system function of FIR filter is given below:

$$H(z) = \sum_{n=0}^{L-1} h[n]z^{-n}$$

where, L is the length of the filter, and h[n] is the impulse response[4].

2. WINDOW AND THEIR TECHNIQUES

The finite impulse response (FIR) filter is one of the most basic elements in a digital signal processing system, and it can guarantee a strict linear phase frequency characteristic with any kind of amplitude frequency characteristic. Besides, the unit impulse response is finite; therefore, FIR filters are stable system. The FIR filter has a broad application in many fields, such as telecommunication, image processing, and so on[5].

Several window function have been proposed. Listed below are some of the most common.

- Hamming window
- Blackman window
- Rectangular window

To reduce the oscillation in fourier series method, the fourier coefficient are modified by multiplying the infinite impulse response by a finite weighing sequence $w(n)$ called a window. Windows are characterize by the main

lobe width which is the bandwidth between first negative and first positive zero crossing and by their ripple ratio. The main lobe far as possible in the main lobe and the energy in the side lobe should be as low as possible[6].

2.1. HAMMING WINDOW

Richard W. hamming observed that the side lobes of the rectangular and HANNING windows are phase reversed relative to each other, so a linear combination of the two would tend to cause them to cancel each other. He searched for the linear combination that minimized the maximum side lobe amplitude and came up with the following formulation, which represents a raised cosine on a rectangular pedestal[7].

$$\omega[n] = \begin{cases} 0.54 - 0.46 \cos\left(\frac{2\pi n}{M}\right), & 0 \leq n \leq M \\ 0, & \text{otherwise} \end{cases}$$

2.2. BLACKMAN WINDOW

Blackman windows are defined as:

By common convention, the unqualified term Blackman window refers to $\alpha = 0.16$, as this most closely approximates the "exact Blackman", with $a_0 = 7938/18608 \approx 0.42659$, $a_1 = 9240/18608 \approx 0.49656$, and $a_2 = 1430/18608 \approx 0.076849$. These exact values place zeros at the third and fourth side lobes[8].

$$W(n) = a_0 - a_1 \cos\left(\frac{2n\pi}{N-1}\right) + a_2 \cos\left(\frac{4n\pi}{N-1}\right)$$

Where;

$$a_0 = \frac{1-\alpha}{2}$$

$$a_1 = \frac{1}{2}$$

$$a_2 = \frac{\alpha}{2}$$

2.3. RECTANGULAR WINDOW

The rectangular window is what you would obtain if you were to simply segment a finite portion of the impulse response without any shapping in the time domain .

$$\omega(n) = \begin{cases} 1, & 0 \leq n \leq M \\ 0, & \text{otherwise} \end{cases}$$

we have studied this function extensively in class and known it's DTFT to be

$$\omega(e^{j\omega}) = \frac{\sin\left(\frac{M\omega}{2}\right)}{\sin\left(\frac{\omega}{2}\right)} e^{-j\frac{\omega M}{2}}$$

compare the plots of the original sinc function above and its magnitude plotted in dB.

$$20\log_{10}(|\omega(e^{j\omega})|) [9].$$

3. SIMULATION AND RESULT

Table-1. Parameter specification

Parameter	Value
Sampling frequency(f_s)	48000Hz
Cut-off frequency(f_c)	10000Hz
Order(N)	30

Table –2.Frequency and magnitude.

friquancy	Window technique		
	hamming	blackman	rectangular
0.1π	-0.038	-0.001	0.114
0.2π	-0.001	1.685	0.056
0.3π	-0.018	0.000	-0.053
0.4π	-0.04	-0.001	0.169
0.5π	-0.015	-0.003	0.188
0.6π	-0.05	-0.140	-0.123
0.7π	-0.029	-0.501	0.186
0.8π	-0.189	-2.195	0.620
0.9π	-2.064	-4.394	-0.589
π	-4.711	-6.754	-6.075

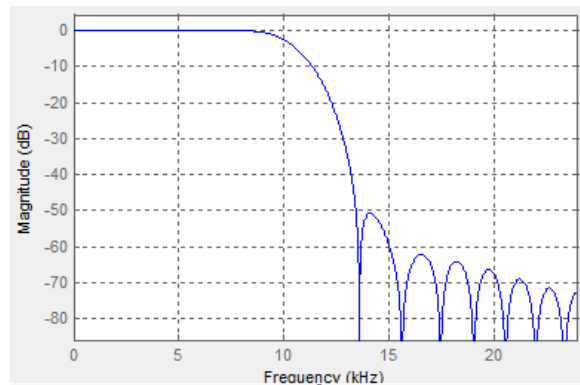


FIGURE-1.Magnitude response of hamming window.

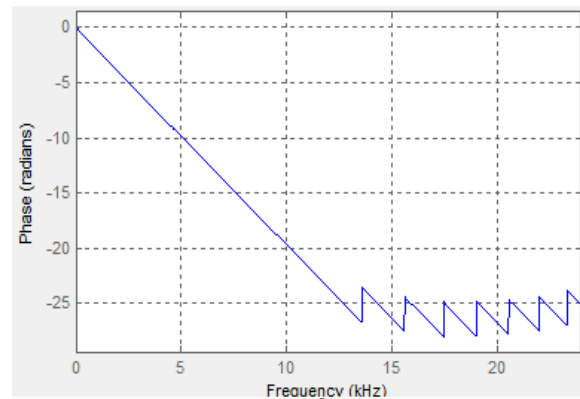


FIGURE-2. Phase response of hamming window.

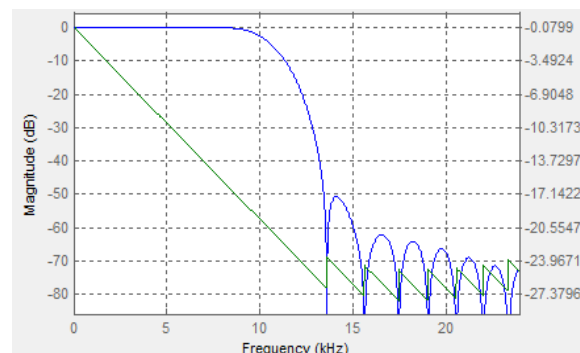


FIGURE-3.Magnitude and phase response of hamming window.

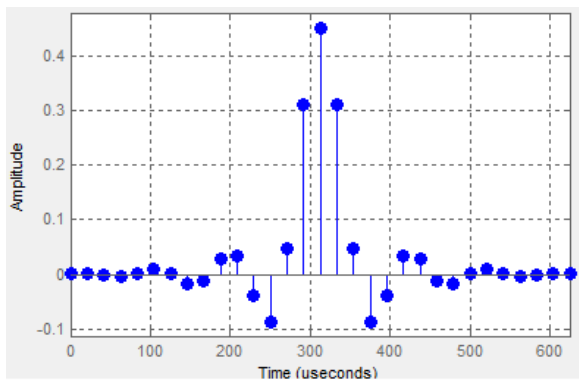


FIGURE-4. Impulse response of hamming window.

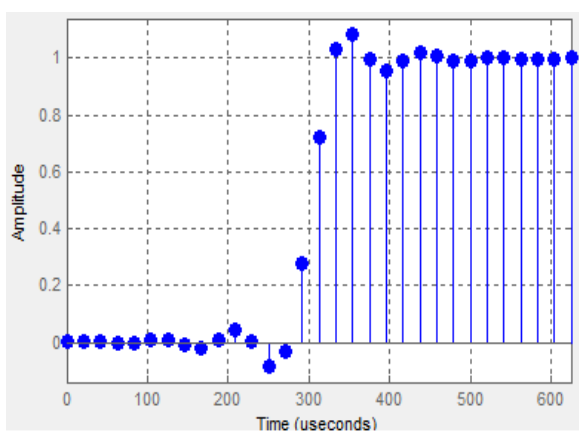


FIGURE-5. Step response of hamming window.

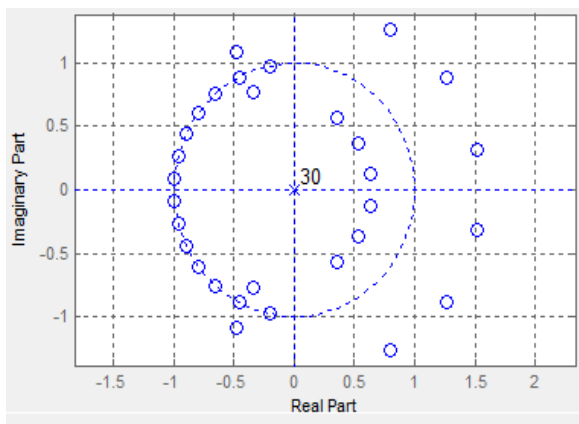


FIGURE-6. Poles and zeros plot of hamming window.

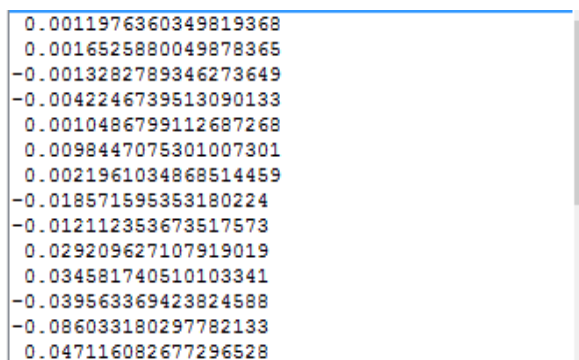


FIGURE-7. Filter coefficient of hamming window.

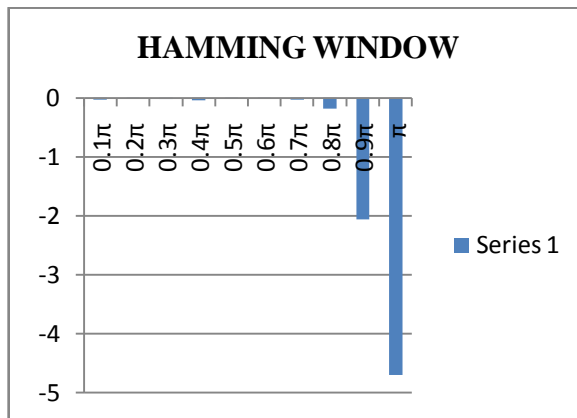


FIGURE-8. Magnitude and frequency plot of hamming window.

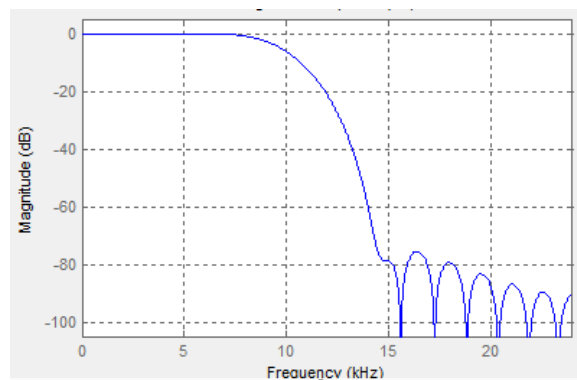


FIGURE-9. Magnitude response of blackman window.

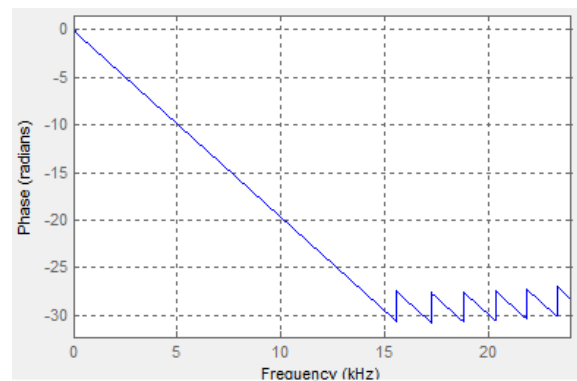


FIGURE-10. Phase response of blackman window.

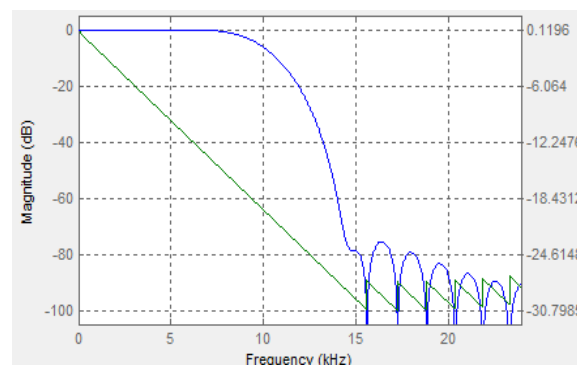


FIGURE-11. Magnitude and response of blackman window.

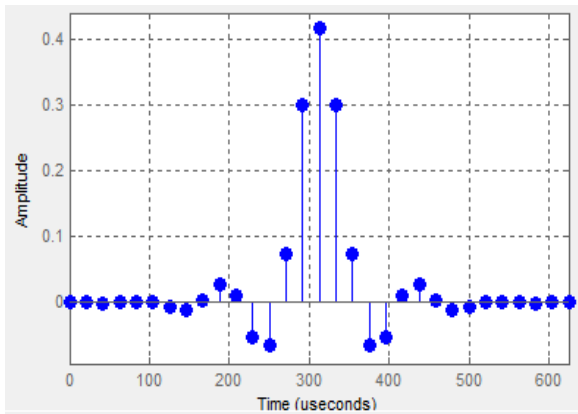


FIGURE-12. Impulse response of blackman window.

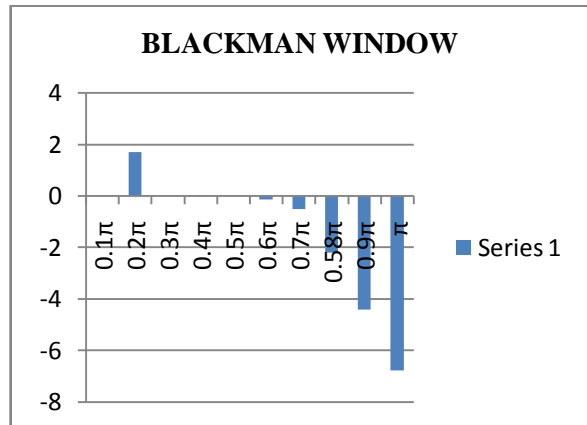


FIGURE-16. Magnitude and frequency plot of blackman window.

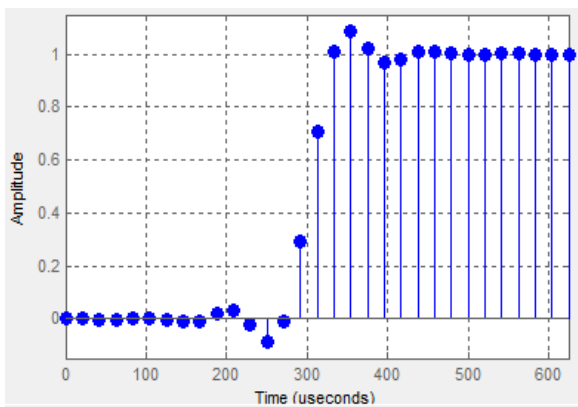


FIGURE-13. Step response of blackman window.

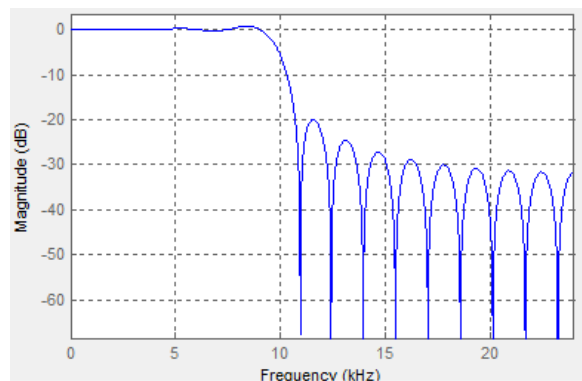


FIGURE-17. Magnitude response of rectangular window.

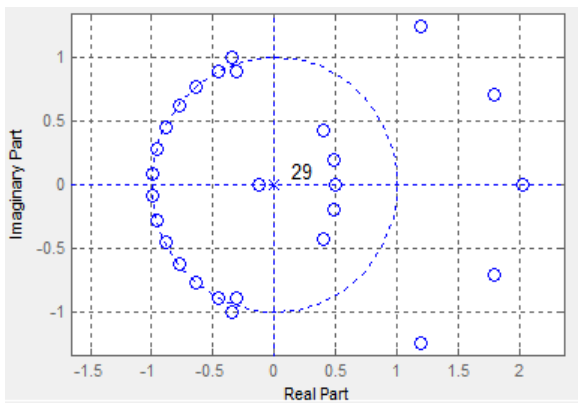


FIGURE-15. Poles and zeros plot of blackman window.

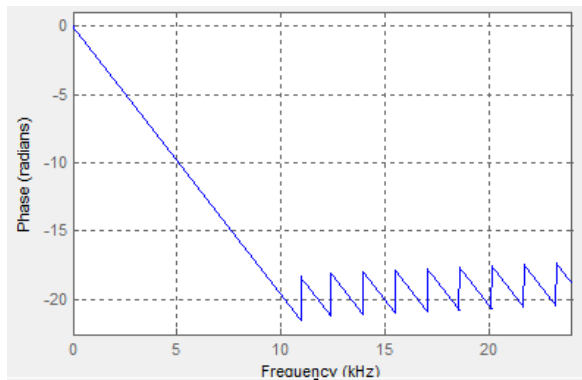


FIGURE-18. Phase response of rectangular window.

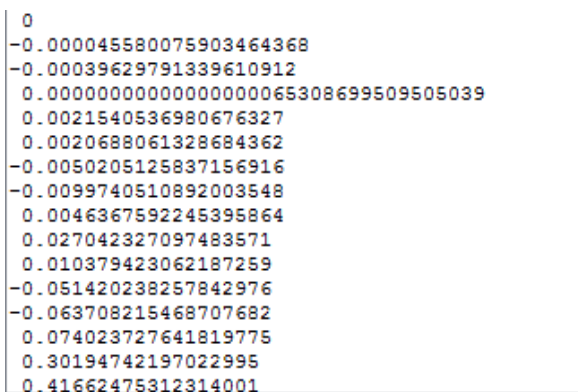


FIGURE-15. Filter coefficient of blackman window.

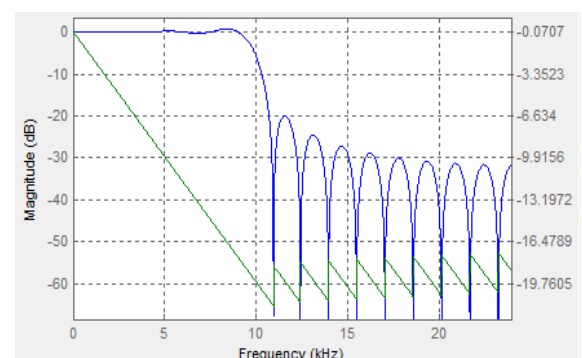


FIGURE-19. Magnitude and phase response of rectangular window.

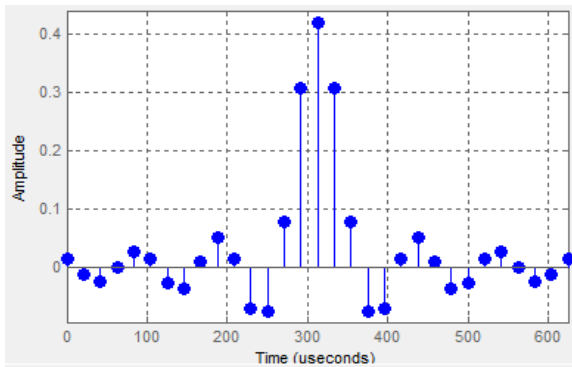


FIGURE-20. Impulse response of rectangular window

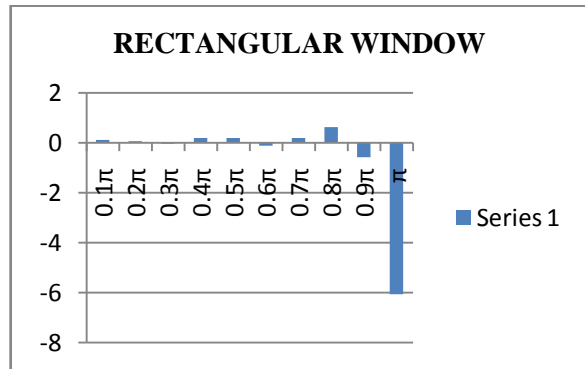


FIGURE-24. Magnitude and frequency plot of rectangular window.

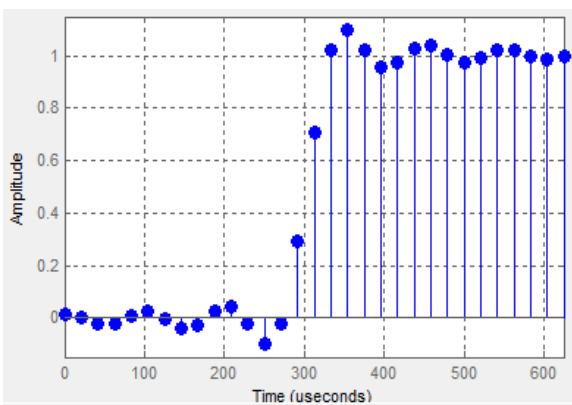


FIGURE-21. Step response of rectangular window.

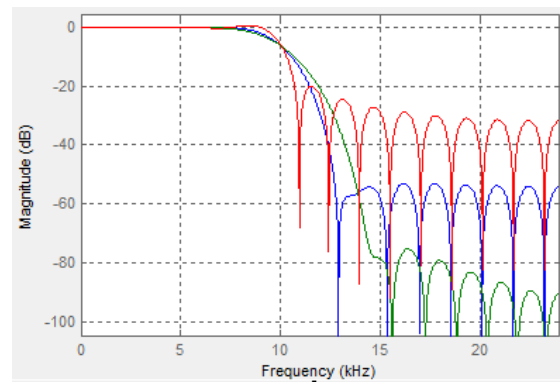


FIGURE-25. Magnitude response comparison hamming, blackman and rectangular window.

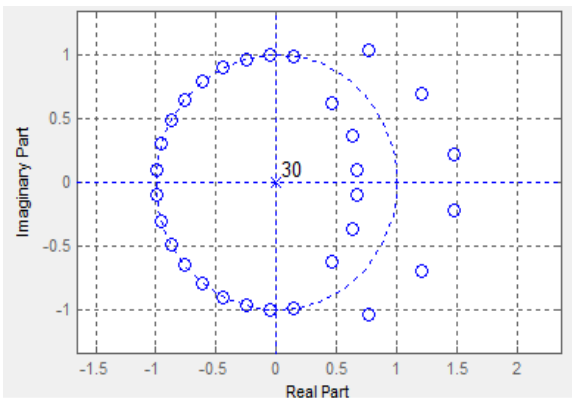


FIGURE-22. Poles and zeros plot of rectangular window.

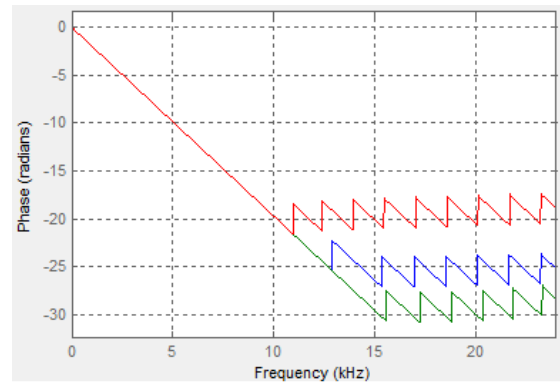


FIGURE-26. Phase response comparison of hamming, blackman and rectangular window.

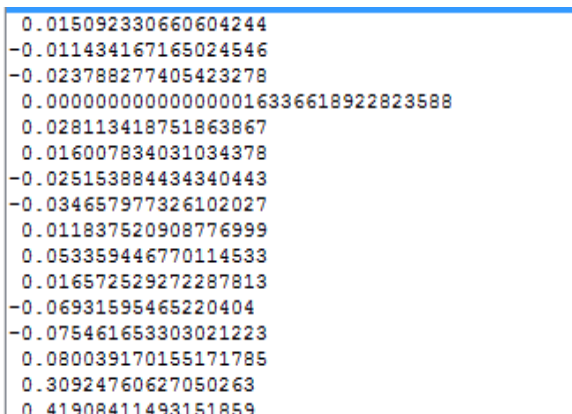


FIGURE-23. Filter coefficient rectangular window.

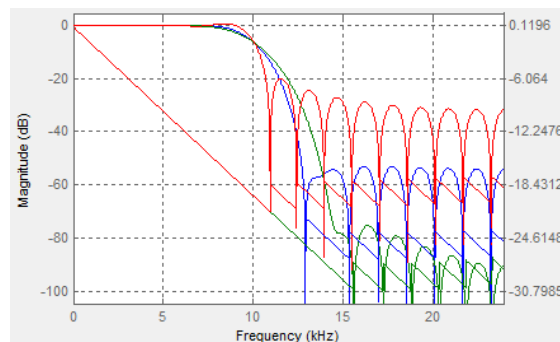


FIGURE-27. Magnitude and phase response comparison of hamming, blackman and rectangular window.

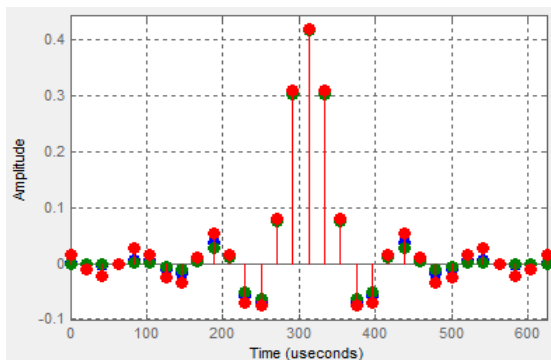


FIGURE-28. Impulse response comparison of hamming, blackman and rectangular window.

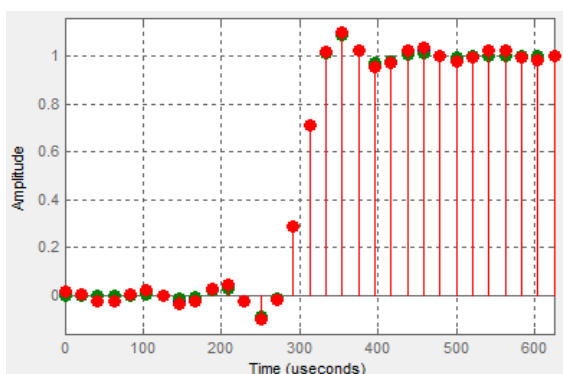


FIGURE-29. step response comparison of hamming, blackman and rectangular window.

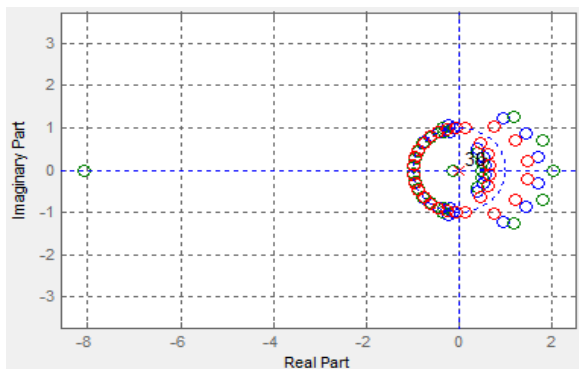


FIGURE-30. Poles and zeros plot comparison of hamming, blackman and rectangular window.

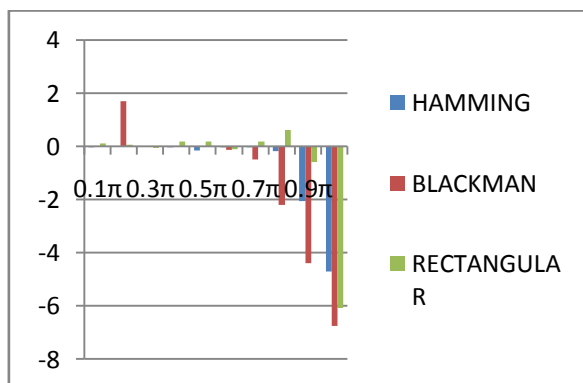


FIGURE-31. Magnitude and frequency comparison of hamming, blackman and rectangular window

4. CONCLUSION

In this research paper low pass FIR filter has been design using MATLAB hamming, blackman and rectangular window technique. It concludes by comparative value of both magnitude and phase response of the filter using above the technique at same frequency.

$$i.e F_s = 48000\text{Hz}$$

$$F_c = 10000\text{Hz}$$

In blackman windowing technique the unwanted signals are not present after the cut-off frequency, but this technique also cuts the wanted signal.

In rectangular windowing technique wanted signals are present in maximum after the cut-off frequency but some unwanted signals are present with the wanted signals too.

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