



# IJEAST

INTERNATIONAL JOURNAL  
OF ENGINEERING APPLIED SCIENCE  
AND TECHNOLOGY



**VOLUME : 4    ISSUE : 03    Print / Issue Publication Date: 02-Sep-2019**



**ISSN : 2455-2143**



**DOI : 10.33564/IJEAST.2019.v04i03.049**

Indexed In



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# A COMPARATIVE STUDY OF WINDOWS FOR SPECTRAL ANALYSIS

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**ABSTRACT - In this paper we presented a spectral analysis of different windows designed based on cosine functions. this paper includes comparative study of different windows based on their spectral characteristics like side lobe attenuation (SLA) half bandwidth (HBW) and side lobe fall of ratio (SLFOR).since windowing method one of the best method in the design of linear phase FIR filters using in digital signal processing applications like audio processing, video processing, speech processing and bio medical signal processing etc. Windows plays major role in design of Finite Length digital filters for removing pikes in stop band and improves pass band attenuation characteristics. And lot of research also done on windows. Many windows are developed based on their side lobe attenuation characteristics. Optimisation techniques also applied in the filed of window based FIR design, which shows better results compare to conventional methods.**

Here we proposed basic mathematical kernel functions to develop window functions.

**Key words: Bartlett window, Hamming window, Hanning window, proposed window functions.**

## I. INTRODUCTION

Windowing technique is used in to process the signals described by Fourier Transform modelled[1].FIR filters are designed by windowing method to remove the noises in ECG signals[2]. Windows are mathematical functions applied to both periodic signals and non periodic signals[3]. Windowing based FIR filters are used in communication systems to design of channel equalizers[4]. The magnitude and phase responses of FIR filters are important for selection of windows while designing.[5] the side lobe attenuation of spectral characteristics is key factor in the design of windows[6]. The sharper magnitude and liner phase response of FIR filters are obtained by windowing technique[7]. The stability and filter coefficients of FIR filters are varied for different window functions[8]. Window is a mathematical function allows the signal between the interval and zero value outside the interval[9]. Hybrid windows are designed which gives better results compare to basic window functions[10].

## II. WHY NEED WINDOWS IN SIGNAL PROCESSING

When converting the continuous signals into discrete signals using sampling before transforming into frequency domain and transmitting there is a present of frequencies other than sampled instants referred as spectral leakage.

Windows are mathematical functions applied to signals either continuous or sampled to reduce the spectral leakage.

## III. BASIC WINDOW FUNCTIONS

In this section we are presenting different presenting mathematical functions of windows used in the design of linear phase FIR filters.

### III.I Bartlett window

The mathematical expression for Bartlett window is

$$w(n) = \frac{2n}{N}, 0 \leq n \leq \frac{N}{2}$$

$$= 2 - \frac{2n}{N}, \frac{N}{2} \leq n \leq N \text{ ----- (1)}$$

### III.II Hamming window

The mathematical expression for Hamming window is

$$w(n) = 0.54 - 0.46 \cos\left(\frac{2\pi n}{N}\right), 0 \leq n \leq N - 1$$

$$= 0 \text{ otherwisw ----- (2)}$$

### III.III Hanning window

The mathematical expression for Hanning window is

$$w(n) = 0.5 - 0.5 \cos\left(\frac{2\pi n}{N}\right), 0 \leq n \leq N - 1$$

$$= 0 \text{ otherwise ----- (3)}$$

## IV. PROPOSED WINDOWS

The window functions are generally continuous cosine functions implemented as a powers of integers of cosine functions which are referred as cosine windows given as

$$w(n) = \cos^\alpha \left[ \frac{n\pi}{N} \right], \frac{-N}{2} \leq n \leq \frac{N}{2}$$

$$= 0 \text{ otherwise ----- (4)}$$



But it is also confirmed that windows are not only continuous but also developed from their second derivatives called as Dirchlet Kernels. The Dirchlet kernels are located about the central kernel which are zeros of central kernel. So the summation of kernels side lobes results the cancellation of side lobes because of opposite phases. so this partial structure of side lobes with three or more kernel functions results to construction of new windows which are described in mathematical function is

$$w(n) = x_0 \cos \frac{2\pi n}{N} - x_1 \cos \frac{4\pi n}{N} + x_2 \cos \frac{4\pi n}{N} - x_3 \cos \frac{6\pi n}{N} + \dots$$

-----(5)

Where  $x=0,1,2,3\text{---}N-1$

The coefficients  $x$  determines  $n$ -tem window where  $n$  is the number of coefficients. So here we proposed the windows with 3 terms and 4 terms and observed their spectral responses with basic conventional windows.

**IV.I Proposed window1:** It is a 3 term window and the mathematical function is

$$w(n) = 0.42323 \cos \frac{2\pi n}{N} - 0.49755 \cos \frac{4\pi n}{N} + 0.07922 \cos \frac{6\pi n}{N}$$

----- (6)

**IV.I Proposed window2:** It is a 4 term window and the mathematical function is

$$w(n) = 0.35875 \cos \frac{2\pi n}{N} - 0.48829 \cos \frac{4\pi n}{N} + 0.14128 \cos \frac{6\pi n}{N} - 0.01168 \cos \frac{8\pi n}{N}$$

----- (7)

V. SIMULATION & RESULTS

In this sections we developed simulation results for spectral responses of Bartlett window, Hamming window, Hanning window and two proposed windows. The simulation results are obtained from MATLAB.

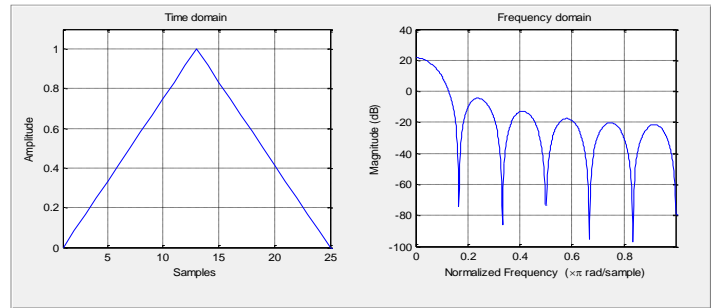


Fig1: Spectral response of Bartlett window

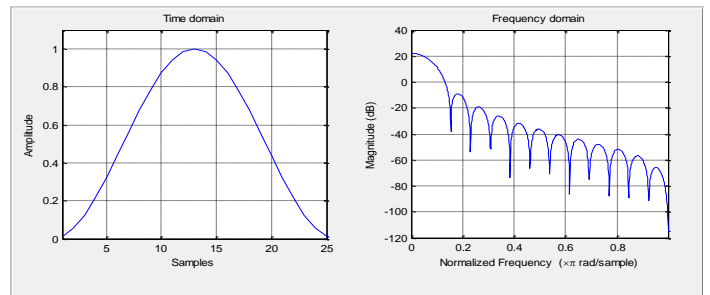


Fig2: Spectral response of Hanning window

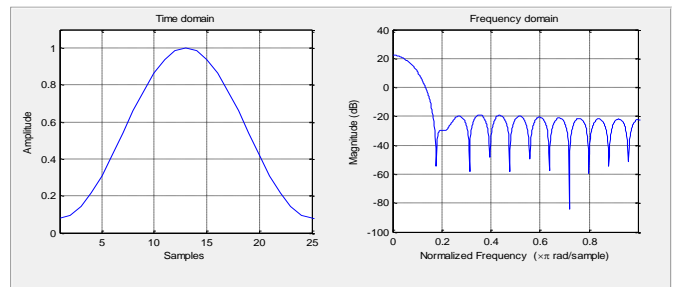


Fig3: Spectral response of Hamming window

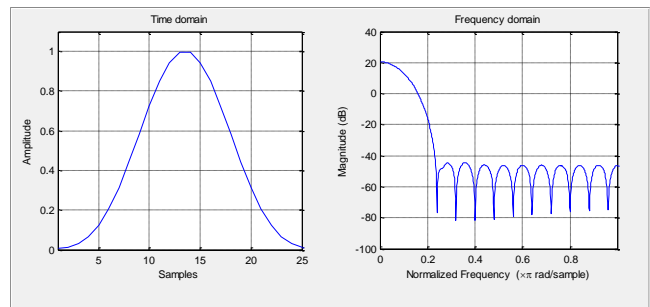


Fig4: Spectral response of proposed window 1

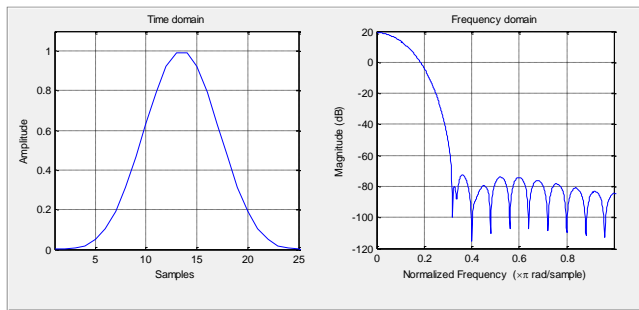


Fig5: Spectral response of proposed window2

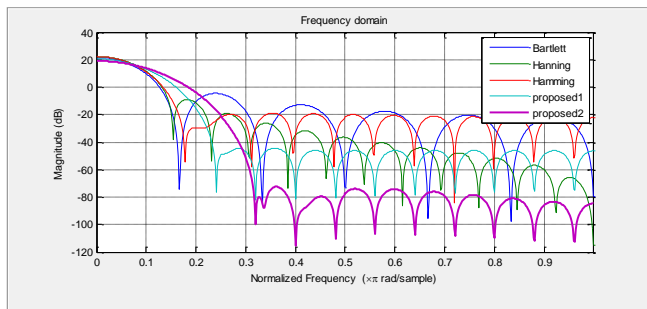


Fig6: Spectral response of all windows

Table1: Spectral characteristics of windows

s.no	Window	Side lobe attenuation SLA(dB)	Half bandwidth HBW(db)	Side lobe fall of ratio
1	Bartlett	-26.1	0.10156	17.28
2	Hanning	-31.5	0.10938	56.36
3	Hamming	-41.2	0.10156	7.39
4	Proposed1	-65	0.125	1.45
5	Proposed2	-91.6	0.14844	12.03

## VI. CONCLUSION

We have examined some cosine function based windows and proposed windows which satisfies their performance towards spectral leakage and harmonic analysis. for multiple speech detection through DFT the windows should exhibit concentrated central lobe width and narrow side lobes which results sharp attenuation in stop band of the filter. We have demonstrated the proposed windows which exhibits higher side lobe attenuation i.e -65dB for 3 term window (proposed window1) and -91.6 dB for 4 term window (proposed window2). See Table1 for reference. And we also presented spectral time and frequency domain analysis of all windows shown from Fig1 to Fig6.

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2455-2143