Design of Window Function in LABVIEW Environment

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ABSTRACT: *Eliminating Gibbs phenomenon, which occurs during design of Finite Impulse Response (FIR) digital filter and which is undesirable, is very important in order to provide expected performance from digital filter. Window functions have been developed to eliminate these oscillations and to improve the performance of the filter in this regard. In this work, an application was developed for designing window function using LABVIEW which is a graphical programming environment produced by National Instruments. LABVIEW offers a powerful programming environment away from complexity. In this work, the performances of cosh and exponential window functions, which are designed by using the possibilities of LABVIEW in programming, are examined and the situations that will occur under various conditions are compared.*

KEYWORDS -*LABVIEW, Window Function, Cosh Window Function, Exponential Window Function*

I. INTRODUCTION

Nowadays, as technology develops rapidly, analog systems leave their place to digital systems. Numerical systems are being developed every day to improve their performance. In any digital system, digital filters are used to achieve the desired output [1]. Digital filters have many advantages, such as having a programmable processor, using it at low frequencies, not being affected by environmental conditions etc.

The digital filters perform the desired filtering process with the signals or digital signals obtained by digitizing the analog signal through many processes. Filters are structures that prevent undesirable values that pass desired values from components of the signals applied to their inputs, distinguish the signals from harmonics, shape the signal, prevent to resonance or create to resonance, regulate the power factor. Digital filters have a variety of applications: Digital signal processing (DSP), communication systems, medical field, etc.

Digital filters can be classified in various forms. Digital filters, when classified by impulse response, consist of two main parts: Infinite Impulse Response (IIR) and Finite Impulse Response (FIR). These filter types are structurally different from each other and are preferred according to their properties.

Two different methods for FIR filter design have been developed: Fourier Series Method and Frequency Sampling Method. These methods have advantages and disadvantages relative to each other and the design method is selected to create the expected characteristic of the filter.

If the Fourier Series Method is selected for FIR filter design, the impulse response must be limited so that the filter can be practically implemented. As a result, unwanted oscillations occur in the field of the sharp cut-off frequency of the filter. These unwanted oscillations are called Gibbs phenomenon. Window functions have been developed to prevent these oscillations. There are many window functions developed in the literature.

The content of the paper is as follows: Section 2 explains window functions and Section 3 describes LabVIEW. In Section 4, results and analysis of the design of window function are available.

II. WINDOW FUNCTIONS

In order to apply the FIR digital filter design by the Fourier Series Method, it is necessary to limit the Fourier Series. As a result of delimitation of the Fourier Series, unwanted

oscillations occur. Window functions are used to eliminate these oscillations. The mathematical expressions of these oscillations were made by Gibbs in 1899 [2]. On the basis of these findings, L. Fejer has carried out studies to destroy the oscillations [3]. Lanczos has improved Fejer's proposal [4]. Adams has suggested a window function as a result of his work [5]. The works of improving the window functions are continued today [6-13].

There are many uses of window functions in the literature. Image processing, digital filter design and digital beamforming are just a few of them. When window functions are classified according to their parameters, they consist of two main parts: Fixed Window Functions, Adjustable Window Functions. Fixed window functions can only adjust the main lobe width of the window function with the window length parameter (N). Since the adjustable window functions have two or more parameters, many spectral parameters of the window function can be set. The spectral representation of the window functions in general is shown below:

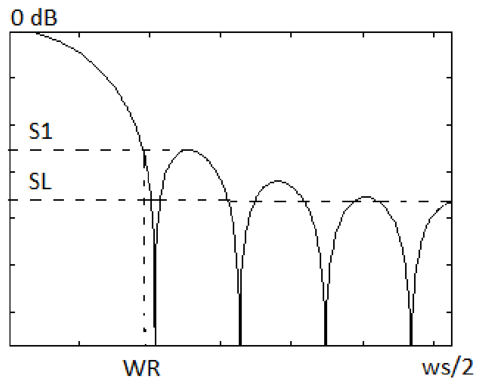

Figure1: A typical Window Function's Amplitude Spectrum

Expressions in the graph can be specified as follows:

R=Max. Sidelobe Amplitude – Mainlobe Amplitude = S1

S=Max. Sidelobe Amplitude – Min. Mainlobe Amplitude

$$S = S1 - SL$$

2WR = Mainlobe Width

From the digital filter designed using the window function, the following properties are expected:

- The width of the mainlobe should be narrower.
- Ripple ratio should be smaller.
- Sidelobe decline rate should be wide [8].

The commonly preferred window functions in the literature can be summarized as follows:

- Kaiser Window Function

$$w[n] = \begin{cases} \dfrac{I_0\left(\alpha_k\sqrt{1-\left(\frac{2n}{N-1}\right)^2}\right)}{I_0(\alpha_k)}, & |n| \le \dfrac{N-1}{2} \\ 0 & , otherwise \end{cases} \quad (1)$$

α_k is an adjustable parameter. I_0 is the Bessel function and its explanation is as follows:

$$I_0(x) = 1 + \left[\frac{1}{k}\left(\frac{x}{2}\right)^k\right]^2 \quad (2)$$

- Exponential Window Function

$$w[n] = \begin{cases} \dfrac{exp\left(\alpha_e\sqrt{1-\left(\frac{2n}{N-1}\right)^2}\right)}{exp(\alpha_e)}, & |n| \le \dfrac{N-1}{2} \\ 0 & , otherwise \end{cases} \quad (3)$$

- Cosh Window Function

$$w[n] = \begin{cases} \dfrac{cosh\left(\alpha_c\sqrt{1-\left(\frac{2n}{N-1}\right)^2}\right)}{cosh(\alpha_c)}, & |n| \le \dfrac{N-1}{2} \\ 0 & , otherwise \end{cases} \quad (4)$$

III. LABVIEW

LabVIEW is an interactive program development and application system based on the graphical programming language (GPL) produced by National Instruments [14]. Thanks to the graphical programming language, the time spent on software development is noticeably reduced, because LabVIEW can produce a faster solution than other graphical programs. In addition to these capabilities, LabVIEW can integrate with many hardware and run in real time. With this feature, data's collection, analysis and presentation can be performed successfully and very accurate measurements can be made.

The LabVIEW screen consists of two main sections, Front Panel and Block Diagram. Front Panel has Control Palette, Block Diagram has Function Palette.

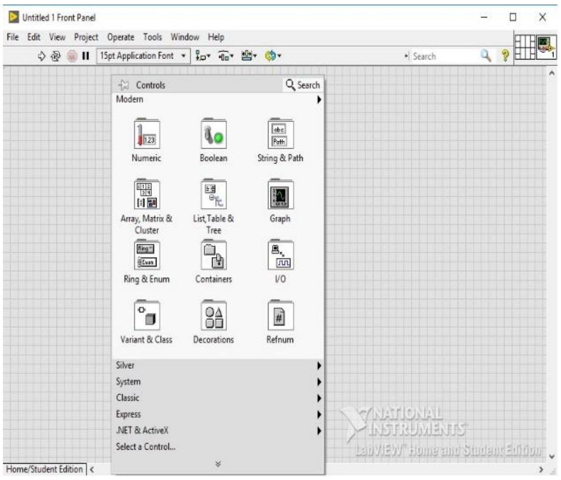

Figure 2: Front Panel

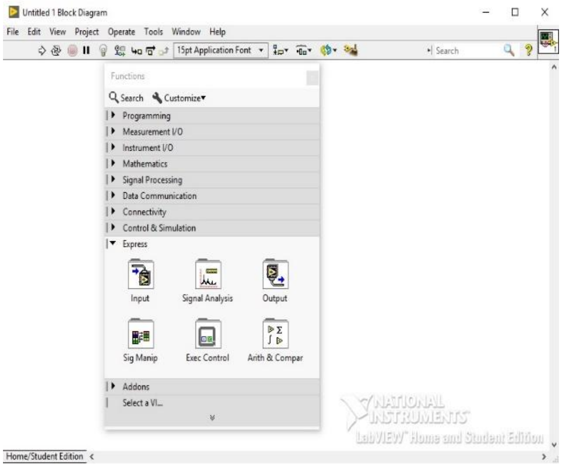

Figure3: Block Diagram

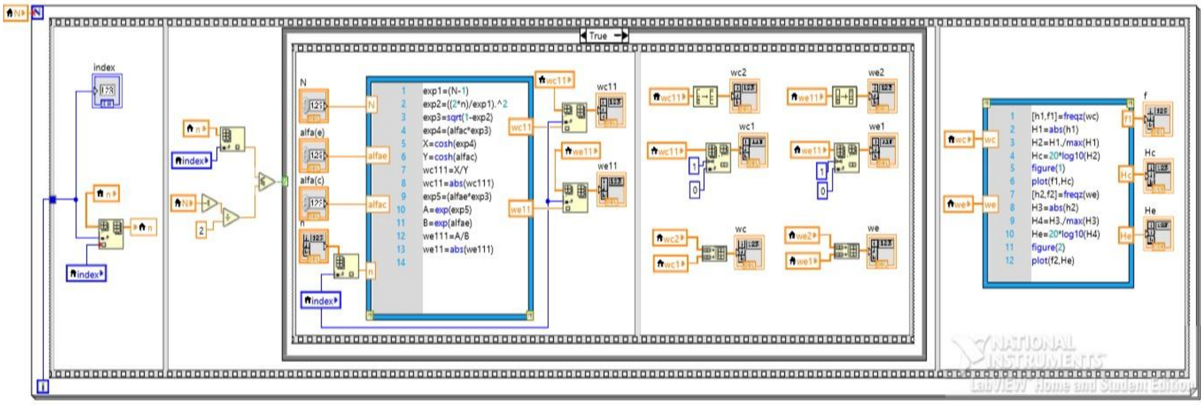

Figure4: Design of cosh and exponential windows using LabVIEW

The design of Cosh and exponential window functions in LabVIEW is shown above. The spectrums of the designed window functions for different parameters are in the next section.

IV. RESULTS AND ANALYSIS OF DESIGN OF WINDOW FUNCTION USING LABVIEW

In this study, the design of cosh and exponential window functions that are widely used among window functions, which play an important role in design of FIR digital filter, has been realized by taking advantage of LabVIEW's easy programmability and fast solution finding capabilities. The characteristics of the designed window functions in various situations are examined and compared with each other.

When N=51 and $\alpha_c = \alpha_e$ = 0.2, cosh and exponential window spectrum:

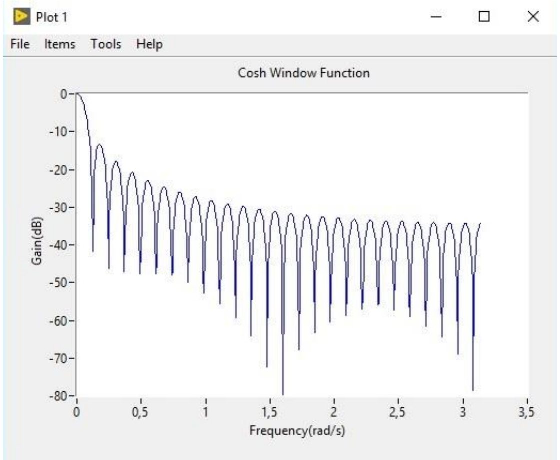

Figure5: N=51 α_c = 0.2 cosh window spectrum

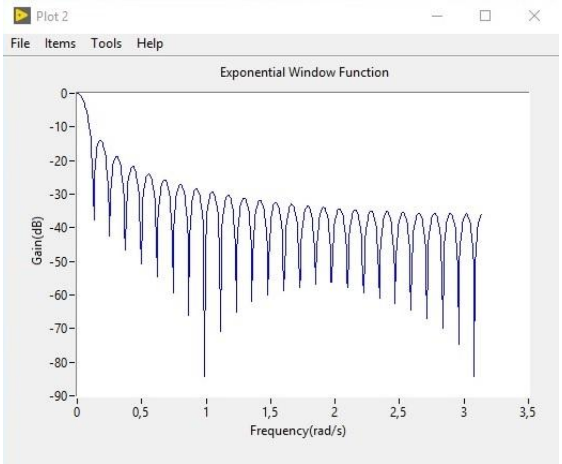

Figure6:*N*=51 $\alpha_e = 0.2$ exponential window spectrum

Table1: Data for cosh and exponential windows for *N*=51 and *α*=0.2

Windows	*N*	α	R	ωR	S
Cosh	51	0.2	-13.38	0.098	20.88
Exponential	51	0.2	-14.03	0.1	21.84

When *N*=21 and $\alpha_c = \alpha_e = 2.2$, cosh and exponential window spectrum:

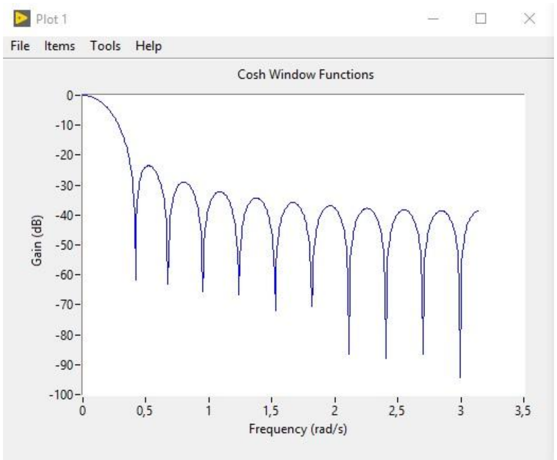

Figure7:*N*=21 $\alpha_c = 2.2$ cosh window spectrum

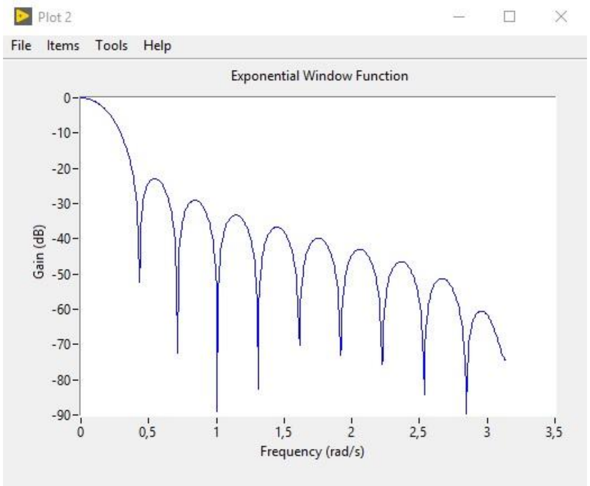

Figure8 : *N*=21 $\alpha_e = 2.2$ exponential window spectrum

Table2: Data for cosh and exponential windows for *N*=21 and *α*=2.2

Windows	*N*	*α*	R	ωR	S
Cosh	21	2.2	-23.55	0.38	15.16
Exponential	21	2.2	-22.9	0.38	37.58

By changing *N* and *α* parameters, width of the mainlobe, ripple ratio and sidelobe decline rate of window functions differentiated.

V. CONCLUSION

This work presents the results of the cosh and exponential window functions that are designed in LabVIEW, which are included in the class of adjustable window functions. Spectrums belonging to these window functions, which occur in different window lengths and different α values, are included in the study. The effects of adjustable parameters in window functions on the amplitude spectrum are observed and interpreted. There are many window design techniques in the literature [15]. Presented as a new option in the design methods in the literature, LabVIEW has succeeded in window design. This work can be improved by exploiting the advantages of LabVIEW in programming.

REFERENCES

[1] D. Schlichthatle, Digital Filters Basics and Design, Springer, No:3-540-66841-1, Germany, 361p, 2000.

[2] J.W. Gibbs, Fourier series, s. 200-606 (1899).

[3] L. Fejer, Sur les fonctions bornees et integrables, Comptes Rendus Hebdomadaries, Seances de l'Academie de Sciences, Paris, 131 984-987, 1900.

[4] J C. Lanczos, Applied Analysis. Van Nostrand, Princeton, NJ. (1956).

[5] J.W. Adams, A new optimal window. IEEE Transactions on Signal Processing. 39 (8) (1991) 1753-1769.

[6] K. Avci, A. Nacaroğlu., A new window based on exponential function, IEEE Ph.D. Research in Microelectronics and Electronics (PRIME 2008). June. Istanbul, Turkey, 69-72 (2008).

[7] T.Kaya, M.C. İnce, Design of FIR Filter Using Modeled Window Function With Helping of Artificial Neural Networks" Journal of The Faculty of Engineering and Architecture of Gazi University,Volume 27-Number 3, pp.599-606, September 2012.

[8] K. Avci, Design of High-Quality Low order Nonrecursive Digital Filters Using the Window Functions, PH. D. Thesis in University of Gaziantep, (2008) Gaziantep.

[9] T. Kaya, M.C. İnce, The Calculation of Adjustable Window Parameters With Helping GA, Applied Automatic Systems (AAS'2009), Ohrid, Republic of Macedonia, 135-138 (2009) September 26-29.

[10] K. Avci, A. Nacaroğlu, Modification of Cosh window family. Proc. of Third International Conference on Information and CommunicationTechnologies (ICTTA'08), Damascus, Syria, 291-292 (2008), April.

[11] A. Kumar, B. Kuldeep, Design of M-channel cosine modulated filter bank using modified Exponential window, Journal of the Franklin Institute, Volume 349, Issue 3, Pages 1304-1315, 2012.

[12] Ramkumar Soni, Alok Jain, Rajiv Saxena, An optimized design of nonuniform filter bank using variable-combinational window function, AEU - International Journal of Electronics and Communications, Volume 67, Issue 7, Pages 595-601, 2013.

[13] Zhi Guo Feng, Ka Fai Cedric Yiu, The design of multi-dimensional acoustic beamformers via window functions, Digital Signal Processing, Volume 29, Pages 107-116, 2014.

[14] http://www.ni.com/company/

[15] T. Kaya, M.C. İnce, The FIR Filter Design By Using Window Parameters Calculated With GA, Soft Computing, Computing with Words and Perceptions in System Analysis, Decision and Control- (ICSCCW 2009), 1-4 (2009) September 2-4.