Adaptable window function having variable parameter for better side-lobe reduction and ripple ratio

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Abstract: In this paper shows changeable spectral parameters window function. Here, suggested window function is merger of some window which has been compared with some standard windows such as hamming, Kaiser and Gaussian window. Comparison of windows has been done with the use of MATLAB simulation software. Comparison of simulation results shows that suggested recommended window function gives good ripple ratio and side lobe roll-off ratio as compared to hamming, and Kaiser and Gaussian window. Comparatively suggested window function shows quite better spectral performances with Compromise of one of the spectral parameter as compared to Kaiser, hamming and Gaussian window function.

Keywords: FIR Filter design, recommended Window Function, spectral parameters.

1.1. Introduction

Introduction to filters, it is a device or system which removes undesired parts from a signal. Basically in digital signal processing, Digital filters are parted into that is FIR filter and IIR filter. The filter partition is depends on the impulse pulse response of system. In digital FIR filter, impulse response of definite duration settles to zero number in definite time.

For effective results of window function, main-lobe width value should be Smaller, higher value of side-lobe fall is required and should be smaller ripple ratio value but here there is some conflict between side lobe fall off ratio and width of main lobe. As the width of main lobe minimizes then value of side-lobe fall ratio maximizes and so vice versa [3-5].

1.2. PARAMETERS OF WINDOW FUNCTION

Here, window function parameters can be explained as:

1. Main-lobe width-This parameter value chooses as minimum as possible. It is mathematically defined as product of main-lobe width with 2π.

2. Ripple-Ratio-This parameter value taken as minimum value for effective window. It can be defined as:
Ripple ratio= Amplitude of Maximum side-lobe (in decibel) – Amplitude of Main-lobe (in decibel)

3. Side-lobe Fall-off ratio-This parameter value chooses must be Maximum for effective window. It is defined as subtraction of amplitude of higher side lobe to the amplitude of lower side-lobe.

The suggested window function is observed with other windows like Kaiser Window, hamming window and Gaussian window with help of MATLAB simulation [1], [2].

1.3. RECOMMENDED WINDOW FUNCTION

The recommended window function in this paper is a merger of Blackman window, Lanczos window and Blackman-Harris window as given in equation (1), (2) and (3) respectively.

The Blackman window function written as given:-

$$P_1[n]=0.42-0.5\cos(2\pi n/N-1)+0.08\cos(4\pi n/N-1) \quad (1)$$

The Lanczos window function written as given:-

$$P_2[n]= \mathrm{sinc}^L (2n/N-1) \quad (2)$$

The Blackman-Harris window function can be given as:-

$$P_3[n]=0.35875-0.48829\cos(2\pi n/N-1)+0.14128\cos(4\pi n/N-1)-0.01168\cos(6\pi n/N-1) \quad (3)$$

Here, N is defined for length of FIR filter formed by using these windows and L is the variable of the Lanzos window.

The recommended window function w[n] is a merger of Blackman window, Lanczos window and Blackman-Harris window can be given as below:-

$$w[n] =G*\{P_2[n]-|P_1[n]*P_2[n]*[P_3[n]/n-1]^r|\}$$

For recommended window function 'r' is the variable parameter and G defines the gain of the window function.

1.4. COMPARISON WITH OTHER WINDOWS

In this paper, recommended window function proposed is a merger of Blackman window, Lanczos window and Blackman-Harris Window that gives superior results than other windows.

1.4.1. Recommended Window with Gaussian window

1.4.1.1 Gaussian window

Syntax of Gaussian window:-

W = Gausswin (L, alpha)

Here, L defines for the length and must be a positive integer.

The Gaussian window function can defined as:

$W(n) = \exp[-1/2(\alpha n/M/2)^2]$

Here n lies from $0 < n \leq M/2$

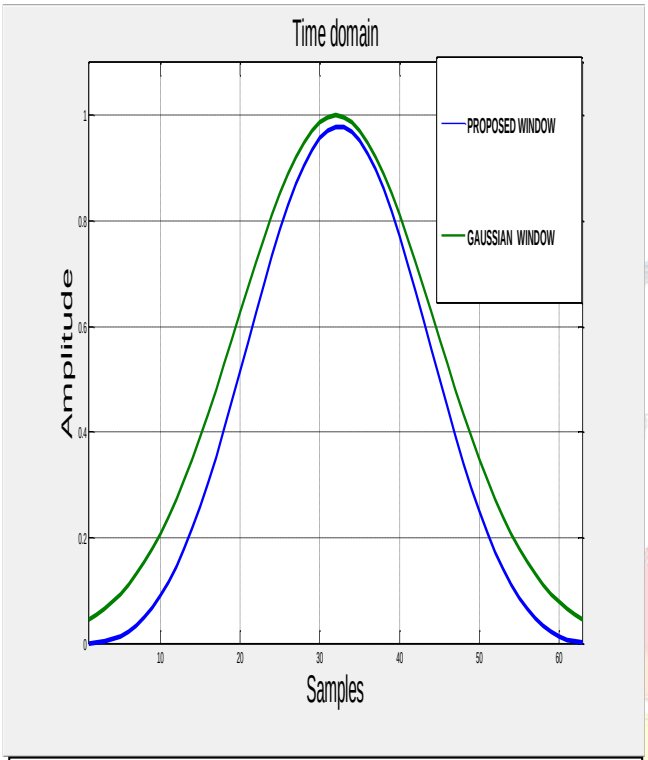

FIGURE 1: COMPARATIVE GRAPH OF RECOMMENDED WINDOW FUNCTION WITH GAUSSIAN WINDOW FUNCTION IN TIME DOMAIN

Here above 'FIGURE 1' shows that the suggested window shows narrower main-lobe width which shows better results for effective window. So the recommended window has better results than the Gaussian window in time domain.

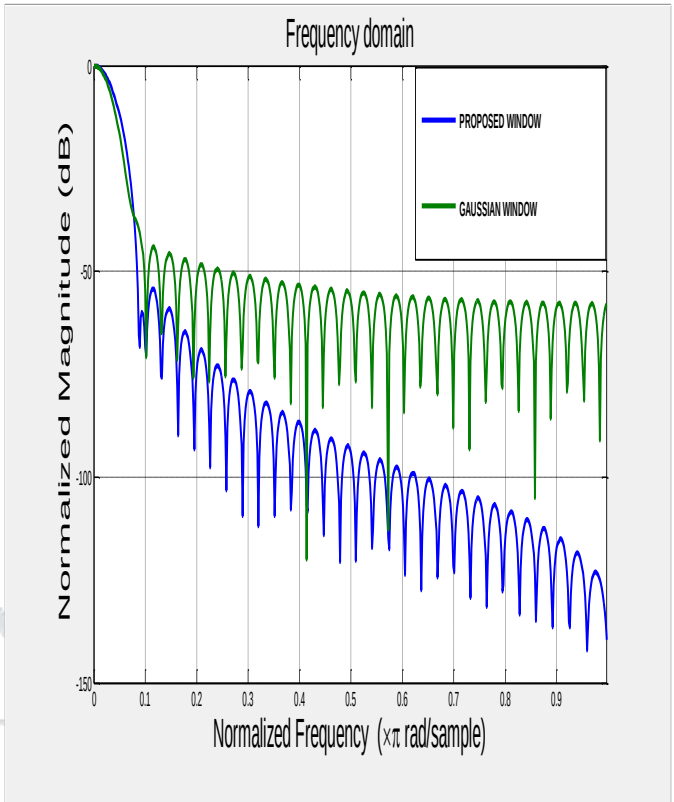

FIGURE 2: COMPARATIVE GRAPH OF RECOMMENDED WINDOW FUNCTION TO GAUSSIAN WINDOW

TABLE 1: OBSERVATION OF SPECTRAL PARAMETERS OF RECOMMENDED WINDOW FUCNTION WITH GAUSSIAN WINDOW FUNCTION

Here above 'FIGURE 2' represents that recommended window shows superior results than Gaussian window in respect of side-lobe fall off ratio and ripple ratio with some adjustment of main lobe width parameter but overall effective results of recommended window is superior than Gaussian window.

1.4.2. Recommended window with Kaiser Window

1.4.2.1 Kaiser Window:-

Window	Main-lobe width	Ripple ratio	Side-lobe fall-off ratio
Recommended window	2π×0.0898	-53.596	68.99
Gaussian window	2π×0.0101	-42.638	13.925

Syntax of Kaiser Window:

W(n)=Kaiser(N,β)

Here N defines for length and must be positive value.β is a variable parameter for Kaiser Window.

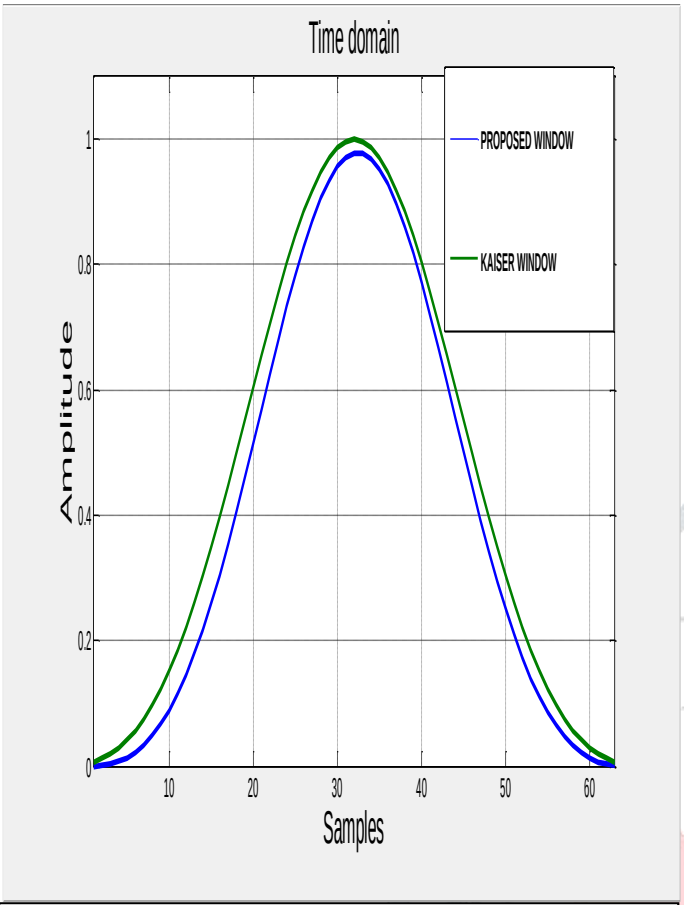

FIGURE 3: COMPARATIVE GRAPH OF RECOMMENDED WINDOW FUNCTION WITH KAISER WINDOW FUNCTION IN TIME DOMAIN

Here above 'FIGURE 3' shows better results of recommended window than the Kaiser window in terms of width of main-lobe. Proposed window has narrower width of main lobe than the Kaiser window which is good for resolution.

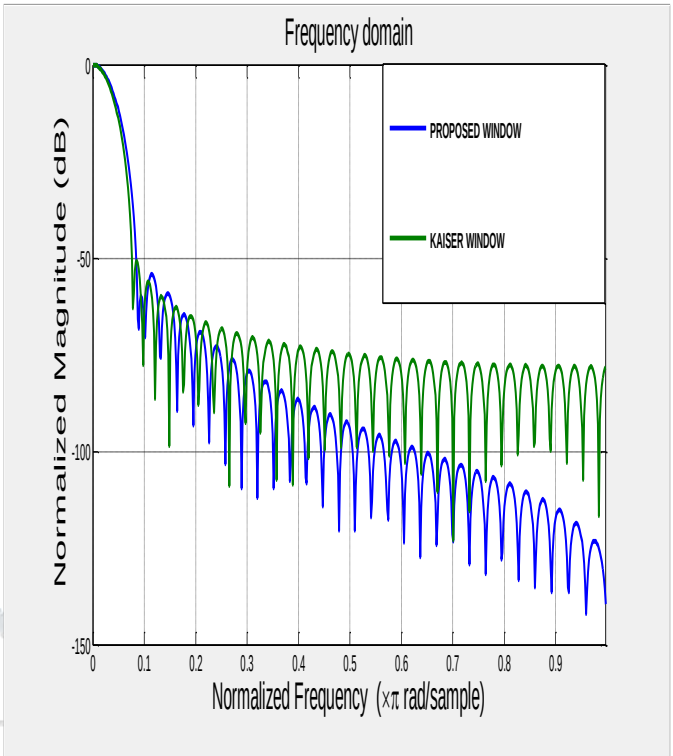

FIGURE 4: COMPARATIVE GRAPH OF RECOMMENDED WINDOW TO KAISER WINDOW IN FREQUENCY DOMAIN

As above given 'FIGURE 4' shows better results of the recommended window than Kaiser window in respect of side-lobe fall off ratio and ripple ratio but some adjustment with main lobe width parameter. Recommended window shows effective parameter results than the Kaiser window.

TABLE 2: OBSERVATION OF PARAMETERS OF SUGGESTED WINDOW FUNCTION WITH KAISER WINDOW FUNCTION

WINDOW	MAIN-LOBE WIDTH	RIPPLE RATIO	SIDE-LOBE FALL-OFF RATIO
PROPOSED WINDOW	2π×0.0898	-53.596	68.99
KAISER WINDOW	2π×0.0781	-50.821	26.537

1.4.3. Recommended window with hamming window

1.4.3.1. Hamming window:

The hamming window function can be written as:

$w(n)= 0.54-0.46\cos(2\pi n/N-1)$

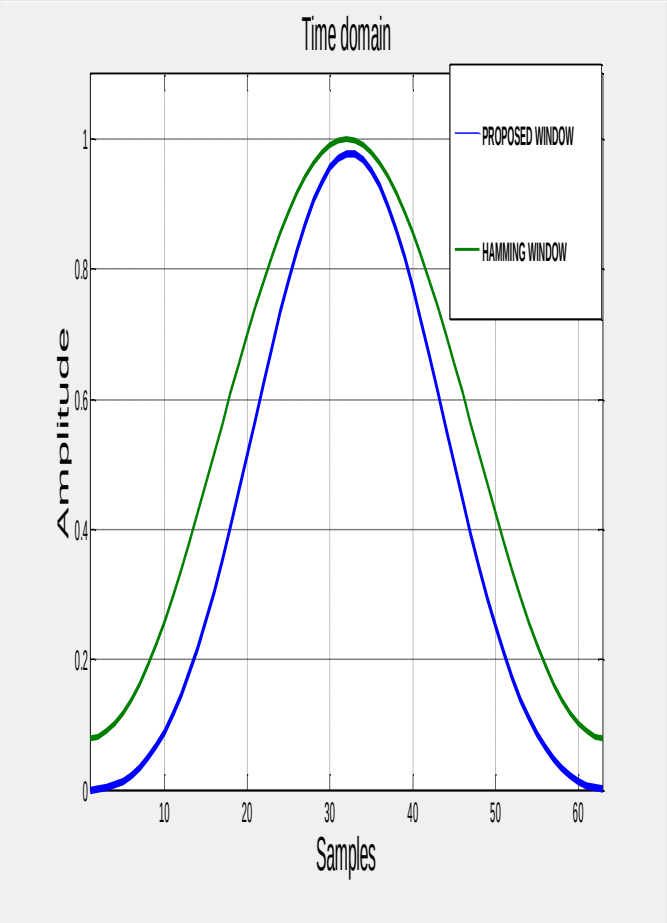

FIGURE 5: COMPARATIVE GRAPH OF RECOMMENDED WINDOW FUNCTION WITH HAMMING WINDOW FUNCTIION IN TIME DOMAIN

Here above 'FIGURE 5' shows better results of recommended window than the hamming window as in time domain the width of main-lobe of recommended window has narrow width than the hamming window which is good for effective window.

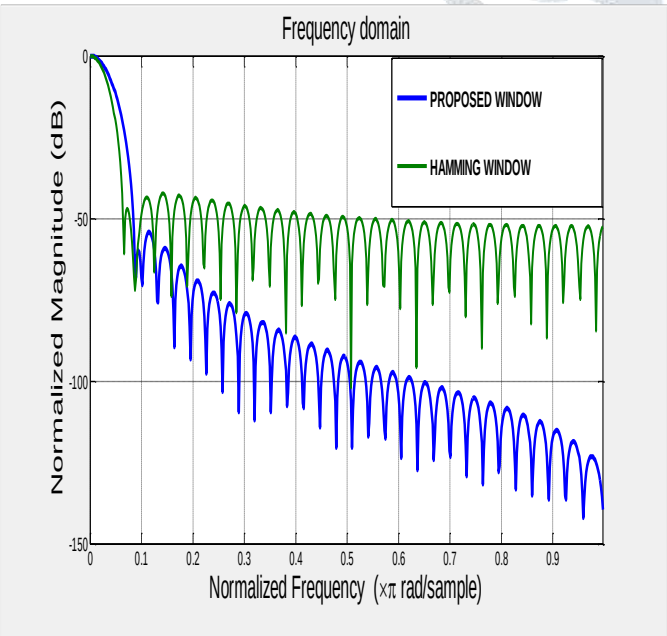

FIGURE 6: COMPARATIVE GRAPH OF RECOMMENDED WINDOW WITH HAMMING WINDOW IN FREQUENCY DOMAIN

Here above 'FIGURE 6' shows better results of recommended window in frequency domain comparatively to hamming domain in respect to ripple ratio and side–lobe fall off ratio with some adjustment of main-lobe width parameter. Recommended window shows overall effective results than the hamming window.

TABLE 3: OBSERVATION OF SPECTRAL PARAMETERS OF RECOMMENDED WINDOW FUNCTION WITH HAMMING WINDOW FUNCTION

WINDOW	MAIN-LOBE WIDTH	RIPPLE RATIO	SIDE-LOBE FALL OFF RATIO
RECOMMENDED WINDOW	$2\pi\times0.0898$	-53.596	68.99
HAMMING WINDOW	$2\pi\times0.0664$	-43.046	8.969

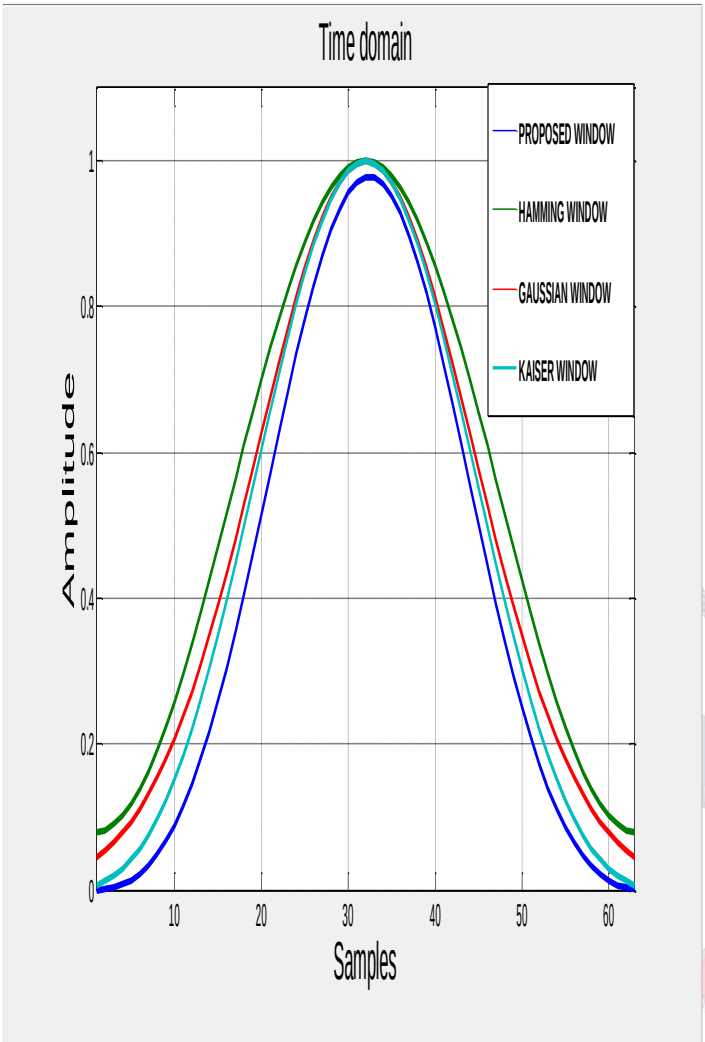

FIGURE 7: COMPARATIVE GRAPH OF RECOMMENDED WINDOW WITH HAMMING WINDOW, KAISER WINDOW AND GAUSSIAN WINDOW IN TIME DOMAIN

As depicted 'FIGURE 7' shows comparative graph of recommended window with Kaiser window, Gaussian window and Hamming window. Recommended window shows narrower width of main-lobe comparatively to Kaiser window, hamming window and Gaussian window which is good for resolution have better effective window.

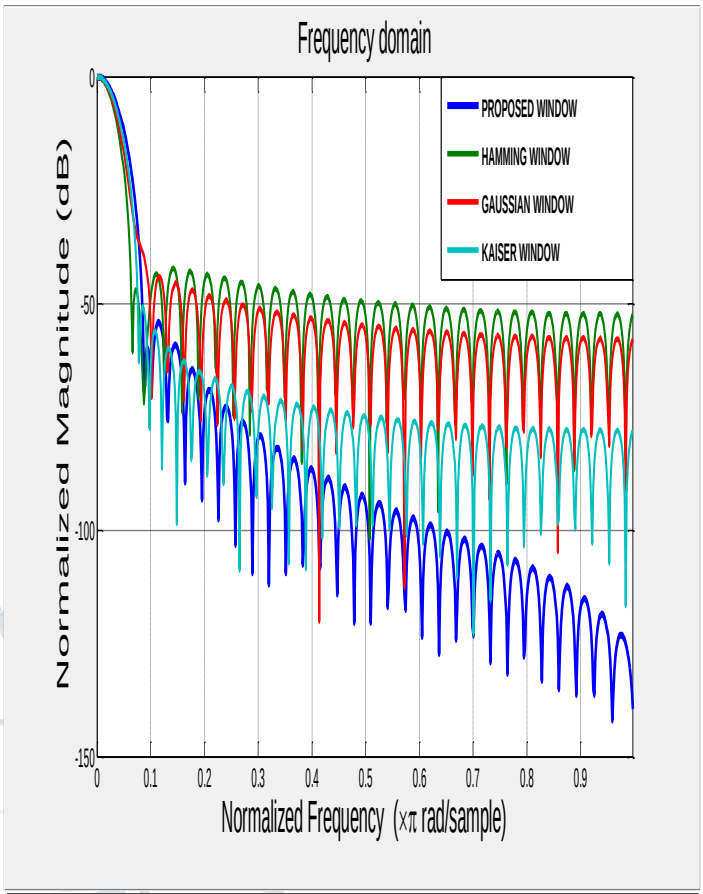

FIGURE 8: COMPARATIVE GRAPH OF RECOMMENDED WINDOW WITH HAMMING WINDOW, KAISER WINDOW AND GAUSSIAN WINDOW IN FREQUENCY DOMAIN

Here above 'FIGURE 8' shows comparative graph of recommended window with Kaiser window, hamming window and Gaussian window which have overall better results of recommended window than Kaiser window, hamming window and Gaussian window. Proposed window has superior side-lobe fall off ratio and ripple ratio than the Kaiser window, hamming window and Gaussian window. Proposed window has better results than Kaiser, hamming and Gaussian window considering side-lobe fall off ratio and ripple ratio spectral parameter, there is some compromise with main-lobe width parameter. Overall graph of recommended window has superior results than Kaiser window, hamming window and Gaussian window. Better results of proposed window in respect of side-lobe fall off ratio minimize aliasing issues and smaller value of ripple ratio reduces power losses so overall designs effective results of window.

TABLE 4: OBSERVATION OF SPECTRAL PARAMETERS OF RECOMMENDED WINDOW WITH HAMMING, KAISER AND GAUSSIAN WINDOW

Window Function	Main-Lobe Width	Ripple Ratio(in dB)	Side-lobe Roll-off Ratio (In dB)
GAUSSIAN WINDOW	$2\pi\times0.0101$	-42.638	13.925
HAMMING WINDOW	$2\pi\times0.0664$	-43.046	8.969
KAISER WINDOW	$2\pi\times0.0781$	-50.821	26.537
PROPOSED WINDOW	$2\pi\times0.0898$	-53.596	68.99

1.5. CONCLUSION

The recommended window function has variable parameter 'r' so that can adjust the spectral characteristics for effective window. Proposed window shows superior performance in two parameters of window that is side-lobe fall-off ratio and ripple ratio than the Kaiser window, hamming window and Gaussian window which reduces aliasing issues and power losses. While comparing with main-lobe width parameter there is some adjustment with other comparative windows but overall results of proposed window are superior comparatively than Kaiser window, Gaussian window and hamming window.

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