Design of Low pass Fir Filter using Hamming, Taylor, and Nuttel Windowing Techniques

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Abstract: This report deals with some of the techniques used to design FIR filters. In the beginning, the windowing method and the frequency sampling methods are discussed in detail with their merits and demerits. Different optimization techniques involved in FIR filter design are also covered, including Rabiner's method for FIR filter design. These optimization techniques reduce the error caused by frequency sampling technique at the non-sampled frequency points. A brief discussion of some techniques used by filter design packages like Matlab are also included.

Keywords: FIR filter, window techniques, DSP (digital signal processing), optimization, frequency sampling, phase and magnitude response etc.

INTRODUCTION

FIR filters are filters having a transfer function of a polynomial in z- and is an all-zero filter in the sense that the zeroes in the z-plane determine the frequency response magnitude characteristic. The z transform of a N-point FIR filter is given by

$$H(z) = \sum_{n=0}^{N-1} h(n) Z^{-n} \quad \ldots\ldots\ldots (1) \qquad [1]$$

FIR filters are particularly useful for applications where exact linear phase response is required. The FIR filter is generally implemented in a non-recursive way which guarantees a stable filter. FIR filter design essentially consists of two parts:-
(i) approximation problem
(ii) realization problem

The approximation stage takes the specification and gives a transfer function through four steps.
They are as follows:
(i) A desired or ideal response is chosen, usually in the frequency domain.
(ii) An allowed class of filters is chosen (e.g. the length N for a FIR filters).
(iii) A measure of the quality of approximation is chosen.
(iv) A method or algorithm is selected to find the best filter transfer function.

The realization part deals with choosing the structure to implement the transfer function which may be in the form of circuit diagram or in the form of a program. There are essentially three well-known methods for FIR filter design namely.
(1) The window method
(2) The frequency sampling technique
(3) Optimal filter design methods [1]

WINDOW TECHNIQUES

A simple and efficient way to design an FIR filter is window method. In the Window Design of digital filter.

Then this unit sample response must be truncated at some point, this process is equivalent to multiplying it by a finite length window function. After truncation and windowing, FFT is used to generate the corresponding frequency response of FIR filter. The frequency response can also be modified by choosing different window functions. Method the unit impulse response of ideal filter is obtained by applying Inverse Fourier Transform to the ideal frequency characteristics

A window is a finite array consisting of coefficients selected to satisfy the desirable requirements. While designing digital FIR filter using window function it is necessary to specify a window function to be used and the filter order according to the required specifications (selectivity and stop band attenuation).Now we are using three window functions which are :-
(1) Hamming window technique
(2) Taylor window technique
(3) Nuttall window technique To design a Lowpass FIR filter with the help of DSP and also Matlab samulations [2]

HAMMING WINDOW TECHNIQUES

To design Lowpass FIR filter hamming window function is used in matlab .
To derive a lowpass FIR filter in Matlab the following equation is required for hamming window techniques which is,

$$w(n) = \begin{cases} 0.54 - 0.46 \cos \frac{2\pi n}{N-1} & 0 \ll N \ll N-1 \; [3] \\ 0 & \text{otherwise} \end{cases}$$

PARAMETERS

Parameters	Values
Sampling frequency(f_s)	48000
Cutoff frequency (f_c)	10800

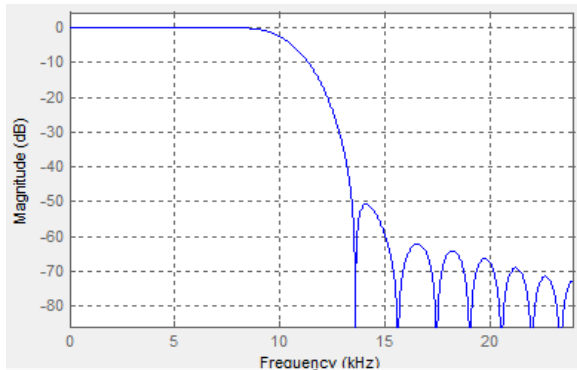## MAGNITUDE RESPONSE OF HAMMING WINDOW TECHNIQUES:-

Fig.(a) magnitude response of lowpass hamming window techniques

Figure (a) shows the magnitude response of lowpass FIR filter using hamming window techniques.

PHASE RESPONSE OF HAMMING WINDOW TWCHNIQUES:-

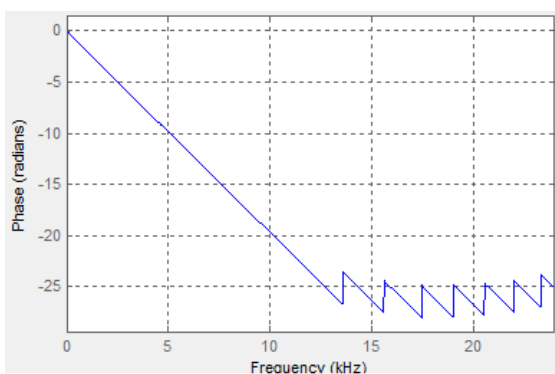Figure (b) shows the Lowpass FIR filter phase response of hamming window techniques.

Fig.(b) phase response of hamming window techniques

Now we are going to comparing both magnitude and phase response between each other.

The figure (c) shows the comparison between phase and magnitude response of hamming lowpass FIR filter window techniques.
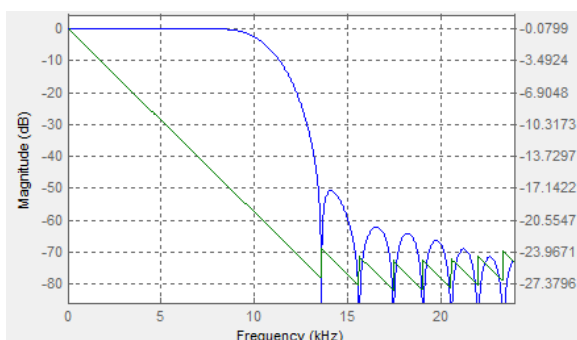
Fig.(c) comparing both phase and magnitude response of hamming window technique.

Above figure (c) shows the magnitude and phase response of lowpass FIR filter using hamming window techniques. Fig. (a,b,c) both are represents with respect to frequency.

IMPULSE RESPONSE OF HAMMING WINDOW TECHINQUES:-

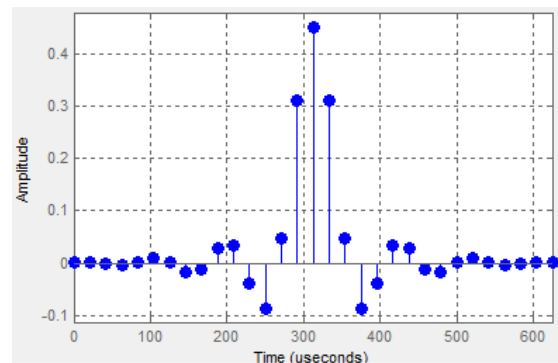Below fig.(d) shows the impulse response of hamming window techniques.

Fig.(d) impulse response of hamming window techniques.

Figure (d) shows impulse response or amplitude with respect to time of hamming window techniques

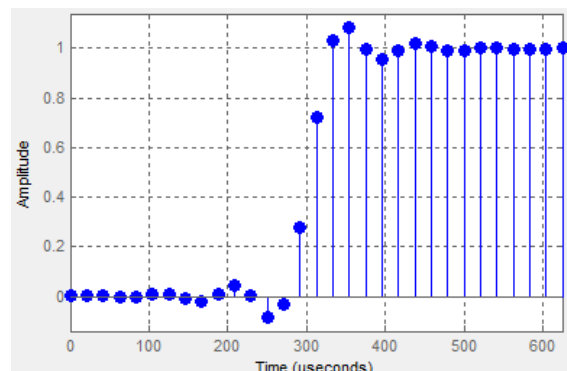## STEP RESPONSE OF HAMMING WINDOW TECHNIQUES:-

Fig. (e) step response of hamming window techniques
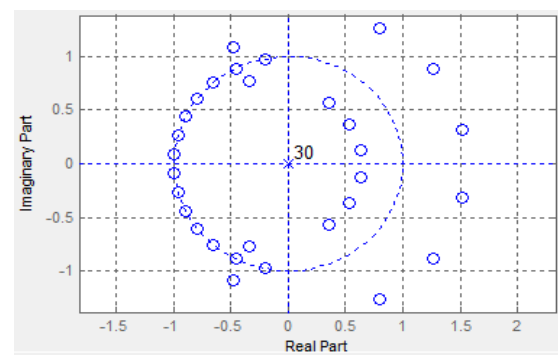
POLE/ZERO PLOT OF HAMMING WINDOW MATHOD:

fig.(f) pole /zero response

FILTER COFFICIEANT OF HAMMING WINDOW TECHNIQUES:-

Fig.(g) filter coefficient of hamming windowing techniques.

TAYLOR WINDOW METHOD

Taylor window techniques is same as wel as hamming window techniques it is also used for design lowpass FIR filter using window techniques. A little difference between hamming and taylor phase shift are deffrent to each other.
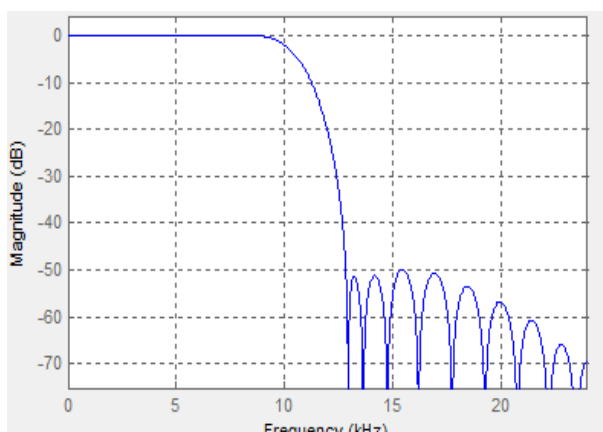
$$\omega(n) = \alpha - \beta \cos {}^{2\pi n}/_{N-1}$$

Zero phase version:-

$$\omega'(n) = \omega\left(n + \frac{N-1}{2}\right)$$
$$= 0.54 + 0.46 \cos {}^{2\pi n}/_{N-1}$$

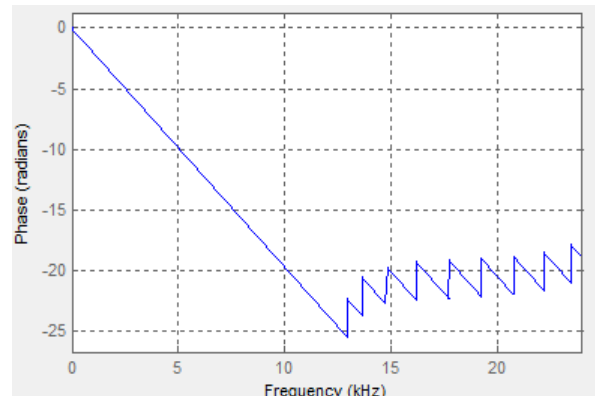this equation is called zero phase equation. [4]

MAGNITUDE RESPONSE OF TAYLOR WINDOW EQUATION:-

Fig(h)phase response of taylor window techniques

MAGNITUDE RESPONSE OF TAYLOR WINDOW TECHNIQUES:-

Figure (h) and figure (i) shows the phase and magnitude response of taylor lowpass FIR filter using windowing techniques.

Fig(i) magnitude response of taylor window method.

COMPARING BETWEEN MAGNITUDE AND PHASE RESPONSE OF TAYLOR WINDOW TECHNIQES:-

Now to compare both magnitude and phase response we use both response equivalent plot which is shown in below figure (j).and both magnitude and phase are with respect to frequency.
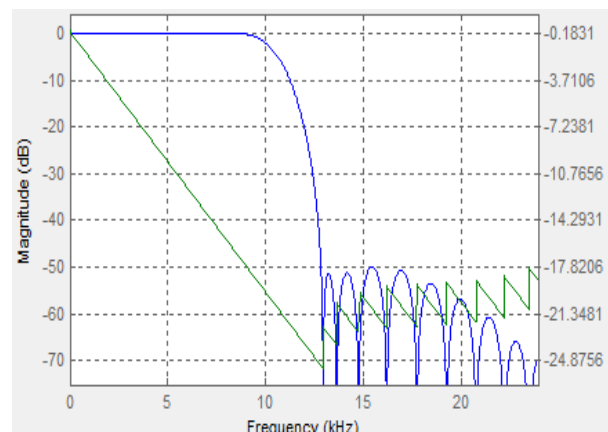

Fig.(j) magnitude and phase response of taylor window function
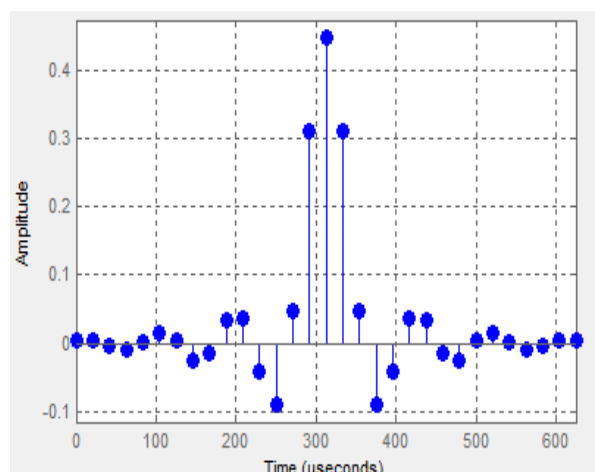
IMPULSE RESPONSE:-

fig.(k) impulse unit response of taylor window function

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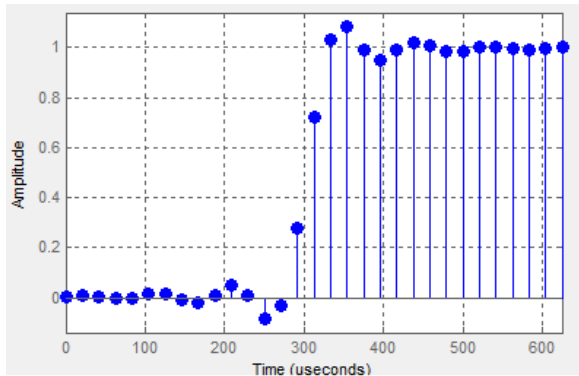
STEP RESPONSE OF TAYLOR WINDOW FUNCTION:-

fig.(l) step response of taylor window function

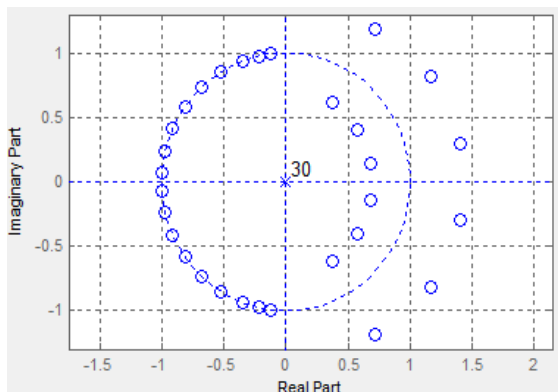## POLE/ZERO RESPONSE OF TAYLOR FUNCTION:-

fig.(m) pole/zero response

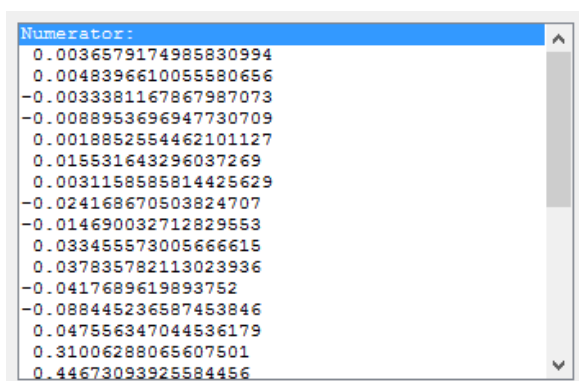## FILTER COFFICIENT OF LOWPASS FIT FILTER USING TAYLOR WINDOW FUNCTION:-

fig.(m) filter coefficient of taylor window function filter

NUTTAL WINDOW FUNCTION

Nuttal window function is also same as both hamming and taylor window function but there phase and magnitude response are little different and also their step response and impulse response are different. nuttal window function can be derived by given equation which is shown in below.

$$w(n) = a' - a1 \cos \frac{2\pi n}{N-1} + a2 \cos \frac{4\pi n}{N-1} - a3 \cos \frac{6\pi n}{N-1}$$
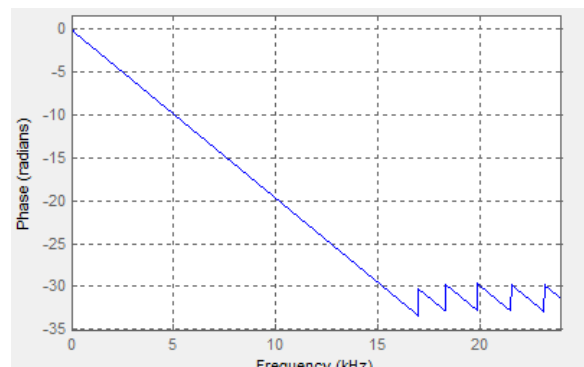
Above equation is the equation for nuttal window function equation.[5]

MAGNITUDE RESPONSE OF NUTTAL WINDOW FUNCTION :-
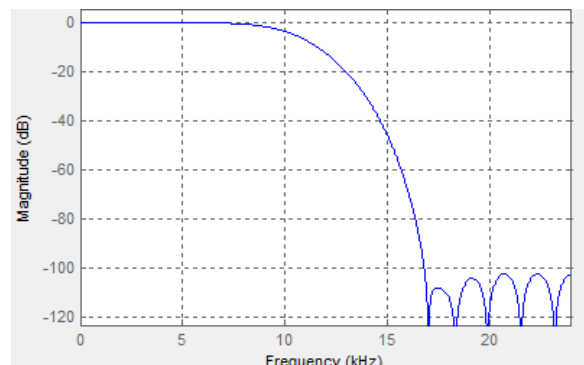
Fig(n) magnitude response of nuttal window function

PHASE RESPONSE OF NUTTAL WINDOW FUNCTION:-

fig(o)phase response of nuttal window function

Now figure (n) and figure (o) are shown magnitude and phase response of nuttal window technique with respect to frequency.

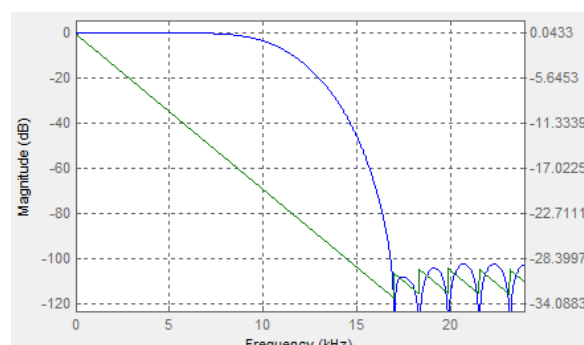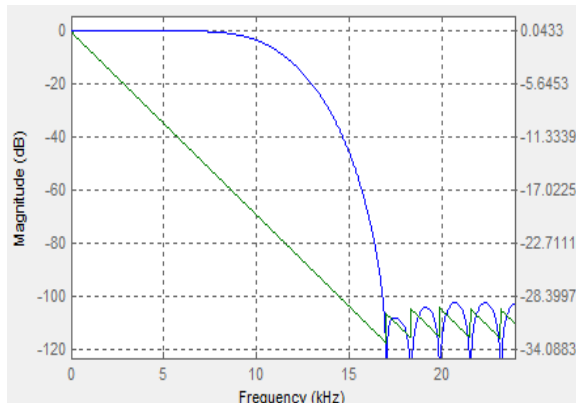## COMPARISION BETEEN PHASE AND MAGNITUDE RESPONSE OF NUTTAL WINDOW FUNCTION:-

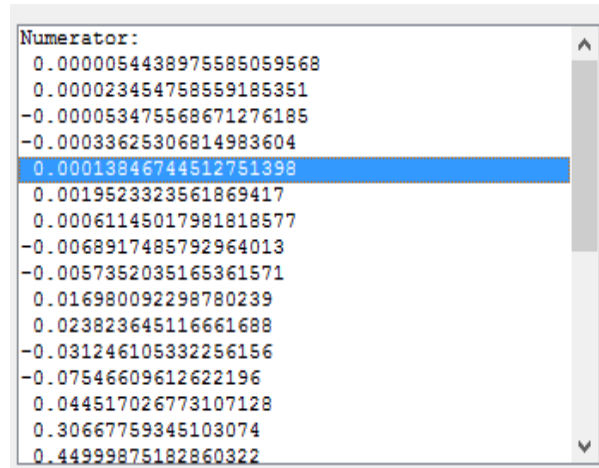fig.(p)magnitude and phase response of nuttal window function

Fig(p) shows the magnitude and phase response of nuttal window function and also with the figure we can compare both phase and magnitude response and their amplitudes.

IMPULSE RESPONSE:-

fig(q) impulse response of nuttal window function
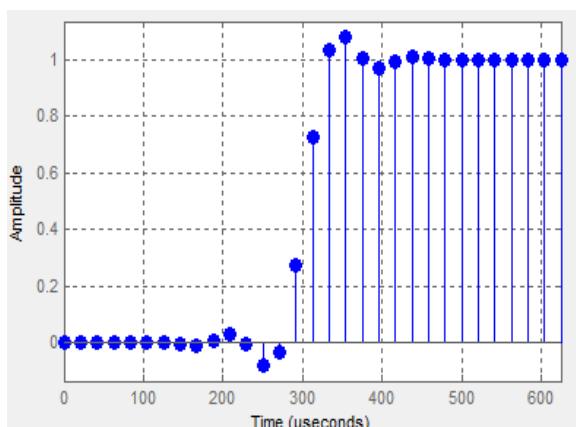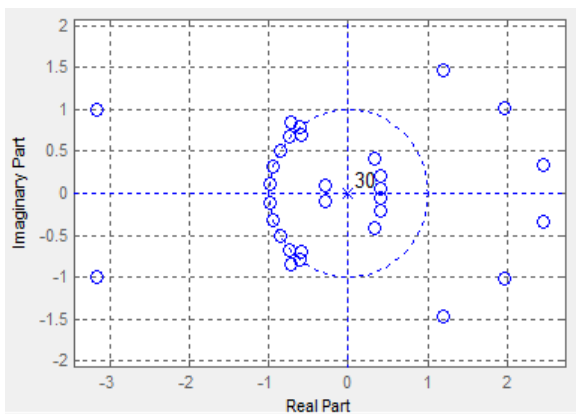
STEP IMPULSE RESPONSE:-

fig(r) step impulse response nuttal window function

Fig(q) and fig(r) shown impulse and step impulse response of nuttal window function.

POLE/ZERO PLOT:-

Fig(s) plot of pole/zero of nuttal window function.

FILTER COFFICIEANT OF NUTTAL WINDOW FUNCTION:-

Numerator:
 0.0000054438975585059568
 0.00002345475855918535l
-0.00005347556867l276185
-0.00033625306814983604
 0.00013846744512751398
 0.00195233235618694l7
 0.0006ll45017981818577
-0.006891748579296401 3
-0.0057352035l65361571
 0.0l6980092298780239
 0.02382364511666l688
-0.031246105332256l56
-0.0754660961262219 6
 0.0445170267731071 28
 0.30667759345103074
 0.44999875182860322

fig(t) filter coefficient of nuttal window function

CONCLUSION

Beside the mathematical comparison among Hamming, Taylor and nuttal window function, in this paper, they have also been encountered with the designed low pass, high pass, band pass and band stop FIR filter with a view to comparing their responses for different parameters like magnitude response, phase response, impulse response, step response, pole/zero respose, si and response in time and frequency domain all done using simulation.

The filter coefficients are considered for the design of the FIR filter. The equivalent noise bandwidth is also calculated for Hamming and taylor and nuttal window. The speech signals have also been encountered using MATLAB simulation, which was the special consideration, and compared the input and output spectrum of the signal.

In all cases, it has been found hamming window showing superiority in performance and demonstrating best functionality among these three windows which is also expected from the theory MATLAB.

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BIOGRAPHIES

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