

Research on Frequency Response in Digital Signal Processing

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Abstract. Though the design of FIR digital filter, let people master the basic method of digital signal processing and the rationality of C language or MATLAB language for computer aided design and simulation verify the design content.

Introduction

The system of FIR digital filter is always stable, and can be designed with linear phase. It has been widely applied in the practical application of the field of data communication, image processing, speech signal processing etc... N order finite impulse response (FIR) digital filter for the system function:

$$H(z) = \sum_{n=0}^{N-1} h(n)z^{-n} \quad (1)$$

The response to unit impulse $h(n)$ of the system is limited long causal ordering of length n . The design method of FIR digital filters are mainly window function method and frequency sampling method.

Computational Process

Example

Using a window function method to design a bandpass FIR digital filter design requirements for frequency response:

$$\begin{cases} |1 - 0.05| \leq |H(e^{j\omega})| \leq |1 + 0.05|, & 0.3\pi \leq |\omega| \leq 0.5\pi \\ |H(e^{j\omega})| \leq 0.05, & 0.55\pi \leq |\omega| \leq \pi \text{ and } |\omega| \leq 0.2\pi \end{cases} \quad (2)$$

Design procedure

(1) According to the requirement of design specifications, including the frequency response of the filter, transition bandwidth, the passband and stopband damping limit.

Passband: $0.3\pi \leq |\omega| \leq 0.5\pi$

Transition zone: $0.2\pi \leq |\omega| \leq 0.3\pi, 0.5\pi \leq |\omega| \leq 0.55\pi$

Stopband: $|\omega| \leq 0.2\pi, 0.55\pi \leq |\omega| \leq \pi$

Minimum stopband attenuation: $20\lg(0.05) = -26.02\text{dB}$

Cut-off frequency: $\omega_L = 0.5 \times (0.2\pi + 0.3\pi) = 0.25\pi, \omega_u = 0.5 \times (0.5\pi + 0.55\pi) = 0.525\pi$

(2) According to the transition bandwidth, the passband and stopband damping limit, determine the type of window and select a function $h(n)$ of column length N .

Minimum stopband attenuation is -26.02dB, looking up table to know Hanning window, Hamming window are in line with requirements. Now with Hamming window, for example: $N = A / \Delta\omega$, by available: $N = 8\pi / 0.1\pi = 80$. Designed to facilitate the calculations when N is odd, it takes $N = 161$.

(3) According to the ideal frequency response $H_d(e^{j\omega})$, by calculating $H_d(e^{j\omega})$ the inverse Fourier transform $h_d(n)$, make $h_d(n)$ right conduct, truncated and window function processing, and seek causal FIR digital filter unit impulse response $h(n)$.

$$h(n) = \frac{\sin(0.525\pi(n-80)) - \sin(0.25\pi(n-80))}{\pi(n-80)} \cdot (0.54 - 0.46 \cos \frac{\pi n}{80}), 0 \leq n \leq 160 \quad (3)$$

(4) Obtained the Fourier transform $h(n)$, verify that it meets the design requirements.

$$H(e^{j\omega}) = \sum_{n=0}^{N-1} h(n)e^{-j\omega n} \quad (4)$$

Depending on the design of the filter, its use of MATLAB simulation, the following picture:

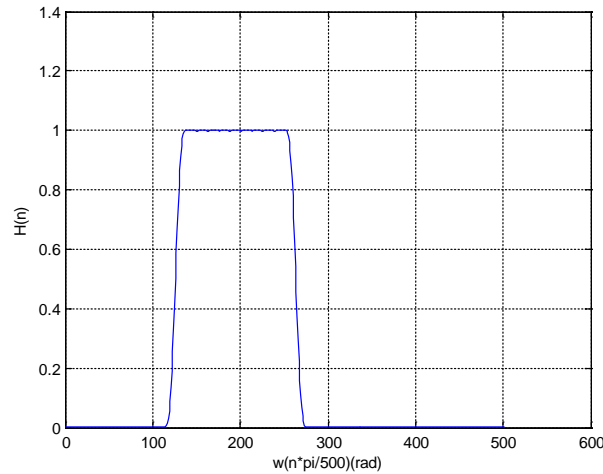


Fig.1 FIR Amplitude-frequency characteristic of a band-pass filter

From The figure we can see passband and stopband meeting the requirements, do the corresponding programming in MATLAB, the output window : Max1=0.0011, Min1 =8.4133e-05, Max2 =1.0016, Min2 =0.9984. So it meet the design requirements.

Given the magnitude of three different frequency sine different sequences were allowed in the stop band, the passband, stopband, getting an image of the three detection signal superimposed:

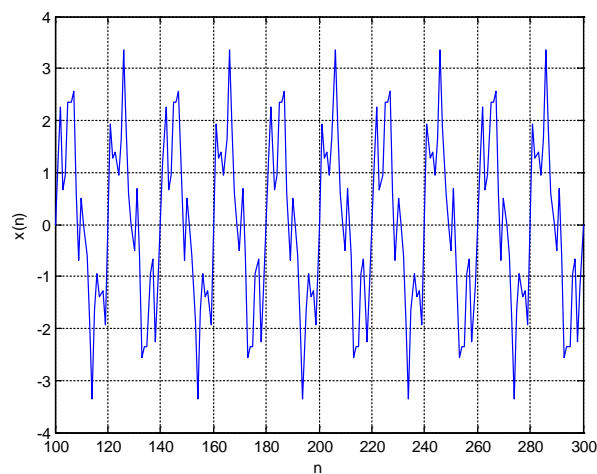


Fig.2 Superimposed on the detection signal

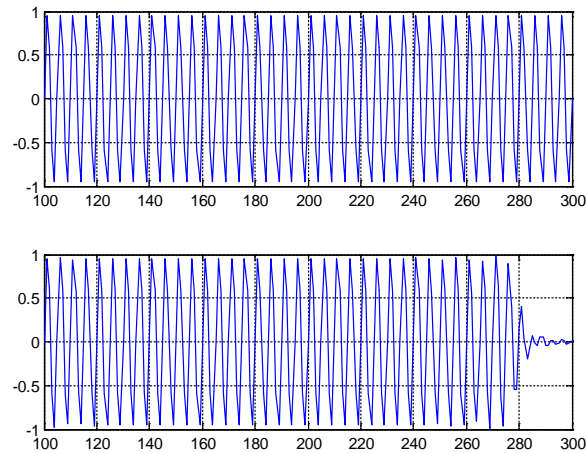


Fig.3 Passband signal and the filtered output signal of the image

By contrast in the image filtered image detecting signal we can see that the frequency sinusoidal signal in the pass band of the filter by the frequency in the stop band signal is filtered out.

Discussion

According to the minimum stop band attenuation we know that we can not apply rectangular window, then what effect will have by using a rectangular window?

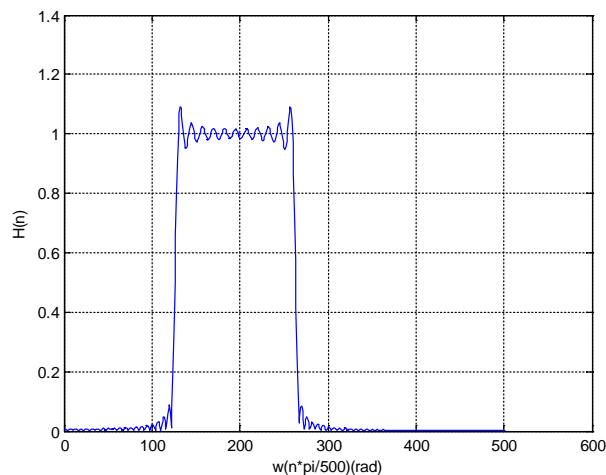


Fig.4 Rectangular window

Max=1.0922, Min=5.3951e-04 Fluctuations in the visible range does not meet the design requirements, beyond the permissible.

Now we look at the effect for the value of N difference in Hamming window.Frequency characteristic:

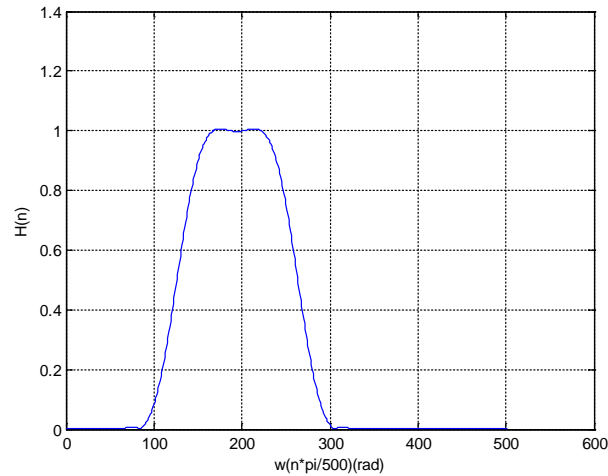


Fig.5 N=41,Hamming window

Output window:Max1=0.0610,Min1=9.3536e-04,Max2=1.0025,Min2 =0.7714.
It shows that it does not meet the requirements of volatility.

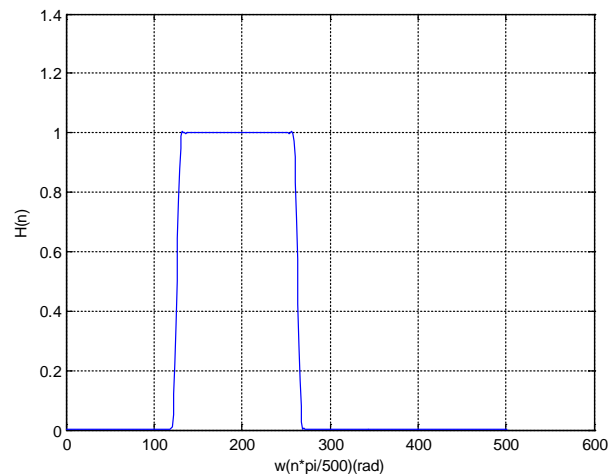


Fig.6 N=300,Hamming window

Output window:Max1=0.0010,Min1=1.7570e-05,Max2= 1.0011,Min2 =0.9988. It shows meet the design requirements.The frequency characteristic can be seen that compared to a value smaller than N, the transition bandwidth is clearly narrowed. However, with the increase in the value of N running time becomes longer and therefore a reasonable choice N value is of great significance. So we can use heuristics to determine the final value of N that is quite satisfactory to meet our requirements for the designed filter.

Summary

Designed FIR digital filter has some steps following the steps we can achieve filter. Our simulation using MATLAB to design a filter performance to meet the design requirements. Since the amplitude characteristic of the main lobe of the window function determines the transition zone amplitude characteristic a digital filter, sidelobe determine fluctuations. Therefore, the choice of window function generally consider the following two aspects: first, to minimize sidelobe window function, so that the energy is concentrated in the main lobe. Such fluctuations can be reduced shoulder and give relatively flat amplitude characteristic, improve the stopband attenuation; second, main lobe width as narrow as possible, in order to obtain a steeper transition zone. However, these two aspects are contradictory, can not have both. Typically used mainly to increase the width of the

main lobe and side lobe suppression methods to construct a window function.

References

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