IIR BANDPASS FILTER DESIGN USING MODIFIED TRANSFER FUNCTION IMPLEMENTATION ALGORITHM

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Abstract: - The following paper presents the design and implementation of IIR narrow band pass filter algorithm which can be used in applications like synthesizing musical signals. The proposed algorithm is derived from a basic notch filter by using inverse system of the notch filter. The proposed algorithm also shows how the width of the pass band changes w.r.t. the sampling frequency. The results have been simulated using MATLAB.
Keywords: - FIR Filter, IIR Filter, Notch Filter, Bandpass, Bandstop

1 Introduction

Band pass filter can be implemented using FIR as well as IIR filters. Several simple IIR filters can be designed with first order and second order function. However to achieve the band pass filter with extremely narrow band you need to have very high order of FIR filter[2]. Using IIR filter the band pass filter can be designed with comparatively very low order but there are limitations on the width of the pass band that can be achieved[6].

2 Theory

2.1 Previous Design

A second order bandpass filter is described by the transfer function [7].

$$H_{BP}(z) = \frac{(1-\alpha)}{2} \cdot \frac{1-z^{-2}}{1-\beta(1+\alpha)z^{-1}+\alpha z^{-2}} \qquad (1)$$

Squared magnitude response of the above function goes to zero at $\omega=0$ and at $\omega=\pi$. It assumes maximum value of unity at $\omega=\omega_0$, called the center frequency of the bandpass filter, where

$$\omega 0 = \cos^{-1}(\beta) \qquad (2)$$

The difference between the frequencies ω_{c1}, ω_{c2} is given by

$$\Delta\,\omega = \cos\text{-}1(2\,\alpha / (1+\alpha^2) \qquad (3)$$

Figures 1 and 2 show the magnitude responses of the bandpass filter for different values of α and β. Figures 3 and 4 show the pole zero placement of the corresponding filters.

A second order bandstop filter is described by the transfer function [1].

$$H_{BS}(z) = \frac{(1+\alpha)}{2} \cdot \frac{1-2\beta z^{-1}+z^{-2}}{1-\beta(1+\alpha)z^{-1}+\alpha z^{-2}} \qquad (4)$$

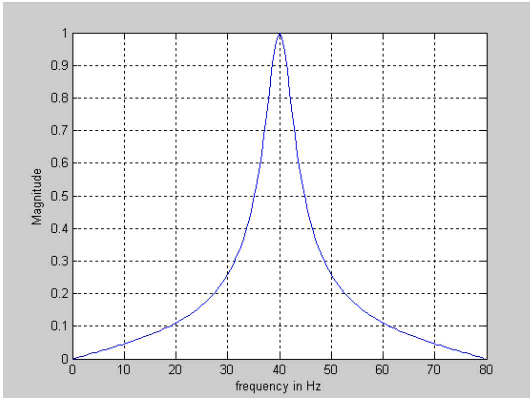

Fig.1 Magnitude response at alpha=0.8, ω0=0.5π and fs=160Hz

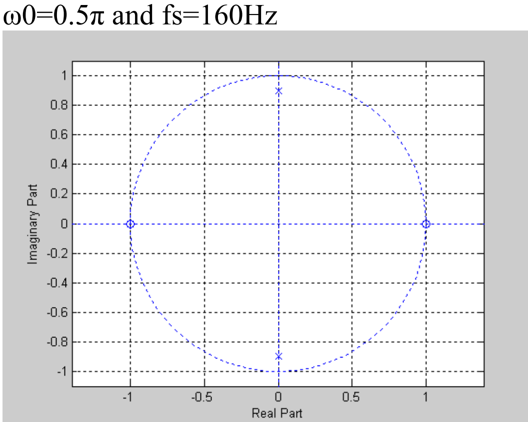

Fig.2 Pole -zero plot for alpha=0.8, ω0=0.5π and fs=160Hz

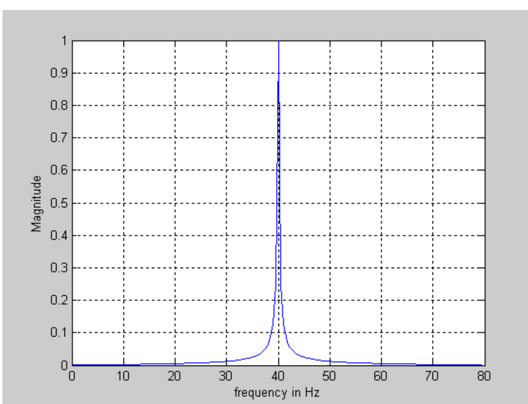

Fig.3 Magnitude response at alpha=0.99, ω0=0.5π and fs=160Hz

Here, the squared magnitude response of the above function takes maximum value of unity at ω=0 and at ω=π. And goes to zero at $\omega=\omega_0$, called the center frequency of the bandpass filter, where ω0 is given by equation (2).

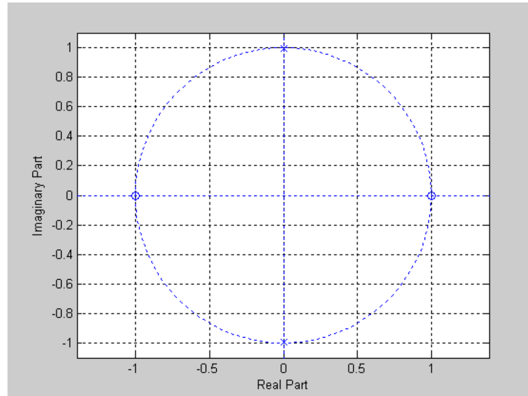

Fig.4 Pole -zero plot for alpha=0.99, ω0=0.5π and fs=160Hz

Figure 5 shows the magnitude responses of the bandpass filter for different values of α and β.

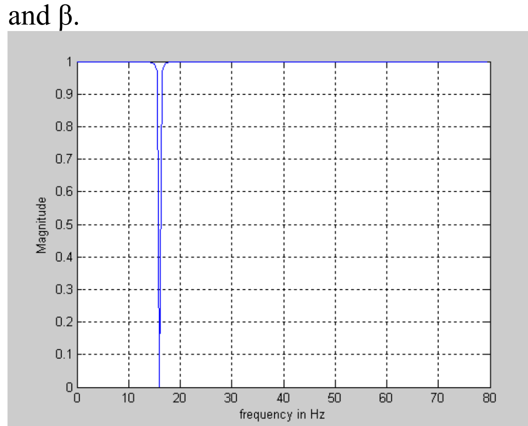

Fig.5 Magnitude response for alpha=0.99, ω0=0.5π and fs=160Hz

2.2 Proposed Design

According to the previous method it is shown that the width of the pass band can not be narrowed further using second order bandpass filter. Therefore it is necessary to find the method to get the narrower pass band. Transfer function of bandpass filter is modified in the proposed method. Conventionally bandpass filter response is equivalent to the inverse response of bandstop filter. Using the fact that inverse system corresponding to a transfer function H (z) is denoted by $H^{-1}(z)$ and is defined as

$$H^{-1}(z) = 1/H(z) \quad (5)$$

The modified transfer function of the second order Bandpass filter can be written as

$$H_{BP}(z) = \frac{2}{(1+\alpha)} \frac{1-\beta\,(1+\alpha)\,z^{-1} + \alpha\,z^{-2}}{1-2\beta\,z^{-1}+z^{-2}} \qquad (6)$$

3 Design Examples and Results

Bandpass filter with modified transfer function is designed by using same values of α and β as that of the previous design. The filter is implemented by writing down simulation program in MATLAB. Figures 6 and 7 show the magnitude responses of the modified bandpass filter for different values of α and β.

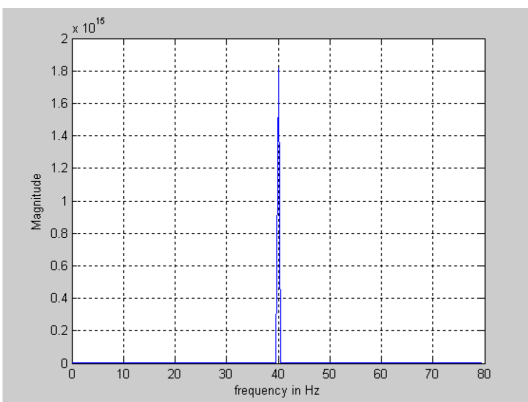

Fig.6 Magnitude response for alpha=0.8, ω0=0.5π and fs=160Hz

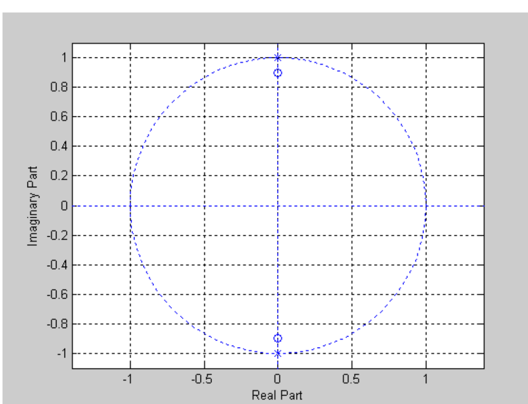

Fig.7 Pole -zero plot for alpha=0.8, ω0=0.5π and fs=160Hz

Figures 8 and 9 show the pole zero placement of the corresponding filters.

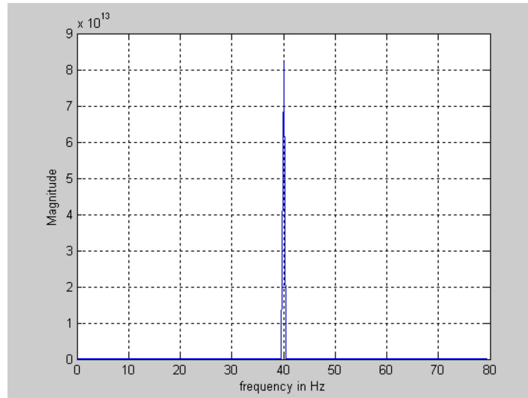

Fig.8 Magnitude response for alpha=0.99, ω0=0.5π and fs=160Hz

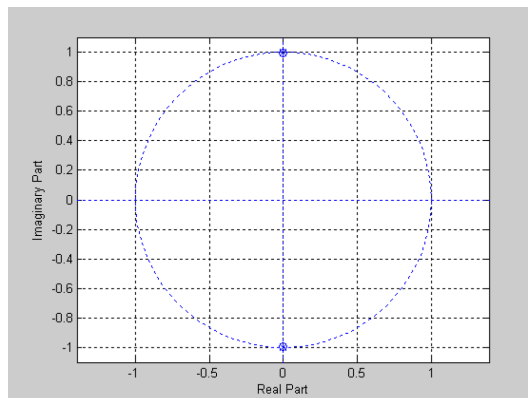

Fig.9 Pole -zero plot for alpha=0.99, ω0=0.5π and fs=160Hz

Bandpass filter is also designed using modified transfer function with different values of sampling frequency keeping the other parameters same. Figures 10 and 11 show the magnitude responses of two such filters where values of α and β are same but values of sampling frequency are different.

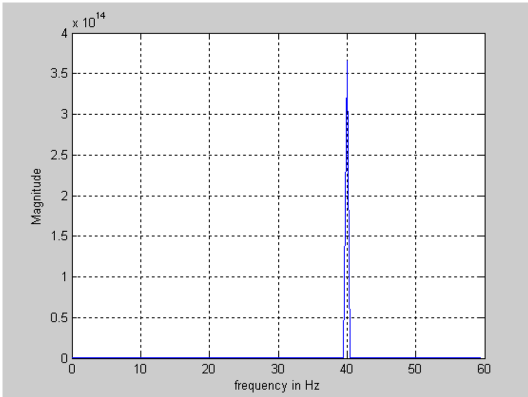

Fig.10 Magnitude response for alpha=0.8, ω0=0.5π and fs=120Hz

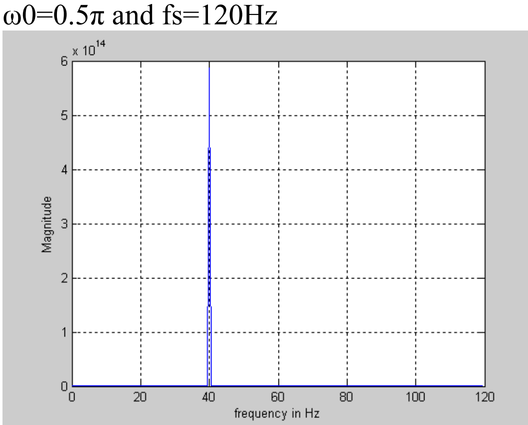

Fig.11 Magnitude response for alpha=0.8, ω0=0.5π and fs=240Hz

4 Conclusion

Experimental results show that the new design of IIR bandpass filter by modifying the transfer function results in the filter giving narrow pass band as compared to the previous design. Further the pass band of the filter could be varied by varying the sampling frequency. The proposed method can be used in synthesizing musical signals where the pass band is required to be very narrow.

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