Design & Analysis of IIR notch filter using Bandwidth Parameter
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Abstract: The purpose of IIR notch filter is to remove Narrow Band Interference signal while leaving Broad Band Signal unchanged in communication system. This research paper presents a method for design of fixed notch filter at center frequency FO (90MHz). We calculate two parametric values like pass band ripple &stop band attenuation by using mathematical modeling. For this purpose we have selected elliptic design method, direct form II transposed SOS algorithm. Bandwidth ranging from 0.2GHz to 200 MHz has been generated with the help of different RF & AF oscillator. Filter approximation and order of the notch filter determine overall performance improvement in presence of Narrow Band Interference. The settling time of the filter should be as low as possible. From the result, minimum settling time, complexity and power consumption have been achieved, with the use of second order filter. The performance and realization of IIR notch filter has been presented in this paper. It is easy to implement in communication at transmitter or receiver, as it has good communication system response. This notch filter can be realized by a computationally efficient lattice structure.


1. INTRODUCTION
A notch filter filters out a specific frequency that may have a particularly high amplitude interfering with a particular signal of interest. Nowadays analog type notch filters are not used because of problem accuracy, difficult realization and unadjustable notch frequencies. This paper presents discussion of digital fixed notch filters which are rated based on value of their q-factor. Generally, lower the bandwidth, the more exact the notch. A notch filter with high bandwidth may effectively notch out a range of frequencies, whereas a low bandwidth notch filter will only delete the frequency of interest. Fixed notch filter is designed to remove a single fixed noise present at single frequency in communication system which is either at transmitter or at receiver. For testing fixed notch filter in the matlab two basic parametric values like pass band ripple &stop band attenuation by using mathematical modeling.

For this purpose we have selected elliptic design method, direct form II transposed sos order section as our filter structure because it uses less number of delay elements and elliptic design algorithm and we change another frequency constraints factor like bandwidth factor from (200MHz - 200Hz) taking the sampling frequency as 2GHZ. There is variation in output gain from (0.9999999999999971:1:1.000000000001187) and fixed bandwidth gain to be -3.0103db for every value of bandwidth factor. We check all the responses for different value of bandwidth and we observed that worst response is observed at bandwidth =200MHz and best response is observed at bandwidth=200Hz. now we calculate, the settling time and 20 dB bandwidths of 2nd order filter it is calculated using simple analytical expression (3) and (4) [1].we find the settling time to be 13.8 nsec and bw 20db to be 9045.3kHz. The 20 dB bandwidth is an indication of the attenuation. For minimum settling time the filter order should be as low as possible, with increasing filter order due to the growing number of multipliers, adders and delay elements [1]. Analog fixed notch filter suffer from problem of accuracy, difficult in realization and unadjustable notch frequencies. Therefore this paper presents discussion of IIR notch filters which are rated based on basis of their bandwidth-factor. The frequency response of digital notch filter satisfies the following constraints:

\[ |H(e^{j\omega})|_{\omega=0,\pi} = 1 \text{ and } |H(e^{j\omega})|_{\omega=0} = 0 \]

2. Mathematical equation to calculate rejection bandwidth & pass band ripple [12]

\[ H_0 (Z) = \frac{1+z^{-1}}{1-2z^{-1}} \]  
\[ A_1 (Z) = \frac{1+z^{-1}}{1-2z^{-1}} \]  
\[ K_1=\cos{\pi f_o} \]  
\[ H_0 (Z) = H_0 (Z) \{ K + (1 - K)\ln (1 - Z) \} \]  
\[ \text{Rejection bandwidth (Bw)} = \frac{1}{2\pi}\arctan\left(\frac{1}{1-K^2}\right) \]  
\[ \text{Pass band ripple (Ap)} = \left(\frac{k^2}{2(1-K^2)}\right) \]
Oscillator used for generation of bandwidth
To generate bandwidth ranging from 0.2GHz to 200 MHz to get sharp notch we use different type of oscillator [4]. We can use either Hartley, colpitt, clapp or crystal oscillators for generation of RF oscillators of \( f > 20\text{kHz} \). RC phase shift and wein bridge is used for generation of AF oscillators of \( f<20\text{kHz} \).

**Description OF ELLIPTIC design method**

**Second Order Notch Filter**
The attenuation at the notch frequency is ideally infinite. However, in practical circuits the attenuation is finite. Therefore, the filter is modeled by the following transfer function:

\[
H(s) = \frac{s^2 + \omega_{BW}s + \omega_0^2}{s^2 + \omega_{BW}s + \omega_0^2}
\]

**Filter structure used**
Direct form –II transposed SOS of iir system; an alternative structure called direct form-II transposed SOS can be realized which uses less number of delay elements than the direct form-I structure. Consider the general difference equation

\[
Y(n) = \sum_{m=1}^{N} a_m y(n-m) - \sum_{m=0}^{M} b_m x(n-m)
\]

3. SIMULATION RESULT & DISCUSSION
We plotted responses at \( BW = 200 \text{ MHz} \) & \( BW = 2 \text{ KHz} \) like pole zero, phase delay, magnitude response, unit step response, impulse response etc. Supposing sampling frequency to be 2GHz.
Fig. (4) Magnitude response for BW=200MHz

Fig. (5) Magnitude response estimate for BW=200MHz

Fig. (6) Impulse response for BW=200MHz

Fig. (7) Group delay for BW=200MHz

Fig. (8) Round of noise power spectrum BW=200MHz
Fig. (9) Phase delay for BW=200Hz

Fig. (10) Phase response for BW=200Hz

Fig. (11) Magnitude response for BW=200Hz

Fig. (12) Magnitude response estimate for BW=200Hz

Fig. (13) Group delay for BW=200Hz
<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Notch/Center Frequency In(GHz)</th>
<th>Order</th>
<th>Bandwidth (in GHz)</th>
<th>Filter Coefs (Output Gain)</th>
<th>Filter Info (Bandwidth Gain In dB)</th>
<th>Settling Time In(nsec)</th>
<th>Fbw 20db In KHz</th>
<th>Multiplier,adder per unit sample &amp; States</th>
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<tbody>
<tr>
<td>1</td>
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<td>2</td>
<td>0.2</td>
<td>0.99999999999999711</td>
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Fig. (14) Unit step response for BW=200Hz

Fig. (15) Round-off noise power spectrum for BW=200Hz

### 4. Realization of the notch filter:

For the realization of 2nd order filter it requires 6 multiplier, 2 delay and 4 adder elements. It is clear that as the order of the filter is high the computational complexity is more i.e. is more number of multiplier, adder and delay elements. Therefore it adds the delay in the response [1].
to get the value of parameter needed to get the simplified model. Input given to these filters are in .wav format from wave file. Thus we see here that there is very large decrease in amplitude of the input waveform when bandwidth-factor=200MHz

<table>
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<tr>
<th>Parameter</th>
<th>Value</th>
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<td>Passband Ripple</td>
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<tr>
<td>Stopband Atten.</td>
<td>0.7655 dB</td>
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<td>Implementation Cost</td>
<td></td>
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<td>Number of Multipliers</td>
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<tr>
<td>Number of Adders</td>
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<td>Number of States</td>
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<tr>
<td>AddPerInputSample</td>
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</tbody>
</table>

5. Testing design model of II notch filter
To get the real time filtration the model in matlab is built. The results of Mathematical equation are used

![Fig. (16)-wave form of notch filter input](image1)

![Fig. (17)-wave form of notch filter output when BW=200MHz](image2)

![Fig. (18)-wave form of notch filter input](image3)

![Fig (19)-waveform of notch filter output when BW=200Hz](image4)

Thus we see here that there is approx. no change in amplitude of the input waveform and only noise at 90MHZ gets filtered out.
6. CONCLUSION
The comparative study of design of fixed notch filter has been presented. The purpose of this paper is to remove the noise present at 90 MHz fixed narrowband interference signal which is unwanted is present in communication system at 90 MHz this notch filter can be realized by a computationally efficient lattice structure. Some response and design method has been demonstrated in good performance after comparing results for different value of bandwidth-factor we obtain for different values of bandwidth-factor ranging from 200MHz-200Hz, it has been observed that all types of response like pole zero plot, amplitude& phase plot, group delay, phase delay, impulse response, unit step response, filter coefficient (output gain), filter information is worst at BW=200MHz and best at BW=200Hz. It has been observed that filter coefficient (output gain) is almost constant, when we vary BW=2KHz to BW=2Hz when model at BW=200MHz has been tested, it has been observed that there is large decrease in amplitude of signals at different frequencies in the output signal and thus resulting in large error. When we go on decreasing the bandwidth factor of notch filter sharpness increases and best notching at 90MHz frequency has been observed between BW=2KHz to BW=200mHz. It has been observed that output signal is same as input signal resulting in very low percentage error. Finally the system has been tested for system response having very less settling time of 13.8ns and Fourier coefficient output gain is in the range of sixteen thousand. This notch filter can be realized by a computationally efficient lattice structure with minimum number of multiplier (6), adder (4) and states (2). The digital IIR notch filter designed in this thesis has been tested and has not been implemented for communication circuit. Based on these results: Best transmitter and receiver section can be developed. Radio Front-End With Automatically Q-Tuned Notch Filter and VCO Can be developed. This method can be extended for 2-D notch filter design.

References