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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 modelling. 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 realization perspective, the filter consumes more power and becomes more complex with increasing filter's order. As a 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.

Keyword: RF&AF-Radio&audio Frequency, NBI-Narrowband Interference, BBS-Broadband Signal, APASS=Passband Ripples ASTOP=Stopband Attenuation, BW-bandwidth

1. INTRODUCTION

A notch filter filters out a specific frequency that may have a particularly high amplitude interfering with a particular signal of interest. now a days 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 parameter (apass and astop) has to be determined keeping constant value k=2 in the equation (1) and (2) we found that astop=0.7659db & apass=0.1547db[2].we know in communication system for example frequency of FM lies between (88MHZ-108MHZ)and our frequency of interest is to remove noise existing at 90MHZ.To achieve this we keep the frequency constraints factor like center frequency or fixed notch frequency at 90 MHz and fix order of the system to be 2nd. we select direct form -ll 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 (0.99999999999999711-1.0000000000011871) 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 $f_{bw\ 20db}$ 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: $\left|H(e^{j\omega})\right|_{\omega=0,\pi} = 1$ and $\left|H(e^{j\omega})\right|_{\omega=\omega 0} = 0$

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

$H_1(Z) = \frac{1+Z^{-1}A1(Z)}{2}$ (1)

$A_1(Z) = \frac{K1+Z^{-1}}{1+K1Z^{-1}}$ (2)

$K_{1=}$ -cos $2\pi f_o$ (3)

$H_n(Z) = H_{n-1}(Z)\{K + (1-k)Hn-1(Z)\}$ (4)

Rejection bandwidth (B_T) $= \frac{1-\sqrt{1+(k^2-1)^2}}{(1-k^2)}$ (5)

Pass band ripple (A_P) = $(\frac{K^2}{2\sqrt{K^2-1}}-1)$ (6)

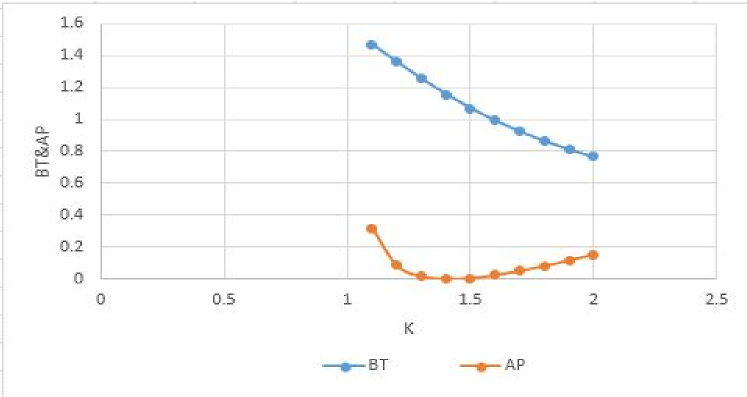

Fig. (1) *Shows B_T and A_P verses k*

Frequency is much higher than the bandwidth and the attenuation at the notch frequency is much greater than 20 dB, the 20 dB bandwidth of the notch filter can be approximated as:

$$F_{BW\ 20db} \approx \frac{f_{bw}}{\sqrt{99}} \qquad (10)$$

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 > 20khz . RC phase shift and wein bridge is used for generation of AF oscillators of f<20khz.

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:

$$H(s) = \frac{s^2+\omega_{Bw}*A_N+\omega_o^2}{S^2+\omega_{BW}*S+\omega_o^2} \qquad (7)$$

Where

A_N is the attenuation at the notch frequency, ω_{BW} is the notch bandwidth and ω_0 is the notch frequency in rad/s. the time response of the filter output for a sinusoidal input is:

$$\sin(\omega_{o*}t) + 2\frac{\omega_O(A_N-1)e^{\frac{-t*\omega_{BW}}{2}}\sin(t*\sqrt{4*\omega_O^2-\omega_{BW}^2}}{\sqrt{4*\omega_o^2-\omega_{BW}^2}} \qquad (8)$$

The first part of (8) is the steady state solution. The second part is the transient solution, which decays exponentially and where the decay time is only a function of the notch bandwidth [9]. The 2% settling time is written as follows

$$T_s=\frac{-2*\ln(.02)}{2*\pi*f_{BW}} \qquad (9)$$

f_{bw} is the 3 dB notch bandwidth in Hz.

ELLIPTIC design is simple method. Elliptic filters offer steeper roll off characteristics than Butterworth or Chebyshev filters, but are equiripple in both the pass- and stopband. In general, elliptic filters meet given performance specifications with the lowest order of any filter type.

Filter structure used

Direct form –ll transposed SOS of iir system: an alternative structure called direct form-ll transposed SOS can be realized which uses less number of delay elements than the direct form –l structure. Consider the general difference equation governing an llR system. In general, the time domain representation of an N^{th} order system is,

$$Y(n) = -\sum_{m=1}^{N} a_m y(n-m) + \sum_{m=0}^{M} b_m x(n-m) \qquad (11)$$

3. SIMULATION RESULT & DISCUSSION

We plotted responses at BW =200 MHz &BW = 2 KHz like pole zero, phase delay, magnitude response, unit step response, impulse response etc. Supposing sampling frequency to be 2GHZ.

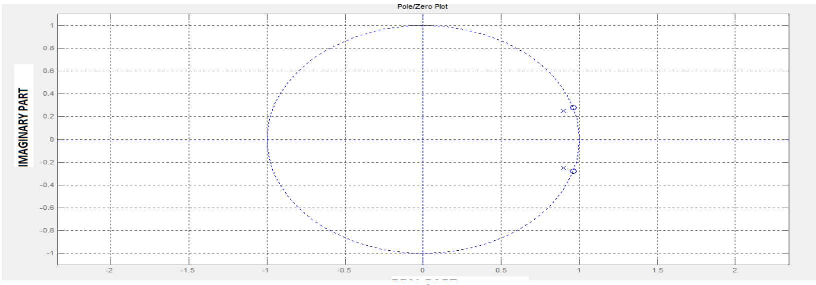

Fig. (3) *Pole zero plot for BW=200MHz*

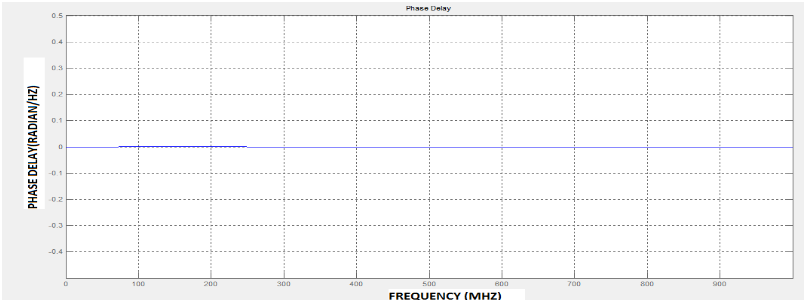

Fig. (4) *Phase delay for BW=200MHz*

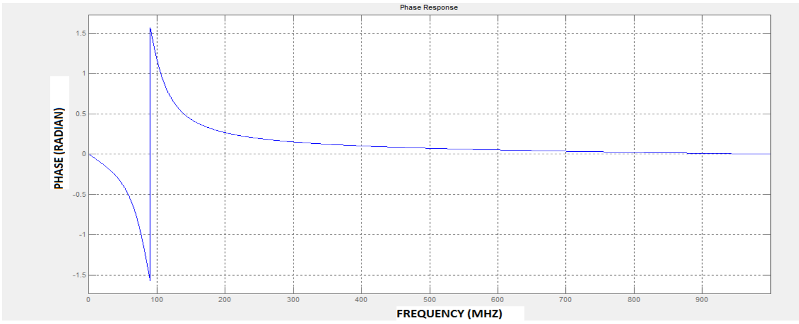

Fig. (5)*Phase response for BW=200MHz*

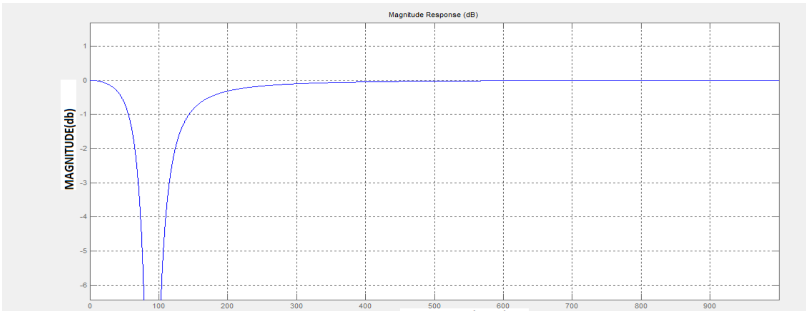

Fig. (6) *Magnitude response for BW=200MHz*

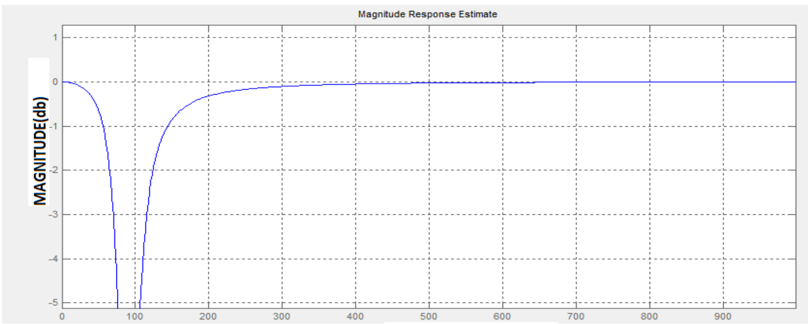

Fig. (7) *Magnitude response estimate for BW=200MHz*

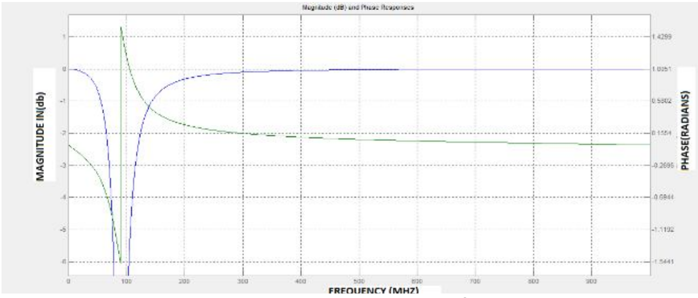

Fig. (8) *Magnitude and phase response for BW=200MHz*

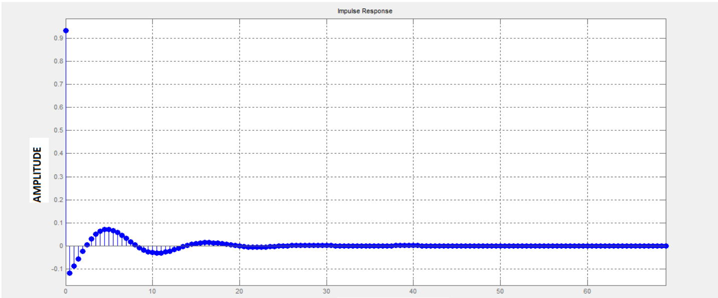

Fig. (9) *Impulse response for BW=200MHz*

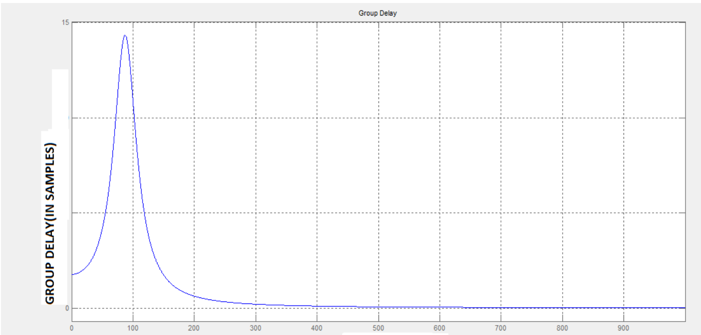

Fig. (10) *Group delay for BW=200MHz*

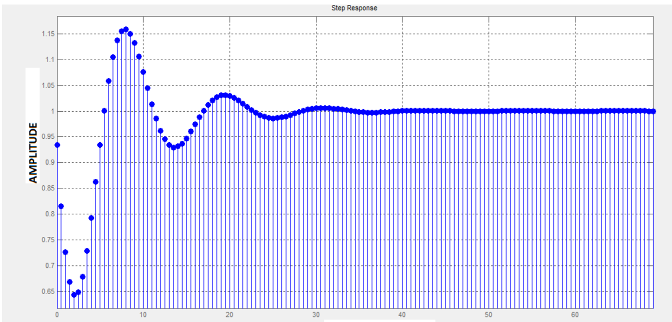

Fig. (11) *Step response for BW=200MHz*

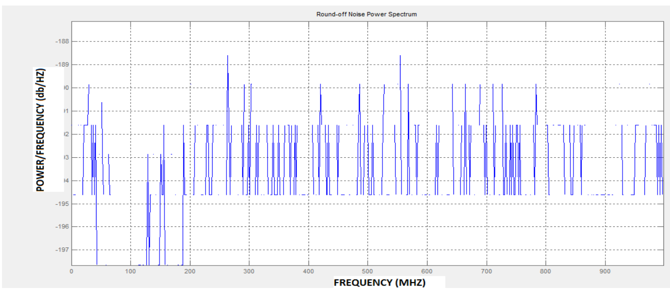

Fig. (12) *Round of noise power spectrum BW=200MHz*

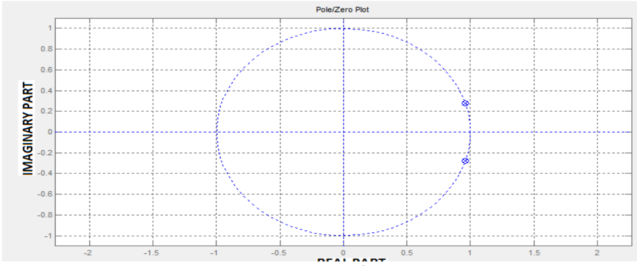

Fig. (13) Pole zero plot for BW=200Hz

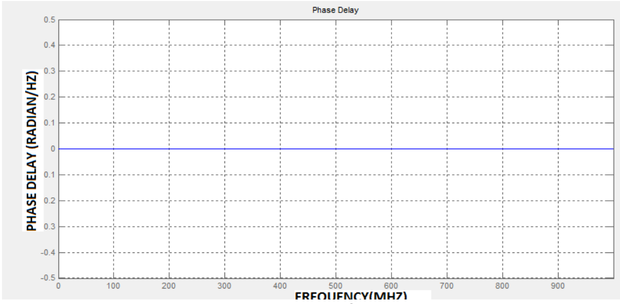

Fig. (14) Phase delay for BW=200Hz

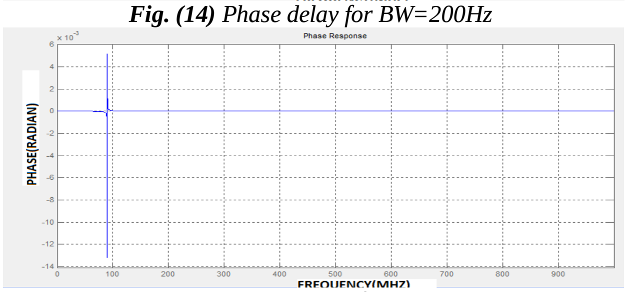

Fig. (15)Phase response for BW=200Hz

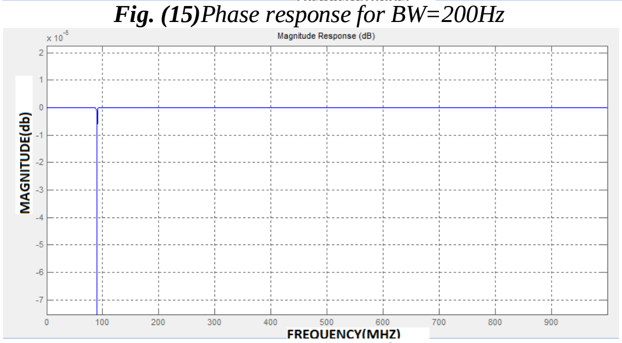

Fig. (16) Magnitude response for BW=200Hz

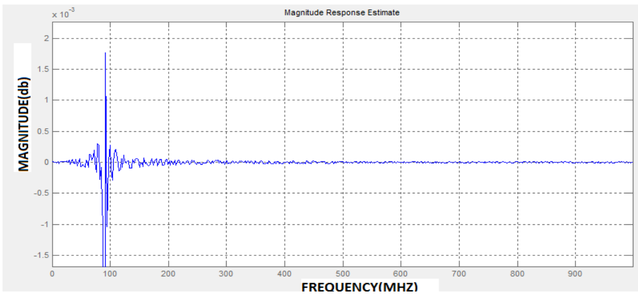

Fig. (17) Magnitude response estimate for BW=200Hz

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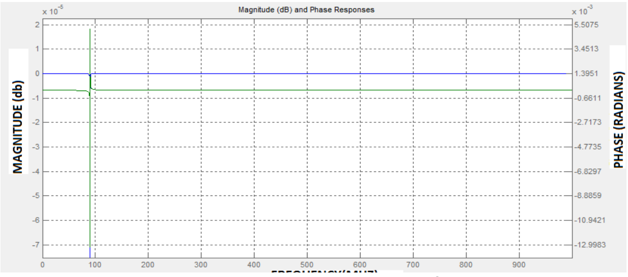

Fig. (18) Magnitude and phase response for BW=200Hz

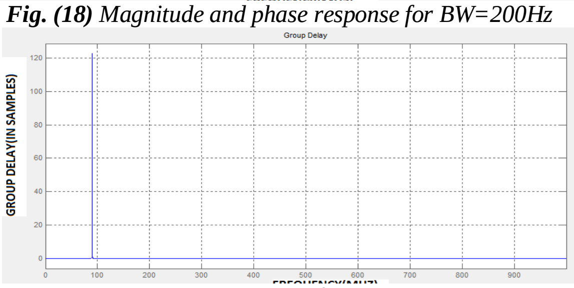

Fig. (19) Group delay for BW=200Hz

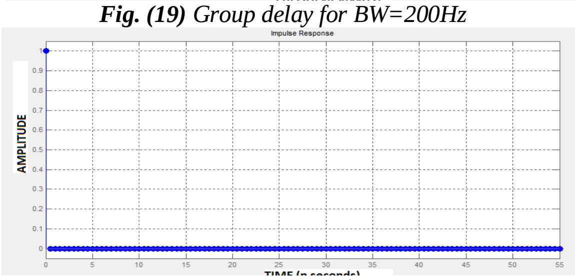

Fig. (20) Impulse response for BW=200Hz

Serial N0.	Notch /Center Frequency In(GHz)	Order	Bandwidh (in GHz)	Filter Coffs.(Output Gain)	Filter Info.(Bandwidth Gain In dB)	Settling Time In(nsec)	Fbw 20db In KHz	Multiplier,adder per unit sample & States
1	.09	2	0.2	0.99999999999999711	-3.0103	13.8	9045.3	6,4,2
2	.09	2	0.02	0.99999999999999711	-3.0103	13.8	9045.3	6,4,2
3	.09	2	0.002	1.0000000000000018	-3.0103	13.8	9045.3	6,4,2
4	.09	2	0.0002	0.99999999999999822	-3.0103	13.8	9045.3	6,4,2
5	.09	2	0.00002	0.99999999999999978	-3.0103	13.8	9045.3	6,4,2
6	.09	2	0.000002	1.0000000000000060	-3.0103	13.8	9045.3	6,4,2
7	.09	2	0.0000002	1.0000000000000033	-3.0103	13.8	9045.3	6,4,2
8	.09	2	0.000000002	1.0000000000000067	-3.0103	13.8	9045.3	6,4,2
9	.09	2	0.0000000002	1.0000000000000313	-3.0103	13.8	9045.3	6,4,2
10	.09	2	0.000000000002	1.0000000000011871	-3.0103	13.8	9045.3	6,4,2

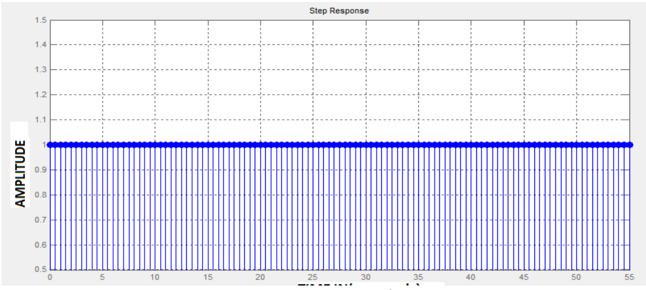

***Fig. (21) Unit** step response for BW=200Hz*

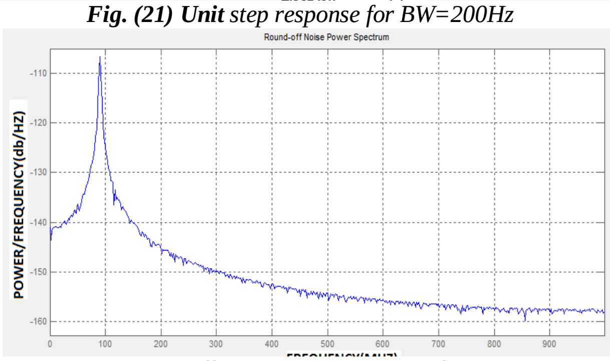

***Fig. (22)** Round –off noise power spectrum for BW=200Hz*

***Table (1)** Various information about notch filter of order 2*

4. Realization of the notch filter:

For the realization of 2^{nd} 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

```
Passband Ripple      : 0.1547 dB
Stopband Atten.      : 0.7659 dB

Implementation Cost
Number of Multipliers : 6
Number of Adders      : 4
Number of States      : 2
MultPerInputSample    : 6
AddPerInputSample     : 4
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***Fig. (23)** Filter information of order=2 and is independent of bandwidth-parameter*

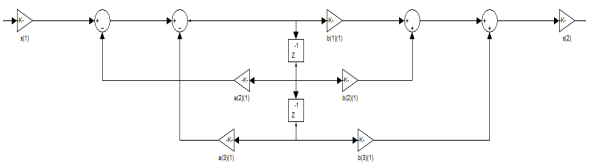

Fig. (24) The lattice form realization of real coefficient notch filter

5. Testing design model of IIR notch filter

To get the real time filtration the model in matlab is built. The results of Mathematical equation are used

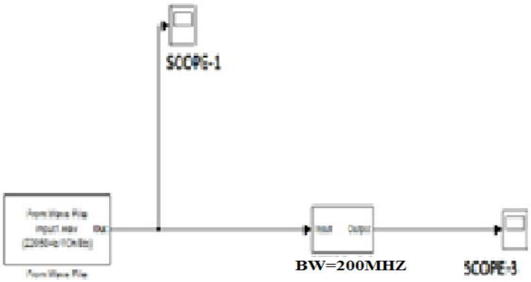

Fig. (25) Input signals are shown in scope (1) and output signals are shown in scope (3)

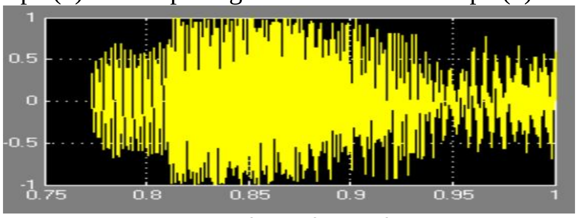

Fig. (26)*-wave form of notch filter input*

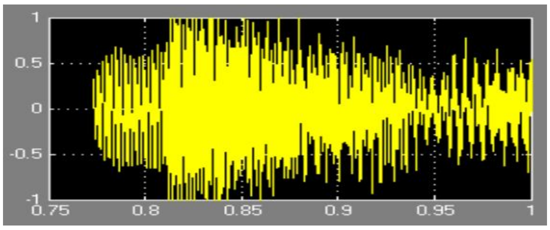

Fig. (27)*-wave form of notch filter output when BW=200MHz*

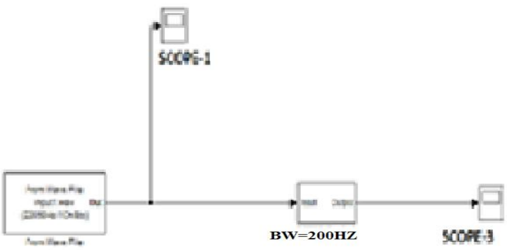

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Fig. (28) Input signals are shown in scope (1) and output signals are shown in scope (3)

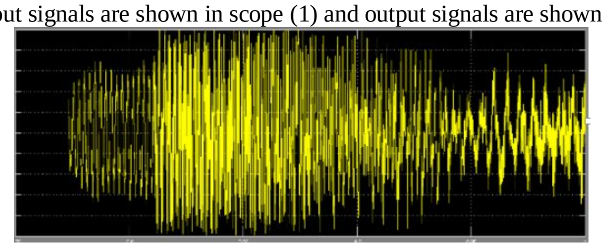

Fig. (29)*-wave form of notch filter input*

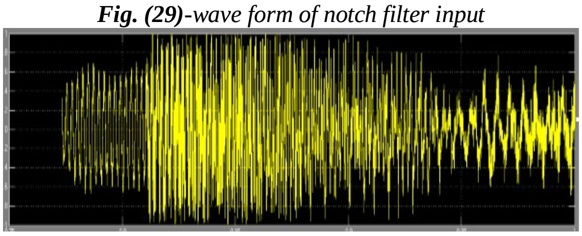

Fig (30)*.-waveform of notch filter output when BW=200Hz*

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 13.8nsec 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

[1]McManus CD, Neubert KD, Cramer E, “Characterization and elimination of AC noise in electrocardiograms: a comparison of digital filtering methods”, Comput Biomed Res. 1993 Feb;26(1):48-67

[2] Burak Kelleci ·Timothy Wayne Fischer ·”Circuits Syst Signal Process” (2008) 27: 475–489 DOI 10.1007/s00034-008-9041-z

[3] K. Hirano, S. Nishimura, and S. K. Mitra, “Design of digital notch filters,” IEEE Trans. Circuits Syst., vol. CAS-21, pp. 540–546, July 1974.

[4]Jacob mill man ,christos c.Halkias “Integrated Electronics “page-no.-495

[5] D. V. B. Rao and S. Y. Kung, “Adaptive notch filtering for the retrieval of sinusoids in noise,” IEEE Trans. Acoust. Speech, Signal Processing, vol. ASSP-32, pp. 791–802, Aug. 1984

[6] A. H. Gray Jr. and J. D. Markel, “Digital lattice and ladder filter synthesis,” IEEE Trans. Audio Electroacoust., vol. AU-21,pp. 491–500 , Dec. 1973.

[7] J. F. Chicharo and T. S. Ng, “Gradient-based adaptive IIR notch filtering for frequency estimation,” IEEE Trans. Acoust. Speech, Signal Processing, vol. 38, pp. 769–777, May 1990.

[8] A. Nehorai, “A minimal parameter adaptive notch filter with constrained poles and zeros,” IEEE Trans. Acoust. Speech, Signal Processing, vol. ASSP-33, pp. 983–996, Aug. 1985.-

[9]Y.v.joshi and s.c.dutta roy “circuits system signal processing” vol.16,no.4,1997,pr.415-427

[10] L. Yang” Ultra-wideband communications” IEEE., vol. 21, pp. 26

